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Diversity, ecology and methods of the research of lichens in old-growth forests in Central Europe

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Abstract

Forests are the native Central European vegetation, which have dominated in the landscape for the last c. 10,000 years. Stands with an oak and hornbeam dominance occupied lower elevations before human colonization, beech and silver fir-beech forests middle elevations and spruce stands at higher elevations. Only a few remnants of forests, which can be regarded as primeval or with a minimal impact of forest management, have survived in densely populated Central Europe. Examples of the most preserved primeval forests are Rothwald (Austria), Białowieża (Poland, Belorussia), Stužica/Stuzhytsia (Slovakia, Ukraine) and Boubín (Czech Republic). Although these sites are small and isolated, they are local diversity centers for many organisms, mainly for fungi, lichens and bryophytes, refugia for numerous endangered species and some of them have their last localities there. Epiphytic and epixylic lichens are an ideal model group for studies about forests because they sensitively indicate management, continuity, heterogeneity and age of a woodland. Therefore they could help us to answer many important questions about the conservation of natural forests.

This thesis comprises several different points of view on lichens in Central European forests and its aim is to join these heterogeneous fields into one complex study. Except two mostly ecological studies, describing more or less similar results as publications from other parts of Europe, it is focused on less well known fields of the topic, i.e. mainly the methodology of field research and total lichen diversity of selected localities. Surprisingly, in a comparison with ecological studies, very few of contributions have been published about these points and with little exaggeration, some of the papers included here could be regarded as pioneering studies. Especially data on species richness in individual woodlands distinctly exceed our previous knowledge and they also indicate overlooking of great number of species by single lichenologists.

Although, the lichen biota in Central Europe is one of the best explored in the world, undescribed species can be discovered in local forests, mainly crustose lichens which reproduce vegetatively. Two papers are focused on the taxonomy of the large genus *Lecanora* and describe one new taxon from beech forests. Descriptions of a few other new species are in preparation and therefore only briefly introduced. The thesis comprises also floristic papers as important additional material. Some records from these contributions are new for Central Europe and they present valuable information about overall distribution and ecology of many species. In total, 10 papers are included, eight already published with impact factor and two manuscripts.

Key words: flood-plain forests, hot spot of epiphytic lichens, *Lecanora substerilis*, silver fir-beech primeval forests, sorediate lichens, underestimated species richness

Abstrakt

Lesy tvoří původní složku středoevropské vegetace, která dominovala zdejší krajině přibližně posledních deset tisíc let. Před příchodem člověka zde převažovaly porosty s dominancí dubu a habru v nižších polohách, bučiny a jedlobučiny ve středních polohách a smrčiny ve vysokých nadmořských výškách. Do současnosti se v hustě obydlené střední Evropě zachoval jen zlomek původních porostů, které lze považovat za pralesy nebo alespoň lesy s minimálním vlivem člověka a lesního hospodaření. Příklady nejlépe zachovalých pralesů jsou Rothwald (Rakousko), Białowieża (Polsko, Bělorusko), Stužica/Stuzhytsia (Slovesko, Ukrajina) a Boubínský prales (ČR). Tato území jsou zpravidla malá a navzájem izolovaná, přesto jsou ale lokálními centry diverzity různých organismů, hlavně hub, lišejníků a mechorostů, a také útočištěm řady ohrožených druhů, z nichž mnohé zde mají své poslední lokality. Právě epifytické a epixylické lišejníky jsou ideální modelovou skupinou ke studiu lesních porostů, protože velmi citlivě reagují na hospodaření, odrážejí kontinuitu, heterogenitu a stáří lesa a mohou nám mimo jiné přinést odpovědi na řadu otázek klíčových pro ochranu zbytků přirozených porostů.

Tato práce nahlíží na problematiku lišejníků ve středoevropských lesích z několika různých úhlů pohledu a tyto pohledy se snaží spojit do jediné komplexní studie. Mimo dvou převážně ekologických studií, které docházejí k víceméně podobným výsledkům jako práce z jiných částí Evropy, se zaměřuje také na méně prozkoumaná zákoutí daného tématu, a to vlastní metodiku terénního průzkumu lišejníků a celkovou diverzitu vybraných území. Překvapivě bylo ve srovnání s ekologicky zaměřenými studiemi na toto téma publikováno jen naprosté minimum prací a s trochou nadsázky lze některé zde zahrnuté články považovat za průkopnické. Zajímavá jsou hlavně data o celkové diverzitě jednotlivých lesních porostů, která výrazně převyšuje naše dosavadní znalosti, a výsledky také poukazují na přehlížení značného množství druhů jednotlivými badateli.

Přestože se střední Evropa může chlubit jednou z nejlépe prozkoumaných lichenoflór na světě, zdejší lesy ukrývají mnohé doposud nepopsané druhy, a to hlavně vegetativně se rozmnožující korovité lišejníky. Dva články se proto zaměřují na taxonomii rozsáhlého rodu *Lecanora* a popisují jeden nový druh z bukových lesů. Popisy dalších nových druhů jsou zatím v přípravě, a tudíž jen stručně zmíněny. Součástí práce jsou i floristické články, které lze považovat za velmi důležitý zdroj primárních dat. Některé zde publikované nálezy jsou nové pro střední Evropu a přinášejí nám tak další nové informace o celkovém rozšířených i ekologii řady druhů. Celkem je v práci zahrnuto 10 příspěvků, z toho osm již publikovaných s impakt faktorem a dva manuskripty.

Klíčová slova: centra diverzity epifytických lišejníků, jedlobukové pralesy, *Lecanora substerilis*, lužní lesy, podhodnocené druhové bohatství, sorediózní lišejníky

Content

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1. Introduction

Forest vegetation has covered most of Central Europe, defined here as Austria, the Czech Republic, Germany, Poland, Slovakia (Hungary, Switzerland and western part of Ukraine considered marginally as well), for the last c. 10.000 years (Ložek 2004). Although woodlands are considered to be a stable vegetation (at least from the perspective of one human lifetime), the character and composition of forests were dramatically changing during the Holocene.

The first Holocene forests were formed by *Pinus sylvestris* and *Betula pendula*. These trees started to be replaced by mixed deciduous forest with *Corylus*, *Quercus*, *Tilia*, *Ulmus*, *Acer* and *Fraxinus* in the Boreal period (c. 9,000 years ago). Rich mixed deciduous forests covered most of Central Europe during the Atlantic (8000–5000 BP). In the Czech Republic, the maximal expansion of this forest type is dated into the period 7500–2000 BP. Their success during so called "Holocene forest optimum" was conditioned by soils rich in nutrients and a climatic optimum (Pokorný 2011). Due to a following acidification process, these stands started to be replaced by beech-dominated forests c. 4000–3000 years ago; a high proportion of conifers, especially *Abies alba*, is characteristic (Pokorný & Kuneš 2005). The great success of beech, which is considered to be the natural dominant at most mid-altitude sites in Central Europe (Ellenberg 1996, Margi 2008), is very characteristic just for the current interglacial period (Pokorný 2011). This situation was constant up to the Middle Ages, when the landscape exploitation gradually increased. More dramatic and faster changes in the forest composition came with planting of trees, which started to be a common phenomenon during the 18th century (Radkau 2011).

Potential natural vegetation (PNV), a concept developed in the mid-1950s (Tüxen 1956), supposed oak and oak-hornbeam-dominated stands to be a dominant vegetation at lower elevations, beech and silver fir-beech-dominated stands at middle elevations and spruce stands at higher elevations. Many others, more or less local forest types, were a part of natural vegetation in Central Europe as well: alluvial forests with *Alnus*, *Fraxinus* and *Salix*, scree forests with *Acer*, *Tilia* and *Ulmus*, Alpine forests with *Larix decidua* and *Pinus cembra*, boggy pine forests, pine forests on sandy soils and rocks etc. (Tüxen 1956, Ellenberg 1996). However, the distribution of dominant tree species is sometimes discussed (e.g. Nožička 1972, Rybníček & Rybníčková 1978). New data on a much greater proportion and distribution of coniferous trees is available; especially *Picea abies* was a dominant tree for approximately 9,000 years, whereas the maximal beech stands cover is estimated up to 10 % (Szabó et al. 2016).

During the past several centuries of human influence on the landscape, the primeval forests have been almost completely destroyed, the total forest area strongly reduced, replaced by non-native trees and changed into intensively managed forests. Introduction of even-aged plantations led to tree age structure simplification, disappearance of old and dead trees and dominance of coniferous monocultures at the expense of tree species rich deciduous and mixed forests (Bengtsson et al. 2000).

Approximately one third of Central Europe is currently covered by woodlands (FOREST EUROPE, UNECE, FAO 2011). Nevertheless, we can confidently state that most of the current human population has no idea of what the primeval forest looks like because managed forests (= wood biomass plantations), btw. suitable for trips and mushroom picking, are the only one generally known forest type. Based on this information, remnants of primeval forests are one of the most endangered habitats in Central Europe and they should have a high priority of nature protection.

An effective protection of forest remnants is impossible without thorough knowledge of their biodiversity, ecology and degree of naturalness. Thus, an assessment of forest quality is a key requirement. Lichens, as well known bioindicators, belong to a very suitable group of organisms for such evaluation because they are able to indicate many aspects of forest quality, such as age, continuity, stand size and heterogeneity, fragmentation, management, disturbance level and history, tree composition etc.

This thesis presents data on forest lichens from several different fields (ecology, floristics, diversity and methods of its survey, taxonomy of woodland lichens), contributing to a better knowledge of Central European forest using lichenized fungi as a model ecological group.

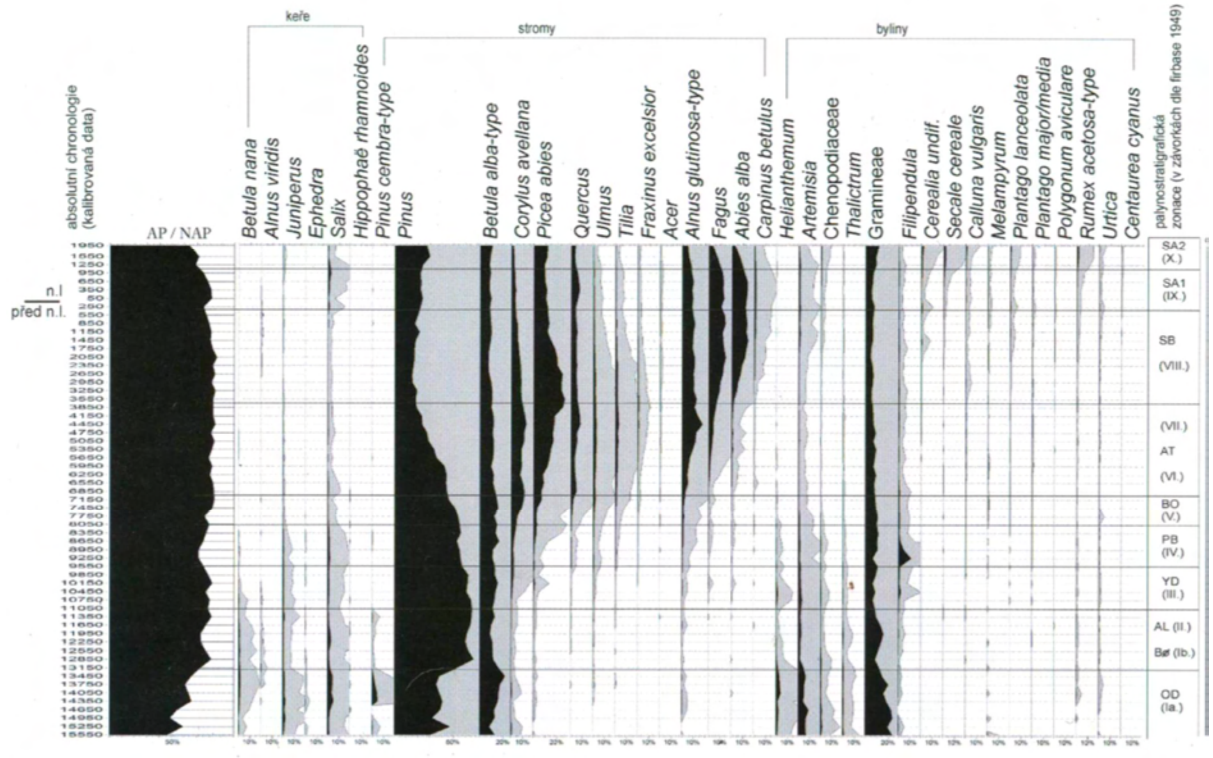

Fig. 1. Average pollen diagram indicating tree and plant dominants in the Czech Republic for the last 17,000 years. Adopted from Pokorný (2011).

1.1. Main questions of this thesis

1. How many lichen species occur in a well preserved old-growth forest in Central Europe?
2. What percentage of this diversity can be captured by an experienced lichenologist?
3. How to improve and make more efficient lichen diversity surveys?
4. Which ecological factors are the most important for lichen diversity and enables survival of red-listed species?
5. Is the lichen biota of Central European forests completely known?
6. Do any members of the *Lecanora subfusca* group prefer any forest type or tree species?
7. Which names are correct for several sorediate *Lecanora* species with atranorin and how can they be distinguished from each other?

1.2. The most valuable old-growth forests in Central Europe

1.2.1. Old-growth forests outside the Czech Republic

The Polish Białowieża (protected since 1921 according to www.bialowieza-info.eu) and Belorussian Biełaviežskaja pušča are usually regarded as the most famous and largest Central European old-growth forests and the most valuable lowland forests in Europe. However, due to an intensive management in the past, even its core parts can't be regarded as a primeval forest. The most valuable stands (alt. c. 150–200 m) are dominated by *Quercus robur*, *Carpinus betulus*, *Tilia cordata* and *Acer platanoides*. It is lichenologically very interesting forest with an occurrence of many rare species, e.g. *Arthonia cinnabarina*, *Bacidia polychroa*, *Bryoria furcellata*, *Cliostomum corrugatum*, *Cyphelium notarisii*, *Lobaria scrobiculata*, *L. virens*, *Ramalina thrausta* and *Usnea ceratina* (Cieslinski & Tobolewski 1988).

In Austria, the Rothwald (alt. 930–1440 m; Fig. 2) is the most valuable forest reserve. The primeval forest covers c. 400 ha and is dominated by *Fagus sylvatica*; *Abies alba* and *Picea abies* are intermixed (Hochebner et al. 2015). The locality is very rich in lichens: *Chaenotheca subroscida*, *Collema nigrescens*, *Cyphelium lucidum*, *Loxospora cismonica*, *Nephroma bellum*, *Ramalina obtusata*, *Sticta sylvatica* etc. (Türk & Breuss 1994). Much smaller is another well-known Austrian virgin forest, the Neuwald in Lahnsattel Forest Reserve (Lower Austria). Tree layer is formed by beech, silver fir and spruce. Its lichen flora is very rich again (Hafellner & Komposch 2007). Wiegenwald and Rauriser Urwald in Hohe Tauern National Park and the Rohrach in Vorarlberg are other valuable montane old-growth forests in Austria.

Slovakia is, probably due to its broken relief of the Carpathians Mts and a lower population density, rich in old-growth forest remnants. Stužica (alt. 650–1200 m) at the border with Poland and Ukraine is the largest Slovak primeval forest, covering 615 ha. Beech is the most common tree, silver fir, sycamore and several other tree species are intermixed. Badínský prales (30 ha), Dobročský prales (51 ha), Rožok (65 ha), Havešová (146 ha) and Vihorlat (28 ha) are also well-known and preserved Slovak primeval beech and beech-silver fir stands. Many montane spruce forests are situated in the Tatra Mts, e.g. Bielovodská dolina (154 ha). Two very valuable and large old-growth spruce stands, Babia hora (250 ha), Bielovodská dolina (154 ha) and Pilsko (431 ha) occur in Oravské Beskydy Mts (www.pralesy.sk). Similarly like in case of Stužica, old-growth forest grows also at the Polish side of Mt Babia hora.

Fig. 2. The most famous Austrian virgin forest Rothwald. The part "Kleiner Urwald" (in the picture) is dominated by *Fagus sylvatica* and *Abies alba*.

Five old-growth beech forest areas are protected by UNESCO in Central and Northeastern Germany: Jasmund, Grumsin, Serrahn, Kellerwald, Hainich (UNESCO 2013). Several remnants of ancient forests occur also in the Bavarian Forest, e.g. the Mittelsteighütte (Printzen et al. 2002) and in Switzerland, e.g. Merliwaldes (Dietrich 1991).

Many of the largest primeval forests in Europe are situated in the Ukrainian Carpathians, sometimes also assigned to Central Europe. They cover much larger areas then most of virgin forests in other Central European countries. The most famous localities, Čornohora, Uholka-Široký luh, Svidovec, Maramoroš, Kuzij – Tribušany Stužica, are protected by UNESCO (UNESCO 2013).

1.2.2. Old-growth forests in the Czech Republic

Many hundreds of old-growth forests, scattered all over the country, are protected in the Czech Republic. Unfortunately, most of them are covered by somewhat modified, near-natural forests (www.pralesy.cz). Only several localities can be evaluated as woodlands without or with a low impact of forest management or grazing in the past. However, these sites are usually very small and they behave like isolated islands lost in intensively managed forests.

Fig. 3. The most famous Czech primeval beech-silver fir-spruce forest – Boubínský prales in the Šumava Mts.

In the Czech Republic, Boubín in the Šumava Mts is the most famous primeval forest. Its core part (46.6 ha, Fig. 3) has never been managed by foresters. It is situated in the altitude of 925–1110 m. Tree layer is dominated by *Fagus sylvatica*, *Picea abies* and *Abies alba*. The age of oldest trees reach up to 400 and 500 years (Albrecht et al. 2003, Vrška et al. 2012). Well preserved old-growth forest remnants, including one of the best montane spruce forests in the Czech Republic situated on the top of Mt Boubín, are dispersed though the whole protected area of Boubínský prales, covering 685 ha in total (Albrecht et al. 2003). The core area is extremely rich in macrofungi with c. 600 recorded species (Holec et al. 2015).

Šumava Mts are generally very rich in old-growth forest remnants. Hraničník, Milešický prales and Stožec are other very valuable natural woodlands dominated by beech. The largest climax spruce forest in the Czech Republic grew on the Mt Trojmezná, however, it was completely destroyed by bark beetle outbreak a few years ago. Other interesting montane spruce forests still occur on Mt Smrčina and Mt Jezerní hora.

Žofínský prales in the Novohradské Mts is the second most famous and valuable Czech primeval forest. Its core area occupies 74.5 ha and it is protected since 1838 as the oldest Central European reserve. The reserve (102 ha) is situated in the altitude of 735–830 m. Tree layer is dominated by *Fagus sylvatica*, *Picea abies* and *Abies alba*; the oldest trees reach ages between 300 and 400 years (Albrecht et al. 2003). Žofínský prales is also extremely rich in macrofungi with c. 800 species recorded (Beran pers. comm. in Holec et al. 2015), lichens with 267 species (Malíček & Palice 2013) and bryophytes with 195 species (Kučera 2009). Another remnant of an old-growth beech forest, Hojná voda (9,1 ha), protected since 1838 as well, is situated in the same mountains.

A high concentration of old-growth forests is in the Beskydy and Javorníky Mts. Mionší, Razula and Salajka are the best preserved localities without (or almost without) a currently visible impact of forest management and they belong to most famous Czech forest reserves. All three woodlands are dominated by *Fagus sylvatica* and *Abies alba*. Natural spruce stands occur in the Beskydy Mts as well; Mt Kněhyně and Mt Lysá hora are the best examples.

Several valuable beech and scree woodland fragments are protected in the Český les Mts. Diana (20.5 ha; 500–531 m a.s.l.; Fig. 4) is the most famous of them. Although the locality was influenced by park treatment, it is very rich in many groups of organisms, including the lichens.

Very interesting remnants of flood-plain forests (150 m a.s.l.) remained at south of Moravia – Cahnov-Soutok (13 ha) and Ranšpurk (19 ha). *Fraxinus angustifolia*, *Acer campestre*, *Carpinus betulus* and *Quercus robur* are the most common trees. These localities were used for forest grazing in the past. The forest interior was probably very light and dominated by old oaks that are still present there and reaching 400–450 years now. The currently shady lowland forest had arisen in the last c. 100 years of spontaneous development (Mackovčin et al. 2007). Both localities are important refuges for many rare lowland microlichens.

Possibly the most valuable montane spruce forests in the present occur in the Hrubý Jeseník Mts, in the surrounding of Mt Praděd (Bílá Opava, Eustaška) and the protected area Šerák-Keprník. Although they were influenced by forest management, both localities have a natural character and cover large areas of several hundreds of hectares. Some small old spruce stands remained in the Krkonoše Mts as well.

Other interesting fragments of small old-growth forests are dispersed in other parts of the Czech Republic, especially at higher elevations, for example in the Českomoravská vysočina Highlands (Velký Špičák, Polom, Žákova hora etc.). Old xerothermic oak forests occur for example in the Podyjí National Park and the Bohemian Karst in Central Bohemia; scree forests mainly in deep river valleys (e.g. Ve Studeném in the valley of the river Sázava and Údolí Oslavy a Chvojnice in Moravia). Boggy pine forests are regarded as a specific type of old-growth forests. Červené blato in the Třeboň region and Rejvíz in the Hrubý Jeseník Mts are the best examples of this habitat.

Fig. 4. Diana Nature Reserve (Český les Mts) – one of the most valuable old-growth forest remnants in the Czech Republic.

1.3. Diversity of lichens

Only 25 years ago, biodiversity was considered a minor issue in environmental policy (Noss 1990). Today, biodiversity conservation has become a key issue in policy and management of all natural resources (Mace et al. 2012, Gao et al. 2014). Since the Rio Earth Summit in 1992, a large number of biodiversity indicators for forests and other ecosystems, and changes in these ecosystems over time, have been proposed in individual studies or by large programmes (Gao et al. 2015).

Surprisingly poor information is available on lichen diversity in forests, especially on species richness in plots of a defined size. An overview of such studies in Central Europe was published by Vondrák et al. (2015). The results refer to a very poor knowledge of this field because the lichen diversity has been well surveyed only at a few localities. A more detailed discussion about this problem is presented in Vondrák et al. (2015), Vondrák et al. (2016) and the chapter 2.4. Methodology of diversity research.

1.3.1. Inventories of old-growth forests in Central Europe

Although lichens are ecologically an important part of old-growth woodlands, only a few forest reserves can be regarded as more or less well explored and their lichen biota having been published: Rothwald in Austria (Türk & Breuss 1994, Bilovitz 2007, Türk 2015, Berger et al., in prep.; Fig. 2), Białowieża in Poland (Cieslinski & Tobolewski 1988 and several additions), Stužica in Slovakia and Ukraine (Pišút & Lackovičová 1992, Vondrák et al. 2015, Kondratyuk et al. 1998, Kondratyuk & Coppins 2000, Motiejūnaitė et al. 1999), Žofínský prales (Malíček & Palice 2013) and Cahnov (Vondrák et al. 2016) in the Czech Republic and Uholka-Shyrokyi Luh in Ukraine (Dymytrova et al. 2013, Vondrák et al. in prep., P8). Data from several other valuable forest reserves from the Czech Republic (e.g. Diana, Hraničník, Pleš, Boubín, Trojmezná) exist, but comprehensive lists remain unpublished. Published detailed surveys of many other forests reserves, usually of some smaller areas, are available as well, but they are often based on several visits and the research wasn't exhaustive (e.g. Dietrich 1991, Guttová & Palice 1999, Guttová et al. 2012, Malíček & Palice 2015). Detailed lichen inventories are available from Luxembourg as well (e.g. Cezanne & Eichler 2013, 2014), which is, however, regarded here as Western Europe.

1.3.2. Diversity within a forest

Generally, the diversity within forests is strongly underestimated as discussed by Vondrák et al. (2016) and in the chapter 2.4. The main reasons are the insufficient effort for a lichen inventory: work in one or two researchers in most cases, rarity of many species (i.e. they are restricted to a few objects in the entire area), presence of substrate specialists restricted to overlooked substrata and the difficulty of studying the canopy lichens. As the result, it is possible to conclude that most of forest diversity studies contain less than a half of the species which are really present. This idea is supported by several very detailed studies on a small scale: 112 lichenized and calicioid fungi in 1 ha and 192 species in 13.5 ha of lowland floodplain old-growth forest in the Czech Republic (Vondrák et al. 2016), 127 lichen species in a montane beech-fir old-growth forest in Austrian Alps (Hafellner & Komposch 2007), 165 and 167 lichens in 2 ha plots of a natural, weakly managed forest in Estonia (Lõhmus et al. 2012), and incredible 228 lichenized and calicioid fungi in a 1 ha plot of old-growth forest in the Ukrainian Carpathians (Vondrák et al., in prep., P10).

Even smaller scale was used by Marmor et al. (2013), who completely explored 15 spruces and 15 pines (trees generally regarded as species poor due to their acidic bark) in Estonia. The mean number of lichens was 41 for a single spruce and 34 for a pine. They also emphasized the very uneven spatial distribution of lichens, where two thirds of species remain unrecorded if only the first 2 m near the ground were surveyed.

1.4. Ecology

This chapter is partially related to the previous one because most publications use the species richness as the most important parameter for ecological studies. However, papers strictly about lichen diversity and its comparison with other sites without any ecological parameters are included in the diversity chapter. The following paragraphs briefly summarize the most important forest and stand characters driving the lichen diversity and species composition in European forests. I divided the forest studies according to the most common types of forest (oak, beech, coniferous) in addition to some general information about woodlands, following this paragraph. Owing to the large number of papers focused on ecology and management in forests, I chose only a representative part of them, mostly such dealing with lichens and focused on European woodlands.

A major part of European lichens have their optimum in forests. For example Wirth et al. (2009) regarded one third of all lichens known from Germany as "forest" lichens. More than 40% of them are restricted to old-growth forests, from those 10% are extinct in the country now. Similar situation can be expected in other Central European countries.

A meta-analysis of 49 published papers and different taxonomic groups of managed and unmanaged forests in Europe demonstrated slightly higher species richness in unmanaged forests (Paillet et al. 2009). These authors also referred to greater species richness of vascular plants in managed forests, but an opposite effect was proved on lichens. Bryophytes and lichens are able to indicate differences in management types. Key factors for species dependent on forest are the cover, continuity, presence of deadwood and large trees (Paillet et al. 2009).

Generally, epiphyte diversity is related to the forest structure and dynamics, and several environmental factors relevant to their dispersal, establishment, and maintenance are affected by forest management. Studies on lichen diversity clearly demonstrate dramatic losses of species caused by forest management in European temperate and boreal forests (e.g. Hauck et al. 2013). The distinct negative effects of habitat fragmentation (decreasing forest size, edge effects and increasing dispersal distances for epiphytic lichens and bryophytes) were demonstrated by Löbel et al. (2006). The main negative effects of forestry are related to the lack of old trees, short rotation cycles, excessive canopy cover, or excessive exposure to direct light in the final part of the rotation cycle, lack of substrate, particularly for dead-wood dwelling species, decrease of structural diversity and lack of forest continuity. Old trees, usually absent in managed forests, provide different and highly variable bark structure as well as other microhabitats such as rot holes, growth anomalies and moss cover. Large old trees also favour the establishment of dispersal-limited species that have more time for colonisation, higher surface availability, and more stable substrate conditions. Moreover, old-growth forests have a more diverse structure and provide different types of substrates for specialized lichens, such as deadwood, which is usually scarce in production forests (Nascimbene et al. 2013). On the other hand, Brunialti et al. (2010)

did not find any correlation with the occurrence of deadwood and the cryptogam community richness. They emphasized old trees, high levels of basal area, a broad range of diameter classes and high understory diversity as the main structural features affecting cryptogamic communities. Nevertheless, the importance of dead wood for various organism groups was repeatedly demonstrated (e.g. Humprey et al. 2002, Spribille et al. 2009, Djupström et al. 2010, Blasy & Ellis 2014).

Bässler et al. (2016) explored functional diversity of forest lichens along an elevation gradient. Species richness increased with elevation, functional diversity decreased. Higher elevations favored species with a complex growth form (advantage of high moisture) and asexual reproductive mode (facilitating reproduction under low temperature).

1.4.1. Oak forests

As expected, one of the most important parameter of epiphytic lichen diversity is the tree and forest age (Ranius et al. 2008, Aragón et al. 2010, Brunialti et al. 2010, Svoboda et al. 2010), closely related with stand and tree micro-habitat variability (Ranius et al. 2008, Aragón et al. 2010). However, in the Czech Republic and Slovakia, air pollution was evaluated as the strongest factor decreasing species richness (Svoboda et al. 2010). Similar results were shown with eutrophication in Atlantic oak woods by Mitchell et al. (2005), who demonstrated an effect of NH_4^+ concentration in the stemflow on species composition and disappearing of sensitive lichens, respectively.

Several studies focused on forest management and fragmentation, also very important factors influencing the lichen diversity. Intensive forest management and replacement of native oaks caused the decline of many of rare lichens within the last two centuries (Nascimbene & Marini 2010). Cyanolichens especially are very sensitive to timber harvesting and require well-preserved stands (Aragón et al. 2010, Zedda 2002). Total species richness is generally greater in oak forest remnants with low management intensity (Aragón et al. 2010), but partial harvesting of dense oak forests can increase the diversity on dead wood without a negative impact on species of conservation concern (Paltto et al. 2008). This is connected with openness and structure of a forest (Horák et al. 2014). Forest fragmentation reduces species richness and causes a disappearance of epiphytic lichens, with the reduction of typical forest species and the appearance of ubiquitous tolerant species, with an overall impoverishment of the lichen biota in Mediterranean oak forests (Brunialti et al. 2012) as well as those in Central Europe (Svoboda et al. 2010). Nevertheless, lichen diversity is higher in marginal zone due to better light conditions (Brunialti et al. 2012). Total epiphytic cover can increase towards the forest interior and some extremely rare lichens only occur at interior stands (Belinchón et al. 2007).

Generally, species richness and composition of oak forests are influenced by elevation, precipitation and radiation (Zedda et al. 2002, Aragon et al. 2010, Svoboda et al. 2010) as well.

1.4.2. Beech and fir-beech forests

Drivers of species richness and composition in European beech forests are quite well known. Most of the studies were done in various beech woodlands in Sweden and Italy. Surprisingly, only several studies were done in Central Europe.

Similarly to the species richness of lichens in oak forests, diversity in beech forests correlate mainly with tree and forest age and stand heterogeneity (e.g. Friedel et al. 2006, Fritz et al. 2009b, Moning & Müller 2009, Dymytrova et al. 2014). However, the continuity of forest vegetation is one of the most important factors probably due to a combination of a higher substrate quality, mainly old beeches, and a longer time available for colonization (Fritz et al. 2008, Fritz & Brunet 2010). Stand variables, such as light availability, moss cover, presence of old and damaged trees and local humidity are keynote for high species richness and presence of rare taxa (Amo de Paz & Burgaz 2009, Fritz 2009, Fritz et al. 2009a, Fritz & Brunet 2010, Dymytrova et al. 2014).

Studying the effect of bark and tree characteristics on species occurrence, the interaction of high bark pH, high tree age and stem damage best explained the number of species of conservation concern (Fritz & Brunet 2010). Especially trees with red holes, locally increasing bark pH and slowing down the growth rate of trees, are very important for such species (Fritz et al. 2009a, Fritz & Heilman-Clausen 2010). Also other microclimatic variables influence lichen diversity – areas with N-exposure and close to water courses as well as N-facing trunks are richer in number of lichen species (Amo de Paz & Burgaz 2009). Dymytrova et al. (2014) indicated a distinct correlation of diversity and altitude. Woodlands in higher elevation have usually higher light availability, an important factor for the species composition (Friedel et al. 2006, Fritz et al. 2009a). Variability from tree base to the canopy was shown by Fritz (2009) and Boch et al. (2013). Fritz (2009) stated that surveying only the base can underestimate both the number of species of conservation concern and their population sizes, because the optimum of such lichens is above 2 m.

Of course, lichen communities are strongly influenced by management (Aude & Poulsen 2000) and lichen diversity is usually higher in unmanaged forests (Friedel et al. 2006). Nascimbene et al. (2007b) demonstrated that species richness on beech stems did not show significant differences between a selectively-cut mixed forest and intensively managed forest of similar age, while most of the rare species were exclusive at the selective-cut sites. Hence, lichen composition was strongly different among the two management regimes. Suboceanic species-sensitive to forest management and habitat modification were present in the selectively-cutting forest, while intensively managed stands were dominated by generalist species common in disturbed habitats. Stands less influenced by management can be situated for example at the base of slopes (Fritz et al. 2009b, Fritz & Brunet 2010).

Fritz (2011) discussed reasons for decrease of some red-listed lichens in Sweden (e.g. *Lobaria pulmonaria*, *Sphaerophorus globosus*)., He mentioned a loss of old host trees as the most probable cause, in combination with a still relatively high nitrogen deposition and competition with bryophytes.

As expected, lichen communities on silver fir are different from beech, but both tree species are important for lichen diversity. However, beech proved to be a more favourable hosting tree for several rare and sensitive species. Species associated with silver firs are mainly acidophytic lichens, while those associated with beeches are foliose hygrophytic lichens (Nascimbene et al. 2009).

1.4.3. Coniferous forests

Ecological papers on coniferous forests have the highest proportion among all publications about forest lichens. Numerous studies come especially from Fennoscandia and also from North America (e.g. Hauck & Spribille 2005). However, I excluded non-European surveys because they deal with different tree species from those occurring in Europe. Most of publications from Europe are focused on Norway spruce (*Picea abies*) forests, a few of them on pine forests dominated by *Pinus sylvestris*.

Fig. 5. Praděd National Nature Reserve (Jeseníky Mts) – the largest old-growth montane spruce forest in the Czech Republic.

It was repeatedly proved that forest age, continuity and tree age significantly increases lichen species richness (e.g. Holien 1996 & 1998, Kuusinen & Siitonen 1998, Hilmo et al. 2009, Lie et al. 2009, Nascimbene et al. 2009 & 2010b, Marmor et al. 2011, Dittrich et al. 2013, Zemanová et al., in prep.). Many rare, red-listed, habitat-specialized or dispersal limited species are characterized by a strong preference for old stands (Marmor et al. 2011, Zemanová et al., in prep.), they are associated with over-mature trees (Nascimbene et al. 2009) and large trees (Kruys et al. 1999), i.e. substrates that are poorly represented in managed forests. Survival of old trees helps to mitigate the impact of disturbances and it increases probability of successful recolonization (Zemanová et al., in prep.). However, Bäcklund et al. (2016) reported decreasing number of lichen species with increasing age of managed spruce forests in Sweden, probably due to canopy closure in mature stands. This trend can be possible in some cases, because the light availability in forests is one of key factors for lichen diversity (Marmor et al. 2012), biomass of macrolichens (Gauslaa et al. 2008) as well as for species composition of individual tree parts (Caruso & Thor 2007). However, the results by Bäcklund et al. (2016) are exceptional in context to other similar studies. Species diversity is positively correlated also with elevation (Holien 1996, Nascimbene & Marini 2015, Bässler et al. 2016), admixture of other tree species, for example *Populus tremula* (Kuusinen & Siitonen 1998), and microclimatic factors like a higher humidity in swamp forests (Kuusinen 1996).

Dead wood is an indispensable forest structure and substrate for many cryptogams. Especially large-diameter deadwood objects in an advanced stage of decay harbor more species than smaller fragments in the early stages of decay (Söderström 1988, Dittrich et al. 2014, Svensson et al. 2014) and they support an occurrence of red-listed species (Kruys et al. 1999). Presence of snags promotes species diversity of calicioid lichens (Holien 1996). In the managed forest landscape, stumps may provide important habitats for rare species (Caruso et al. 2008).

Similarly as in oak and beech forests, management plays a very important role for species richness in coniferous woodlands and many papers include suggestions for an improvement of current forestry in the maintenance of cryptogam diversity. Compared with old-growth forests, managed forests are characterized by low heterogeneity (Nascimbene et al. 2010b, Strengbom et al. 2011), low light intensity of even-aged monocultures with dense canopies, short rotation times and low availability of coarse woody debris (Strengbom et al. 2011). Logging obviously decreases the cover and species richness in all epixylic species groups (Rabinowitsch-Jokinen et al. 2012). Additionally, Lommi et al. (2010) suggested that long history of forest management might be behind the lower lichen species richness. Negative effect of forest fragmentation was demonstrated Hilmo & Holien (2002). Esseen & Renhorn (1998) presented also a negative impact of forest edges on *Alectoria sarmentosa* populations.

The epiphytic lichen species diversity was lower at the forest margin than in the forest interior, however in the case of north-exposed edges, the lichen diversity was independent of the distance from the forest margin (Kivistö & Kuusinen 2000). Generally, one of the main problems of forest management is the limited dispersion of rare species and substrate specialists, whose populations are usually too far separated (Dettki 1998, Hedenås and Ericson, 2008, Hilmo et al. 2009). Hilmo & Sastad (2001) performed a sowing experiment, supporting the idea about dispersion limits, with three old-forest species (*Lobaria scrobiculata*, *Platismatia glauca* and *P. norvegica*), which grew as rapidly in the young as in the old forest.

1.4.4. Indicators

A great number (probably a few hundreds) of studies dealing with lichens as bioindicators has been written so far. Lichens are usually used as sensitive indicators of various types of air pollution (e.g. Nash 1976, Loppi 1996, Conti & Cecchetti 2001, van Herk 2002, Bosch-Roig et al. 2013) or other ecological problems (e.g. Osyczka et al. 2016). Many publications describe this group of organisms as being very influenced by forest continuity, age, management as well as various forest types. Numerous studies present lists of such lichen indicators, however, this is usually applicable at a local scale only. Generally, it was established that numbers of indicator and Red-listed lichens correlate with the total species richness (Nordén et al. 2007).

Fig. 6. Trees covered by *Lobaria pulmonaria* in coastal forests in Scotland. This species is a great indicator of ancient forests, however except the oceanic regions.

As the most famous indicator species of primeval and ancient forests with long continuity, *Lobaria pulmonaria* is considered (e.g. Nilsson et al. 1995, Kuusinen 1996, Printzen et al. 2002, Kalwij et al. 2005, Nascimbene et al. 2007b, Brunialti et al. 2010, Nascimbene et al. 2010a). In some studies, the whole Lobarion community is used for indication of such forest types (Kondratyuk et al. 1998, Potenza Fascetti 2010). However, this concept can be used only outside the oceanic climatic zone (Campbell & Fredeen 2004).

Numerous regional studies have compiled lists of other epiphytic indicator species with respect to forest age, continuity, naturalness and conservation potential. Most of them are from Fennoscandia (Tibell 1992, Kuusinen 1996, Nilsson et al. 1995, Thor 1998, Johansson & Gustafsson 2001, Nilsson et al. 2001), some others from Central Europe (Printzen et al. 2002, Svoboda et al. 2011), the British Isles (Rose 1976, Coppins & Coppins 2002, Ellis 2016), Estonia (Marmor et al. 2011) and northwestern Russia (Kuznetsova et al. 2007). In Estonia, calicioid fungi as potential indicators of old-growth forests were discussed by Lõhmus & Lõhmus (2011).

Alectoria sarmentosa is probably the most famous indicator of coniferous woodlands (Esseen et al. 1996, Nillson et al. 2001, Esseen 2006). *Usnea longissima* and *Sphaerophorus globosus* are two other species attributed to well-preserved coniferous habitats (Nilsson et al. 2001, Cameron & Bondrup-Nielsen 2012). In Estonia, *Arthonia leucopellaea*, *Chrysothrix candelaris*, *C. flavovirens* and *Lecanactis abietina* are regarded as good indicators of old coniferous forests with long continuity (Marmor et al. 2011).

As a big group of high diversity forests with long continuity, cyanolichens such as *Collema* spp., *Nephroma* spp., *Pannaria pezizoides*, *Parmeliella triptophylla* are regarded (Kuusinen 1996, Nillson et al. 2001). In Sweden, *Arthonia vinosa* was evaluated as the best indicator of woodland key habitats (Johansson & Gustafsson 2001). Tibell (1992) designed an Indicator Species Index of Forest Continuity (ISIFC) which is strongly correlated with forest continuity. Interestingly, *Arthonia vinosa* is included here as one of 20 crustose lichens indicating forest continuity in boreal coniferous forests. Other examples of indicator species of natural oak forests in Central Europe are *Acrocordia gemmata*, *Caloplaca lucifuga* and *Flavoparmelia caperata* (Svoboda et al. 2011); of unmanaged beech forest for example *Pyrenula nitida* (Friedel et al. 2006), *Thelotrema lepadinum*, *Biatora veteranorum* and *Lecanora thysanophora* (Hofmeister et al. 2016). Distribution areas of *Biatora helvola* and *B. mendax* correspond to a natural geographical range of *Picea abies* and *Abies alba*, respectively; the species also prefer these conifers as a substrate in some regions (Printzen 1995, Printzen et al. 1999). As an interesting addition, a toxitolerant and acidophilous forest species, *Lecanora conizaeoides*, can be regarded as an indicator of bark with very low pH and a high content of sulphur, disappearing with decreasing sulphur content (Hauck et al. 2001) and increasing bark pH (Hauck et al. 2011).

An unusual perspective was presented by Whittet & Ellis (2013), who highlighted that lichen indicators of ecological continuity represent working hypotheses developed by expert field biologists, which are often cautiously interpreted on the basis of local site context. As a prediction for future years, Ellis (2015) supposed a decline of forest indicators established by Coppins & Coppins (2002) because they are going to be more intensive due to the loss of habitats, especially in case of continental sites.

2. Results and Discussion

2.1. Diversity

Two papers are placed into this part. They deal with a detailed research of two of the most valuable Central European primeval forests: Žofínský prales and Stužica. Numerous new country records, discussion on distribution, ecology and variability for many taxa, and a comparison of selected forest reservations in Central Europe are included. Unpublished data on a comparative study of Czech old-growth beech and spruce forests and a short overview of several new forest lichens follow this chapter.

2.1.1. Diversity of Czech beech and spruce old-growth forests

The currently ongoing research is focused on lichen diversity in old-growth vs. managed forests in beech/beech-fir and montane spruce forests in the Czech Republic (with participation of J. Vondrák, Z. Palice and J. Kocourková). We apply our new method of several competing lichenologists who are working at a subjectively selected 1 ha plot in a locally expected hot spot, following Vondrák et al. (in prep., P8). Ten plots of each forest type were chosen, i.e. 40 plots in total. Obtained data enable a comparison of localities across the Czech Republic in the context to several other Central European forests and an assessment of lichen indicators of old-growth forests.

The preliminary data show a very high diversity in spruce forests exceeding 120 lichenized and facultatively lichenized fungi on the best 1 ha plots in montane spruce forests in the Šumava Mts (Table 1.). The diversity of some managed forests is surprisingly high as well. The semi-natural managed forests (localities Smrčina, Fig. 7, and Jelení potok) are especially very rich in lichens, although they are quite young and with distinct signs of forest management. As expected, there is a big difference in the species richness of old-growth and managed forests. Additionally, a much higher abundance of red-listed species was recorded in non-managed forests. For a comparison, a similar study from Finnish woodlands (Kuusinen & Siitonen 1998) indicated analogous epiphytic diversity in both forest types (mean for mature managed forests = 69, for old-growth forests = 88). However, the authors included only epiphytic species, so the total species richness in Finish managed forests is very probably higher.

The total diversity of beech forests is slightly higher. The best preserved localities (e.g. Boubín and Diana) have c. 150 species on 1 ha plot. However, there is much bigger difference between managed and unmanaged types because the managed types are usually very shady and poor in lichens, rarely exceeding 50–60 species.

locality	managed	old-growth
Králický Sněžník	57	80
Jeseníky - Eustaška	63	104
Jeseníky - Bílá Opava 1	60	94
Jeseníky - Bílá Opava 2	50	91
Krkonoše - Jelení potok	82	110
Boubín - horský	80	129
Boubín - údolí	83	145
Smrčina	102	124
mean	**72**	**110**

Table 1. Preliminary results of old-growth and managed 1 ha plots in spruce forests in the Czech Republic. The numbers represent a species richness of lichenized and facultatively lichenized fungi (results of J. Malíček, Z. Palice and J. Vondrák).

Fig. 7. The structure of semi-natural spruce forest close to top of Mt Smrčina in the Šumava Mts, the most species rich 1 ha plot in the category of managed forests.

2.1.2. Unrecognized diversity

During our research of old-growth forests, we discovered at least 10–15 unidentifiable species which should be described in the following years. A short overview of taxa known from more localities with preliminary names and some basic information is presented below. Other candidates for undescribed species (*Lecanora*, *Biatora*, *Caloplaca*, *Porina*) are not included in the table because we have material from a single locality and their identity is usually not very clear.

Species	Ecology	Description
Bacidia albogranulosa (Fig. 8)	subneutral bark, especially lowland forests, widely distributed in Central Europe	sterile sorediate species resembling *Lepraria*, containing atranorin
Japewia dasaea	deciduous trees in montane forests, on ±acidic bark	sterile sorediate brown crust very similar to *Placynthiella dasaea*, with fatty acid(s)
Lecanora glabrescens (Fig. 9)	common in beech forests mainly in the Mediterranean	slightly larger than *L. glabrata*, containing the terpenoid *campestris*-unknown
Loxospora aff. *confusa*	old-growth beech forests in the Carpathians and Alps, probably rare	sorediate crust resembling *Pertusaria amara* with planaic acid
Micarea inconspicua	pioneer species on wood in humid forests	apothecia resembling *M. micrococca*, but thallus without goniocysts and lacking secondary lichen compounds
Verrucaria soralifera	deciduous trees (oaks, beech) in lowland forests	small sorediate squamules very similar to *Rinodina degeliana*, but without secondary compounds

Table 2. Examples of undescribed species from Central European forests with provisional names and a basic characterization.

Fig. 8. *Bacidia albogranulosa*, an undescribed sorediate species resembling *Lepraria*.

Fig. 9. *Lecanora glabrescens* shares the ecology and morphology with *L. glabrata*. Both species differ chemically and they have different distribution. Photo from Sicily.

For a comparison, description of twelve new epiphytic or epixylic taxa was based exclusively or partly on Central European material during the last 10 years: *Absconditella rubra* (van den Boom et al. 2015), *Agonimia flabelliformis* (Guzow-Krzemińska et al. 2012), *Bacidia pycnidiata* (Czarnota & Coppins 2006), *Caloplaca substerilis* (Vondrák et al. 2013), *Candelariella boleana* (Etayo et al. 2009), *Lecanora pseudosarcopidoides*, *L. subsaligna* (van den Boom & Brand 2008), *Micarea nowakii*, *M. tomentosa* (Czarnota 2007), *Micarea soralifera* (Guzow-Krzemińska et al. 2016), *Opegrapha trochodes* (Coppins et al. 2008) and *Porina pseudohibernica* (Tretiach 2014). Most of them occur predominantly in woodlands. Several other species were described from North America but soon reported also from Central European forests, e.g. *Biatora ligni-mollis* (Malíček & Palice 2013) or *Candelaria pacifica* (Westberg & Clerc 2012). This is strong evidence that Central European lichen biota is still not completely known and many taxa remain to be undiscovered.

Lichens of the virgin forest reserve Žofínský prales (Czech Republic) and surrounding woodlands

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Abstract: MALÍČEK, J. & PALICE, Z. 2013. Lichens of the virgin forest reserve Žofínský prales (Czech Republic) and surrounding woodlands. – Herzogia **26**: 253–292.
Žofín virgin forest in the Novohradské hory Mts is one of the most valuable woodland localities in the Czech Republic. This old reserve covering 102 ha is dominated by beeches, spruces, and silver firs. We have explored the nature reserve (itsvirgin forest including the protection zone) as well as managed forests and avenues in the surrounding area. Žofínský prales nature reserve is currently the area with the highest diversity of epiphytic and epixylic lichens in the Czech Republic. In total, 312 lichenized, 14 lichen-allied and 11 lichenicolous fungi species were recorded in a broad area of Žofín woodland region. 267 species altogether were recorded from the reserve, including three recently published taxa not confirmed by us. Fifteen lichenized fungi (*Arthonia excipienda*, *Biatora ligni-mollis*, *Candelariella xanthostigmoides*, *Cliostomum leprosum*, *Fellhanera gyrophorica*, *Fuscidea pusilla*, *Lecania croatica*, *Lecanora thysanophora*, *Lecidella subviridis*, *Micarea parva*, *Mycobilimbia pilularis*, *Opegrapha trochodes*, *Rhaphidicyrtis trichosporella*, *Rinodina degeliana, R. excrescens*) and three lichen-allied fungi often associated with algae (*Agyrium rufum*, *Kirschsteiniothelia aethiops*, *Peridiothelia fuliguncta*) are reported for the first time from the Czech Republic. Several suboceanic species, and many rare and critically endangered lichens regarded sometimes as old-growth indicator species, have been recorded. Macrolichens are relatively rare in the reserve in comparison to similar habitats in the neighbouring Šumava Mts. The reserve serves as an important source of diaspores for surrounding woodlands. Several rare lichens appear to have spread from the virgin forest into the surrounding "old" forests (which are more or less extensively managed). Forty-six interesting, rare or poorly known lichenized and lichen-allied taxa are discussed in more detail, sometimes amended with additional records from other regions of the Czech Republic and Slovakia. Five species are new for Slovakia (*Agonimia flabelliformis*, *Biatora albohyalina, B. mendax*, *Lecidella subviridis*, *Rinodina degeliana*).

Key words: Epiphytic and epixylic lichens, biodiversity, old-growth forest, sorediate lichenized Ascomycota

Introduction

Virgin and old-growth forests are among the most strongly endangered ecosystems in the Czech Republic. Their distribution is concentrated in South Bohemia (Šumava Mts.) and Northern Moravia (Beskydy Mts.). Several more or less preserved old-growth forest areas are dispersed in other mountain regions all over the country. In fact, only a few of them have developed almost without human encroachments. Boubínský prales in the Šumava Mts. and Žofínský prales in the Novohradské hory Mts. belong to the most valuable, quite well-preserved virgin-like forests. The main problem of these ecosystems is their quite small area which does not exceed 1 km^2 for a single reservation. Old-growth forests are regarded as the refugia for sensitive epiphytic and epixylic lichens. Especially in South Bohemia, the impact of acid rain in the past was not as destructive as in other parts of the Czech Republic (MOLDAN 1990). This is one of the main reasons of regionally well developed epiphytic lichen communities in south-Bohemian woodlands.

Our research has been focused on a detailed survey of the Žofínský prales National Nature Reserve and different types of forests in its surrounding area. We tried to compare species richness and composition in selected areas of 0.25 ha, which include intensively managed, extensively managed, primeval and at the same time deciduous, coniferous and mixed forests. This study uses a floristic data set recorded during our field research on selected 0.25 ha square areas in addition to full-area survey of the reserve and several other floristic records. A comparison of the variability of lichen diversity between different types of forest in the region will be elaborated separately in another study.

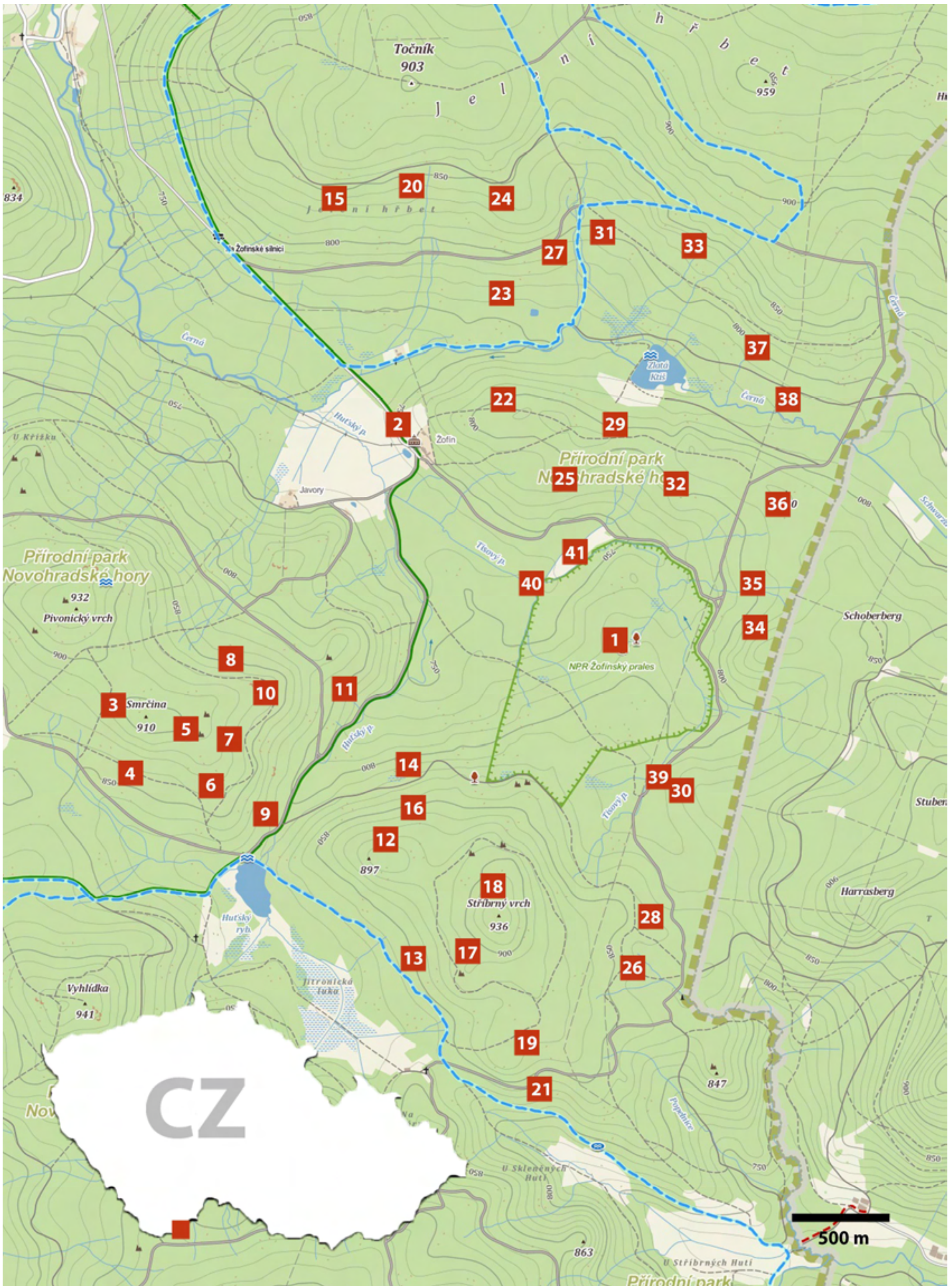

Fig. 1. Topographic map of the Žofín area including studied localities

Material and methods

Our field research was performed between 2009 and 2011. Several additions originate from the autumn field meeting of lichenologists and bryologists in October 2012. Lichens were collected and identified by standard methods. Chemical analyses were performed by TLC (in solvents A, B' and C) according to the methods summarized by ORANGE et al. (2001). An asterisk „*" marks the analysed specimens. Specimens are deposited in the herbaria of J. Malíček (JM), Z. Palice (ZP – PRA) and several duplicates in PRC. Some data were provided by F. Berger (FBe), F. Bouda (FB – PRM), O. Peksa (OP – PL), and J. Vondrák (JV – CBFS). Selected critical specimens were revised by specialists. Lichen nomenclature and categories of the Red List follow LIŠKA & PALICE (2010) with exceptions of four accepted recent nomenclatoric changes: *Gyalecta fagicola* (BALOCH et al. 2010), *Melanelixia glabratula* (ARUP & SANDLER BERLIN 2011), *Varicellaria hemisphaerica* (SCHMITT et al. 2012) and *Violella fucata* (SPRIBILLE et al. 2011). Lichenicolous fungi, lichen allied fungi, and lichenized fungi missing in that paper are given with authorships. Non-lichenized fungi (lichenicolous and lichen-allied fungi traditionally studied by lichenologists) are marked by „#". Lichens new to the Czech Republic are indicated by an exclamation-mark „!". Taxa recorded in the reserve Žofínský prales are highlighted – in bold. GPS coordinates are defined in the WGS-84 system.

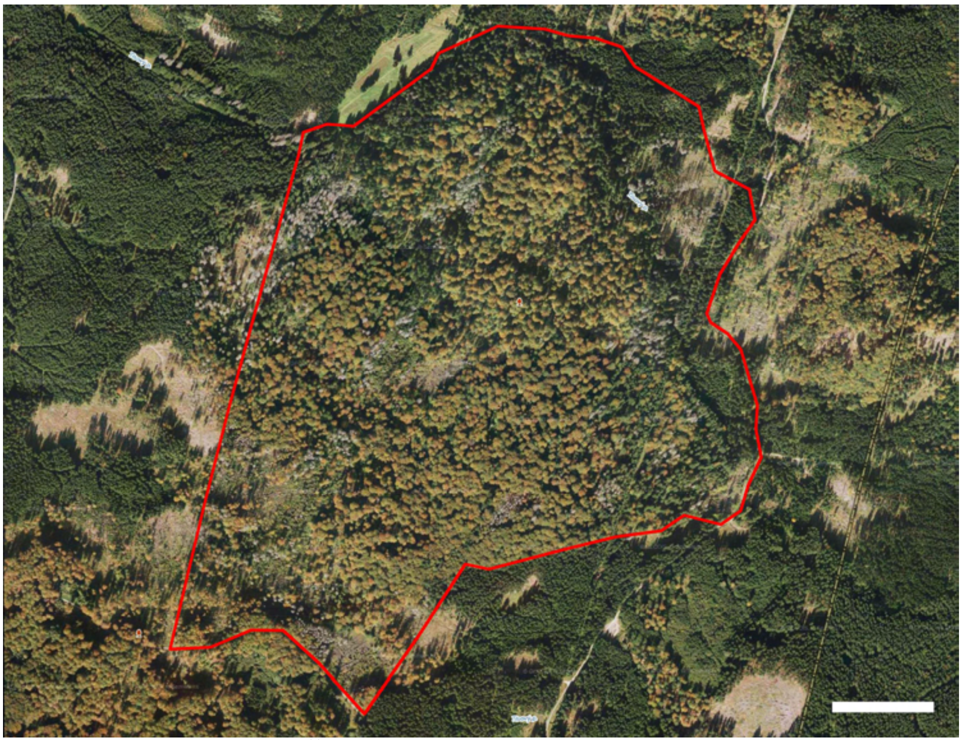

Fig. 2. Aerial photo of Žofín virgin forest; red line marks the border of reserve (scale = 200 m).

Basic characteristic of the study area

Žofín Virgin Forest National Nature Reserve (total area 102 ha) is located in the Novohradské hory Mts, at the southern border of the Czech Republic. It is one of the oldest reserves in Europe, with a core area (74.5 ha) that has been under strict protection since 1838. The reserve is a well-preserved remnant of natural spruce-silver fir-beech forest. Its altitude ranges from 735 to 830 m a.s.l. Topography is rather simple: the ridge in the southern part of the reserve gives way to gentle slopes and a flat plateau with several wetlands and peat springs areas. Annual precipitation varies between 800 and 950 mm, and mean annual temperature is 4.3 °C (PRŮŠA 1985, ALBRECHT et al. 2003). The geological bedrock of the whole area is formed by middle-grained, biotite-rich granodiorite of the Weinsberg-type (PAVLÍČEK 2004). Groups of stones and small shaded rocky outcrops are distributed in several places within the reserve. The northern and eastern border is lined by the brook Tisový potok. Few other tributaries of this brook are dispersed in the protected area. *Galio odorati-Fagetum*, a mesotrophic beech forest, is the most common vegetation type (BOUBLÍK et al. 2009). Tree layer is mainly composed of *Fagus sylvatica* (49 %), *Picea abies* (45 %), and *Abies alba* (5 %) according to the basal area of living trees in the core area (74.5 ha) in 1997 (KENDERES et al. 2009, KRÁL et al. 2009). However, according to total number of living trees in the core area *Fagus sylvatica* covers 68 %, *Picea abies* 29 %, and *Abies alba* 2 % (KRÁL et al. 2009). PRŮŠA & VOKOUN (1984) list from the core area (50.5 ha) similar numbers: *Fagus* (79 %), *Picea* (15 %) and *Abies* (5 %). *Acer pseudoplatanus*, *A. platanoides* (very rarely), and *Ulmus glabra* (rarely) are intermixed in the core part and do not exceed 1 %. The oldest silver firs and spruces reach ages between 300 and 400 years (ALBRECHT et al. 2003). Woodlands in the surrounding of the Žofín Virgin Forest are intensively or extensively managed. Middle-aged and older spruce forests (60–110 years) predominate, exceptionally older monocultures, but less than 120 years (with one exception). Beech forests are less common but locally forming continuous stands, their age reaching up to 200 years.

Fig. 3. Southern part of the virgin forest dominated by beeches.

Although there has been no organized forestry in the area since 1838, like many other forest reserves in Europe the Žofín Virgin Forest has a history of human impacts over the last 170 years (PRŮŠA 1985). After the windfall caused by a serious storm, dead trees were extracted from the damaged belt, which was then replanted with Norway spruce between 1810 and 1820. During the first half of 20th century dead tree removal was documented several times. Another important although indirect human impact on the reserve is related to the problems caused by large herbivores. Žofín was part of a game reserve from 1849 to 1940s. The density of large herbivores increased further after the Second World War. In order to weaken the resulting extremely strong browsing effect on the dynamics of regeneration in the reserve, an attempt was made to control game density by hunting, and the whole reserve was fenced in 1991 (KENDERES et al. 2009). In 2007, a large area of the virgin forest has been affected by windfall caused by a strong windstorm "Kyrill". All fallen trees have been left for natural processes. The above mentioned fence protection of the reserve and the wind-catastrophic event are apparently one of main reasons why the proportion of dominant trees has been markedly changing during recent years in favour of *Fagus* which is evidently quickly increasing due to massive spontanous regeneration in many parts of the reserve. On the other hand, overall number of standing living *Picea* trees has drastically decreased in large spots, also thanks to more intensive attacks by bark beetle.

History of the lichenological survey

An overview of lichens in the Novohradské hory Mts was published by PEKSA et al. (2004). The authors did not deal with saxicolous lichens and recorded 168 epiphytic and epixylic species. They extensively explored the most valuable and protected forest reserves in the area: Žofínský prales and Hojná Voda Virgin Forests, natural monuments with fragments of old-growth beech and scree forests 'Ulrichov' and 'Myslivna' and a raised peat-bog 'Pohořské rašeliniště'. Apart of that, many records come from avenues and solitary trees by road-sides in the surroundings of settlements. In total, 95 lichen species have been reported from area around Žofín settlement, of which about half (47 species) occurred in the reserve. *Arthonia leucopellaea*, *Bacidia biatorina*, *B. incompta*, *Biatora fallax*, *Gyalecta flotowii*, *Hypogymnia vittata*, *Lecanactis abietina*, *Lecanora albella*, *Lobaria pulmonaria*, *Lopadium disciforme*, *Menegazzia terebrata*, *Peltigera degenii*, *Thelotrema lepadinum* and *Usnea florida* represent the most valuable records. Several localities at the Czech and Austrian side of the Novohradské hory Mts were visited during the bryo-lichenological meeting in 2012 (MALÍČEK et al. 2013). The authors recorded 239 lichenized and 19 lichenicolous and lichen-allied fungi. They explored e.g. the old-growth private forest Luxensteinwand in Austria and the small virgin forest Hojná voda. Several single findings from the study area are mentioned in other papers: SVRČEK & KUBIČKA (1971), KUTHAN (1981), LIŠKA & PIŠÚT (1995), LIŠKA et al. (1996), KOCOURKOVÁ-HORÁKOVÁ (1998), PALICE (1999), ALBRECHT et al. (2003), JANSOVÁ & SOLDÁN (2006), SVOBODA & PEKSA (2006), MALÍČEK et al. (2010), MALÍČEK et al. (2011) and GUZOW-KRZEMIŃSKA et al. (2012). Records from the above mentioned works are not included in the list with the exception of taxa based on our recent collections or those taxa that we did not confirm during recent inventories.

Localities

1. Žofínský prales National Nature Reserve, old-growth fir/beech/spruce forest, alt. 735–830 m

2. Žofín – solitary old deciduous trees in and nearby the settlement, alt. 745–760 m [the point refers to localities n. 12b, 12c and 12f in PEKSA et al. 2004]

3. managed spruce forest between Pivonické skály Mt. (932 m) and Smrčina Mt. (910 m), 2 km SW of Žofín settlement, 48°39'48''N, 14°40'22''E, alt. 910 m

4. glade on WSW facing slope of the Smrčina Mt. (910), 2.2 km SW of Žofín settlement, 48°39'37''N, 14°40'26''E, alt. 860 m

5. mixed beech-spruce forest at the top plateau of the Smrčina Mt. (910 m), 1.9 km SW of Žofín settlement, 48°39'44''N, 14°40'38''E, alt. 900 m

6. forest clearing on SE facing slope of the Smrčina Mt. (910 m), 2 km SW-SSW of Žofín settlement, 48°39'34''N, 14°40'46''E, alt. 860 m

7. beech forest on E facing slope of the Smrčina Mt. (910 m), 1.7 km SW-SSW of Žofín settlement, 48°39'43''N, 14°40'50''E, alt. 890 m

8. spruce forest on NNE facing slope of the Smrčina Mt. (910 m), 1.4 km SW-SSW of Žofín settlement, 48°39'56''N, 14°40'51''E, alt. 865 m

9. old spruce forest at SE foot of Smrčina Mt. (910 m), ESE facing slope, just N of "Huťský rybník" pond, 1.9 km SSW of Žofín settlement, 48°39'31''N, 14°41'00''E, alt. 830 m

10. old beech forest on ENE facing slope of the Smrčina Mt. (910 m), 1.4 km SSW-SW of Žofín settlement, 0.8 km N of "Huťský rybník" pond, 48°39'49''N, 14°40'59''E, alt. 880 m

11. young beech forest on ESE facing slope in the valley of Huťský potok, 1.2 km SSW of Žofín settlement, 1 km NNE of "Huťský rybník" pond, 48°39'51''N, 14°41'19''E, alt. 810 m

12. spruce-beech forest on N facing slope of an unnamed hill (897 m), 0.7 km ENE of Huťský rybník, 2 km S of Žofín settlement, 48°39'27''N, 14°41'29''E, alt. 880 m

13. managed spruce forest on SW facing slope ca 0.5 km WSW of the top of Stříbrný vrch Mt. (936 m), 0.9 km ESE of Huťský rybník, 2.6 km S of Žofín settlement, 48°39'06''N, 14°41'37''E, 860 m

14. fragment of old beech forest on NNW facing slope in the valley of Huťský potok, 1.6 km S of Žofín settlement, 0.9 km NE of Huťský rybník pond, 48°39'39''N, 14°41'34''E, alt. 815 m

15. old beech forest on S facing slope of Točník Mt. (903 m), 0.7 km SSW-SW of the top, 1.3 km NNW of Žofín settlement, 48°41'11''N, 14°41'16''E, alt. 830 m

16. beech forest on N facing slope of an unnamed hill (897 m), 0.9 km NE-ENE of Huťský rybník, 1.8 km S of Žofín settlement, 48°39'31''N, 14°41'36''E, alt. 880 m

17. young shaded spruce forest on a plain ca 0.2–0.3km SW of the top of Stříbrný vrch Mt. (936 m), 1.1 km ESE of Huťský rybník, 2.6 km S-SSE of Žofín settlement, 48°39'07''N, 14°41'50''E, alt. 915 m

18. beech forest on N-facing slope of the Stříbrný vrch Mt. (936 m), just 150 m N-NNW of the top, 2.3 km SSE of Žofín settlement, 48°39'18''N, 14°41'56''E, alt. 920 m

19. managed spruce forest on S-SSE facing slopes of the Stříbrný vrch Mt. (936 m), 0.6–0.7 km from the top, 3 km SSE of Žofín settlement, 48°38'53''N, 14°42'04''E, alt. 890 m

20. old beech forest on S facing slope of Točník Mt. (903 m), 0.5 km S of the top, 1.3–1.4 km N of Žofín settlement, 48°41'14''N, 14°41'36''E, alt. 850 m

21. young deciduous forest on S-facing slopes 0.9 km SSE of the point Stříbrný vrch Mt. (936 m) near abandoned settlement "Skelná Huť", 3.3 km SSE of Žofín settlement, 48°38'44''N, 14°42'07''E, alt. 860 m

22. beech forest with intermixed spruce on N-facing slopes of an unnamed hill (809 m), just NNE of the point, 0.5 km NE of Žofín settlement, 48°40'39''N, 14°41'58''E, alt. 805 m

23. valley of Černá brook, forest clearing on S facing slopes at foothill of the Točník Mt. (903 m), ca 1.1 km SSE of the top, 0.9 km NNE-NE of Žofín settlement, 48°40'56''N, 14°41'58''E, alt. 785 m

24. spruce forest on S-SSE-facing slopes of the point Točník Mt. (903 m), 0.7–0.8 km SE of the point, 1.4 km NNE of Žofín settlement, 48°41'11''N, 14°41'58''E, alt. 860 m

25. beech forest on S-facing slope of the forested ridge (809 m) 0.7–0.8 km E of Žofín settlement, 0.7 km SW of Zlatá Ktiš pond, 48°40'26''N, 14°42'13''E, alt. 810 m

26. young spruce forest on E-facing slope in a valley of an unnamed tributary of Lužnice stream, 0.7 km ESE of the Stříbrný vrch Mt. (936 m), 2.8 km SSE-SE of Žofín settlement, 48°39'06''N, 14°42'31''E, alt. 860 m

27. spruce-beech forest on SE-facing slope at foothill of Točník Mt. (903 m), 1.1–1.2 km SE of the top, 1.2–1.3 km NNE-NE of Žofín settlement, 48°41'03''N, 14°42'11''E, alt. 800 m

28. managed spruce forest on E-facing slope at foothill of the Stříbrný vrch Mt. (936 m), 0.7–0.8 km E of the top, 2.6 km SSE-SE of Žofín settlement, 48°39'14''N, 14°42'34''E, alt. 860 m

29. managed spruce forest on N-NNE facing slopes just 0.3 km SSW of Zlatá Ktiš pond, 1 km E-ENE of Žofín settlement, 48°40'34''N, 14°42'26''E, alt. 820 m

30. old beech-spruce forest on W-facing slope at foothill of the crest of Stubenberg Mt., in the end valley of "Tisový p." brook, 2.2 km SE of Žofín settlement, 48°39'34''N, 14°42'42''E, alt. 850 m

31. young mixed forest on SW facing slopes beneath the Jelení hřbet crest, 1.3 km SE of Točník Mt. (903 m), 1.5 km NE of Žofín settlement, 48°41'06''N, 14°42'24''E, alt. 800 m

32. spruce forest on SW-SSW facing slopes 0.5–0.6 km S of Zlatá Ktiš pond, 1.3 km E of Žofín settlement, 48°40'25''N, 14°42'40''E, alt. 805 m

33. glade on SSW facing slopes beneath Jelení hřbet crest, 0.6 km N-NNE of Zlatá Ktiš pond, 1.7–1.8 km NE of Žofín settlement, 48°41'03''N, 14°42'46''E, alt. 835 m

34. beech forest on NW-facing slope E of Žofínský prales, 1.9–2 km ESE-SE of Žofín settlement, 48°40'02''N, 14°43'01''E, alt. 850 m

35. beech forest on W-facing slope E-NE of Žofínský prales, 1.8–1.9 km ESE of Žofín settlement, 48°40'09''N, 14°43'00''E, alt. 840 m

36. beech forest on W-facing slope NE of Žofínský prales, 0.9 km SE of Zlatá Ktiš pond, 1.8–1.9 km E-ESE of Žofín settlement, 48°40'21''N, 14°43'05''E, alt. 805 m

37. managed spruce forest on SW facing slopes 0.5 km ENE of Zlatá Ktiš pond, 1.8 km ENE of Žofín settlement, 48°40'47''N, 14°43'01''E, alt. 795 m

38. valley of Černá brook, spruce forest on SSW facing slopes just 0.5–0.6 km E of Zlatá Ktiš pond, 1.9 km ENE of Žofín settlement, 48°40'39''N, 14°43'08''E, alt. 780 m

39. small sand pit along the road 2 km SE of Žofín settlement, 48°39'36.5''N, 14°42'37''E, alt. 805 m

40. dead spruces on bank of "Tisový p." brook next to the NW border of Žofínský prales, 48°40'08.5''N, 14°42'06.5''E, alt. 735 m

41. meadow near SW border of Žofínský prales National Nature Reserve, 48°40'12.5''N, 14°42'15.5''E, alt. 740 m

List of taxa

#Abrothallus bertianus De Not. – 1; on thallus of *Melanelixia glabratula* on bark of *Fagus* in uppermost part of the reserve (ZP/14574)

Absconditella celata (DD) – 1, 38; on hard, slowly decaying wood of *Picea* in humid microsites, lying trunk as well as cutting-flat of stump (ZP/13147, 15007)

Absconditella delutula (NT) – 1; collected twice in the primeval forest, a pioneer on recently exposed surfaces of granite stones (ZP/14365, 14673 – with *Micarea* sp.)

Absconditella lignicola (LC) – 1, 4, 7–14, 20, 26, 27, 30, 35, 36, 38; very common on various types of dead wood (JM/2047, 2052, 2675; ZP/12794, 13178, 13218, 13729, 13737, 13739, 13740, 13759, 13883, 13891, 13894, 13906, 13932, 14410, 15009)

Agonimia flabelliformis Halda, Guzow-Krzemińska & Czarnota – 1; rarely recorded on *Fagus*, on wood of decaying snag and bark at base of living trees (JM/2083 – isotype; ZP/12763 – holotype, 13736, 14515)

Agonimia repleta (DD) – 1, 7, 10, 12, 15, 20, 22, 35; frequent to scattered on bases and exposed roots of *Fagus sylvatica*, rarely on bark of *Acer pseudoplatanus* and once at foot of huge dead *Picea*, also on wood or terricolous, common in old-growth forest (JM/2011, 2044, 2048, 2702, 2825; ZP/12800, 12802, 13244, 13734, 13863, 13897, 14035, 14039, 14525, 14542, 14670)

#Agyrium rufum (Pers.) Fr. – 1; a lichen-allied fungus, local in the reserve on wet, slowly decaying wood in boggy sites and on wooden fence (JM/3493; ZP/14411)

Alectoria sarmentosa (CR) – 1; several thalli found on branches of dead lying *Picea* on bank of Tisový brook (JM/3544; PRC; JV/7990)

Amandinea punctata (LC) – 1, 2, 21, 30, 31, 35; scattered on bark and wood of *Acer pseudoplatanus*, *Fagus sylvatica* and *Fraxinus excelsior*, in primeval forest recorded on *Ulmus* only (JM/3494; ZP/14618)

Anisomeridium polypori (LC) – 1, 10, 21, 22, 31, 34; frequent in old-growth forest, on bark of *Fagus*, *Picea*, *Ulmus*, *Acer pseudoplatanus*, rarely found with perithecia; scattered outside the reserve, especially on *Fagus* (JM/3546; PRC; ZP/13862, 14061, 14687, 14749)

Arthonia didyma (VU) – 1, 5, 16, 35, 36; in old beech or mixed forests on bark of *Fagus*, *Acer pseudoplatanus* and *Ulmus* (JM/2061, 2071, 2821; ZP/14155, 14341, 14419, 15618)

Arthonia excipienda (Nyl.) Leight. (!) – 1; recorded once on shaded bark of *Acer platanoides* (ZP/12796)

Arthonia leucopellaea (EN) – 1; scattered on *Picea*, rare on *Fagus* and *Abies* (JM/1993); previously collected also outside the reserve on *Alnus glutinosa* (Peksa et al. 2004)

Arthonia mediella (VU) – 1* [Peksa et al. 2004: 293], 2, 20; on bark of *Fagus* (ZP/13102)

Arthonia muscigena (NT) – 1; recorded once on smooth bark of *Fagus* (ZP/14569)

Arthonia radiata (VU) – 1, 5, 7, 15, 16, 20, 22, 25, 34, 35; quite rare in the reserve, scattered outside the reserve, especially on *Fagus*, recorded once on *Ulmus* (ZP/14630)

Arthonia ruana (VU) – 1; rare, on *Acer pseudoplatanus* (JM/3142)

Arthonia spadicea (NT) – 1, 5, 7, 12, 15, 16, 22, 27, 34, 35; common on bark of *Fagus*, rare on *Abies*, *Acer pseudoplatanus* and *Picea*, also on wood (JM/1986, 3510; ZP/13717, 13745, 13788, 14742, 14760)

Arthonia vinosa (VU) – 1, 27; scattered in the reserve, on bark of *Fagus* and on wood of a conifer (JM/2799; ZP/13155)

Arthrorhaphis citrinella (LC) – 39; on acidic soil (JM/3501)

Arthrorhaphis grisea (LC) – 1; rare, on *Baeomyces rufus*

Bacidia biatorina (CR) – 2 [PEKSA et al. 2004: 293]

Bacidia circumspecta (CR) – 1, 35; rare in the reserve, on bark of *Fagus* (JM/2671, 2826; ZP/12863, 13743, 13766)

Bacidia incompta (CR) – 1; rare, on weathered/spongy bark of old *Fagus* and *Ulmus* in N and E part of the reserve (JM/1998, 3507; ZP/12857, 14623, 14891)

Bacidia laurocerasi (RE>CR) – 1, 5; rare, on smooth bark of *Fagus* and *Acer pseudoplatanus* in S and E part of the reserve and managed mixed forest (JM/3140; ZP/13770, 13884, 14532)

Bacidia rosella (EN) – 1; collected once on bark of old *Acer platanoides* in S part of the reserve (JM/3487)

Bacidia rubella (VU) – 1, 2; scattered, on bark of *Fagus*, *Acer platanoides* and *Ulmus* (JM/2077; ZP/14554)

Bacidia subincompta (VU) – 1, 2; scattered, on bark of *Fagus*, *Ulmus*, *Acer pseudoplatanus*, and *Aesculus hippocastanum* (JM/3593; ZP/13604, 14400, 14720)

Bacidia vermifera (CR) – 1; recorded once on *Fagus* in SE part of the reserve (ZP/13907)

Bacidina chloroticula (LC) – 9, 30, 33, 38; on hard wood of stumps of *Picea* and *Fagus* (JM/1977, 2819, 2975; ZP/13107, 13157, 13871)

Bacidina inundata (VU) – 1; rare, on granite stones in the brook (JM/2682)

Bacidina neosquamulosa (DD) – 2; recorded once on solitary *Ulmus* (ZP/13614)

Bacidina phacodes (EN) – 1; on weathered bark of *Fagus* (JM/3587, 5448; ZP/13189, 14644)

Bacidina sulphurella (LC) – 1; frequent on decaying bryophytes, wood and bark (JM/3490; ZP/12798, 13171, 13780, 14418, 14524, 14545, 14589, 14676)

Baeomyces rufus (LC) – 1, 9, 10, 14, 34, 37, 38, 39; frequent on soil and siliceous stones, rarely found on stump and exposed roots

Biatora albohyalina (EN) – 1; recorded several times on smooth bark of *Fagus* (JM/2072; ZP/13161, 14534, 14570)

Biatora chrysantha (VU) – 1, 2, 7, 10, 12, 14, 22, 25, 27, 34; especially on bryophytes at bases of *Fagus*, scattered in the reserve (JM/1951, 1962, 2703; ZP/13221, 13707, *13889, 14391, 14394)

Biatora efflorescens (VU) – 1, 2, 5, 10, 12, 14, 22, 25, 27, 34, 35; common on smooth bark of *Fagus* in old-growth forest, but recorded also on bark of a conifer snag; scattered in beech forests surrounding the reserve (JM/1956, 2004, 2990; ZP/12797, 13154, 13865, 14549, *14695, 14757)

Biatora fallax (EN) – 1, 2, 12, 16, 28, 34, 35; on bark and bryophytes (mainly at bases) on trees and snags of *Fagus* and *Picea*, local in the reserve and scattered in old managed beech forests (JM/1989, 2062, 2838, 2844; ZP/14641, 14655, 14728, *14740); previously published both within and outside the reserve by PEKSA et al. (2004)

Biatora globulosa (VU) – 1, 2, 34; local, on bark of *Acer pseudoplatanus* and *Ulmus* (JM/2810, 3141, 3527, 3558; ZP/14357, 14583)

Biatora helvola (EN) – 1, 7; scattered on bark of *Fagus* (JM/2005, 2041; ZP/14562)

Biatora ligni-mollis T.Sprib. & Printzen (!) – 1; recorded three times both on hard and soft wood, as well as bark of *Abies* and *Picea* in wetland areas of the reserve (ZP/13577, 13706, *14609)

Biatora mendax (CR) – 1; recorded once on bark of *Fagus* in S part of the reserve (ZP/14731)

Biatora ocelliformis (EN) – 1; scattered on bark of *Fagus*, once collected on a planted *Fraxinus* (JM/1987, 3492; ZP/12804, 14156, 14557, 14571)

Biatora veteranorum (EN) – 1, 10, 21; frequent on wood and bark of *Abies* and *Picea* in the old-growth forest where frequently with apothecia, recorded twice outside the reserve on wood of decaying stumps (JM/2679, 2847, 2973, 2984, 5450; PRC; ZP/13712, 13909, 14375, 14753)

Biatoridium monasteriense (VU) – 1; scattered on weathered bark of *Fagus* and *Ulmus* (JM/1995, 3504; ZP/14457)

Bryoria capillaris (CR) – 1, 40; abundant on branches of *Picea* (JM/*2691, *3418, 3522)

Bryoria fuscescens (VU) – 1, 2, 13 (cf.), 38; rare, on *Picea abies* (JM/*3581)

Bryoria implexa s.str. (EN) – 1, 40; chemotype with psoromic acid, abundant on branches of *Picea* (JM/*2692, *3498, *3515, *3521)

Buellia disciformis (VU) – 15, 20; on bark of *Fagus* (ZP/13130, 13212)

Buellia erubescens (CR) – 1, 20; scattered on bark of *Fagus* (JM/1983, 2674, 3555; ZP/12803, 13213)

Buellia griseovirens (LC) – 1, 2, 5, 10, 12, 14, 15, 20, 22, 25, 27, 30, 34–36; common on bark of deciduous trees, especially on *Fagus* (ZP/13182)

Buellia schaereri (VU) – 1; collected once on bark of old *Picea* in E part of the reserve (ZP/14679)

Calicium glaucellum (NT) – 1; found once on wood of *Picea* snag in valley of a brooklet in W part of the reserve (ZP/14595)

Calicium salicinum (VU) – 1, 7, 30; mainly on wood (deciduous trees as well as conifers), also on bark (*Fagus* and *Ulmus*), scattered in the reserve (JM/2043, 3513)

Calicium viride (VU) – 1; scattered on bark of *Fagus*, *Abies*, *Ulmus* and *Acer pseudoplatanus* (JM/3136)

Caloplaca cerinella (VU) – 1; recorded once on bark of old *Fagus* in a well-lit site in S part of the reserve (ZP/14548)

Caloplaca chrysodeta (NT) – 1; recorded once on dry bark of old *Fagus* (JM/1984; ZP/13165)

Caloplaca lucifuga (EN) – 1; recorded once on bark of *Ulmus* (ZP/14698)

Caloplaca obscurella (NT) – 2; on bark of *Acer platanoides* and *A. pseudoplatanus* (JM/1973; ZP/12806)

[*Candelariella efflorescens* s.l. – 1, 2, 12, 25, 31, 41; on fallen branch of *Fagus* and bark of *Acer pseudoplatanus*, *Fagus*, *Fraxinus* and *Sambucus racemosa* (ZP/13864); sterile sorediate specimens may belong in part or all of them to *C. xanthostigmoides*)]

Candelariella subdeflexa (DD) – 2; on bark of *Ulmus* (JV/7918)

Candelariella vitellina (LC) – 2 [PEKSA et al. 2004: 293]

Candelariella xanthostigma (LC) – 1, 2; in the primeval forest recorded only once on bark of well-lit *Fagus*

Candelariella xanthostigmoides (Müll. Arg.) R.W. Rogers (!) – 2; on bark of *Acer pseudoplatanus* (ZP/15669 – det. M. Westberg)

Catillaria nigroclavata (VU) – 2; on bark of *Acer pseudoplatanus* (ZP/15669 – with *Candelariella xanthostigmoides*)

Catinaria atropurpurea (EN) – 1, 2, 14, 30; on hard decaying wood and bark of *Acer platanoides* (JM/2986, 3597; ZP/13800 – with *Gyalideopsis helvetica*, ZP/15689)

Cetrelia cetrarioides (EN) – 1, 27; at one site in the primeval forest on *Acer pseudoplatanus* together with *Lobaria pulmonaria*, one small thallus on bark of old *Fagus* outside the reserve (JM/*2801, *3540; ZP/*14068)

Cetrelia monachorum (DD) – 1; scattered in the primeval forest on mossy bark and thick branches of *Fagus*, both standing and broken lying trunks (JM/*2073, *3553; ZP/*12762, *12954, *13801)

[***Cetrelia olivetorum*** (DD) – this taxon in a strict sense was not confirmed for this area, specimens published by PEKSA et al. (2004) deposited in PRC refer to *C. cetrarioides*]

Chaenotheca brachypoda (VU) – 1, 35; scattered on wood of dead trunks (JM/1991, 2000, PRC)

Chaenotheca brunneola (NT) – 1, 10; rare on stumps and snags of *Abies* and *Picea* (JM/3582; ZP/13705, 13755)

Chaenotheca chlorella (EN) – 1; scattered on dead trunks and snags of *Fagus* and *Abies* or on bark of *Ulmus* (JM/2003, 3589; ZP/13167)

Chaenotheca chrysocephala (NT) – 1, 2, 4, 9, 12, 28, 30, 34, 35; especially on bark of *Picea*, rare also on deciduous trees (e.g. *Ulmus*) (JM/2846)

Chaenotheca ferruginea (LC) – 1, 2, 5, 8, 9, 12, 13, 18–20, 22–25, 28–30, 32, 34–38; common, especially on bark of *Picea*, also on wood, dry twigs and exposed roots of wind-blown tree (spreading onto soil) (JM/2999, PRC)

Chaenotheca furfuracea (LC) – 1, 34; common in the reserve, usually on very bases of various trees as well as exposed roots of wind-blown trees, often spreading onto detritus and soil (JM/3145)

Chaenotheca sphaerocephala (CR) – 1; recorded twice on shaded bark at base of old *Abies*, in boggy sites in NW part of the reserve and in the valley of Tisový brook near N border of the reserve (JM/3531; ZP/14405)

Chaenotheca stemonea (VU) – 1; recorded on bark of *Ulmus*, dead trunk of *Fagus* and as a sterile thallus at foot of old *Picea* (JM/3511; ZP/*13704)

Chaenotheca trichialis (NT) – 1, 16, 32; on dead wood and bark of various trees (JM/2842)

Chaenotheca xyloxena (VU) – 1, 7, 30; in the reserve scattered on dead wood, mainly on snags (JM/3543; ZP/13725)

#Chaenothecopsis viridireagens (Nádv.) Alb.Schmidt – 1; on dry wood of *Picea* stump (ZP/13705 – with *Chaenotheca brunneola*)

Cheiromycina flabelliformis (DD) – 1; on bark of *Fagus* near Tisový brook, only a few sporodochia intermingled within the sample of *Biatora ocelliformis* (ZP/14571); the species was previously reported outside the reserve from bark of *Fraxinus* (Peksa et al. 2004)

Chrysothrix candelaris (VU) – 1, 2; scattered on *Abies* and *Fagus*, in the Žofín settlement on *Quercus robur*

Cladonia cenotea (LC) – 1, 9, 24, 27, 30, 36, 37; on bases of *Picea*, rare on stumps and decaying trunks (JM/3557)

[***Cladonia chlorophaea*** s.l. (LC) – 1, 6, 10, 14; on bases of trees, stumps and soil]

Cladonia chlorophaea s.str. (LC) – 1; on decaying wood of lying trunk (ZP/*14653)

Cladonia coniocraea (LC) – 1, 2, 3–38; very common, especially on bases of trees, stumps, decaying trunks and soil (ZP/13169, 14047)

Cladonia digitata (LC) – 1, 4–6, 8–10, 12–15, 20, 22–38; very common in similar habitats as *C. coniocraea* (JM/2968)

Cladonia fimbriata (LC) – 1, 3–6, 8–10, 12–15, 18–20, 23–33, 35–38; common in similar habitats as *C. coniocraea* (ZP/14750)

Cladonia furcata (LC) – 1; recorded once in the reserve

Cladonia floerkeana (LC) – 38; on base of *Picea* (JM/1966)

Cladonia macilenta (LC) – 1, 4, 6, 8, 9, 24, 31, 33, 36, 37; on bases of trees, stumps and soil

Cladonia merochlorophaea (DD) – 9, 23; on stump and base of *Picea* (JM/*1953, *2996; PRC)

Cladonia norvegica (VU) – 1, 3, 8, 9, 12–14, 18–20, 23, 24, 26–29, 32, 36–38; common in spruce and spruce-beech forests on decaying wood and bases of trees, quite a rare species in the reserve (JM/1954, 2057; PRC; ZP/13236)

Cladonia ochrochlora (LC) – 1, 14; rare on bases of trees, usually not distinguished from *C. coniocraea* (JM/3538 – rev. T. Ahti)

Cladonia squamosa (LC) – 1, 13, 14; on wood and bark of *Picea*, on base of *Fagus* and on stumps (JM/2985 – det. T. Ahti; ZP/*13903, 14314)

Cliostomum leprosum (Räsänen) Holien & Tønsberg (!) – 1; recorded at two microlocalities in SW and W part of the reserve, on dry bark of both living trees and snags of *Abies*, material fertile (one specimen with apothecia and pycnidia, another one with pycnidia) (ZP/14531, 14544)

Coenogonium pineti (LC) – 1, 2, 3, 5, 8–19, 21, 22, 24–32, 34–37; very common on various types of acidic bark and decaying wood (ZP/12789, 13723, 13727, 13778, 13919, 14052)

#*Cryptodiscus foveolaris* (Rehm) Rehm – 10; a lichen-allied fungus; on wood of fallen branch of *Fagus* (ZP/13937)

#*Cyrtidula hippocastani* (DC.) R.C.Harris – 5; a lichen-allied ascolocular fungus; on smooth bark of *Fagus* (ZP/13920)

Dictyocatenulata alba (DD) – 1, 12, 14, 27; a synnematous lichenized hyphomycete; at very bases of *Fagus*, scattered in the old-growth forest and managed beech forests (JM/1985; ZP/12761)

Elixia flexella (DD) – 1; on soft wood of snag of *Picea* (ZP/14615)

Enterographa zonata (VU) – 1; on vertical to overhanging shaded surfaces of granite boulder within the forest (ZP/*14747)

#***Epigloea* cf. *renitens*** (Grumm.) Döbb. – 1; a lichen-allied algicolous fungus, on slowly decaying wood of lying trunk of a conifer in a well-lit place; the ascospores are somewhat broader than reported for this species (ZP/14348)

Evernia divaricata (CR) – 1; collected once on fallen twig of *Abies* (?) in NW part of the reserve in the area of small wetland with predominating firs (JM/3517)

Evernia prunastri (NT) – 1, 2, 25; on bark of various deciduous trees

Fellhanera bouteillei (CR) – 1, 40; scattered in humid microsites on needles and twigs of *Picea*, abundant in the valley of Tisový brook, outside the reserve along the road to the Žofín settlement (JM/2693, 3146, 3497; PRC; ZP/13585, 13637, 14072)

Fellhanera gyrophorica Sérus., Coppins, Diederich & Scheid. (!) – 1; recorded once on bark at base of old *Picea* in NE part of the reserve (ZP/13160); since the specimen is rather small the presence of gyrophoric acid was tested by spot C reaction

Fellhanera subtilis (NT) – 1; on decaying wood of a conifer (ZP/14622)

Fellhaneropsis vezdae (VU) – 1, 36; in old-growth forest a common pioneer on bark and wood of various trees in humid and shaded microsites (*Acer pseudoplatanus*, *Fagus*, *Picea*, *Ulmus*), switching also to decaying bryophytes, usually forming only pycnidia (JM/1988, 2006, 2822, 2979; ZP/12795, 13162, 13172, 14316, 14339, 14412, 14564, 14683, 14713, 14738)

Flavoparmelia caperata (EN) – 2; on bark of *Quercus*

Fuscidea arboricola (DD) – 12, 14; on bark of *Fagus* (JM/*2991; ZP/*13934)

Fuscidea pusilla Tønsberg (!) – 29; on bark of *Picea* (JM/*1958)

Graphis scripta s.l. (VU) – 1, 5, 7, 10–12, 14–16, 20, 22, 25, 27, 30, 34–36; common on bark of *Fagus*, rare on *Acer pseudoplatanus* and *Fraxinus*, in primeval forest recorded once on bark at base of old *Picea* (JM/2050; ZP/14646, 14737)

Gregorella humida (Kullh.) Lumbsch – 39; recorded as sterile thallus on acid soil (ZP/14284)

Gyalecta fagicola (Hepp) Kremp. [syn. *Pachyphiale fagicola*] (EN) – 2; on bark of *Acer platanoides* (ZP/12799; JV/10116)

Gyalecta flotowii (CR) – 1; scattered in the reserve, on weathered bark of old *Fagus*, *Acer platanoides* and *Ulmus* (JM/1997, 3548; PRC; ZP/13163, 13183, 14523, 14654, 14694)

Gyalecta truncigena (CR) – 2; recorded once on the weathered bark of *Acer platanoides* (ZP/15547)

Gyalideopsis helvetica (DD) – 1, 20; rare on decaying wood (JM/*1960, 2087; PRC; ZP/13800)

Halecania viridescens (DD) – 2, 31; on smooth bark of deciduous trees (*Acer pseudoplatanus*, *Fagus*, *Fraxinus*, *Ulmus*) in well-lit sites (JM/2814; ZP/15667)

Hypocenomyce caradocensis (LC) – 1, 8, 9, 12, 13, 20, 24, 28–30, 32, 35–38; common on *Picea* in well-lit spruce forests

Hypocenomyce scalaris (LC) – 1, 2b, 3–5, 8–10, 12, 13, 15, 20, 24, 25, 27–31, 33–38; common on wood and bark, especially on *Picea* (ZP/13103)

Hypogymnia farinacea (VU) – 1* [JANSOVÁ & SOLDÁN 2006: 76]; the phytosociological relevé record by JANSOVÁ & SOLDÁN (2006) is surprisingly the only known report of the species from the reserve. In Novohradské hory Mts it was recorded from two additional localities, on bark of deciduous trees in managed forests (PEKSA et al. 2004).

Hypogymnia physodes (LC) – 1, 2, 3–10, 12–38, 40; very common on various trees

Hypogymnia tubulosa (NT) – 1, 2, 25, 40; in the old-growth forest mainly on twigs of *Picea*

Hypogymnia vittata (EN) – 1; on bark of *Picea* (ZP/14275)

Icmadophila ericetorum (EN) – 1; recorded rarely on a strongly decaying stump of a conifer (JM/3556, ZP/13754)

Jamesiella anastomosans (DD) – 1, 5, 12, 18; scattered on decaying wood, twigs of *Picea* and base of *Fagus*, also on wooden fence, usually only with thlasidia (JM/2064, 2659; PRC; ZP/12855, 13720, 13751, 14063, 14066, 14333, 14369)

Japewia subaurifera (NT) – 1; on wood of *Picea* branch (ZP/14451)

#***Kirschsteiniothelia aethiops*** (Berk. & M.A.Curtis) D.Hawksw. – 1; a non-lichenized saprophytic corticolous species, recorded once on shaded bark of *Ulmus* (ZP/14714, rev. A. Aptroot)

#***Kirschsteiniothelia recessa*** (Cooke & Peck) D.Hawksw. (!) – 1; recorded twice on bark of *Abies* (ZP/13789, 14329 – det. A. Aptroot)

Lecanactis abietina (EN) – 1, 38; frequent on bark at bases of *Picea* and *Abies*, rare on *Fagus* (JM/1992, 3530; PRC; ZP/13741)

Lecania croatica (ZAHLBR.) KOTLOV (!) – 1; collected several times on bark of *Fagus* and *Acer pseudoplatanus*, sterile (JM/*2672, *2982, *3139, 5475; ZP/*14558)

Lecania cyrtella (LC) – 31, 35, 41; on bark of *Fraxinus*, *Fagus* and *Sambucus racemosa* (JM/2831)

Lecania naegelii (NT) – 31, 38, 41; on bark of *Fraxinus*, *Sambucus racemosa* and wood of stump of a conifer (ZP/13157 – with *Bacidina chloroticula*)

Lecanora albella (EN) – 1, 2, 14, 20; rare on bark of *Fagus* (JM/1968, 2075, 2992; ZP/13782)

Lecanora argentata (NT) – 1, 2, 5, 7, 10, 12, 14, 15, 20, 22, 25, 27, 30, 34, 35; common especially on bark of *Fagus* (JM/1961, 1963, 1969, 1972, 1980, 2080, 3489; ZP/13912, 14648)

Lecanora carpinea (NT) – 1, 2, 21, 25 (cf.); on branches of *Fraxinus* and *Fagus* (JM/2680)

Lecanora chlarotera (LC) – 21, 31; on *Fraxinus* (JM/2815, 2853); records by PEKSA et al. (2004) from virgin forest and the Žofín settlement are incorrect and refer to *L. argentata*

Lecanora compallens (DD) – 1; recorded on bark of *Fagus* and hard wood of *Picea* snag (JM/*2079; ZP/*13941)

Lecanora conizaeoides (LC) – 1, 2, 3, 5, 7–10, 12–16, 18–38; very common on various organic acidic substrates (mainly on twigs), scattered in the old-growth forest (ZP/13732, 13779, 14424)

Lecanora expallens (LC) – 1, 2, 5, 10, 14 (cf.), 25, 30 (cf.), 34; mostly on bark of *Fagus* and *Abies*, rare on wood of standing dead trunks and snags (JM/*3486, *3495; PRC; ZP/*13577 – with *Biatora ligni-mollis*, *14656)

Lecanora filamentosa (VU) – 38; on the rootplates of wind-blown *Picea* (ZP/13176)

Lecanora glabrata (DD) – 5; on bark of *Fagus* (JM/*2965)

Lecanora intumescens (VU) – 1, 14, 25, 35, 36; rare on bark of *Fagus* (JM/1981, 2820, 2829, 2834; PRC; ZP/*14533)

Lecanora leptyrodes (DD) – 31; on bark of *Fraxinus* (JM/2816)

Lecanora persimilis (NT) – 21, 31, 41; on bark of *Fraxinus excelsior*, *Sambucus racemosa* and *Sorbus aucuparia* (JM/2852)

Lecanora phaeostigma (DD) – 1; on wood of *Picea* snag (ZP/14607)

Lecanora pulicaris (LC) – 1, 5, 10, 11 (cf.), 12, 14, 16, 23, 25, 27, 30, 31, 33, 34, 36–38; common especially on bark of *Fagus*, rare in the reserve (JM/1970, 2059, 2665)

[*Lecanora saligna* s.l. (LC) – 10, 31; on dead wood and twigs (JM/2811)]

Lecanora saligna s.str. (LC) – 1, 30; on bark of *Picea* and wood of *Fagus* snag (JM/3529; ZP/*13878)

Lecanora sarcopidoides (DD) – 1, 38; on hard wood of a stump and on bark of *Picea* and *Abies* in the old-growth forest, on exposed roots outside the reserve (JM/1957; ZP/13156, 13173, 13732 – with *Lecanora conizaeoides*, *13785)

Lecanora symmicta (NT) – 38; on the rootplates of wind-blown *Picea* (ZP/13153)

Lecanora thysanophora R.C.Harris (!) – 1; scattered on bark of *Fagus* (JM/*2683; ZP/12860, *13344, *13345, *14539)

Lecidea ahlesii (Körb.) Nyl. – 1; on intermittantly inundated stones in the bedrock of Tisový brook, (JM/3537; ZP/14659)

Lecidea huxariensis (DD) – 33; on hard wood of the stump of *Picea* (JM/2818)

Lecidea leprarioides (EN) – 1; recorded on wood and bark of *Picea* and *Abies* (JM/3496, ZP/13195, *14603)

Lecidea lithophila (NT) – 1; on half-shaded granite boulder in forest and on wet granite stone in bedrock of the Tisový brook (ZP/*14661 (cf.), *14366 (cf.), 14395)

Lecidea nylanderi (VU) – 1, 9, 10, 12–14, 20, 22, 24, 25, 27, 30, 34–38; frequent, especially on bark of *Fagus* and *Picea* (JM/1946, *1967, *2078, 2085; ZP/*12765 – det. T. Tønsberg, *13877, 14051, *15671, *15683)

Lecidea pullata (NT) – 10, 20, 23; rare on bark of *Fagus* and on bark of the stump of *Picea* (ZP/*13870)

Lecidea sanguineoatra (EN) – 1; over mosses at the base of *Fagus* in E part of the reserve (JM/3552; JV/7914)

Lecidea turgidula (VU) – 1; recorded once on wood of *Picea*, closely associated with *Lecidea leprarioides* (ZP/*14603)

Lecidella elaeochroma (NT) – 1, 2, 5, 7, 14, 15, 20, 22, 25, 31, 35; scattered in beech forests on bark of *Fagus*, in the reserve recorded once on *Ulmus* (JM/2817; ZP/13928 – as *L. achristotera*, 14352)

Lecidella flavosorediata (VU) – 2, on bark of solitary *Acer platanoides* and *Acer pseudoplatanus* (ZP/15669 – with *Candelariella xanthostigmoides*)

Lecidella subviridis Tønsberg (!) – 10, 15, 16, 30; recorded four times in managed forests, on bark of *Fagus* (JM/*2060, *2977; ZP/*13168, *13885)

[***Lepraria* sp.** – 1–38; very abundant on various substrates]

Lepraria ecorticata (DD) – 1; on bark of various trees (JM/*2663, *3584, *3505)

Lepraria incana (LC) – 1, 2, 23; common on various substrates (JM/*1959, *3580; ZP/*14675, *14736)

Lepraria jackii (LC) – 1; on bark of *Abies* (JM/*3518)

Lepraria lobificans (LC) – 1, 2, 11, 16; very common on various substrates, under recorded (JM/*3508; ZP/*14417, *14520, *14722)

Lepraria rigidula (LC) – 1, 2; on mossy trunks of *Fagus* (ZP/*14387, *14739)

Lepraria vouauxii (LC) – 2 [PEKSA et al. 2004: 294]

Leptogium teretiusculum (EN) – 1; a small fragment of thallus at base of *Fagus* in E part of the reserve (ZP/13728 – rev. A. Guttová)

Lichenomphalia umbellifera (LC) – 1, 13, 24, 29, 31, 37; frequent on moribund wood of decaying stumps (ZP/14036)

Lobaria pulmonaria (CR) – 1; only one thallus recorded on *Acer pseudoplatanus* on the bank of the Tisový brook near N border of the reserve

Lopadium disciforme (EN) – 1, 35; frequent in the reserve on both younger and older *Fagus* trees, rare on bark of other trees (*Acer pseudoplatanus*, *Ulmus*, *Picea*/*Abies*) at humid microsites, often sterile (JM/1979, 3512; PRC; ZP/13164, 14516, 14669)

Loxospora elatina (VU) – 1, 5, 12, 25, 27, 30, 34, 35; scattered on bark of *Fagus* and *Picea*/*Abies* (JM/*2007, 2667, 2802; ZP/*13873, *13888)

Macentina abscondita (LC) – 1, 2; on weathered bark of *Fagus* and *Acer platanoides* (ZP/15678)

Macentina dictyospora (LC) – 1, 12, 16; on weathered bark of *Fagus* and *Picea*, and on decaying wood (JM/2055; ZP/13735, 13902, 14526)

Melanelixia glabratula (Lamy) Arup & Sandler [syn. *M. fuliginosa* p.p. max.] (LC) – 1, 2, 5, 7, 12, 14–16, 20–22, 25, 27, 30, 31, 34, 35; common, especially on bark of *Fagus* (ZP/14732)

Melanelixia subargentifera (VU) – 2 [PEKSA et al. 2004: 295]

Melanelixia subaurifera (VU) – 2; on bark of *Acer platanoides*

Melanohalea exasperatula (LC) – 2; on branch of *Quercus robur*

Menegazzia terebrata (CR) – 1; rare in the reserve in its E part, recorded on bark of *Fagus* (6 trees) and *Acer pseudoplatanus* (1 tree) (JM/3554; ZP/14724)

Micarea adnata (CR) – 1, 24, 28, 29; on bark at bases of *Picea*, *Abies* and rarely on *Fagus*, also on strongly decaying wood at humid microsites of the reserve, few times recorded on bark of younger trees in managed spruce forests (JM/2662, 2670, 2786, 2845; PRC; ZP/13210, 13757, 13765, 14048, 14688, 14716)

Micarea botryoides (LC) – 1; collected once on dry sheltered wood of rootplates of wind-blown tree, fertile! (ZP/14758)

Micarea byssacea (DD) – 29; on decaying wood of lying *Picea* trunk (ZP/*13240)

Micarea cinerea (RE>CR) – 1; collected twice on wood near the brook, recorded once on bark of *Fagus* in N part of the reserve (JM/3586, 3592; PRC; ZP/14125)

Micarea denigrata (LC) – 4, 9, 10, 14, 20, 30, 31, 36, 38; mainly on hard desiccated wood, single records from bark and fallen branch of *Fagus* and on the rootplate of wind-blown tree (ZP/13190, 13193, 13217, 13925, 14064)

Micarea hedlundii (EN) – 1; recorded several times on moribund wood of conifers in N part of the reserve (JM/2008; ZP/12940, 14704)

Micarea lithinella (LC) – 1; on recently exposed granite stones, collected once on by soil impregnated roots of dead *Fagus* (ZP/13714, 14358, 14367)

Micarea lutulata (VU) – 1; on overhanging granite stone by the Tisový brook (ZP/14370 – with *Micarea sylvicola*)

Micarea melaena (LC) – 1; found twice on decaying wood of stump of *Abies* and exposed roots of *Picea* (JM/3590; ZP/13930)

Micarea micrococca (LC) – 1, 3, 5, 8–12, 15, 17–20, 22, 24–29, 30–38; one of the most common lichens especially on decaying wood, as well as on bark and branches/twigs of *Picea* and *Fagus* (JM/*2038, *2045, *2056, 2661, 2673, 2789, 2796; ZP/12764, 12783, *13129, *13890, 13895, 13916, 14406)

Micarea misella (LC) – 1, 4, 9, 10, 13, 14, 20, 27, 30, 31, 36–38; common on decaying wood, often without apothecia (JM/2009, 2791, 2970, 3003, 3524; PRC; ZP/12805, 13220, 13222, 13253, 13777, 13868, 13899, 14445, 14709)

Micarea myriocarpa (NT) – 1; recorded once on soil impregnated roots of wind-blown *Picea* in the valley of Tisový brook (JM/3532; ZP/14759)

Micarea nigella (DD) – 1, 11, 13; on decaying soft wood of *Picea* and *Abies* (JM/2067; ZP/13718, 13769, 13784, 13933, 13938, 14328, 14342)

Micarea parva Coppins (!) – 1; on freshly exposed granite stone beneath a wind-blown tree in central part of the reserve (ZP/14322)

Micarea peliocarpa (LC) – 1, 24; recorded several times on decaying wood and on bark of *Fagus* (JM/2787, 3591; ZP/*13258, 13856)

[***Micarea prasina*** s.l. (LC) – 1–38; very common on decaying wood, bark and twigs]

Micarea prasina s.str. (LC) – 1, 21; on decaying (often strongly moribund) wood and on bark of older trees (rarely), rather common in the virgin forest, certainly collected only once in a managed forest, nevertheless many of the field records filed as *M. prasina* s.l. may belong here (JM/*2848, *3528, *3598, *5449; ZP/*12942, *13234, 13240, *13730, *13731, 13750, *13758, *13764, *13798, *13875, 14686, 14707, 14726)

Micarea sylvicola (LC) – 1, 10; common on siliceous stones near ground, also on shaded bark and slowly decaying wood (JM/2681, 3149; ZP/13177, 13715, 13896, 14370, 14431, 14605)

Micarea synotheoides (CR) – 1; recorded once on bark of young *Fagus* in E part of the reserve (ZP/13768)

Micarea viridileprosa (NT) – 26; on decaying trunk (JM/2056)

#Microcalicium ahlneri Tibell – 1; on dead wood of *Fagus* (OP/s.n.)

#Microcalicium arenarium (Hampe ex A.Massal.) Tibell – 1; on roots, parasitic on thallus of *Psilolechia clavulifera* (JM/3526; ZP/14536)

#Microcalicium disseminatum (Ach.) Vain. – 1; on bark of *Abies* (JM/2843; ZP/15624)

#Mniaecia nivea (P.Crouan & H.Crouan) Boud. – 1; associated with decaying *Riccardia* sp. and other liverworts on moribund wood of a conifer trunk (ZP/12787)

Multiclavula mucida (EN) – 1, 5, 8, 9, 38; on wet, strongly decaying wood of *Picea* and *Fagus*, scattered in the virgin forest as well as in managed forests (JM/1978, 2054, 2076, 2998; PRC; ZP/13043)

Mycobilimbia pilularis (Körb.) S.Ekman & Printzen (!) – 1; recorded once on nutrient rich bark of *Fagus* on margin of a boggy microsite in central part of the reserve (ZP/14535)

#Mycocalicium subtile (Pers.) Szatala – 1, 4; on wood of stump of *Picea* (JM/2969; PRC)

Nephromopsis laureri (CR) – 1; found twice on twigs of *Picea* along the Tisový brook (JM/3583)

Ochrolechia androgyna (VU) – 1, 2, 14, 25, 27, 30, 35; on bark of *Fagus*, *Picea* and *Abies*, abundant in the old-growth forest; following the new taxonomy of *Ochrolechia androgyna* s.l. by KUKWA (2011) our specimens belong to *O. androgyna* s.str. (= chemotype B sensu TØNSBERG 1992) (JM/*1990, *2685, *2690, 2797; ZP/*13803)

Ochrolechia microstictoides (VU) – 1, 18, 38 (cf.); on bark of *Fagus* and wood or bark of *Picea* (JM/*2066, *3519; ZP/13847)

Ochrolechia turneri (VU) – 2; on bark of *Acer pseudoplatanus* (JM/*3551)

Opegrapha niveoatra (NT) – 1, 34; on bark of *Acer pseudoplatanus*, *Fagus*, *Ulmus* and old *Picea*, quite frequent in the reserve (JM/2070, 2809, 2837, 3143; ZP/12790, 14313, 14538, 14568, 14639, 14651, 14657, 14680, 14705, 14744)

Opegrapha rufescens (VU) – 1; on bark of *Fagus* (JM/2678)

#*Opegrapha thelotrematis* Coppins – 1; on thallus of *Thelotrema lepadinum* (FBe/26774)

Opegrapha trochodes Coppins, F.Berger & Ertz (!) – 1; scattered on shaded and weathered bark of *Fagus* trunks and snags, also on *Ulmus* and *Acer pseudoplatanus* (JM/2664, 3545; ZP/13763, 14519, 14551, 14608, 14708)

Opegrapha varia (NT) – 1, 2, 35; on dry bark of *Fagus*, *Acer platanoides* and *Ulmus*, also on wood and bark of snags, rather frequent in the reserve (JM/1999, 2002, 2830, 3514; ZP/13159, 13188, 14521, 14677, 14743)

Opegrapha vermicellifera (VU) – 1; recorded on wood of *Fagus* snag and at the base of a living *Ulmus* (ZP/13152, 14647)

Opegrapha viridis (EN) – 1, 22; very rare on bark of *Fagus*, in the SE part of the reserve (JM/1965; ZP/13911)

[*Opegrapha vulgata* s.l. (NT) – 22, 30, 35; noted mostly on bark of *Fagus*; *O. vulgata* s.str. probably does not grow in the study area, all collected specimens tentavily assigned to *O. vulgata* s.l. belong to *O. niveoatra* and the same will hold true very likely for the field records]

Parmelia saxatilis (LC) – 1, 2, 14, 22, 25, 27, 30, 35, 36; rather common on bark of *Fagus*, in the reserve also on other phorophytes; we did not distinguish *Parmelia ernstiae* which was recorded in the reserve by PEKSA et al. (2004)

Parmelia submontana (EN) – 1; recorded once on fallen trunk of *Fagus*

Parmelia sulcata (LC) – 1, 2, 5, 10, 21, 25; mostly on branches of *Fagus*

Parmeliopsis ambigua (LC) – 1, 2, 5, 7, 9, 10, 12, 14, 15, 16, 20, 22, 25, 27, 30, 34–36, 38; common especially on *Fagus* and *Picea* (JM/2995)

Parmeliopsis hyperopta (NT) – 1, 6, 9, 10, 12, 14, 30; on bark of *Picea* and *Fagus* (JM/2997)

Peltigera canina (VU) – 1; collected once on dead lying trunk above a small brook (JM/3588)

Peltigera degenii (VU) – 1; scattered on bases and dead lying trunks of *Fagus* (JM/2684, 3137, 3534; ZP/13804)

Peltigera didactyla (LC) – 2, 38; on soil (ZP/13146)

Peltigera horizontalis (EN) – 1, 7; at bases of *Fagus* and lying trunks (JM/2049, 3138; PRC)

Peltigera neopolydactyla (EN) – 1; recorded at humid microsites on decaying lying trunks, bases of trees and boulders covered by bryophytes (ZP/13721, 13781, 14361, 14540)

Peltigera polydactylon (VU) – 1; recorded once on dead lying trunk (JM/2688)

Peltigera praetextata (NT) – 1, 35; in the reserve relatively frequent at bases of *Fagus* trees and lying trunks (JM/1994, 1996, 2827; ZP/13708, 14612)

#*Peridiothelia fuliguncta* (Norman) D.Hawksw. – 1; recorded once on weathered bark of *Fagus* (ZP/13719 – det. A. Aptroot)

Pertusaria albescens (NT) – 2; on bark of *Acer platanoides*

Pertusaria amara (NT) – 1, 2, 14, 20, 25, 27, 30, 34–36; mostly on bark of *Fagus* (JM/1976; ZP/14543)

Pertusaria coccodes (VU) – 1, 2, 14, 20, 30, 34, 35; on bark of *Fagus* and *Fraxinus* (JM/1975, 2840, 3579; ZP/*14577)

Pertusaria constricta (CR) – 1, 5; collected twice on bark of *Fagus* (JM/2677; ZP/*13892)

Pertusaria coronata (VU) – 1, 5, 7, 22, 25; on bark of *Acer pseudoplatanus* and *Fagus* (JM/1964, 2040, 3594; ZP/14273, 14334, *14512)

Pertusaria hymenea (EN) – 1; collected twice on bark of *Fagus* in S part of the reserve (ZP/13927, 14518)

Pertusaria leioplaca (VU) – 1, 5, 15, 20, 22, 25, 34 (cf.), 35; scattered on *Fagus* (JM/2836, 2841, 3585; ZP/13216, 13219)

Pertusaria pertusa (EN) – 1, 5, 7; rare, on smooth bark of *Fagus* (JM/2042, 3488; ZP/13749, *13904, 14530, 14550, 14733)

Pertusaria pupillaris (VU) – 1, 27, 30; rare on bark of *Fagus* and *Abies* (JM/2800, 3533; ZP/13924, *14610)

Phaeophyscia endophoenicea (EN) – 1, 2, 15, 35; rare on bark of *Fagus* in the old-growth forest and in well-lit beech forests and avenues (JM/3509; ZP/14555; JV/10117)

Phaeophyscia nigricans (LC) – 2; on bark of *Acer pseudoplatanus* (ZP/15669 – with *Candelariella xanthostigmoides*)

Phaeophyscia orbicularis (LC) – 2, 14; on bark of *Acer platanoides*, *A. pseudoplatanus* and on base of *Fagus*

#Phaeopyxis punctum (A.Massal.) Rambold, Triebel & Coppins – 1; on thallus of *Cladonia coniocraea* and *C. digitata* on decaying wood of *Picea*/*Abies* (ZP/14053; FBe/26773)

Phlyctis argena (LC) – 1, 5, 7, 20, 22, 25, 27, 34–36; especially on bark of *Fagus*, abundant in the reserve (JM/2081, *2088; ZP/13783)

Physcia adscendens (LC) – 2, 21 (cf.); on bark of *Acer pseudoplatanus* and *Fraxinus*

Physcia dubia (LC) – 2; on bark of *Acer pseudoplatanus*

Physcia stellaris (VU) – 2, 21; on branch of *Fraxinus* and *Acer pseudoplatanus*

Physcia tenella (LC) – 1, 2, 12, 31 (cf.), 35, 36, 41; on bark of *Fagus*, *Acer pseudoplatanus* and *Picea*

Physconia distorta (VU) – 2 [PEKSA et al. 2004: 295]

Physconia enteroxantha (VU) – 2; on bark of *Acer pseudoplatanus* (ZP/15608)

Physconia perisidiosa (VU) – 2; on bark of *Acer pseudoplatanus*

Piccolia ochrophora (NT) – 2; on bark of *Acer pseudoplatanus* (ZP/15669 – with *Candelariella xanthostigmoides*)

Placynthiella dasaea (LC) – 1, 3–16, 18–20, 22, 23, 27, 29, 30, 32, 37, 38; common on decaying wood, rare on bark of *Picea abies* and *Fagus* trees (JM/2039, *2669, 2792, *2798, *3596; ZP/13149, 13242, 13787, 13881, *13913, 13989, 13996, 14727; analysed samples det. T. Tønsberg)

Placynthiella icmalea (LC) – 1, 3–16, 18–39; very common on decaying wood and on bases of trees, noted once on freshly exposed siliceous stone near the ground (ZP/13184, 13192, 13238, 13762, 13964)

Placynthiella oligotropha (LC) – 6, 20, 23, 33, 39; on soil, especially on clear-cuts

Placynthiella uliginosa (LC) – 9, 10, 20, 27; rare on soil in open forests (JM/2793)

Platismatia glauca (NT) – 1, 2, 7, 9, 12–14, 22, 24–30, 32, 36–38; frequent on *Fagus* and *Picea*

Porina aenea (LC) – 1, 5, 7, 10–12, 14–16, 21, 22, 25, 31, 34–36; common especially on *Fagus*; in the reserve collected also on *Abies* (ZP/14331)

Porina chlorotica (LC) – 1; scattered on shaded siliceous rocks and stones (ZP/14613, 15666)

Porina leptalea (EN) – 1; scattered in the reserve on bark of *Fagus* (JM/2983, 5473; ZP/13922, 14619, 14645, 14725)

Porpidia aff. *crustulata* – 39; on small siliceous stones (JM/3502 – det. A. Jabłońska)

Porpidia macrocarpa (LC) – 1, 39; abundant on granite stones along the Tisový brook (JM/3151 – rev. A. Jabłońska, 3503 – det. A. Jabłońska; ZP/14572 (cf.), 14606)

Porpidia soredizodes (LC) – 1; on siliceous stones along the brook; the latter specimen richly fertile (JM/3150 – rev. A. Jabłońska; ZP/*14640)

Pseudevernia furfuracea (NT) – 1, 2, 3, 5, 7–10, 16, 17, 19, 23–26, 28, 29, 32, 34, 35, 37, 38, 40; a common species especially on branches of *Picea*

Psilolechia clavulifera (LC) – 1; on exposed roots (JM/2981, 3525; ZP/13738)

Psilolechia lucida (LC) – 1; scattered on shaded overhanging surfaces of siliceous boulders

Psoroglaena stigonemoides (DD) – 1; recorded once on shaded bark of *Ulmus* in N part of the reserve (ZP/14741)

Punctelia jeckeri (VU) – 2 [PEKSA et al. 2004: 296, as *Punctelia subrudecta*]; specimens reported by PEKSA et al. (2004) as *P. subrudecta* held in PRC belong here

Pyrenula laevigata (RE>CR) – 1; recorded once on smooth bark of old *Fagus* in E part of the reserve (ZP/13701)

Pyrenula nitida (EN) – 1, 5, 7, 10, 15, 16, 20, 22, 25, 34–36; very abundant in the old-growth forest, scattered in managed beech forests mostly on old *Fagus* trees

Ramalina farinacea (VU) – 1, 2, 25, 31, 35 (cf.); scattered on various deciduous trees (JM/2069, 3541)

Ramalina fastigiata (EN) – 2; on bark of *Acer pseudoplatanus* and *A. platanoides*

Ramalina fraxinea (EN) – 2; on bark of *Acer pseudoplatanus* and *A. platanoides*

Ramalina pollinaria (NT) – 1, 2; scattered on various deciduous trees (JM/3135)

Reichlingia leopoldii (DD) – 1; on bark of *Acer pseudoplatanus* (ZP/14179)

Rhaphidicyrtis trichosporella (Nyl.) Vain. (!) – 1; scattered on bark of old *Fagus* trees (JM/2978; ZP/12941, 14541, 14682, the last two specimens rev. B. Aguirre-Hudson)

Rhizocarpon reductum (LC) – 1; on freshly naked granite stone (ZP/14552)

Rinodina degeliana Coppins (!) – 1, 2, 5; on bark of *Acer pseudoplatanus*, *A. platanoides* and *Fagus* (JM/3595; JV/10108 – fertile!; ZP/*12858, *13901, 14513, *14522, *14561, 15636 – fertile!)

Rinodina efflorescens (VU) – 1, 2; on bark of *Fagus* and *Acer pseudoplatanus* in well-lit sites (ZP/14575 – fertile!, 15689 – with *Catinaria atropurpurea*)

Rinodina excrescens Vain. (!) – 2; abundant and fertile on bark of single trees of old *Fraxinus* and *Quercus* (JM/1974; ZP/*12679 – det. H. Mayrhofer, 15658)

Rinodina exigua (VU) – 2, on bark of *Acer platanoides* (JV/10109)

Rinodina freyi H. Magn. – 21; on branch of *Fraxinus excelsior* (JM/2852 – with *Lecanora persimilis*, det. H. Mayrhofer)

Rinodina pityrea (LC) – 2; on bark of *Ulmus* (JV/7921)

Rinodina pyrina (VU) – 31, 41; on bark of young *Fraxinus* and *Sambucus racemosa* (JM/3550)

Ropalospora viridis (LC) – 1, 2, 5, 7, 10, 12, 14, 15, 18, 20, 22, 25, 27, 30, 34–36, 38; common on bark of *Fagus* as well as rare on other trees, and also on twigs of *Picea* (JM/1982, *2051, *2065, *2084, *2668, *2832, *2980; ZP/12792, *12861, *13346, 13908, *13918, *13935, 14345, *14368, *15684)

Sarcosagium campestre (LC) – 1; recorded once on decaying trunk of *Abies*

Schismatomma pericleum (EN) – 1; collected once on bark of *Ulmus* in N part of the reserve (ZP/14667)

Sclerophora pallida (CR) – 1; recorded once on old *Acer platanoides* in S part of the reserve (ZP/14556)

Sclerophora peronella (EN) – 1; on wood in hollow trunk of old *Picea* in N part of the reserve (FB/400)

Scoliciosporum chlorococcum (LC) – 1, 2, 3, 5, 7, 10–12, 14–16, 20, 25, 29–31, 34, 35, 38; frequent on bark of *Fagus* and *Picea* (JM/2828; ZP/13742, 13917)

Scoliciosporum sarothamni (LC) – 1, 9–12, 14–16, 20, 21, 24, 31, 36, 38, 41; frequent especially on *Fagus* (JM/2813, 2993; ZP/13995)

Scoliciosporum schadeanum (DD) – 1, 14, 25; on smooth bark of *Fagus*, probably partly overlooked (JM/2082, 2835, 2994, as *Bacidia hemipolia*, 5474; ZP/12768)

#*Sphinctrina turbinata* (Pers.) De Not. – 5; on thallus of *Pertusaria pertusa* on bark of *Fagus* (ZP/13904 – filed under *Pertusaria pertusa*)

Steinia geophana (LC) – 1, 9, 14; on wet decaying wood (JM/2988, 3001; ZP/13174)

#*Stictis radiata* (L.) Pers. – 1; a lichen-allied fungus; on bark of *Ulmus* (JM/3601; ZP/14649)

Strangospora moriformis (NT) – 10; on wood of a stump of *Fagus* (ZP/13925 – with *Micarea denigrata*)

#*Taeniolella delicata* M.S.Christ. & D.Hawksw. – 1; on thallus of *Ropalospora viridis* (FBe/26771)

Thelenella vezdae (NT) – 21; collected once on bark of *Fraxinus* (JM/2851)

Thelocarpon epibolum (LC) – 1, 5, 8, 9, 14, 17, 25, 27, 30; on dead wood, especially on stumps (JM/2053, 2833, 2967, 2987; ZP/13786, 13910, 13936, 14038)

Thelocarpon intermediellum (NT) – 1, 10; on decaying wood of *Fagus* and *Picea* (?) (ZP/12791, 13874)

Thelocarpon laureri (LC) – 2 [PEKSA et al. 2004: 296]

#***Thelocarpon lichenicola*** (Fuckel) Poelt & Hafellner – 1; on algal layer coverings freshly exposed small stones (ZP/13998, as *Ahlesia l.*)

#*Thelocarpon strasseri* Zahlbr. – 9; on soil, associated with algae; possibly an extreme morphological form of the preceding species (JM/3002)

Thelopsis rubella (CR) – 1; recorded on three trees in S part of the reserve (twice on *Fagus* and once on *Acer platanoides*) (JM/2676; ZP/13752, 14546)

Thelotrema lepadinum (EN) – 1, 25, 27; common in the reserve on *Fagus*, recorded also on *Abies*, *Acer pseudoplatanus*, *Picea* and *Ulmus* (JM/2001, 2010)

Trapelia coarctata (LC) – 1; on intermittently splashed stones along the brook and on freshly exposed siliceous stones (JM/3148; ZP/14681)

Trapelia corticola (EN) – 1, 10, 12, 21; scattered on bark of *Picea* and *Fagus*, and on wood of decaying stumps (JM/2849, 2972; PRC; ZP/13185, 14386)

Trapelia glebulosa (LC) – 1, 12; on freshly exposed siliceous stones and on fallen branch of *Fagus* (ZP/13861)

Trapelia placodioides (LC) – 1; on stones along the Tisový brook (JM/3147)

Trapeliopsis flexuosa (LC) – 1, 2, 4, 9, 11, 14–16, 23, 30, 31, 33, 36; on dead wood, rare on bark (ZP/13879)

Trapeliopsis gelatinosa (NT) – 10, 14, 27; on soil and decaying stump of *Fagus* (JM/2795, 2971 – as *T. aeneofusca*, 2989, 3547; PRC – as *T. aeneofusca*; ZP/13869 – as *T. aeneofusca*)

Trapeliopsis glaucolepidea (NT) – 1, 7, 10, 23–25, 27–29, 33, 34, 36, 37; on decaying wood and bark at base of *Abies* (JM/1945, 1952, 2790; ZP/12786, 13186, 14049)

Trapeliopsis granulosa (LC) – 1, 4, 5, 10, 12, 13, 14 (cf.), 15, 20, 23, 24, 27, 28, 30, 31, 35, 36; mostly on decaying wood (JM/2687, 2812; ZP/13158)

Trapeliopsis pseudogranulosa (LC) – 12, 17, 22, 24, 34, 37; on decaying wood, soil, and bark at bases of trees (JM/2788, 2824, 2966; PRC; ZP/13187)

Trapeliopsis viridescens (VU) – 1, 21, 29; on strongly decaying wood of *Picea*, *Fagus* and *Abies*, quite common at humid microsites in the reserve (JM/3549; ZP/13211, 13782)

#***Tremella hypogymniae*** Diederich & M.S.Christ. – 1; on thallus of *Hypogymnia physodes* (FBe/26772)

#***Tremella lichenicola*** Diederich – 1, 15, 20; a frequent parasite of *Violella fucata* (ZP/13079, 13080)

#***Trichonectria anisospora*** (Lowen) Van den Boom & Diederich – 1; on thallus of *Hypogymnia physodes* (FBe/26772)

Tuckermannopsis chlorophylla (NT) – 1, 2, 28, 38, 40; in the reserve scattered on twigs of *Picea*

Usnea dasypoga (VU) – 1, 2; common on branches of *Picea* (JM/*2086 – rev. P. Clerc, *3542 – rev. P. Clerc)

Usnea florida (EN) – 1* [PEKSA et al. 2004: 296]

Usnea glabrescens (EN) – 1; one thallus collected in the valley of Tisový brook near N border of the reserve, the specimen belongs to the "*fulvoreagens*" morphotype (JM/*3539 – det. P. Clerc)

Usnea hirta (VU) – 1, 2, 40; on branches of dead *Picea*, found with apothecia (JM/*3500, PRC)

Usnea scabrata (CR) – 1, 36 (cf.), 37, 38; on *Abies*, *Picea* and *Fagus*, especially on branches, frequent in the reserve (JM/1950, *3516)

Usnea subfloridana (EN) – 1, 40; common on branches of *Picea*, on *Quercus robur* in front of entry to the reserve, both chemotypes detected by TLC (JM/*2068, *2686 – rev. P. Clerc, *2689, *3499, *3520 – det. P. Clerc; ZP/*14274, *14528, *14553)

Varicellaria hemisphaerica (Flörke) I.Schmitt & Lumbsch [syn. *Pertusaria h.*] (EN) – 1, 34; scattered on bark of *Fagus* in the reserve, rarely found on bark of *Ulmus* and *Abies*/*Picea* snag, one poorly developed thallus collected on *Acer pseudoplatanus* outside the old-growth forest (JM/2074, *2808; ZP/*14594)

Verrucaria corticola (DD) – 1; on exposed root of *Fagus* (ZP/13791)

Verrucaria dolosa (LC) – 1; on periodically inundated stone in the bedrock of Tisový potok brook and on freshly exposed stones below the wind-blown beech tree in central-eastern part of the reserve (ZP/14343, 14365 – with *Absconditella delutula*)

Verrucaria funckii (VU) – 1; rare on inundated stones in Tisový brook (JM/3536, 3600)

Verrucaria hydrela (VU) – 1; common on inundated stones in Tisový brook and an unnamed brooklet (JM/3535, 3599; ZP/14338, 14364)

Verrucaria margacea (VU) – 1; on splashed granite stones in upper part of the reserve (ZP/14407)

Vezdaea aestivalis (NT) – 1; on mossy bark of *Fagus* (JV/10121)

Violella fucata (Stirt.) T.Sprib. [syn. *Mycoblastus fucatus*] (LC) – 1, 5, 7, 9, 10, 12, 14–16, 20, 22, 25, 27, 30, 34–36; common on bark of *Fagus* and twigs of *Picea* (JM/1947, 2063, *2823, 3000; ZP/13079, 13080, 13337, 13926, *14408)

Vulpicida pinastri (NT) – 1, 2, 6, 36; on bark of *Fagus* and *Picea*, on stump and worked timber (JM/3134)

Xanthoria candelaria (LC) – 2, 21, 25, 31, 41; on various deciduous trees

Xanthoria fulva (VU) – 2, on bark of *Ulmus glabra*

Xanthoria parietina (LC) – 2, 21, 25; on *Acer pseudoplatanus*, *Fraxinus* and *Fagus*

Xylographa parallela (VU) – 1, 7, 30; rare on slowly decaying dead wood (JM/2974, 3144; ZP/14674)

#*Xylopezia inclusa* (Pers.) Sherw. – 1; a lichen-allied fungus; on dry wood of *Abies* snag (ZP/12784)

Comments on selected species

Agonimia flabelliformis

A recently described taxon allied to *Agonimia allobata* (Guzow-Krzemińska et al. 2012) characterized mainly by distinctly developed coralloid thallus. An extraordinarily well developed specimen (ZP/12763) collected in the reserve was designated as holotype for this newly distinguished taxon (Guzow-Krzemińska et al. 2012). Like other species of *Agonimia* it shows wide ecological altitude amplitude, and may grow on various organic substrates including raw humus.

Additional records: S Bohemia, Šumava Mts., Volary, Černý Kříž: Mt. Jelení vrch (ca 3 km SSW of Černý Kříž), 48°50'00–05"N, 13°51'20"E, remnants of beech forest on E slope, on dry wood of hollow *Fagus*, alt. 860–900 m, 4.V. 2002, Z. Palice 8058; S Bohemia, distr. Písek, nature reserve Krkavčina ca 1.8 km W of Oslov, a small waterless valley with a mixed forest at W-facing slope above Vltava river, 49°24'02"N, 14°11'10"E, on bark at base of dead *Sambucus* stem, alt. 380 m, 15.V. 2010, Z. Palice 13572; S Moravia, distr. Jihlava, Třešť: close-to-primeval forest (*Fagus sylvatica*, *Abies alba*, *Picea abies*, *Acer pseudoplatanus*) at WSW-facing slopes of Mt. Velký Špičák [734], 0.6–0.7km SSE of the top, 2.4 km NE of Třešť, 49°18'21"N 15°30'51"E, on bark of old *Fagus*-snag, alt. 700 m, 10.IX. 2010, I.Černajová, J. Malíček & Z. Palice 13974; N Bohemia, Ještědsko-kozákovský hřbet Mts, Liberec, Karlov pod Ještědem: Karlovské bučiny National Nature Reserve, E part of reserve, 50°46'26"N, 14°58'28"E, alt. 450 m, on base of *Acer platanoides*, 17.X. 2012, J. Malíček 4777& J. Vondrák; **Slovakia**: W Carpathians, distr. Revúca, Muráň: a brookless valley just N of village, beech forest, 48°44'47"N, 20°02'44.5"E, on humus among roots of *Fagus*, alt. 473 m, 3.V. 2010, J. Halda & Z. Palice 13439.

Alectoria sarmentosa

Historical sources mention this species from bark of old conifers in several mountain regions in the Czech Republic (Černohorský et al. 1956). Recently it was recorded mainly in mountain spruce forests in the Šumava Mts. (Liška & Pišút 1995, Liška et al. 1998) and a stunted specimen was collected also in a boggy boreal forest in W Bohemia (see below).

Additional record: W Bohemia, Slavkovský les: Kladské rašeliniště peatbog, „Tajga“ near village Kladská, on dry branch of *Picea abies*, alt. 820 m, 26.IV. 1997, Z. Palice s.n.

Arthonia excipienda

This species can be easily overlooked or mistaken for e. g. *A. punctiformis* and *A. radiata*. However *A. excipienda* has a well-developed exciple-like margin and 1-septate spores (COPPINS & APTROOT 2009a). Other similar species is *A. dispersa* which differs in smaller apothecia, larger spores and colour of epihymenium (WIRTH 1995, DOLNIK 2004). *A. excipienda* is an oceanic species in Europe, which is very rare in Central Europe. It has been recently reported from Germany (DOLNIK 2004) and Austria (BERGER et al. 2009). According to DOLNIK (2004) *A. excipienda* may expand to the east.

Bacidia circumspecta

The species resembles *B. subincompta* and *B. vermifera* in the field. It is quite a rare taxon in Central Europe and it is listed among potential old-growth forest indicator species by PRINTZEN et al. (2002). On the other hand in oceanic Norwegian spruce forests, it may tolerate small-scale forest management (HOLIEN 1998). Recent records in the Czech Republic are sparse, it has been reported from Brdy Mts (MALÍČEK 2013a) and a single locality in the Šumava Mts (PALICE 1998) but more unpublished records from the territory exist.

Bacidia incompta

A rare *Bacidia* which has been recently reported three times from the Czech Republic: from Šumava Mts (VĚZDA 1995), “Soutok” in South Moravia (GRUNA 2000), and Žofín Virgin Forest (PEKSA et al. 2004). It is a rather specialized and hence very local epiphytic species demanding higher pH of substrate, often growing on overmature trees and/or trees infected by wood-inhabiting fungi, beneath so called rot-holes (FRITZ & HEILMANN-CLAUSEN 2010).

Additional records: W Bohemia, Šumava Mts, Zhůří: valley of Pěnivý potok brook, nearby the settlement Bílý Potok, 49°06.4'N, 13°34.08'E, on weathered bark of *Ulmus laevis*, alt. 750 m, 28.IX. 2005, Z. Palice 9386 & J. Palicová; S Bohemia, distr. České Budějovice, Hluboká nad Vltavou, nature monument Baba, scree forest at E-facing slope above Vltava river, 49°04'30"N, 14°27'10"E, on bark at base of *Fagus*, alt. 390 m, 31.XII. 2012, Z. Palice 16020.

Bacidia laurocerasi

While this is a frequent species in the British Isles (COPPINS & APTROOT 2009b), it has quite rarely been recorded in continental Europe during recent decades and apparently has been declining in Central Europe (WIRTH 1995, BERGER et al. 2010). It is also an endangered species in all Fennoscandian countries (JÄÄSKELÄINEN et al. 2010, TIMDAL et al. 2010, THOR et al. 2010). In Germany it is regarded as extinct (WIRTH et al. 2011) as well as in the Czech Republic (LIŠKA & PALICE 2010). In the past, it was known from only few localities (cf. VĚZDA & LIŠKA 1999). The species was growing in shaded habitats on more or less smooth bark of not too old *Fagus* trees both in managed and primeval forest. We anticipate the species may tolerate small scale forestry practices but as for stable humidity and air quality it is a sensitive species surviving only in more less continuous woodland areas.

Bacidia vermifera

In the Czech Republic it is clearly a species of long forest continuity. Only three recently published records from Šumava Mts (VĚZDA 1997, as *B. hegetschweileri*) and Brdy Mts (MALÍČEK 2013a) exist.

Additional records: S Bohemia, Šumava Mts, Volary: Mt Jelení vrch, remnants of old-growth deciduous forest, on moribund bark of old *Fagus*, alt. 850–900 m, 29.XII. 1994, 25.IX. 1994, 26.IV. 1996, Z. Palice 12662, 12663, 12665; S Bohemia, Šumava Mts, Volary: Mt Stožec – NNW slope, on *Fagus* near forest-road, alt. 880 m, 9.III. 1996, Z. Palice 12664; S Bohemia, Šumava Mts, Horní Planá, Želnava: Bulov Mt. 2 km NE of village, 48°49'26''N, 13°59'08''E, alt. 930 m, on bark of *Fagus sylvatica*, 23.V. 2010, J. Malíček 2780 & Z. Palice; S Moravia, Podyjí, Vranov nad Dyjí, Bítov, below ruin of Cornštejn, 48°56'02.5"N, 15°42'52.1"E, on bark of *Quercus*, alt. 370 m, 2.IV. 2011, J. Vondrák 8449.

Biatora albohyalina

This is a new record for the Czech Republic. It has been mentioned in several old papers from Moravia (cf. VĚZDA & LIŠKA 1999) but preserved voucher specimens studied (OLM, PRA-Vězda) belong to *Biatora helvola* and *Cliostomum corrugatum*, respectively. The species does not belong to *Biatora* s.str. (PRINTZEN 1995) and according to combined phylogeny of mtSSU and ITS data sequences in SPRIBILLE et al. (2009: 123–124) the species comes close to *Lecania cyrtella*. From other epiphytic species currently belonging to *Biatora* and *Lecidea* s.l. the species is easily identifiable due to its pale apothecia and relatively large immersed pycnidia with long septate filiform conidia. It seems to be a pioneer taxon. The apothecia appear to be fairly fast-growing often occupying smooth bark of young deciduous trees. Younger apothecia often bear freely protruding excipular hyphae making the impression the apothecia are villose. This feature was not emphasized in previous publications.

Additional records: S Bohemia, Šumava Mts, České Žleby: Mt. Spáleniště – SE slope, a relatively young managed stand with *Picea*, *Fagus* and *Fraxinus* predominant, 48°52'40"N, 13°48'50"E, on shaded trunk of middle-aged *Fraxinus*, alt. 900–920 m, 9.VIII. 1998, Z. Palice 839; S Bohemia, Šumava Mts, Vimperk, Zátoň: virgin forest Boubínský prales, 200–250 m NW–WNW of Boubínské jezírko pond, old-growth mixed forest, 48°58'29.4"N, 13°48'58.7"E, on bark of *Fagus*, alt. 950 m, 16.XI. 2012, E. Jungwirthová & Z. Palice 15855; **Slovakia**: W Carpathians, Muránska planina plateau: Javorníková dolina valley (48°44'10"N, 20°00'30"–20°01'20"E), on *Corylus avellana*, alt. 460 m, 8.V. 2001, A. Guttová, J. Halda & Z. Palice 5343.

Biatora ligni-mollis

The species may form quite large and distinctive sessile pycnidia somewhat reminiscent to those of *Fellhanera gyrophorica*, but they are unevenly distributed forming groups and in parts only red-brown glossy biatoroid apothecia are formed on thalli. The ascospores are strikingly narrowly bacilliform, mainly one to two-celled and unlike other *Biatora* species *Micarea*-type of asci are produced. In British Columbia (Canada), *Biatora ligni-mollis* grows on soft, punky wood of conifer snags in humid old-growth forests (SPRIBILLE et al. 2009). It is also reported from old woodlands in Western and Central Europe, where it is a rare lichen growing on old bark or lignum of deciduous or coniferous trees (SÉRUSIAUX et al. 2010). Bohemian specimens are richly fertile and TLC of the richest collection (ZP/14609) confirmed presence of lobaric acid reported from B.C. material. Unlike the West-European samples (SÉRUSIAUX et al. 2010) the studied Bohemian specimen contains no roccellic acid in addition to lobaric acid.

Biatora mendax

B. mendax is a very rare lichen in Central Europe. According to PRINTZEN (1995) the species follows more or less distribution area of *Abies alba*. It prefers bark of young trees in humid localities. In the Czech Republic, it has been recorded at a single locality in the Šumava Mts (PRINTZEN & PALICE 1999).

Additional record: Slovakia: W Carpathians, Muránska planina plateau: the Hrdzavá valley – fir-beech dark forest below the peat-bog "V machoch", 48°44.93'N, 19°59.87'E, on bark of *Fagus sylvatica*, alt. 650 m, 23.V. 2007, D. Blanár, A. Guttová, J. Halda & Z. Palice 11382.

Buellia erubescens

B. erubescens may resemble *Lecidella elaeochroma* superficially in the field. From other forest species of *Buellia* with large ascospores (*B. disciformis*, *B. arnoldii*, *B. sanguinolenta*) it is distinguished by the absence of oil droplets in hymenium, norstictic acid is not always detectable in thalli (COPPINS et al. 2009). It has been recorded only twice in the Czech Republic before – in Průhonice Park near Prague on bark of *Aesculus hippocastanum* in 1955 by M. Svrček (LIŠKA & VĚZDA 1990) and in the Šumava Mts. (DĚTINSKÝ 1997).

Candelariella xanthostigmoides

Initially we determined sorediate *Candelariella* specimens in the area as *C. reflexa*, the taxon which is characterized by eight-spored asci, squamulose, rosette-like thalli and soredia initiated in centres of squamules (LENDEMER & WESTBERG 2010). This taxon is apparently not so common as formerly believed and it often has been misidentified by earlier authors (cf. LENDEMER & WESTBERG 2010, WESTBERG & CLERC 2012). We follow the concept outlined in the mentioned works in treating sterile sorediate *Candelariella* specimens as *C. efflorescens* agg. Members of this group form soredia on margins of areoles/squamules that early dissolve into soralia and the two currently accepted taxa are identifiable only when fertile on account of number of ascospores. The only fertile specimen contained eight-spored asci and hence it is referrable to *C. xanthostigmoides* as well as few other specimens collected in S and W Bohemia. The presence of *C. efflorescens* s.str. in the Czech Republic is very likely. The whole the group is not taxonomically resolved yet and in need of revision (M. Westberg, in litt.).

Additional records: S Bohemia, distr. Český Krumlov, Kaplice, Natural Park 'Poluška', margin of meadow, ca 0.3 km N of Výnězda settlement, 5 km W of Kaplice, 48°44'28"N, 14°25'37"E, on dead stem of *Corylus avellana*, alt. 785 m, 11.VIII. 2012, Z. Palice 15696 & K. Palicová, det. M. Westberg; S Bohemia, Šumava Mts, Volary, Černý Kříž: confluence of Studená Vltava and Hučina streams, 48°51'44.7"N, 13°52'02.7"E, on bark of *Salix fragilis*, alt. 740 m, 16.III. 2013, Z. Palice 16209; W Bohemia, distr. Domažlice, Kdyně, Smržovice: E-exposed slopes of "Zadní kopec" hill, 49°22'49.9''N, 13°05'38.0''E, on bark of *Fagus sylvatica*, alt. 650 m, 5.VII. 2010, J. Malíček 2937; W Bohemia, Český les Protected Landscape Area, Klenčí pod Čerchovem, Capartice: at bank of a small pond in N part of the settlement, 49°25'04.7''N, 12°47'23.8''E, alt. 750 m, on bark of *Salix*, 18.IV. 2013 J. Malíček 5661 et al.

Chaenotheca sphaerocephala

In the Czech Republic this is a very rare lichen previously published from high altitudes between 1100–1300 m in the area of Plechý Mt. in the Šumava Mts (PALICE 1999). Since that time recorded several times also in other parts of this range as well as in W Sudetes (see below). It is an inhabitant of humid woodlands with indigenous *Picea abies*, where it grows mostly on very shaded bases of trees, overgrowing also detritus and bryophytes, and more rarely occurring on siliceous boulder underhangs (PALICE 1999, TIBELL 1999).

Additional records: E Bohemia, W Sudetes, Krkonoše Mts, Mt. Sněžka: Koulový potok brook valley below Růžohorské sedlo saddle, a climatic spruce forest, 50°43'40"N, 15°45'E, complete base of old *Picea*, + *Chaenothecopsis viridireagens*, alt. 1200 m, 30.VIII. 2000, Š. Bayerová, J. Liška & Z. Palice 5151; W Bohemia, Šumava Mts, the Vydra valley: well-lit relic pine forest on a boulder scree above the trail leading from

Turnerova chata chalet to Čeňkova Pila, 49°05'05–10" N, 13°30'40" E, on hanging bryophytes on vertical side of gneissic boulder, alt. 860 m, 22.X. 2003, Z. Palice 8156; W Bohemia, Šumava Mts, Modrava, Javoří Pila: just N of Mt. Medvěd, the top plateau – a spruce plantation with dispersed old maple soliters, 49°00.4'N, 13°25.17'E, on shaded bark at foot of *Picea abies* not far from the forestry-road, alt. 1135 m, 26.X. 2005, F. Bouda, Z. Palice 9635, O. Peksa & J. Steinová; S Bohemia, Šumava Mts, Nová Pec: margin of bouldery field/glacial lake moraine with *Pinus mugo*, *Picea abies* and *Betula* SE of the Plešné jezero lake, 48°46'33"N, 13°52'23"E, on tufts of bryophytes on overhanging shaded face of granite boulder, alt. 1060–1070 m, 21.IX. 2007, Z. Palice 11560.

Cliostomum leprosum

This often sterile lichen may resemble e.g. *Lecanora expallens*. It forms grayish-white to dull yellowish soralia that are discrete at first, but rather soon become more or less confluent. It is easily recognizable due to regular presence of black pycnidia with K+ purple wall and shortly elipsoid conidia that tend to be ± pyriform. The yellowish apothecia are developed very rarely (found once in the reserve). *C. leprosum* contains atranorin and caperatic acid, and (when fertile) usnic acid in apothecia. Apparently, it is an indicator of old coniferous forests, where it grows on spruces (TØNSBERG 1992). Recently, it was collected also in Šumava Mts on bark and wood of *Picea*. All collected specimens contain characteristic pycnidia. New to Central Europe.

Additional records: S Bohemia, Šumava Mts, Volary, Nové Údolí, N-slope of Mt Trojmezná, on spruce bark, alt. 1280–1350 m, 14.V. 2011, Z. Palice, V. Pouska & J. Vondrák 8951 (CBFS); Ibid.: on wood and bark of *Picea*, alt. 1250 m, 15.XI. 2012, Z. Palice 15712, 15730, V. Pouska & J. Vondrák; S Bohemia, Šumava Mts, Vimperk, Zátoň: virgin forest Boubínský prales, 50–100 m NW of Boubínské jezírko pond, humid dark forest with *Picea* dominating, 48°58'28"N, 13°49'05.5"E, on bark at foot of old *Picea*, alt. 930 m, 15.XI. 2012, E. Jungwirthová & Z. Palice 15848.

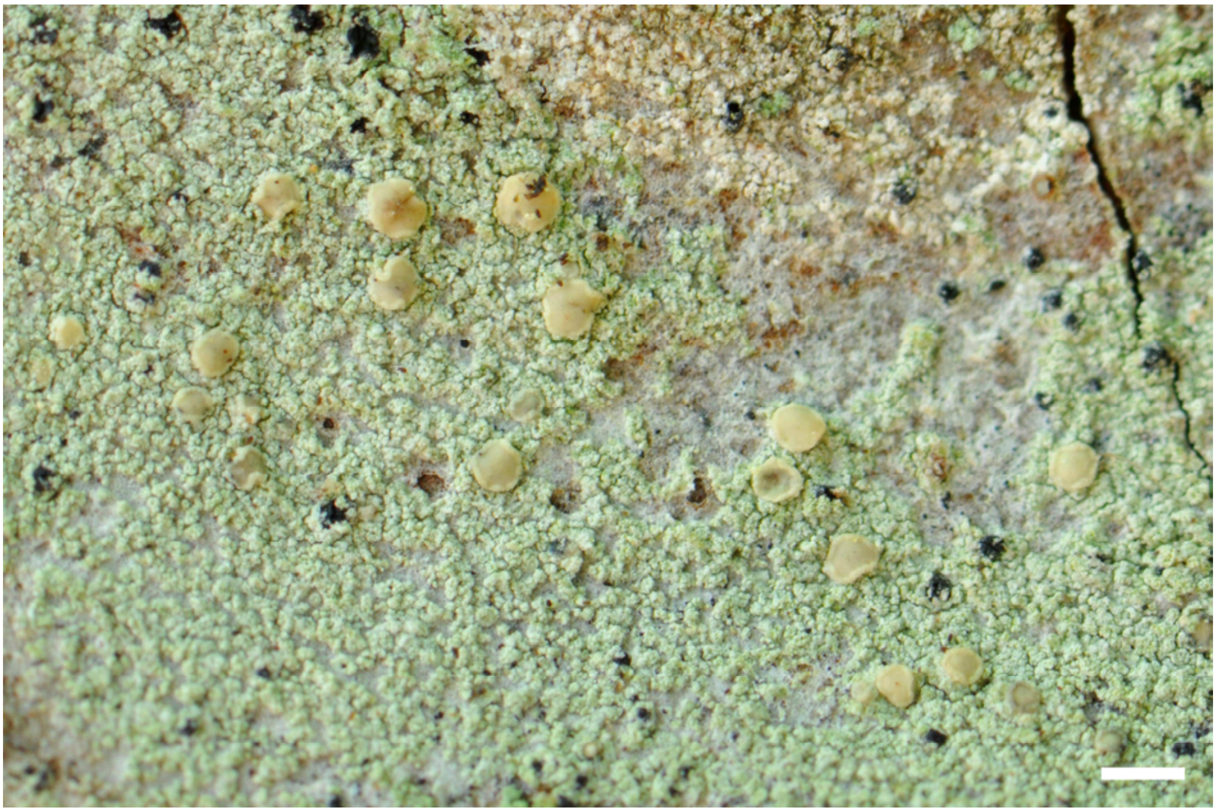

Fig. 4. Fertile specimen of *Cliostomum leprosum* with typical black pycnidia (scale = 1 mm).

Dictyocatenulata alba

A lichenized synnematous hyphomycete reported from Europe a few years ago. In the Czech Republic, it is known from several localities in the Šumava Mts and Krkonoše Mts. *Dictyocatenulata alba* grows mainly on smooth bark on basis of deciduous trees in humid broad-leaved and mixed forests (DIEDERICH et al. 2008). It is evidently not an old-growth forest species, but preferably growing at humid places at very bases of beeches.

Evernia divaricata

In the Czech Republic, the species grew in mountain regions on acidic bark of spruce in the past but started to disappear with increasing atmospheric pollution. In the 1990s it was known only from twelve localities in the Šumava Mts. (LIŠKA et al. 1996). The abundance of populations in this region has been probably still decreasing. Nowadays the species spreads together with other epiphytic lichens that were considered rare in the Czech Republic (for example *Evernia mesomorpha*, *Usnea* spp.) into untypical habitats – shrubby areas dominated by *Prunus spinosa* and *Crataegus* sp. or on branches of *Larix decidua* (HALDA et al. 2011). *Evernia divaricata* is reported here for the first time from the Novohradské hory Mts.

Fig. 5. *Fellhanera bouteillei* grows mostly on spruce needles, where it forms bluish sorediate thallus (scale = 1 mm).

Fellhanera bouteillei

In the field a quite easily recognized species due to its bluish sorediate thallus, pinkish pycnidia, eventually also apothecia and distinctive ecology. In the Czech Republic, *F. bouteillei* was recorded sporadically in the first half of 20th century in the lower elevations with no recent records (cf. VĚZDA & LIŠKA 1999). For ca 10 years until 2006 when the species was recorded in a humid gorge in Central Bohemia (PEKSA et al. 2007), the lichen was targetedly searched by the second author in habitats with developed foliicolous lichen assemblages but without success. During last 5 years records of the species has been increasingly growing. Therefore we conclude it is very likely a rapidly spreading lichen in suitable humid habitats in Bohemia. During a few last years it has been collected several times mainly on needles and twigs at basal branches of *Picea abies* (see additional records). However as a pioneer colonizer it is known to occur on a wide range of substrates (SPIER et al. 2002) and locally it might have been also partly overlooked.

Additional records: N Bohemia, Vysoká Lípa: National Park "České Švýcarsko", a forest-crossroads of yellow and blue tourist trails near Dolský Mlýn, ca 150 m S of the bridge over Kamenice river, 50°50.83'N, 14°20.86'E, on twigs and needles of young *Picea*, alt. 210–220 m, 28.V. 2008, Z. Palice 12291; N Bohemia, Jetřichovice: National Park "České Švýcarsko" [Czech Switzerland], crossroads of Hluboký důl and Česká silnice, 0.7–0.8 km S of abandoned village Zadní Jetřichovice, 50°53'35"N, 14°21'35"E, on twigs of young *Picea*, alt. 254 m, 29.VII. 2009, Z. Palice 12767; S Bohemia, Šumava Mts, Volary: boggy, taiga-like forest with *Pinus* dominating near the Hučina brook, ca 0.6 km ESE from the railway-stop Černý Kříž, 48°51'30"N, 13°52'11"E, on dry twigs of young *Picea*, alt. 740 m, 4.IV. 2010, J. Halda & Z. Palice 13351; S Bohemia, Šumava Mts, Volary, Černý Kříž: Hučina valley, 48°51'17"N, 13°51'51"E, on twigs and needles of *Picea*, alt. 740 m, 21.V. 2010, J. Malíček 2721 & Z. Palice 13702; C Bohemia, distr. Benešov, Roudný: margin of young *Picea* forest near the sanatorium complex at a former gold-mining area, 49°36'54.4"N, 14°48'34.9"E, on needles and twigs of young *Picea*, alt. 480 m, 16.V. 2010, Z. Palice 13595; S Bohemia, PLA Třeboňsko, nature reserve Soví les, boggy pine forest with *Picea* and *Betula* ca 3.5 km SE of Třeboň town, 48°58'56"N, 14°49'04"E, on twigs (and needles) of young *Picea*, alt. 435 m, 2.III. 2012, Z. Palice 15096; S Bohemia, PLA Třeboňsko, Suchdol nad Lužnicí, Červené blato National Nature Reserve, S part of reserve, on stems of *Vaccinium myrtillus*, alt. 470 m, 27.VIII. 2011, J. Malíček 3713; E Bohemia, Orlické hory Mts, Bartošovice v Orlických horách, valley of Bartošovický potok, loc. 'Údolíčko', 50°11'05.7"N, 16°31'11.3"E, on twigs and needles of *Picea abies*, alt. 705 m, 20.IV. 2012, J. Halda & Z. Palice 15127; C Bohemia, Praha, Průhonice, at pond in park at chatteau, 49°59'58"N, 14°33'28"E, alt. 290 m, on needles and twigs of *Picea*, 11.IV. 2011, J. Vondrák 8479.

Fellhanera gyrophorica

F. gyrophorica often lacks apothecia but usually forms conspicuous sessile pycnidia whose outer walls produce gyrophoric acid. It is known from many European countries including Central Europe (Austria, Poland, Slovakia, and Switzerland). It seems to be typical inhabitant of well-preserved, rather shaded and humid, broad-leaved forests at lower elevations (SÉRUSIAUX et al. 2001).

Fuscidea pusilla

Sterile lichen morphologically very similar to *Ropalospora viridis*. However, the latter species is usually much larger and often more intensively green. Chemically *R. viridis* is distinct from *Fuscidea pusilla* in containing perlatolic acid as its major substance instead of divaricatic acid (TØNSBERG 1992). We have analysed most of our collections from Žofín area putatively assigned to *Ropalospora viridis* and only one specimen from bark of spruce proved to contain divaricatic acid. *Fuscidea pusilla* seems to be a toxitolerant species (TØNSBERG 1992). The species was not reported from the Czech Republic before and additional specimens that were confirmed by TLC are listed below.

Additional records: N Bohemia, Krásná Lípa: National Park "České Švýcarsko", the Kamenice valley near the junction with Soorgrund, ca 5.2 km WNW of Jetřichovice, ca. 50°51'45–50"N, 14°19'10"E, on bark of dead *Picea*, alt. 165m, 15.VIII. 2001, Š. Bayerová, Z. Palice 5880, O. Peksa & L. Voříšková; W Bohemia, Šumava Mts, Prášily, mixed forest 700 m SE of "Laka" lake, 49°06'24''E, 13°20'08''E, on bark of *Fagus sylvatica*, alt. 1160 m, 13.IX. 2009, J. Malíček 2153; S Bohemia, Novohradské hory Mts, Pohoří na Šumavě: Pohořské rašeliniště peat-bog, on branch of *Pinus* × *pseudopumilio*, alt. 895 m, 4.VI. 2001, Z. Palice 5952; S Bohemia, Šumava Mts, Volary: boggy, taiga-like forest with *Pinus* dominating near the Hučina brook, ca 0.6 km ESE from the railway-stop Černý Kříž, 48°51'34"N, 13°52'11"E, on twigs of young *Picea*, alt. 740m, 4.IV. 2010, J. Halda & Z. Palice 13350.

Hypogymnia vittata

This *Hypogymnia* has not been recorded by us during the current survey, but two (sub)recent collections exist in herbaria and hence the species is very likely still surviving in the virgin forest. The record on *Picea* published by PEKSA et al. (2004) was revised by JM in 2011 (PRC). An unpublished specimen from the virgin forest was revealed by ZP among his older collections from 1994.

Kirschsteiniothelia recessa

A non-lichenized saprophytic corticolous species which has not been previously reported from Europe. Bohemian material somewhat deviates from North American specimens by slightly larger, usually distinctly sole-shaped ascospores with finely verruculose surface (1000× magnif.) and a greenish pigment in inner wall of perithecia (cf. HAWKSWORTH 1985b, APTROOT 2002a). Clearly sole-shaped and distinctly papillate ascospores are indicative of *Mycomicrothelia pachnea* (Körb.) D.Hawksw. (HAWKSWORTH 1985a), a species described from *Abies* and hence easily misidentified for this species. However the perithecial wall of large, prolonged angular cells arranged in one direction in pallisades clearly place all Bohemian specimens to genus *Kirschsteiniothelia* (HAWKSWORTH 1985b). The status of European material needs further studies.

Additional record: S Bohemia, Šumava Mts, Vimperk, Zátoň: virgin forest Boubínský prales, valley of Kaplický potok creek, 200–250m WNW of Boubínské jezírko pond, old-growth mixed forest, 48°58'32.8"N 13°48'56.4"E,on bark at foot of 150 years old *Abies*, alt. 958 m, 15.VIII. 2012, E. Jungwirthová, det. Z. Palice 16167.

Lecania croatica

A sorediate epiphytic species resembling a *Biatora* species. Recently it was dealt with and described in detail by HARRIS & LENDEMER (2010). According to phylogenetic study by REESE NÆSBORG et al. (2007) the closest currently accepted genus is *Bilimbia*. The voucher specimens are sterile with pale green to brownish delimited soralia and TLC revealed no secondary lichen metabolites. It was compared to fertile specimens from Slovakia housed in PRA. In Germany it was collected in Rheinland-Pfalz and Baden-Württemberg in recent decades (CEZANNE et al. 2008). It is apparently a quite rare, locally occurring species of humid forests that however is very likely overlooked in suitable habitats. Illustrative photo of the sterile lichen specimen is provided by EICHLER et al. (2010).

Lecanora thysanophora

This sorediate species is distinctive mainly by its arachnoid prothallus and chemistry. In the field it may resemble *Haematomma ochroleucum*, *Lecanora expallens*, *Loxospora elatina* or *Phlyctis argena*. *L. thysanophora* can be easily separated by TLC. It produces atranorin, usnic acid, zeorin and specific terpenoids called “*thysanophora*-unknowns” (HARRIS et al. 2000, KUKWA 2005). In the Czech Republic it seems to be quite rare confined to humid mountain forests.

Additional records: Šumava Mts, Modrava, Javoří Pila: Mt. Medvěd, NE slope, a spruce plantation with dispersed old maple soliters, 49°00.51'N, 13°25.24'E, on bark of *Acer pseudoplatanus*, alt. 1125 m, 27.X. 2005, F. Bouda, Z. Palice 9345, O. Peksa & J. Steinová; W Bohemia, Šumava Mts, Modrava: well-lit mixed forest in a saddle area between the points 1132.6 and <1120, 0.5 km WSW–SW of former bridge over Roklanský potok brook, 49°00.96'N, 13°26.61'E, on bark of solitary old *Acer pseudoplatanus*, alt. 1120 m, 28.VI. 2006, E. Loskotová, Z. Palice 10924 & O. Peksa; W Bohemia, Šumava Mts, Modrava: remnants of old-growth deciduous forest W of Rokytecká slať bog just along the borderline, ca 6.5 km W of Modrava, 49°01.1'N, 13°24.1'E, on bark of old *Fagus*, alt. 1085–1090 m, 27.VI. 2006, E. Loskotová, Z. Palice 10956, 10975 & O. Peksa; S Bohemia, Šumava Mts, Nová Pec: Mt. Hraničník, NNW slope, remnants of mountain mixed forest, 48°45.25'N, 13°54.15'E, on bark of *Fagus* snag, alt. 1170 m, 9.V. 2007, Z. Palice 11333; Ibid.: 22.IX. 2007, J. Malíček 1113.

Lecidea ahlesii

This *Lecidea* s.l. was only recently reported as new to the Czech Republic (HALDA et al. 2011). Specific blue-violet (K+ green) granules often occurring in hymenium and hypothecium were not observed in our collections from the locality.

Lecidea huxariensis

One of the smallest and most inconspicuous lichens of all. However, it is very distinctive due to its anatomy and ecology. *L. huxariensis* is known usually as a pioneer species of hard exposed worked timber rarely associated with other lichens or just intermingled with juvenile thalli of e.g. *Micarea denigrata*, *Lecanora saligna* agg., and *Trapeliopsis flexuosa*. Recent collections from the Czech Republic originate mainly from exposed surfaces of elaborated conifer wood (e.g. fences). In the area we collected this species on vertical surface of stump of *Picea abies* in a glade, which is a kind of native habitat of the species apparently. There exists only one recent record published in exsiccat from the Czech Republic (FARKAS 2011), the other recent colletions from the Czech Republic are listed below.

Additional records: W Bohemia, Františkovy Lázně: nature reserve Soos, open swamp, 50°09.02'N, 12°24.22'E, on wood of rail along the tourist footpath, alt. 435 m, 19.IV. 2009, P. Czarnota, J. Malíček 1782, A. Müller, Z. Palice 12781 & J. Vondrák; W Bohemia, Krušné hory Mts, Boží Dar, meadows 700 m NNW of village, 50°25'06''N, 12°54'57''E, fence, on worked timber, alt. 1000 m, 14.IX. 2011, J. Malíček 3910; W Bohemia, Šumava Mts, Železná Ruda: abandoned village Nová Hůrka, at park-place near the bus stop, 49°08'45.6"N, 13°19'37.0"E, on wood of humble-down bench, alt. 885 m, 29.IX. 2011, Z. Palice 15025; W Bohemia, Šumava Mts, Horská Kvilda: abandoned village Zhůří, pastures on N slope of the point Břemeno, 49°04'42.2"N, 13°33'25.2"E, on wooden fence around a well, alt. 1145 m, 8.X. 2007, Z. Palice 11631, J. Palicová & Jul. Palicová; S Bohemia, Šumava Mts, Volary, Černý Kříž, game-keeper's house, 48°51.653'N, 13°51.505'E, on elaborated wood of front-part of bed of a transport vehicle, alt. 740 m, 6.VII. & 23.IX. 2007, 1.V. 2008, Z. Palice 11540, 11600, 12161; S Bohemia, Šumava Mts, Borová Lada, on meadow near Hrabická Lada settlement, 49°00'16.5''N, 13°40'05.6''E, on worked timber, alt. 910 m, 21.I. 2011, J. Malíček 3354, I. Černajová & L. Syrovátková; C Bohemia, distr. Příbram, Prostřední Lhota, by road-side in direction to Chotilsko village, 49°45'11.9"N, 14°20'29.1"E, on elaborated wood, alt. 405 m, 18.V. 2012, Z. Palice 15242, Jul. Palicová & K. Palicová.

Lecidea sanguineoatra

L. sanguineoatra resembles *L. hypnorum*, but differs in reddish to dark brown apothecia, narrower simple spores and ecology. Both species are characterized by the presence of blue-green crystals in hymenium and hypothecium (APTROOT et al. 2009). These crystals have not been found in our colletion. *L. sanguineoatra* grows mainly on bryophytes over acidic bark, rarely on rocks (WIRTH 1995, APTROOT et al. 2009). It is likely a very rare lichen restricted to continuous woodland areas. Recently not published from the Czech Republic but known also from three collections in Šumava Mts.

Additional records: W Bohemia, Šumava Mts, Železná Ruda: Debrník (= Ferdinandovo údolí), the lower part of old avenue, 49°06'56"N, 13°14'18"E, over mosses on bark of old *Tilia*, alt. 725 m, 7.VIII. 1994, Z. Palice 4119 (conf. C. Printzen); W-Bohemia, Šumava Mts, Modrava: managed beech forest between bogs Rokytecká slať and Hochschachten Filze (Vorderer Sulz) near the Bohemian/Bavarian borderline, 49°01.37'N, 13°24.42'E, on bark of dead younger/middle-aged *Fagus*, alt. 1130–1140 m, 27.VI. 2006, E. Loskotová, Z. Palice 10961 & O. Peksa; S Bohemia, Šumava Mts, Nová Pec, old-growth spruce-beech forest above road 1,5 km NNE of top of Smrčina Mt., 48°45'01''N, 13°55'41''E, on mosses on base of *Fagus sylvatica*, alt. 1170 m, 27. 9. 2012, J. Malíček 4704, F. Bouda & L. Syrovátková.

Fig. 6. *Jamesiella anastomosans* is a relatively common lichen in mountain areas in the Czech Republic, but apothecia are present very rarely (scale = 1 mm).

Fig. 7. Rare species *Micarea cinerea* strongly resembles *M. peliocarpa*, but it differs in more septate spores (scale = 1 mm).

Lecidea turgidula

The species is included in the list with some hesitation. We list a specimen growing side by side with sorediate thalli of *L. leprarioides.* TLC of non-sorediate thalli revealed both placodiolic acid (characteristic for *Lecidea turgidula*) as well as pseudoplacodiolic acid (diagnostic substance of *Lecidea leprarioides*) and we interpret pseudoplacodiolic acid as a contamination from sorediate thalli. An alternative explanation is that whole the sample belongs to *L. leprarioides* which in parts forms endoxylic thalli and produces both substances. We, however, follow TØNSBERG (1992) who admits endoxylic forms of *Lecidea leprarioides* may exist and discriminate these two taxa chiefly on chemical background, placodiolic acid is not reported by him from numerous specimens of *Lecidea leprarioides* tested by him.

Lecidella subviridis

Interestingly, we collected this taxon exclusively in managed beech forests outside the reserve. Mostly sterile sorediate lichen may resemble *Lecanora expallens*. TØNSBERG (1992) distinguishes two morphological forms – the first one with more or less punctiform soralia and the second one with mostly leprose thallus. Our specimens belong to the second morphotype which predominates also in Switzerland (DIETRICH 2007). In one colletion (JM/2977) a few apothecia were found. *Lecidella subviridis* is a chemically distinctive species. It contains atranorin, thiophanic acid, *expallens*-unknown and ± arthothelin. It prefers acidic-barked trees (TØNSBERG 1992, DIETRICH 2007).

Additional record: Slovakia: W Carpathians, distr. Revúca, Muráň: a brookless valley just N of village, beech forest, 48°44'49"N, 20°02'46.5"E, on bark of dry *Fagus*, alt. 490 m, 3.V. 2010, J. Halda & Z. Palice 13522.

Leptogium teretiusculum

This is the third published record from the Czech Republic. Previously it was collected in S Moravia and Šumava Mts (VĚZDA 1972, PALICE 1999). The latter case refers to a historic collection by A. Hilitzer in 1925. The occurrence of *Leptogium teretiusculum* on both sites has not been recently confirmed (cf. VĚZDA 1998, PALICE 1999). It is an easily overlooked species growing preferrably on bark of older trees, but may also rarely switch to rock or soil (JØRGENSEN 2007). Several records from such habitats were recently published from the Czech Republic (MALÍČEK 2013b).

Micarea adnata

In the Czech Republic, this rare lichen has been known previously only from two old-growth forest localities in the Šumava Mts (PALICE 1999). According to COPPINS (1983) its distribution coincides with an annual rainfall of over 1000 mm per year, which is not the case of Bohemian localities however. In the Žofínský prales reserve and its surrounding it was recorded at approximately 10 microlocalities. Sometimes only characteristic sporodochia were developed and it was once recorded also at base on young tree in managed spruce forest. We therefore conclude that favourable meso-microclimatic conditions may play an important role. It is perhaps rather more a humid woodland species than an indicator of old-growth forest.

Micarea cinerea

A mostly epiphytic or epixylic member of the genus *Micarea*, which is very similar to the common *M. peliocarpa*. However that species is characterized by 3-septate spores while *M. cinerea* has mostly 5-7-septate ascospores. Additionally *M. cinerea* produces characteristic, straight, long macroconidia. In Central Europe it is most frequently collected in the Alps and Carpathians (COPPINS 1983, CZARNOTA 2007) but occassionally recorded elsewhere (WIRTH 1995, BERGER et al. 2010). *M. cinerea* is a rare species occuring in humid mountain areas with continuous woodlands. It has not been published from the Czech Republic recently.

Micarea myriocarpa
Two pigment apothecial/pycnidial forms (with or without green pigment in hymenium or wall of pycnidium) occur side by side in collected specimen but forming discrete colonies. CZARNOTA (2007) suggests the variability in pigmentation might reflect environmental factors, i. e. light regime; however the two forms seem to be sharply delimited in our specimens as well as in other samples collected by the second author in the Šumava Mts. We anticipate a genetic background must exist, similarly like expected for albinomorphs of some other lichen species (GILBERT 1996). We recorded the species only once but it is an overlooked species of specific dry habitats.

Micarea parva
A poorly known inconspicuous epilithic lichen which has been reported from several colletions in Western Europe so far (COPPINS 2009). The species is a characteristic pioneer lichen, one of the first lichen colonizers of low siliceous shaded rocks. In the reserve it occupied a recently exposed stones below a wind-blown tree together with *Absconditella delutula* and *Micarea lithinella*.

Micarea prasina s.l.
Most records refer to *M. micrococca* and *M. prasina* s.str. and perhaps partly to *M. byssacea*. *M. viridileprosa* seems to be much rarer and has not been recorded with certainty in the old-growth forest. Several finely sorediate specimens with delimited soralia (when young) contained micareic acid and may represent a distinct undescribed taxon. These specimens are not listed under *Micarea prasina* s.str.

Micarea synotheoides
A rare *Micarea* easily confused with several common species, e.g. *M. prasina* or *M. denigrata*. It is rectricted mainly to strongly oceanic European regions. Collections from Central Europe probably belong to an undescribed species (CZARNOTA 2007, COPPINS 2009). In contrast to west European specimens well developed pycnidia bearing mesoconidia resembling those produced by *M. denigrata* are present. *M. synotheoides* has been known from only one locality in the Czech Republic, from climatic spruce forest in the Šumava Mts (CZARNOTA 2007).

Mycobilimbia pilularis
This is a lichen with finely granular thallus resembling some *Biatora* species. In Central Europe it seems to be rare, restricted to humid old-growth forests, where it grows on bark of deciduous trees. We have not recorded the related *Mycobilimbia carneoalbida* which occurs in similar habitats in Šumava Mts. For the ecology see also WIRTH (1995).

Nephromopsis laureri
In the past, it was regarded as a rare lichen in the Czech Republic known only from two areas: Šumava Foothills and Rakovník Region in W Bohemia (ČERNOHORSKÝ et al. 1956). Recently, one small thallus of this species has been found in the Železné hory Mts (LIŠKA & PIŠÚT 1995) and Brdy Mts (MALÍČEK 2013a).

Opegrapha trochodes
This recently described corticolous species is characterized by rounded to shortly elongated gyrose apothecia, inconspicuous thallus and 3-septate ascospores (COPPINS et al. 2008). On the first view this lichen resembles a non-lichenized fungus with hysterioid apothecia. *Opegrapha trochodes* is a widely distributed species growing on shaded bark

of deciduous trees. In the British Isles it is confined to ancient woodlands (COPPINS et al. 2008). It is quite frequent on rough bark of old beeches in the Žofínský prales. Probably it is an overlooked but local *Opegrapha* species in the Czech Republic growing in shaded and microclimatically suitable habitats of river valleys and old-growth forests.

Additional records: N Bohemia, Hřensko: National Park České Švýcarsko, the valley of Kamenice – Tichá soutěska, ca 2 km E of Hřensko, 50°52.3'N, 14°15.63'E, on bark of *Ulmus glabra*, alt. 120–125m, 29.V. 2008, Z. Palice 12281; N Bohemia, Jetřichovice: National Park České Švýcarsko [Czech Switzerland], valley of Křinice brook upstream of abandoned village Zadní Jetřichovice, N of Jankův kopec [348 m], 50°53.89'N, 14°22.86'E, on shaded bark of *Acer pseudoplatanus*, alt. 255 m, 28.VII. 2009, J. Malíček & Z. Palice 12759; S Bohemia, střední Povltaví, Hluboká nad Vltavou, Zámostí, on left bank of Vltava River, ca 3 km NEN of village, 49°05'29"N, 14°28'01"E, on mossy bark of *Tilia* in humid forest, alt. ca 400 m, 24.IV. 2010, J. Vondrák 7764 (CBFS); S Bohemia, Šumava Mts, Vimperk, Zátoň: virgin forest Boubínský prales, 200–250 m WNW of Boubínské jezírko pond, old-growth mixed forest, 48°58'28.5"N, 13°48'56"E, on weathering bark of *Fagus*, alt. 960 m, 16.XI. 2012, E. Jungwirthová & Z. Palice 15839.

Peridiothelia fuliguncta

This is a non-lichenized saprophytic corticolous species. According to HAWKSWORTH (1985a) it is confined to *Tilia* but in fact it has much broader range of host trees (see e. g. APTROOT 2002b). Upper spore-length limit slightly exceeds the measurements given by HAWKSWORTH (1985a) and APTROOT (2002b).

Pertusaria constricta

It strongly resembles several other *Pertusaria* species, e.g. *P. leioplaca* and *P. pertusa*. It differs in 8-spored asci and more-elevated (rarely ± contricted) warts containing 3–6 apothecia (ERICHSEN 1935). WIRTH (1995) regards *P. constricta* as a mountain lichen with an oceanic bias of distribution preferring bark of beech trees. It has been reported only once from the Czech Republic from the Krkonoše Mts (KUŤÁK 1952).

Pyrenula laevigata

Nowadays it is considered to be extinct in the Czech Republic (LIŠKA & PALICE 2010). Despite an exhaustive search for this species it has been found on one single tree.

Rhaphidicyrtis trichosporella

This inconspicuous lichen could by distinguished by white to grey thallus containing *Trentepohlia* as a photobiont, small perithecia, I+ deep blue hymenial gel, and filiform ascospores (AGUIRRE-HUDSON 2009). The amyloidity character may be misleading since our specimens exhibit I+ red reaction of hymenial gel, blue only after pretreatment with K. It resembles fertile specimens of *Anisomeridium polypori*. *Rhaphidicyrtis* grows in similar habitats to the latter taxon but produces perithecia only. Endophloedal *Trentepohlia* filaments were quite scanty but always present in our specimens. This species was recently reported from bark of apple trees from a land-used area of Germany (CEZANNE et al. 2008). Some authors regard the species as a saprophytic fungus (WIRTH et al. 2011) and this is perhaps also the reason why the taxon is not included among Fennoscandian lichenized fungi (SANTESSON et al. 2004) although it was described from Finland. Quite recently this taxon was reported from Sweden (EKMAN et al. 2013). The authors observed clearly lichenized thallus in four of five studied samples except one older herbarium specimen. The seeming absence of algae is interpreted as a possible artefact due to storage of the material. EKMAN et al. (2013) regard the lichen as an indicator species of long forest continuity which is in accordance with our observations.

Additional record: S Bohemia, Šumava Mts, Vimperk, Zátoň: virgin forest Boubínský prales, ca 450 m WNW of Boubínské jezírko pond, old-growth mixed forest, 48°58'32.5"N, 13°48'50.5"E, on bark of *Fagus*, alt. 995 m, 16.XI. 2012, E. Jungwirthová & Z. Palice 16108.

Rinodina degeliana

This is usually a sterile lichen intermingled among other lichens on smooth bark of broad-leaved trees. The species forms characteristic, rather firmly attached, greyish-white dispersed areoles or squamules with marginal to lip-shaped soralia that may later become confluent (TØNSBERG 1992). Most specimens from the virgin forest were analysed by TLC and atranorin and zeorin were detected as characteristic for the species (MAYRHOFER & MOBERG 2002). The specimens from the Žofín settlement collected on *Acer platanoides* (JV/10108, ZP/15636) were fertile. Apothecia were unknown in Cenral European material up to now. Well developed apothecia are characterized by the distinct presence of both dark true and grey thalline exciple. *R. degeliana* seems to be partly an overlooked species in the Czech Republic, at least in woodlands of West and Southern Bohemia. It grows both in continuous forests as well as avenues (see the localities below). Illustrative pictures of the lichen are provided by KUBIAK (2010).

Additional records: W Bohemia, distr. Plzeň-jih, Blovice: nature reserve Chejlava, deciduous forest, 49°32'04"N, 13°33'21"E, on bark of *Acer pseudoplatanus*, alt. 630 m, 16.VI. 2009, Z. Palice 12541; W Bohemia, Šumava Mts, Železná Ruda: glacial cirque of Černé jezero lake, beneath a dripping rock, on bark of *Acer pseudoplatanus*, alt. 1230 m, 12.X. 1995, Z. Palice 15314 (PRC); W Bohemia, Šumava Mts, valley of Vydra river, Čeňkova Pila, avenue, bark of *Tilia*, alt. 630 m, V. 2001, O. Peksa (PRC, with *Micarea prasina*); W-Bohemia, Šumava Mts., Modrava, Javoří Pila: just N of Mt. Medvěd, the top plateau, a spruce plantation with dispersed old maple soliters, along forestry roadside, 49°00.43'N, 13°25.16'E, on bark of *Acer pseudoplatanus*, alt. 1138–1139m, 27.VI. 2006, E. Loskotová, Z. Palice 10916 & O. Peksa; S Bohemia, Šumava Mts., Nová Pec: Mt. Hraničník – NNW slope, remnants of mountain mixed forest, ca 48°45'10–15"N, 13°54'15–20"E, on bark of *Acer pseudoplatanus*, alt. 1150–1200 m, 22.IX. 2007, Z. Palice 11601; S Bohemia, Šumava Mts, Želnava: ca 1.5 km NE of village, a former forested meadow at S slope of an unnamed point [946 m] just SW–SSW of Mt. Bulov, 48°49'05"N, 13°59'13"E, on stems of *Corylus avellana*, alt. 930 m, 23.V. 2010, J. Malíček & Z. Palice 13636; S Bohemia, Šumava Mts, Želnava: Mt. Bulov – the top with deciduous forest, ca 2 km NE of village, 48°49'20.6"N, 13°59'23.3"E, on bark of young *Ulmus glabra*, alt. 965m, 23.V. 2010, J. Malíček & Z. Palice 13689; S Bohemia, Šumava Mts, Vimperk, Zátoň: virgin forest Boubínský prales, ca 350 m WNW of Boubínské jezírko pond, old-growth mixed forest, 48°58'29.5"N, 13°48'50.5"E, on bark of *Fagus*, alt. 1000 m, 16.XI. 2012, E. Jungwirthová & Z. Palice 15856; S Bohemia, distr. České Budějovice, Hluboká nad Vltavou, Vltava valley, on the left bank of the river ca 2.5 km NE of the castle Hluboká, on bark of *Fagus*, alt. 372 m, 49°04'13.5"N, 14°27'29"E, 31.XII. 2012, Z. Palice 16019; C Bohemia, Vltava River valley, Prostřední Lhota, Vymyšlenská pěšina Nature Reserve, S-exposed rocky slopes dominated by oaks and pines, 49°44'36''N, 14°22'23''E, on bark of *Quercus petraea*, alt. 275 m, 1.IV. 2012, J. Malíček 4419, K. Knudsen, J. Kocourková & J. Vondrák; Ibid.: 49°44'42.1''N, 14°21'37.4''E, on bark of *Quercus petraea*, alt. 280 m, 9.IV. 2012, J. Malíček 4442; **Slovakia:** W Carpathians, Muránska planina plateau, Muráň: nature reserve Šiance, well-lit oak forest at SSE-facing slopes ca 0.2 km SSW of the point Nižná Skalka [980], 0.5 km NW of Muránská Huta, 48°46'29.8"N, 20°05'51.0"E, on bark of *Quercus* (N-side), alt. 881 m, 19.V. 2011, F. Bouda, I. Černajová, J. Malíček, Z. Palice 14450, L. Syrovátková & J. Vondrák; W Carpathians, Veporské vrchy hills, N.P. Muránská planina: nature reserve Čertova dolina, 1 km SW of the top of Mt. Kucalach [1141], mixed forest at steep SSW facing slope, 48°44'20.4"N, 19°52'01.0"E, on bark of *Acer pseudoplatanus*, alt. 935 m, 6.VI. 2012, A. Guttová, J. Malíček & Z. Palice 15481.

Rinodina excrescens

R. excrescens is characterized by its discrete, coarse, bullate to subsquamulose areoles that often bear soredia or blastidia, and contain pannarin (Pd+ orange). Apothecia tend to be pruinose (epipsamma present) containing *Physcia*-type ascospores (GIRALT et al. 1994, GALANINA et al. 2011). The Bohemian material was collected on old solitary trees in an avenue, where it covered large flanks of trunks accompanied by rather nitrophilous lichen assemblages (not *Xanthorion* community). Our material is richly fertile, devoid of blastidia or soralia, while the other European and Asian specimens form apothecia very rarely (GIRALT et al. 1994, GALANINA et al. 2011). *R. excrescens* seems to be a quite widespread in E Asia and East-north America (see GALANINA et al. 2011 and references therein), while in Europe it is one of the rarest *Rinodina* species known only from single dispersed localities. It has been reported from Austria, Croatia (GIRALT et al. 1994), Spain (ARAGÓN et al. 2004) and Crete (SPRIBILLE et al. 2006). Just recently a sterile population has been found in Brdy Mts (Central Bohemia) – on bark of *Quercus* at border of scree (MALÍČEK 2013a).

Rinodina freyi

The specimen refers to *Rinodina glauca* Ropin (ROPIN & MAYRHOFER 1993) which has been treated together with *Rinodina freyi* as the synonyms of *Rinodina septentrionalis* by GIRALT & MAYRHOFER (1995). SHEARD (2010) has distinguished *Rinodina freyi* and *R. septentrionalis* and he has placed *R. glauca* in the synonymy of *R. freyi*. We do not publish this species as new for the Czech Republic because the records of *R. septentrionalis* mentioned by PALICE (1999) and VONDRÁK et al. (2006) refer very probably to this taxon.

Thelopsis rubella

From the Czech Republic this species is reported only from Bílé Karpaty Mts (SUZA 1916), Brdy Mts (VĚZDA 1957), and recently from the Boubín Virgin Forest in the Šumava Mts (SVOBODA & BOUDA 2009). *Thelopsis rubella* is a rare lichen growing mainly on weathered bark of old beeches accompanied by bryophytes (VĚZDA 1957). In Central Europe it prefers humid beech woodlands.

Results

In total, 312 lichens (20.5 % of the lichen flora of the Czech Republic), and 25 lichenicolous and lichen allied-fungi have been recorded in the study area. 267 lichenized, lichen-allied and lichenicolous fungi are known from the virgin forest reserve Žofín, of that 247 lichenized, 11 lichen-allied and 10 lichenicolous fungi species. 89 % of lichens in the old-growth forest (n = 220) were growing as epiphytes or epixylic/epibryophytic species on trunks (accidental occurrences of primarily saxicolous species like *Micarea sylvicola* and *Trapelia glebulosa* were not considered in the number). The saprophytic lichen-like pyrenocarpous fungus *Kirschsteiniothelia recessa* is reported for the first time from Europe. Fifteen lichenized fungi (*Arthonia excipienda*, *Biatora ligni-mollis*, *Candelariella xanthostigmoides*, *Cliostomum leprosum*, *Fellhanera gyrophorica*, *Fuscidea pusilla*, *Lecania croatica*, *Lecanora thysanophora*, *Lecidella subviridis*, *Micarea parva*, *Mycobilimbia pilularis*, *Opegrapha trochodes*, *Rhaphidicyrtis trichosporella*, *Rinodina degeliana, R. excrescens*) and three lichen-allied fungi often associated with algae (*Agyrium rufum*, *Kirschsteiniothelia aethiops*, *Peridiothelia fuliguncta*) are published for the first time from the Czech Republic. Three species considered to be extinct in the Czech Republic (LIŠKA et al. 2008, LIŠKA & PALICE 2010) have been refound (*Bacidia laurocerasi*, *Micarea cinerea*, *Pyrenula laevigata*). Many other very rare and critically endangered lichens have been recorded, e.g. *Bacidia circumspecta*, *B. vermifera*, *Biatora mendax*, *Buellia erubescens*, *Chaenotheca sphaerocephala*, *Micarea adnata*, *M. synotheoides*, *Pertusaria constricta*, *Sclerophora pallida*, and *Thelopsis rubella*. Previously recorded specimens of *Cetrelia olivetorum, Lecanora chlarotera* and *Punctelia subrudecta* from the Žofín Virgin Forest (PEKSA et al. 2004) were revised and found to belong to *Cetrelia cetrarioides*, *Lecanora argentata* and *Punctelia jeckeri*, respectively. During our research, we did not confirm several rare macrolichens mentioned by PEKSA et al. (2004) and JANSOVÁ & SOLDÁN (2006), namely *Hypogymnia farinacea, H. vittata* and *Usnea florida*. These species might have been overlooked by us as they are supposedly rare and very local in the reserve. Among microlichens mentioned by PEKSA et al. (2004) in the reserve we did not confirm *Arthonia mediella*, a species that was very likely overlooked by us.

The character of forest stand that is dominated by beeches is very dark. Undergrowth is dominated by fairly fast-growing young beeches and other tree species are rarely encountered. Young silver-fir trees are almost absent. The overall darkness is apparently the main reason why macrolichens are quite sparsely developed, dominated by few common species (e.g. *Hypogymnia physodes*, *Parmelia saxatilis*, *Platismatia glauca*). Rare macrolichens are very local present mainly in well-lit spots of forest spring areas. Most of them have been found as single or a few thalli on several trees (e.g. *Alectoria sarmentosa*, *Cetrelia cetrarioides*, *C. monachorum*, *Evernia divaricata*, *Lobaria pulmonaria*, *Menegazzia terebrata*, *Nephromopsis laureri*, *Usnea glabrescens*). It is a difference comparing the Žofín virgin forest to the old-growth forests in the Šumava Mts or especially more oceanic European regions, where macrolichens are usually richly represented, like e.g. species of genera *Collema*, *Heterodermia*, *Hypotrachyna*, *Nephroma*, *Pannaria*, *Sphaerophorus*, *Sticta* etc. However, well developed microlichen communities predominate in the Žofín protected area. The Žofín Virgin Forest National Nature Reserve definitely belongs to the areas with the highest species richness of epiphytic and epixylic lichens in the Czech Republic. Several species with suboceanic distribution are reported from this locality, e.g. *Arthonia excipienda*, *Lecidea ahlesii*, *Micarea cinerea*, and *M. synotheoides*.

The substantial part of rare as well as common lichens in the virgin forest has been found on bark of *Fagus*. Among characteristic and distinctive species preferrably occurring on bark of *Fagus* that are distributed more or less all over the reserve we may list *Pyrenula nitida*, *Thelotrema lepadinum*, *Lopadium disciforme*, *Graphis scripta* s.l., *Melanelixia glabratula* and *Lecanora argentata*. Less distinctive but also frequent species, preferrably growing on smooth bark of younger stems of beeches, include mainly *Porina aenea, Biatora efflorescens, Ropalospora viridis,* and *Fellhaneropsis vezdae*. Frequent species at very bases of trunks are *Agonimia repleta* and *Anisomeridium polypori*. Beeches with rough, more nutrient rich bark host several rare species like *Gyalecta flotowii*, *Bacidina phacodes*, *Mycobilimbia pilularis*, *Bacidia incompta* etc. Other distinctive species occurring preferrably on *Fagus* are unevenly distributed in the reserve and sometimes were recorded only at one or several trees only. We may list e.g. *Menegazzia terebrata*, *Buellia erubescens*, *Biatora ocelliformis*, *B. mendax*, *Pertusaria constricta*, *P. hymenea*, *Bacidia circumspecta*, *B. laurocerasi*, *Pyrenula laevigata*, *Micarea synotheoides* etc. A similar lichen flora is developed on *Acer pseudoplatanus*, which however hosts less diverse spectrum of species, nevertheless several taxa were recorded only on this tree species in the reserve: *Arthonia ruana*, *Cetrelia cetrarioides*, and *Lobaria pulmonaria*.

Very important phorophytes are also conifers like *Picea abies* and *Abies alba*, although distinctly less diversified than on *Fagus* and other deciduous trees. Characteristic species on spruces and silver-fir trees include mainly skiophilous taxa like e. g. *Arthonia leucopellaea*, *Biatora veteranorum*, *Lecanactis abietina*, and *Micarea adnata*. Specific habitats are occupied by *Fellhanera bouteillei* (twigs and needles) and *Chaenotheca sphaerocephala* (very shaded bases of old trees). On illuminated sites (forest gaps like swamps and spring-areas) preferrably beard lichens occur, especially on branches of dead trees: *Alectoria sarmentosa* (rarely), *Bryoria capillaris*, *B. implexa*, *Nephromopsis laureri* (rarely), and *Usnea* sp. div. but these species are quite local. The most interesting records on conifers were done in a swampy area in W part of the reserve where two rare species *Cliostomum leprosum* and *Biatora ligni-mollis* were recorded on several trees and snags.

It is worth noting that more than 35 lichen species were recorded only once on one single tree in the reserve. Except rare or easily overlooked epiphytic species we should emphasize rare occurrences of several nitrophytic species. The rarity of the ubiquitous epiphytes *Amandinea punctata* and *Lecidella elaeochroma* is astonishing and we explain this by overall darkness of the old-growth stand and unavailability of suitable substrates. Interestingly all three *Caloplaca* species were recorded each at one single tree. Clearly these species require specific niches and are restricted to microhabitats that are very exceptional and stochastically dispersed in the area, e.g. occurrence of *Caloplaca chrysodeta* (common species of calcareous areas) may depend on affinity to overmature trunks and snags with higher bark pH, that is caused by wood-inhabiting fungi resulting in 'rot-holes', see FRITZ & HEILMANN-CLAUSEN 2010). Remarkably several lichen taxa (*Arthonia excipienda*, *Bacidia rosella*, *Caloplaca lucifuga*, *Psoroglaena stigonemoides*, *Sclerophora pallida*, *Schismatomma pericleum*) were recorded exclusively on elms or Norway maples, trees with relatively high bark pH. Moreover both tree species are very rare in the reserve.

A large amount of decaying wood is distributed all over the reserve. Dead standing trunks and snags of beeches are often occupied by calicioid lichens like e.g. *Chaenotheca brachypoda* and *C. chlorella* or hysterioid *Opegrapha varia*. Among pioneer species on decaying wood we may mention very common *Absconditella lignicola* and *Thelocarpon* species. On more decomposed wood of shaded habitats we have noted frequently *Micarea nigella*, *M. prasina* s.str., *Multiclavula mucida*, *Peltigera* sp. div., and *Trapeliopsis viridescens*. On the other hand *Icmadophila ericetorum* and *Micarea hedlundii* were rarely seen. Only several lichen species have been found on shaded granite stones and rocky outcrops in forest: *Enterographa zonata*, *Lepraria* sp. div., *Micarea lutulata*, *M. sylvicola*, *Porina chlorotica*, and *Psilolechia lucida*. A few inconspicuous pioneer microlichens were recorded on small stones – *Absconditella delutula*, *Micarea lithinella*, and *M. parva*. A little bit richer lichen assemblages are growing on occassionally inundated stones in the Tisový brook, e.g. *Bacidina inundata*, *Baeomyces rufus*, *Lecidea ahlesii*, *L. lithophila*, *Porpidia macrocarpa*, *P. soredizodes*, *Trapelia coarctata*, *T. placodioides*, *Verrucaria dolosa*, *V. funckii*, and *V. hydrela*.

Discussion

At the first sight, many uncommon lichens are restricted to virgin forest only. However, the reserve serves as an important source of diaspores for surrounding woodlands. Especially in old-growth beech forests bordered with virgin forest, rare lichens are significantly represented in epiphytic communities. As an example of 'old-growth forest' species growing within managed forests outside the reserve the following lichens may be listed: *Bacidia circumspecta*, *B. laurocerasi*, *Biatora fallax*, *Buellia erubescens*, *Cetrelia cetrarioides*, *Lecanactis abietina*, *Lecanora albella*, *Lopadium disciforme*, *Micarea adnata*, *Pertusaria constricta, P. pertusa*, *Thelotrema lepadinum*, *Trapelia corticola* and *Varicellaria hemisphaerica*. Most of them are restricted to bark of beech, rarely other trees. Another type of epiphytic community occurs in the Žofín settlement which is dominated by various solitary trees on more illuminated sites and often with subneutral bark. Macrolichens from the family *Parmeliaceae* are well represented, but microlichens

Candelariella subdeflexa, *Gyalecta truncigena*, and *Rinodina excrescens* are the most valuable records from this habitat.

Surprisingly several sorediate epiphytic microlichens were found exclusively in managed forests (including avenues) only: *Fuscidea arboricola*, *F. pusilla, Halecania viridescens, Lecidea pullata, Lecidella flavosorediata*, and *L. subviridis*. The reason of seeming absence within the reserve surely differs among species as they have different ecological preferences both for the nutrients and light regime. We anticipate all mentioned taxa do occur also in the reserve and were overlooked by us within extensive lichen mosaics. In managed forest they may form larger colonies due to less competition from other crustose species. Some of the mentioned species may preferentially occur in crowns of trees because of prevalence of shaded habitats within the reserve. The crowns of trees were not studied by us and only accidently we screened fallen branches or crowns of recently broken trees. It is also of interest that in spite of focused intensive searching for specific 'old-growth forest' microlichen taxa which are regularly encountered in neighbouring Šumava Mts we failed to record these species in the Žofín area and Novohradské hory Mts. at all. Examples are *Cyphelium inquinans*, *Gyalecta ulmi*, *Mycobilimbia carneoalbida*, *Mycoblastus sanguinarius*, and *Strigula stigmatella*. The reason remains unknown to us.

For comparison, 209 vascular plants (LEPŠÍ et al. 2007), 195 bryophytes (KUČERA 2009), and more than 600 species of macromycetes (ALBRECHT et al. 2003) have been reported from the virgin forest Žofín. Especially within the last twenty years, a number of floristic studies on old-growth and virgin forest has been published all over Europe.
Undoubtlessly, with 247 recorded lichenized species (220 epiphytes) the Žofínský prales belongs to the lichen richest old-growth forest reserves in Central Europe. However, it is quite difficult to compare species richness of the Žofín with other virgin forests because other studied European forest reserves with dominating *Fagus* markedly differ in their size (usually several times larger) and geomorphology (usually more craggy relief). What is more, the surveys of most of them were not studied in much detail and are rather based on results of several short visits; hence the real diversity must be several times higher. From other European old-growth beech forest reserves usually more macrolichen and less sorediate microlichen taxa are reported. As examples of comparable areas, two similarly sized virgin forests in Slovenia could be mentioned with dominating beech, silver fir and spruce: Rajhenavski Rog (51 ha) with 100 taxa of lichens (BILOVITZ et al. 2011) and Ždrocle Forest Reserve (184 ha) with 88 taxa (PRÜGGER et al. 2001). Similarly, lichen survey of Stužica virgin forest (659 ha) in Slovak Eastern Carpathians with dominating beech and silver-fir (but absent spruce) yielded 116 lichen species including earlier subrecent (?extinct), non confirmed records (PIŠÚT & LACKOVIČOVÁ 1992). In Ukrainian Eastern Carpathians a small fragment of the largest European virgin-forest reserve – the Uholsko-Shyrokoluhanskyi primeval beech forest was intensively studied recently (DYMYTROVA et al. 2013). The authors recorded 203 epiphytic taxa of lichenized and lichen-allied fungi from 352 sampling plots. This vast area (hundred times larger than the Žofín reserve) however displays a rugged relief and includes a number of various biotopes that were not studied. In the Austrian Alps a detailed survey was done in nature reserve Rotwald on limestone bedrock (TÜRK & BREUSS 1994), with additions (BILOVITZ 2007) giving a sum of 194 epiphytic lichens for the area of ca. 3 km^2. Interesting data are provided by HAFELLNER & KOMPOSCH (2007) from another Austrian old-growth forest "Urwaldrest Neuwald". They carried out a detailed survey of epiphytic and epixylic lichen flora within two one hectare plots – the first one in beech-silver fir-spruce old-growth forest (128 species) and the second one in

managed forest (58 species). The first number indicates relatively high diversity of local lichen flora, expectedly higher than in case of Žofínský prales area. Partly it may be explained by geology (calcareous underground) and the generally richer lichen flora in the Alps than in Hercynian region.

The biota of the Žofínský prales is exceptional although still incompletely known. We hope that this lichenological survey will stimulate the study of other endangered and vanishing central European old-growth forests.

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Epiphytic lichens of Stužica (E Slovakia) in the context of Central European old-growth forests

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Abstract. Based on recent lichen inventories, we report 230 epiphytic and epixylic species in the Slovakian old-growth beech-dominated forest Stužica. Microlichens represent 75% of species. Lichen lists of three other central European forests exceeded 200 species, and none of them reached 230. Lichen diversity is very unequally distributed in Stužica; the extensive south-facing slopes are poor in species, whereas damp brook valleys and upper parts of slopes above 1000 m alt. are rich.

Twelve species are new to Slovakia: *Epigloea urosperma*, *Graphis macrocarpa*, *Kirschsteiniothelia recessa*, *Lecidea sanguineoatra*, *Lepraria ecorticata*, *Micarea nigella*, *Opegrapha trochodes*, *Parmotrema arnoldii*, *Pertusaria waghornei*, *Ramonia chrysophaea*, *Sclerophora amabilis* and *Tetramelas chloroleucus.* Three recorded species were considered regionally extinct in Slovakia: *Arthonia byssacea*, *Sclerophora coniophaea* and *Sclerophora farinacea*.

Some rare macrolichens like *Heterodermia speciosa* and *Parmotrema crinitum* were collected in Stužica about 50 years ago, but we did not find them. Their voucher specimens from 1964 often represent well-developed and uninjured lichens. It suggests that some old-growth forest macrolichens have disappeared or become much rarer during the last fifty years.

Slovakian Stužica is connected to the much larger old-growth forest complex in Ukraine (Stuzhytsia), where 218 lichen species were recently recorded. Lists of species from both areas differ considerably, especially in tiny microlichens. The total number of species for the whole territory (Slovakian plus Ukrainian part), including historical records, is almost 300 species. Although remnants of Central European beech-dominated forests have similar species composition, most localities differ from Stužica in having fewer rare macrolichens and epiphytic cyanolichens. The exceptions are two large and well-preserved complexes "Ugolka - Shyrokyi Luh" (Ukrainian Carpathians) and Rotwald (Austria), which are richer in both.

Key words: beech, DCA, diversity inventory, Eastern Carpathians, forest conservation, lichenised fungi, microlichen, Sørensen's similarity index, Stuzhytsia, Ukraine, virgin forest.

Introduction

Lichen inventories in various woodland areas provide data for forest conservation, but few such inventories have been published for Central Europe (e.g. DYMYTROVA et al. 2013, GUTTOVÁ & PALICE 2004, GUTTOVÁ et al. 2012, HAFELLNER & KOMPOSCH 2007, MALÍČEK & PALICE 2013). Other detailed inventories of various central European old-growth woodlands have been made recently, but their data are unpublished (Table 3). Here we present a lichen list for the Slovakian virgin forest Stužica and compare its outstanding lichen diversity with other central European old-growth woodlands.

The national nature reserve Stužica is a virgin beech-fir woodland in the NE corner of Slovakia, in Bukovské vrchy upland. It is the largest virgin forest in Slovakia, but it is only a smaller part (761 ha) of an old-growth forest complex, most of which is in Ukraine – Regional landscape reserve Stuzhytsia with 2492 ha (STOYKO & KOPACH 2012). It belongs to the largest old-growth forest remnants in Europe. The Slovakian part was studied in the past and its lichen diversity inventory has been published (PIŠÚT & LACKOVIČOVÁ 1992) with additions by PIŠÚT (1995) and PIŠÚT et al. (2007). The Ukrainian part has also been surveyed (KONDRATYUK et al. 1998, MOTIEJŪNAITE et al. 1999, KONDRATYUK & COPPINS 2000).

The altitude of Slovakian Stužica ranges from 650 to 1200 m. *Fagus sylvatica* dominates at all altitudes. *Acer pseudoplatanus* occurs at all altitudes, but is abundant only in patches, mainly at upper altitudes (often on scree). *Abies alba* is frequent at lower altitudes but almost absent in the uppermost part, while *Sorbus aucuparia* occurs only in the uppermost parts. *Ulmus glabra* is usually represented by young trees which mostly follow valley bottoms. *Fraxinus excelsior* and *Corylus avellana* are present only in the lower part, in the valley of the river Stužica. Only one tree of *Acer platanoides* was observed. Most of the stands are tall with high canopies, but the uppermost forests (c. >1100 m alt.) consist of low, contorted trees with low branching. The annual precipitation is about 1200 mm, the annual average temperature about 4–6 °C (http://globus.sazp.sk/atlassr/). The main part of the territory is on a steep south-facing slope and so is very dry, with a low abundance of epiphytic macrolichens. Bedrock consists of sandstone and schist that is generally acidic but probably with base-rich intrusions.

Not all of the 630 ha is formed by virgin forests. Large areas, e.g. along the Stužica River, are young forests that originated after clear cuts during the Second World War. During this period, a railway was built in the Stužica River valley to facilitate timber production (http://en.pralesy.sk). These young beech forests have distinctly smaller tree diameters and are characterized by scattered *Betula*, *Salix caprea* and *Picea abies*, the latter only in the lowest part of the valley.

Material and methods

Epiphytic and epixylic lichens (Table 1, upper part), lichenicolous fungi and non-lichenised microfungi were recorded (Table 1, bottom), but only data on lichens, facultatively lichenised fungi (e.g. *Arthopyrenia salicis*), the non-lichenised genus *Chaenothecopsis*, and *Microcalicium disseminatum* were analysed.

Data from Stužica (Slovakian part)

Slovakian part of Stužica is delimited as the area of the National Nature Reserve Stužica (http://uzemia.enviroportal.sk/main/detail/cislo/687). We considered three sources of recent lichen diversity data. (1) Records from our first field trip on 26–27th October 2013 (J. Malíček & J. Vondrák, about 10 hours). (2) Records from our second field trip on 5–8th June 2014 (J. Šoun & J. Vondrák, about 20 hours). (3) Records by Zdeněk Palice from 2002 (partly published in PIŠÚT et al. 2007). These three data sets are independent in Table 1 and Fig. 2, but they are lumped for analyses (e.g. Figs 3, 4, Table 2).

In our field trips we tried to include all microhabitats, but canopies and the upper parts of trunks are difficult to study. This problem was partly solved by examination of fallen twigs and by occasionally climbing trees. However, during our second field trip we took advantage of windfalls from a recent storm, so we were able to study these microhabitats fairly effectively.

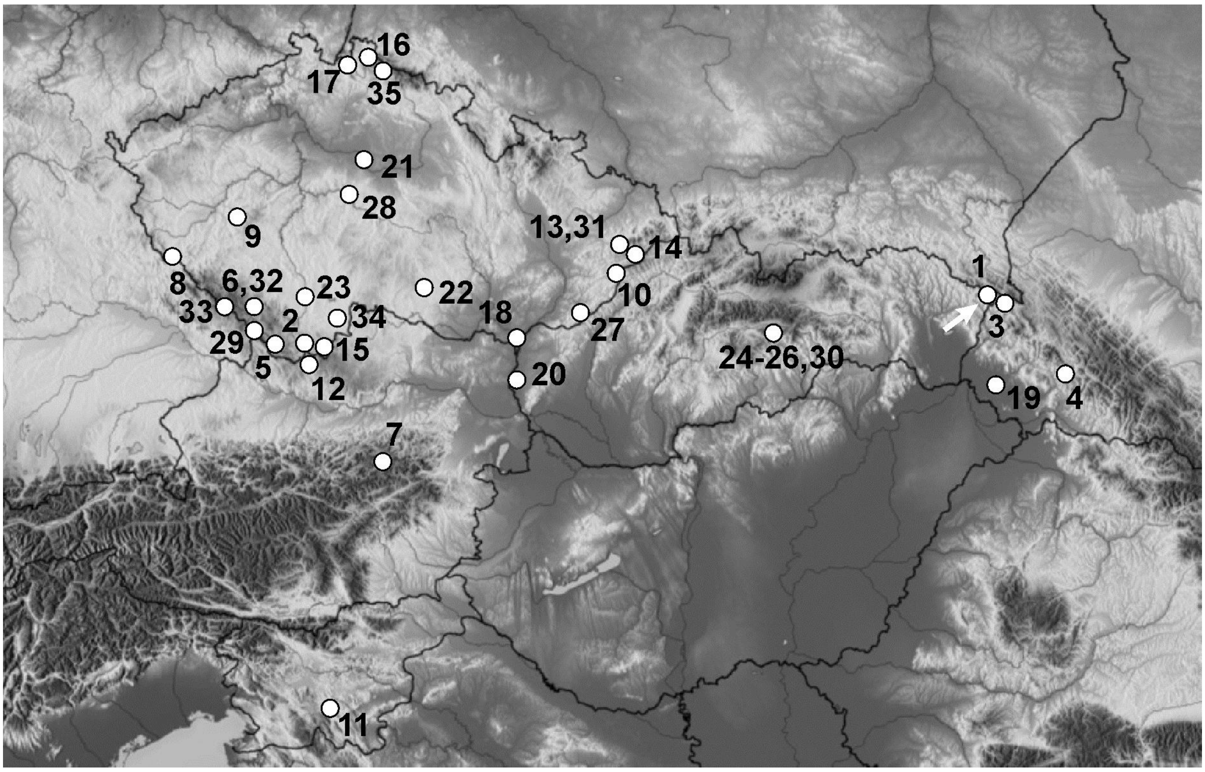


Fig. 1. Localities of Central European old-growth forest inventories. Numbers correspond to Table 3. White arrow shows Stužica.

Material was identified using routine methods. TLC analysis (ORANGE et al. 2010) was done for specimens indicated by an asterisk in Table 1. Voucher specimens are deposited in the herbarium PRA (Jan Vondrák) and private herbaria of the other authors. Vouchers are named by author acronyms in Table 1.

Literature data have been extracted from PIŠÚT & LACKOVIČOVÁ (1992), PIŠÚT (1995), PIŠÚT et al. (2007) and DIEDERICH et al. (2008). To make the extracted data more reliable, we revised all voucher material collected by Ivan Pišút (available in BRA and SAV). Extracted data from the Slovak part are compared with our recent data, to detect possible turnover in lichen species, though with caution as the data samplings are not comparable.

Extraction of data from Stuzhytsia (Ukrainian part)

The lichen list of Stuzhytsia was extracted from recent lichen inventories (KONDRATYUK et al. 1998a, KONDRATYUK & COPPINS 2000, MOTIEJŪNAITE et al. 1999). Three other publications (COPPINS et al. 1998, KONDRATYUK et al. 1998b, COPPINS et al. 2005) largely contain data duplicates and do not provide additional relevant information. Except for

MOTIEJŪNAITE et al. (1999), these papers are poorly organised and it is difficult to obtain correct data about the records. Many listed records refer to sites outside Stuzhytsia. For some species it is unclear whether they even occur in the territory, no substrate is specified for some records and there are no data at all about vouchers. Some missing information and clarifications were provided by B. J. Coppins (personal communication). Additional data from Stuzhytsia have been extracted from COPPINS et al. (2008), CZARNOTA & COPPINS (2000), HILITZER (1939–1940), SÉRUSIAUX et al. (2001), TIBELL (1971) and TRETIACH (2014).

Data from other Central European old-growth forests

To evaluate the similarity with other Central European old-growth woodlands, we extracted data on the presence/absence of lichen species (excluding lichenicolous fungi and epiphytic microfungi) from 34 sites: 16 forests dominated by beech, 6 lowland deciduous forests, 5 deciduous forests on scree, 7 coniferous forests (Table 3). This data set consists of 610 species with 3900 occurrences. The number of species was counted and compared with Stužica (Fig. 3, upper part). Sørensen's similarity index (SØRENSEN 1948) was used for comparison of presence/absence data (Table 3; Fig. 3, lower part). Presence/absence data were also analysed using Detrended Correspondence Analysis (DCA) with downweighting of rare species in Canoco 5 (TER BRAAK & ŠMILAUER 2012) to display similarities of sites in species assemblages (Fig. 4).

Nomenclature

Names not included in the Slovakian checklist (Guttová et al. 2013) are listed with author abbreviations in Table 1.

Results

Epiphytic lichen diversity in Slovakian Stužica

230 epiphytic and epixylic lichen species have recently been recorded in the Slovakian Stužica (Table 1), which is slightly more than was recorded in the Ukrainian Stuzhytsia (Tables 1,3). Another 10 species of non-lichenised epiphytic microfungi or lichenicolous fungi are listed (Table 1, bottom). Nine lichen species were reported from Stužica in the past but not confirmed recently (see Discussion). We found high diversity in the genera *Biatora* (6 species), *Chaenothecopsis* (3), *Fuscidea* (3), *Gyalecta* (4), *Hypogymnia* (4), *Lecanora* (18), *Nephroma* (3), *Opegrapha* (6), *Pertusaria* (9) and *Sclerophora* (5). On the other hand, we found few species and very low abundances in bearded and some fruticose lichens, *Bryoria* (1), *Evernia* (1), *Ramalina* (1) and *Usnea* (2), and also in nitrophilous lichens, e.g. *Physcia* (3), *Physconia* (1) and *Xanthoria* s.lat. (2).

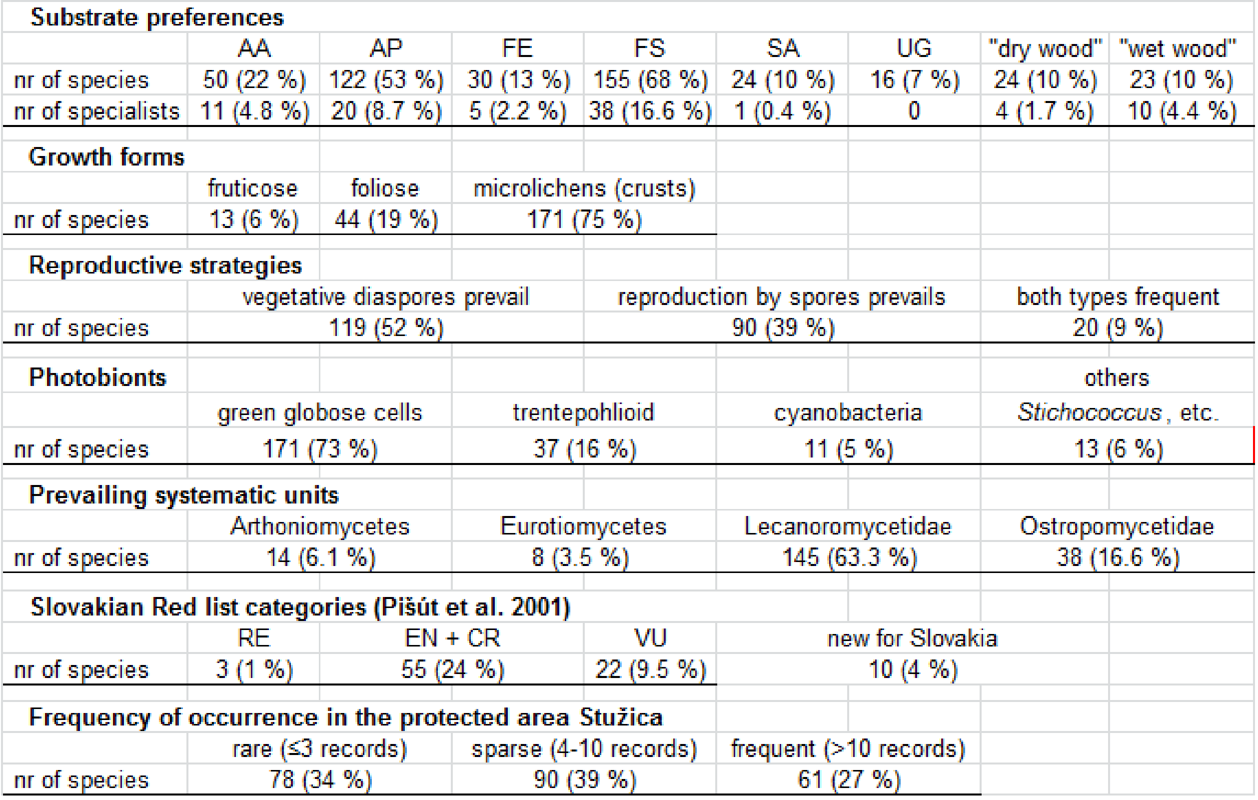
We found the following lichenised fungi, which are not included in the recent checklist of Slovakian lichens (GUTTOVÁ et al. 2013): *Bacidia pycnidiata* (already published by MALÍČEK et al. 2014), *Caloplaca flavocitrina* (FAČKOVCOVÁ et al. 2014), *Fuscidea pusilla* (GUTTOVÁ et al. 2012a), *Graphis macrocarpa*, *Lecanora persimilis* (GUTTOVÁ et al. 2012b), *Lecidea sanguineoatra*, *Lepraria ecorticata*, *Melaspilea gibberulosa* (published from Slovakia by e.g. ZAHLBRUCKNER 1923, as *M. deformis*), *Micarea nigella*, *Opegrapha trochodes*, *Parmotrema arnoldii*, *Pertusaria waghornei*, *Ramonia chrysophaea*, *Sclerophora amabilis* and *Tetramelas chloroleucus*. Lichenicolous *Epigloea urosperma* and the non-lichenised saprophytic corticolous fungus *Kirschsteiniothelia recessa* are also new to Slovakia.

forest type	**locality**	**Nr of lichen taxa**	**Shared taxa with Stužica**	**Sørensen Similarity Index to Stužica**	**altitude (m)**	**ratio of conifers**	**source**
beech-fir	Stužica (SK)	230	230	**1.00**	970	1	Pišút et al. 2007, this paper
beech-fir	Žofínský prales (CZ)	223	133	**0.58**	780	1	Malíček & Palice 2013
beech-fir	Stuzhitsa (UK)	218	162	**0.73**	850	1	Kondratyuk et al. 1998, Kondratyuk & Coppins 2000, Motiejūnaitė et al. 1999
beech-fir	Ugolka (UK)	197	127	**0.59**	880	0	Dymytrova et al. 2013
beech-spruce-fir	Hraničník (CZ)	188	123	**0.59**	1150	1	Z. Palice (unpublished)
beech-spruce-fir	Rotwald (A)	175	105	**0.52**	1180	1	Türk & Breuss 1994, Bilovitz 2007
beech-fir	Boubínský prales (CZ)	140	98	**0.53**	1040	1	E. Budějcká (unpublished)
beech-fir	Neuwald (A)	127	84	0.47	950	1	Hafellner & Komposch 2013
beech	Čerchov (CZ)	106	89	**0.53**	900	0	O. Peksa (unpublished)
beech	Chejlava (CZ)	90	78	0.48	580	0	O. Peksa (unpublished)
beech-fir	Razula (CZ)	90	80	**0.50**	785	1	our unpublished data
beech-fir	Rajhenavski Rog (SLO)	87	63	0.39	885	1	Bilovitz et al. 2011
beech-fir	Luxensteinwand (A)	85	71	0.45	850	1	Malíček et al. 2013
beech	Čertův mlýn (CZ)	77	70	0.45	1070	1	our unpublished data
beech-fir	Hojná Voda (CZ)	67	66	0.44	840	1	Malíček et al. 2012
beech-fir	Salajka (CZ)	57	54	0.37	765	1	our unpublished data
beech	Jizerskohorské bučiny (CZ)	40	36	0.26	740	0	our unpublished data
beech	Karlovské bučiny (CZ)	30	26	0.20	440	0	our unpublished data
floodplain	Soutok Moravy a Dyje (CZ)	212	123	**0.56**	150	0	our unpublished data
floodplain	Otok, Mukachevo (UK)	159	98	0.50	190	0	our unpublished data
floodplain	Horný les (SK)	101	67	0.40	140	0	our unpublished data
floodplain	Libický luh (CZ)	71	58	0.38	200	0	our unpublished data
oak-hornbeam	Oslava a Chvojnice (CZ)	130	130	0.50	350	0	J. Šoun (unpublished)
oak-hornbeam	Hluboká (CZ)	81	81	0.40	400	0	our unpublished data
mixed on scree	Cigánka (SK)	148	88	0.46	700	0	Guttová & Palice 2005
mixed on scree	Hrdzavá (SK)	104	71	0.42	860	0	Guttová & Palice 1999
mixed on scree	Javorniková dolina (SK)	95	70	0.43	790	0	Guttová & Palice 2002
mixed on scree	Javořina (CZ)	77	66	0.43	750	0	our unpublished data
mixed on scree	Ve Studeném (CZ)	64	56	0.38	375	0	our unpublished data
spruce	Trojmezná (CZ)	147	76	0.40	1275	2	our unpublished data
spruce	Fabova hoľa (SK)	114	71	0.41	1380	2	Guttová et al. 2012
spruce	Kněhyně (CZ)	64	42	0.28	1130	2	our unpublished data
spruce	Boubín - top (CZ)	58	39	0.27	1280	2	our unpublished data
spruce	Reschbach Klause (DE)	58	39	0.27	1140	2	our unpublished data
peat-bog pine	Červené blato (CZ)	62	39	0.27	470	2	our unpublished data
peat-bog spruce, pine	Rašeliniště Jizery (CZ)	52	32	0.22	850	2	Malíček & Vondrák 2014

Table 1. Selected characteristics of recently surveyed Central European old-growth forest remnants used for comparison with Stužica (first locality in the list). Sørensen similarity indexes ≥ 0.5 are in bold. Ratio of conifers: 0, rare or absent; 1, mixed with deciduous trees; 2, dominant.

Arthonia byssacea, *Sclerophora coniophaea*, and *S. farinacea* were considered regionally extinct in Slovakia (PIŠÚT et al. 2001). We recorded 55 species that are considered critically endangered or endangered by PIŠÚT et al. (2001), for instance the rare old-growth forest macrolichens *Hypotrachyna revoluta*, *Leptogium cyanescens*, *Leptogium saturninum*, *Lobaria pulmonaria*, *Menegazzia terebrata*, *Nephroma bellum*, *N. parile*, *N. resupinatum*, *Parmelina pastillifera*. Further noteworthy records of microlichens are *Belonia herculina*, *Biatora ocelliformis*, *B. vernalis*, *Buellia erubescens*, *Caloplaca substerilis*, *Coenogonium luteum*, *Gyalecta carneola*, *G. truncigena*, *Ochrolechia pallescens*, *Parmeliella triptophylla*, *Ramonia luteola* and *Rinodina degeliana*.

Table 2 summarises our data about epiphytic and epixylic lichens in Stužica. Epixylic lichens are few; only 14 species are restricted to wood. The dominant tree species, *Abies alba*, *Acer pseudoplatanus* and *Fagus sylvatica*, harbour the main part of the epiphytic lichen diversity. Surprisingly few lichen species were found on *Ulmus glabra*. Microlichens dominate our species list (75%). Among reproductive strategies, vegetative dispersal dominates. It is the preferred strategy in 52% of species and it is more frequent in canopies, or on tree trunks in lit forests of higher altitudes. Our list includes many lichens with trentepohlioid photobiont (37 species), but they are not equally distributed. While they are dominant in some shaded habitats in valley bottoms at lower altitudes, many species are scarcer at higher altitudes. Only eleven species have cyanobacteria, but that is a high number for Central European forests (more in the discussion).



Substrate preferences								
	AA	AP	FE	FS	SA	UG	"dry wood"	"wet wood"
nr of species	50 (22 %)	122 (53 %)	30 (13 %)	155 (68 %)	24 (10 %)	16 (7 %)	24 (10 %)	23 (10 %)
nr of specialists	11 (4.8 %)	20 (8.7 %)	5 (2.2 %)	38 (16.6 %)	1 (0.4 %)	0	4 (1.7 %)	10 (4.4 %)
Growth forms								
	fruticose	foliose	microlichens (crusts)					
nr of species	13 (6 %)	44 (19 %)	171 (75 %)					
Reproductive strategies								
	vegetative diaspores prevail			reproduction by spores prevails			both types frequent	
nr of species	119 (52 %)			90 (39 %)			20 (9 %)	
Photobionts							others	
	green globose cells		trentepohlioid		cyanobacteria		*Stichococcus* , etc.	
nr of species	171 (73 %)		37 (16 %)		11 (5 %)		13 (6 %)	
Prevailing systematic units								
	Arthoniomycetes		Eurotiomycetes		Lecanoromycetidae		Ostropomycetidae	
nr of species	14 (6.1 %)		8 (3.5 %)		145 (63.3 %)		38 (16.6 %)	
Slovakian Red list categories (Pišút et al. 2001)								
	RE	EN + CR		VU	new for Slovakia			
nr of species	3 (1 %)	55 (24 %)		22 (9.5 %)	10 (4 %)			
Frequency of occurrence in the protected area Stužica								
	rare (≤3 records)		sparse (4-10 records)		frequent (>10 records)			
nr of species	78 (34 %)		90 (39 %)		61 (27 %)			

Table 2. Selected characteristics of lichen diversity in Slovakian Stužica (i.e. 230 recently recorded species). Substrate abbreviations are as in Table 1. "Substrate specialists" means species recorded from only one type of substrate.

Unequal distribution of lichen diversity in Slovakian Stužica

More than half of the area is rather poor in lichens. This includes south-facing slopes below c. 1000 m altitude, which are obviously dry, and where many trees, including those with very thick trunks, are almost without lichens. Ancient firs here are also poor in species: usually they have only xerophilous pin-headed lichens and a few other common species. Most of the species found on beeches or on wood are common and are also frequent in secondary forests.

The lichen diversity hot spots are humid valleys with a watercourse at lower altitudes and humid slopes and mountain ridges above 1000 m, but the lichen composition in these two environments is different. At lower altitudes microlichens dominate (at least on the lower parts of trunks), and many have trentepohlioid photobiont; e.g. *Arthonia helvola*, *Coenogonium luteum*, *Dictyocatenulata alba*, *Gyalecta flotowii* and *G. truncigena*. Also some cyanolichens were found mostly in valleys, e.g. *Collema flaccidum*, *Leptogium cyanescens* and *Nephroma parile*. Rare parmelioid macrolichens (*Hypotrachyna revoluta* and *Parmotrema arnoldii*) were recorded at low altitudes, but in the upper, and probably more sunlit, parts of trunk.

Macrolichens are abundant at higher altitudes in Stužica, and even south facing slopes, which are dry and almost without epiphytic lichens at low altitudes, support well-lit forests with rich lichen communities above about 1000 m. Many rare macrolichens were restricted (or almost restricted) to altitudes above 1000 m: *Hypogymnia vittata*, *Leptogium saturninum*, *Lobaria pulmonaria*, *Melanelixia glabra*, *Menegazzia terebrata*, *Nephroma bellum*, *N. resupinatum* and *Parmelina pastillifera*. Upper altitudes also have some montane lichens, such as *Frutidella pullata*, *Lecanora subintricata* and *Pycnora leucococca*.

Distinct but unidentified taxa

***Bacidia* cf. *viridescens*.** Our specimen resembles *B. viridescens*: thallus areolate, without any propagules; hypothecium slightly brownish to colourless; epihymenium olive, K-; excipulum largely colourless but with orange-brown area at the top, K+ darkening; ascospores acicular, c. 40 × 1.5 µm. However, *B. viridescens* is not thought to be epiphytic, so our specimen may belong to another, perhaps undescribed taxon.

***Lecanora* cf. *farinaria*.** Three samples of a sorediate crust from Stužica contain atranorin and roccellic acid, alone or together with an unknown fatty acid. This crust is usually sterile, but one "*Lecanora subfusca*-type" apothecium was found. Morphologically, it strongly resembles *L. farinaria*, an oceanic species restricted mainly to wood and acid bark (TØNSBERG 1992). Our samples are identical with *L. farinaria* in the character of soralia, sorediate apothecial margin, large crystals in amphithecium and in chemistry. However, the epihymenium in our fertile specimen belongs to the *chlarotera*-type (coarse granules mainly at paraphyses tips, soluble in HNO_3 after several minutes) and the thallus is thick and frequently verrucose. The species is probably undescribed.

***Pertusaria alpina* and *P. constricta*.** It is not clear to us whether these are distinct species and here we do not distinguish them. They are said to differ slightly in thallus thickness and in the shape of the base of apothecial warts (ERICHSEN 1936). Both are rare in Central Europe. According to ERICHSEN (1936) and WIRTH et al. (2013), they have slightly different ecology. *Pertusaria alpina* prefers young trees and branches whereas *P. constricta* occurs on trunks, usually of beeches. PIŠÚT & LACKOVIČOVÁ (1992) reported *P. alpina* in Slovakian Stužica, but KONDRATYUK et al. (1997) reported both taxa from Ukrainian Stuzhytsia.

***Placynthiella* cf. *dasaea*.** This is probably an undescribed sorediate *Placynthiella* without gyrophoric acid and morphologically similar to *P. dasaea* (TØNSBERG, personal communication). According to our collections from the Czech Republic and Slovakia, it is distributed in well-lit forests in montane regions on acidic bark of beeches, where it sometimes dominates lichen communities. It possesses one or two compounds of aliphatic character. (They are not necessarily fatty acids; one of the spots on TLC plates has a slightly coloured tinge.)

***Rinodina freyi* and *R. septentrionalis*.** SHEARD (2010) distinguishes these, but notes that young but fertile thalli of *R. freyi* may be indistinguishable from *R. septentrionalis*. Our specimen includes only two small thalli with few apothecia and seems closer to *R. septentrionalis*: the thallus is not areolate but of broadly-spreading verrucae; apothecia are scattered, with constricted bases. Our specimen was on smooth bark of a twig, which also fits *R. septentrionalis*. However, *R. septentrionalis* is a boreal/arctic lichen, whereas *R. freyi* would be expected in our region.

***Vezdaea* cf. *cobria*.** Our specimen from rough bark of old beech consists of a sterile thallus formed of numerous goniocysts. As in *V. cobria*, the goniocysts are formed by only one photobiont cell, but the cell diameter (10–40 μm), is larger than expected for that species.

Revision of voucher specimens corresponding to literature data

We have revised specimens collected in Slovakian Stužica by Ivan Pišút (available in BRA and SAV) and by Zdeněk Palice (PRA). Most material was correctly identified, but specimens called *Cetrelia olivetorum*, *Lecanora cinereofusca*, *Parmelia elegantula* and *Pertusaria flavida* belong to other species. We confirmed the identification of several specimens of *Usnocetraria oakesiana* and *Parmotrema crinitum* containing well-developed and large thalli. However, we did not collect these two macrolichen species ourselves.

List of revised samples: *Arthopyrenia salicis* (PRA ZP6433, as *Arthopyrenia* sp.), *Belonia herculina* (BRA CR11697), *Calicium viride* (BRA CR11698), *Cetrelia monachorum* (SAV, s.n., as *C. olivetorum*), *Collema flaccidum* (BRA CR11699), *Flavoparmelia caperata* (BRA CR11700, as *Parmelia c.*), *Fuscidea cyathoides* (BRA CR11701), *Graphis pulverulenta* sensu NEUWIRTH & APTROOT 2011 (BRA CR11702, as *Graphis scripta*), *Lecanora argentata* (BRA CR11704, CR11705), *L. carpinea* (SAV, s.n.), *L. pulicaris* (SAV, s.n., as *L. cinereofusca*), *L. subcarpinea* (BRA CR11706, as *L. nemoralis*), *Leptogium cyanescens* (BRA CR11707 – CR11709), *L. lichenoides* (BRA CR11710 – CR11712), *Lobaria pulmonaria* (BRA CR11714), *Mycobilimbia tetramera* (PRA ZP6432), *Nephroma bellum* (BRA CR11719), *N. resupinatum* (BRA CR11721 – CR11723), *Melanelixia glabratula* (BRA CR11713 – CR11718, as *P. elegantula*), *Ochrolechia androgyna* (BRA CR11018), *Parmelia saxatilis* (BRA CR11727, CR11728), *Parmelia sulcata* (BRA CR11729), *Parmotrema crinitum* (BRA CR11730 – CR11734, as *Parmelia c.*), *Pertusaria albescens*

(BRA CR11735), *P. amara* (BRA CR11736), *P. coccodes* (BRA CR11737), *P. coronata* (BRA CR11741, as *P. flavida*), *Phlyctis argena* (BRA CR11742), *Platismatia glauca* (BRA CR11743), *Pseudevernia furfuracea* (BRA CR11744), *Pyrenula nitida* (BRA CR11745 – CR11747), *Ramalina pollinaria* (BRA CR11748), *Thelotrema lepadinum* (BRA CR11750 – CR11753), *Usnocetraria oakesiana* (BRA CR11724 – CR11726, as *Cetraria o.*), *Varicellaria hemisphaerica* (BRA CR11754 – CR11756, as *Pertusaria hemisphaerica*), unidentified lichen (BRA CR11738 – CR11740, as *Pertusaria flavida*, isidia absent but thallus sorediate; soredia c 15–25 µm diam.; thallus K+ yellowish, KC+ yellow-orange, C+ orange, Pd-, UV+ dark orange; TLC: atranorin, usnic acid, zeorin).

Discussion

Lichen diversity in Slovakian Stužica (previous versus our data)

Unfortunately, we cannot reasonably compare turnover of microlichens between our and previous data sets, because microlichens were significantly under-recorded in previous studies (Fig. 2). We recorded 115 new microlichen species in Stužica. Some epiphytic macrolichens recorded in Stužica in the past (PIŠÚT & LACKOVIČOVÁ 1992) were not found by us: *Cladonia polydactyla*, *C. squamosa*, *Heterodermia speciosa*, *Nephromopsis laureri*, *Parmotrema crinitum*, *Peltigera hymenina*, *Phaeophyscia pusilloides*, *Punctelia subrudecta*, and *Usnocetraria oakesiana*. We saw voucher specimens only for some of these (see the results), which makes comparison of datasets difficult. For instance, the record of *Nephromopsis laureri* may be based on incorrectly identified *Usnocetraria oakesiana*, and *Peltigera hymenina* may be *P. degenii*, which does occur in Stužica.

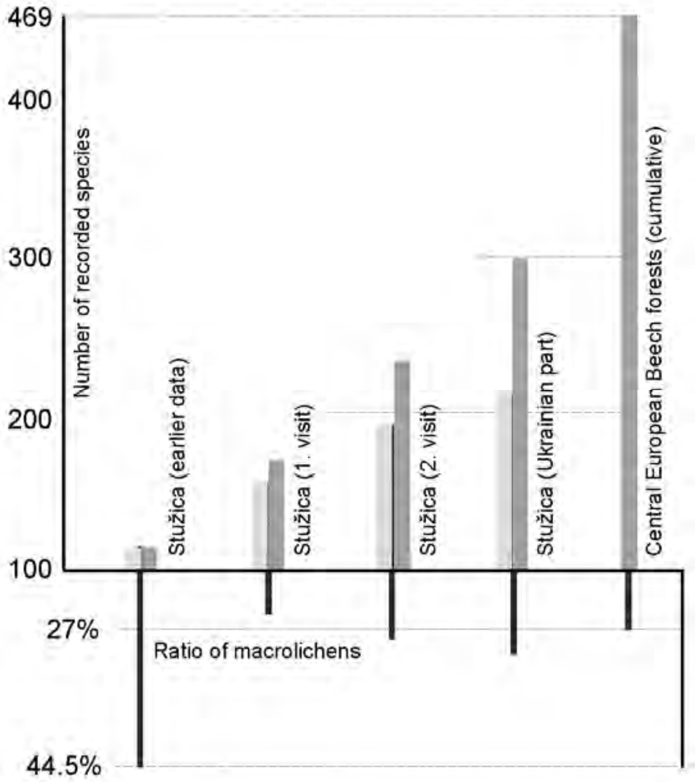


Fig. 2. Lichen diversity captured in particular surveys of Stužica forest (pale columns) and cumulative number of species (dark columns). Ratios of macrolichens are shown in the bottom as a measure of survey quality.

However our reassessment of vouchers for *Nephroma bellum* (one specimen), *N. resupinatum* (4), *Usnocetraria oakesiana* (3) and *Parmotrema crinitum* (5), including well-developed, unharmed lichens, suggests that some of the old-forest macrolichens have retreated or perhaps even disappeared. Of these, we recorded only one well-developed thallus of *N. bellum* and a few small thalli of *N. resupinatum*. We recorded some macrolichens for the first time, e.g. *Leptogium saturninum*, *Nephroma parile* and *Parmotrema arnoldii*, but most of them were extremely rare in Stužica, usually recorded from one site only.

Comparison of lichen diversity in Slovakian Stužica and Ukrainian Stuzhytsia

The Ukrainian part has been thoroughly surveyed (see the Methods). Table 1 shows differences in species lists between Slovakian and Ukrainian parts. Surprisingly, the lists differ considerably, mainly in microlichens, e.g. in the genera *Eopyrenula* and *Megalaria*. 48 species known from the Ukrainian part were not recorded from Slovakian Stužica; vice versa for 60 species. Because the woodland appears to be fairly homogeneous, this suggests that surveys of both territories were not complete. However, the difference between the two parts is distorted and exaggerated by inconsistent identifications of particular lichens. The lichen called *Caloplaca chrysophthalma* in the Ukrainian dataset is probably the same as our *C. flavocitrina*. Other examples are Ukrainian *Haematomma ochroleucum* (perhaps *Lecanora thysanophora*). *Caloplaca cerina* (possibly *C. monacensis*), *C. ulcerosa* (almost certainly *C. substerilis*), *C. chlorina* (almost certainly *C. turkuensis*) etc. Almost 300 species were found in both parts of Stužica, which is more than 65 % of the epiphytic lichen diversity known in beech-dominated forests in Central Europe (Fig. 2). The Ukrainian part is expected to have more species, because it is approximately four times larger and has more diverse topography and microclimate.

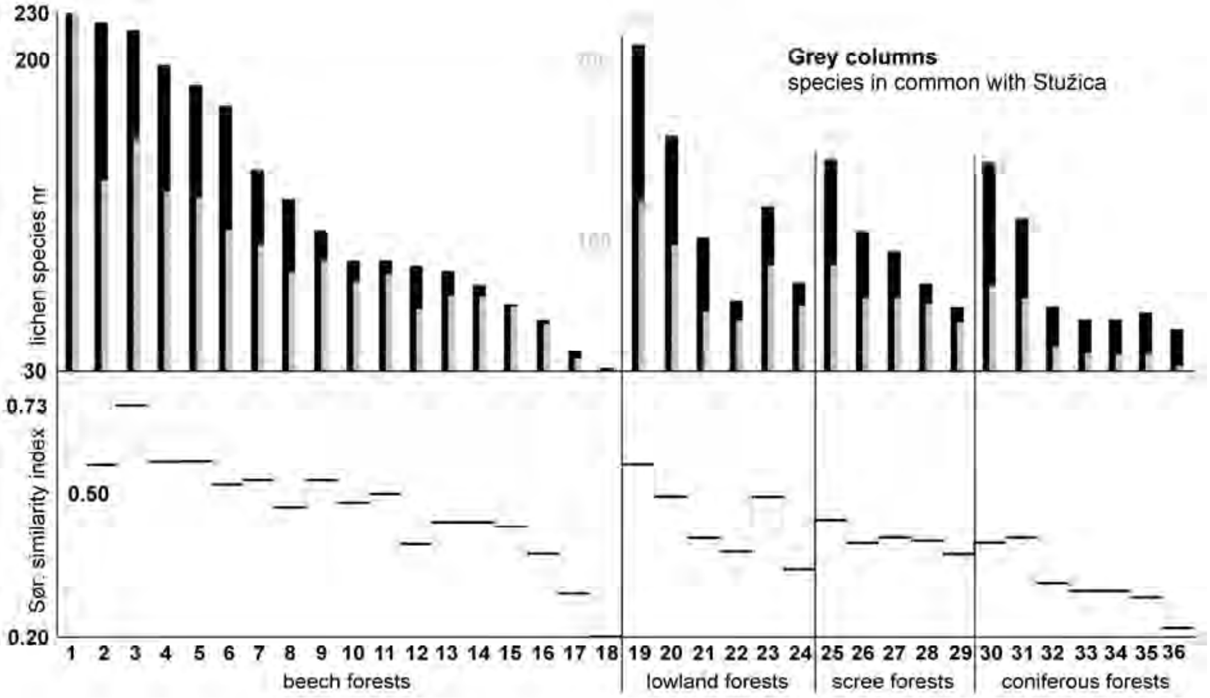


Fig. 3. Upper chart: number of lichen species captured in 36 lichen inventories of Central European old-growth forests (black columns); number of species shared with Stužica (thin grey columns). Lower chart: Sørensen similarity index of each locality to Stužica. Numbers on x-axis correspond to Table 3.

Lichen diversity in Slovakian Stužica versus other Central European old-growth forests

The number of species recorded in the Slovakian part of Stužica is the highest among Central European old-growth forest localities included in Table 3 and Fig. 3. Only three other forest inventories report more than 200 epiphytic and epixylic species. One of them is the Ukrainian part of Stužica, which is also the closest in species composition, with Sørensen's similarity index 0.72 (details discussed above).

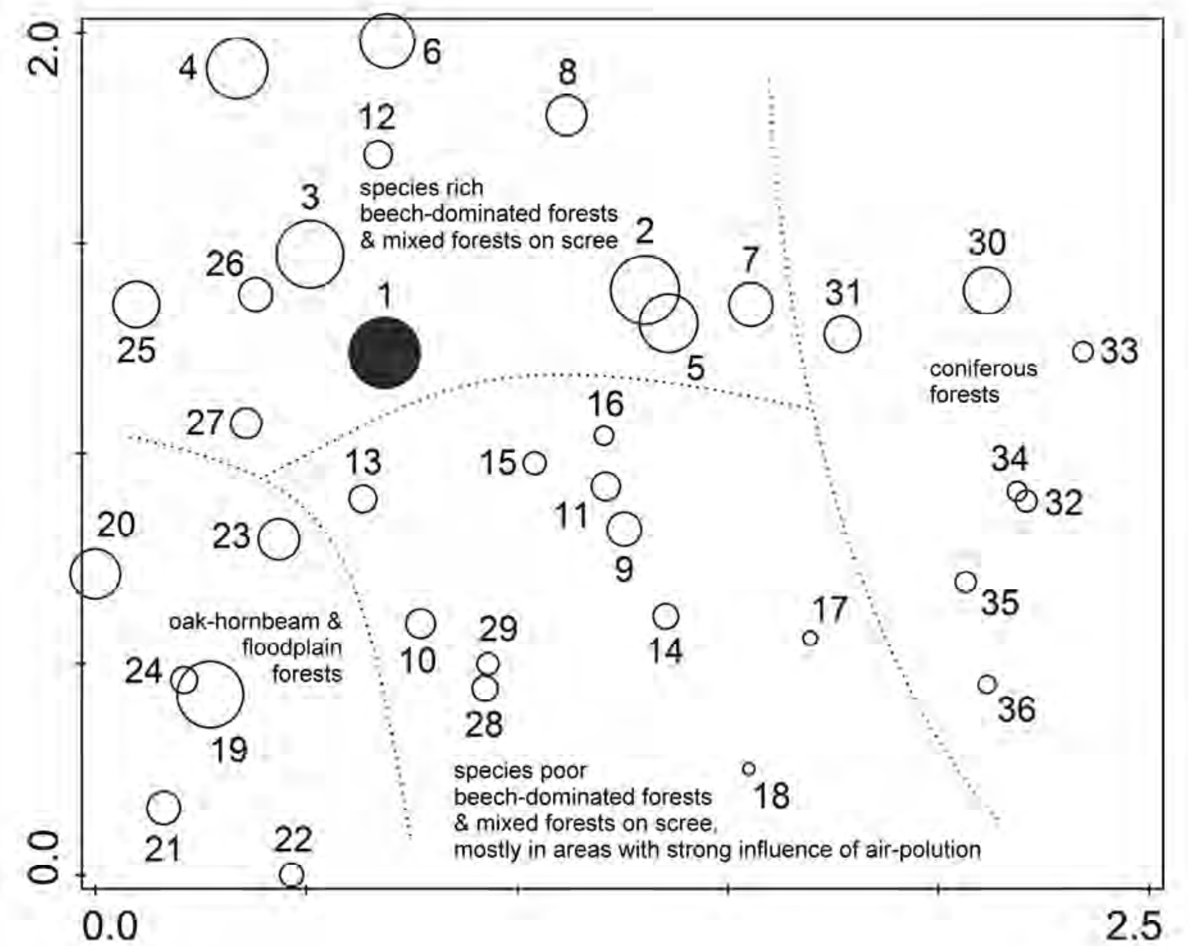


Fig. 4. DCA ordination diagram showing similarities in lichen species composition among Central European old-growth forest localities. The first two axes are shown, explaining 19.7 % of the variability in species data. Numbers correspond to Table 3. The size of circles corresponds to the number of species. Black circle is Stužica.

Another locality with more than 200 species is a beech-fir forest Žofínský prales (MALÍČEK & PALICE 2013), but its species composition is rather different. It is dominated by lichen crusts. Macrolichens constitute only 20 % of species and few rare, old-growth forest macrolichens are present, e.g. *Cetrelia cetrarioides*, *Lobaria pulmonaria* and *Menegazzia terrebrata*. However bearded and some fruticose species are more diverse: *Alectoria sarmentosa*, *Evernia* (2 species), *Ramalina* (2) and *Usnea* (6), mainly because natural spruce stands are present, unlike Stužica. Cyanolichens are distinctly fewer in Žofínský prales, except for epiphytic/epixylic *Peltigera* (6). Among microlichens, it differs for instance in higher diversity of *Biatora* (10) and *Micarea* (13), but lower diversity of *Fuscidea* (0) and *Gyalecta* (1), and absence of *Belonia herculina*, common in

Stužica. Žofínský prales also has a high amount of dead wood and thus a higher diversity of epixylic species.

The third forest inventory reaching 200 species was done in the flood-plain forest "Soutok Moravy a Dyje" (VONDRÁK et al., unpublished). Its species composition is different (Fig. 4), but not very different (Sørensen similarity index 0.56). The flood-plain forest differs in the absence of rare parmelioid macrolichens and cyanolichens and in the high abundance and diversity of nitrophilous species. Characteristic genera are *Anisomeridium*, *Arthonia*, *Bacidia*, *Bacidina*, *Lithothelium*, *Phaeophyscia*, *Physcia*, *Physconia* and *Schismatomma*.

Almost 200 species were recorded in the East Carpathian beech forest Ugolka – Shyrokyi Luh (DYMYTROVA et al. 2013), but the inventory does not include lichens on wood. Among central European beech forest inventories, this includes the highest number of cyanolichens and rare macrolichens: *Collema* (2 species), *Hypotrachyna revoluta*, *Leptogium* (4), *Lobaria* (2), *Menegazzia terebrata*, *Nephroma* (2), *Pannaria conoplea*, *Parmeliella triptophylla*, *Parmotrema* (3), *Peltigera* (5), including the rare *Peltigera collina*, and *Sticta fuliginosa*. In comparison with Stužica, it has e.g. fewer *Arthonia* (4), *Fuscidea* (0) and *Sclerophora* (2), but it includes *Arthopyrenia* (3), *Megalaria laureri* and *Thelopsis* (2). ~~H~~A high number of rare macrolichens was recorded also from the largest Austrian beech dominated virgin forest, Rotwald (Türk & Breuss 1994, Bilovitz 2007).

The species composition of Central European beech dominated forests is fairly uniform, and resembles that of mixed forests on scree, but lowland forest types and montane coniferous forests differ, and they form clusters not mixed with the two former types in the DCA ordination (Fig. 4). Carpathian localities nr. 3, 4, 25, 26 and 27 and localities 6 and 12 in the Alps group together with Stužica (loc. 1) in DCA. These localities are mixed forests but their common characters are not entirely clear. They are mostly species-rich with occurrence of rare macrolichens and cyanolichens and an abundance of lichen crusts characteristic of old-growth forests.

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Appendix 1. Lichen species recorded in the whole of Stužica including Slovakian and Ukrainian parts. Taxa newly recorded in the Slovakian part are in bold. Previous data adopted from [1] PIŠÚT & LACKOVIČOVÁ 1992, [2] PIŠÚT 1995, [3] PIŠÚT et al. 2007, [4] KONDRATYUK et al. 1998, [5] KONDRATYUK & COPPINS 2000, [6] MOTIEJŪNAITE et al. 1999, [7] HILITZER 1939-1940, [8] TIBELL 1971, [9] DIEDERICH et al. 2008, [10] SÉRUSIAUX et al. 2001, [11] CZARNOTA & COPPINS 2000, [12] COPPINS et al. 2005, [13] COPPINS et al. 2008, [14], TRETIACH 2014. Abundance assessment is based on our field experiences: rare, recorded 1-3 times; sparse, recorded 4-10 times; frequent, recorded more than 10 times. Substrates: AA, *Abies alba*; AI, *Alnus incana*; AP, *Acer pseudoplatanus*; APlat, *A. platanoides*; BP, *Betula pendula*; CB, *Carpinus betulus*; FE, *Fraxinus excelsior*; FS, *Fagus sylvatica*; SA, *Sorbus aucuparia*; SC, *Salix caprea*; UG, *Ulmus glabra*. Substrate data from our survey together with substrate data from previous inventories are included. JM, JŠ and JV are acronyms of the authors followed by the number of collected specimens (if collected more than once); asterisk indicates samples with TLC data; "rec." means recorded without voucher specimens.

Taxa	**Substrates**	**Previous data from Slovak / Ukrainian part**	**our data (2013 / 2014)**	**Abundance assessment**
Absconditella lignicola	AA (rotten wood)	[1]/[5]	JV, JM / rec.	frequent
Acrocordia gemmata	AP, FS	[1]/[5]	JV(3), JM / rec.	frequent in lower altitudes
Agonimia allobata	AP (base of trunk)	0/[5]	non / JŠ	rare
Agonimia repleta	AP, FS, UG (bases of trunks)	0/[5,11]	JV(2), JM(2) / JŠ, JV	frequent
Agonimia tristicula	FS (among mosses)	0/[4,5]	JV / rec.	rare
Amandinea punctata	AP, FS, wood of AA snags	0/[4,5]	JV(3), JM / JŠ, JV	frequent on lit AP bark
Anaptychia ciliaris	APlat, FS	0/[5,7]		not recorded
Anisomeridium polypori	AP, FS, UG	[3]/[4,5, sub *A. nyssaegenum*]	JV(2) / JŠ	frequent
Arthonia byssacea	AP	0/[4,5]	non / JV	rare
Arthonia didyma	AA, AP, FS	0/[4,5]	JV / JV	sparse in lower altitudes
Arthonia helvola	AA, AP, FS (bases of trunks)	0/0	JV / JŠ, JV	sparse in lower altitudes
Arthonia mediella	AP,FS	0/[4,5]		not recorded
Arthonia radiata	FE, FS	0/[4,5]	JM / rec.	sparse
Arthopyrenia punctiformis	AI	0/[4,5]		not recorded
Arthopyrenia salicis	FS (branch & young trunk)	[Palice 6433!; not published]/[5, outside Stuzhytsia]		not recorded
Arthonia ruana	FS	0/[4,5 sub *Arthothelium r.*]		not recorded
Arthonia spadicea	AA, AP, FS	0/[4,5]	JV / JŠ	frequent
Arthonia vinosa	AA, AP, FS	0/[5]	JM / JŠ, JV(3)	sparse
Bacidia circumspecta	FS	[3]/[4,5]	non / JV(3)	sparse
Bacidia incompta	AP (weathered wood of old hollow trunk)	[3]/0		rare
Bacidia pycnidiata **Czarnota & Coppins**	AP (mosses on bark)	0/0	JV / non	rare
Bacidia rosella	AP/FS	0/[5]	rec. / non	rare
Bacidia rubella	AP, FS	[1]/[4,5]	JV / JV	frequent
Bacidia subincompta	AP, FE, FS, UG	[3]/[4,5]	JV(5) / JŠ, JV(3)	frequent
Bacidia **cf.** ***viridescens***	FS	0/0	non / JV	rare
Bacidia viridifarinosa	AP	0/[5]		not recorded
Bacidina phacodes	FS	0/0	JM, JV(2) / rec.	sparse
Bacidina sulphurella **(Samp.) M. Hauck & V. Wirth**	AP, FS	0/[4,5 sub *B. arnoldiana*]	rec. / rec.	sparse
Baeomyces rufus	AA (wet base of trunk), rotten wood	0/0	rec. / rec.	rare

Belonia herculina	AP, FS, (SC), bases of trunks	[1,3]/[4,5]	JM, JV(2) / JŠ	frequent
Biatora chrysantha	AA, AP, FS (partly on bark mosses)	[3]/[4,5]	JV(3) / JV	sparse
Biatora efflorescens	AP, FS, SA	0/0	JV / JŠ	frequent in higher altitudes
Biatora globulosa	FS, GU, wood of snags	0/[4, sub *Catillaria g.*]	JM, JV / JV(3, with albinomorph)	sparse
Biatora ocelliformis	FS	0/[4,5]	JM / JV(2)	sparse
Biatora vernalis	AP, FS (mossy bark)	[3]/[5]	JM, JV(4) / JŠ, JV(2)	frequent in lower altitude; mostly in valleys
Biatora veteranorum	AA (bark and wood of snags)	[3, sub *Catillaria alba*]/[4, sub *C. alba*]	JM, JV / JV	sparse
Biatoridium monasteriense	FS, UG (partly on bark mosses)	[3]/[4,5]	JM(2), JV(3) / JV(2)	sparse
Bilimbia sabuletorum	FS (bark mosses)	0/[4, sub *Mycobilimbia s.*]	JM, JV / JV	sparse
Bryoria bicolor	mossy bark and rocks	0/[7, sub *Alectoria b.*]		not recorded
Bryoria fuscescens	AA, FS	[1]/[7, sub *Alectoria jubata*]	non / JV	rare
Buellia disciformis	FS	0/[5]	JM(2) / JV	sparse
Buellia erubescens	FS	0/[4, unclear note]	non / JV	rare
Buellia griseovirens	AP, FE, FS, SA	0/[4,5]	JV / JŠ (fertile), JV(2)	frequent
Buellia schaereri	AP	0/[4,5]		not recorded
Calicium glaucellum	dry wood of snags	0/[4,5]	rec. / rec.	sparse
Calicium salicinum	AP, dry wood of snags	[1]/[4,5]	rec. / rec.	sparse
Calicium viride	AA, AP	[1]/[4,5]	non / rec.	rare
Caloplaca cerina	AP	0/[4,5]		not recorded
Caloplaca chrysophthalma	APlat	0/[4, possibly *C. flavocitrina*]		not recorded
***Caloplaca flavocitrina* (Nyl.) H. Olivier**	AP	0/[4, sub *C. citrina*]	JV / non	rare
Caloplaca herbidella	AP, (FS)	[1]/[4,5]	JM, JV / JŠ, JV	sparse, in higher altitudes
Caloplaca substerilis	AP, FS	0/[5, sub *C. ulcerosa*]	JV(3) / JV	sparse
Caloplaca turkuensis	AP, FS	0/[4, sub *C. chlorina*]	non / JV	sparse in higher altitudes (mostly sterile)
***Candelaria concolor* s.str.**	FA (canopy)	0/[4,5]	non / rec.	rare
***Candelariella efflorescens* s.str.**	AP, FS, SA, UG	0/0	JV(2) / JŠ, JV(2)	frequent
Candelariella reflexa s.str.	FS	[1, s.lat.]/[4,5, s.lat.]	JV / JŠ	rare

Candelariella xanthostigma	AP, FS, SA, UG	[1]/[4,5]	rec. / rec.	sparse
Catillaria nigroclavata	FE	0/0	non / JV	rare
Cetrelia cetrarioides	FS	0/0	JV / JŠ*	rare
Cetrelia monachorum	AP, FS	[1, sub *C. olivetorum*]/[4, sub *C. olivetorum*]*	JM, JV(3) / JŠ*	frequent in higher altitudes
Chaenotheca brachypoda	FS (bark), dry wood of snags	0/[4,5]	rec. / rec.	sparse
Chaenotheca brunneola	AA (bark), dry wood of snags	0/[4,5]	JV / JV	sparse
Chaenotheca chrysocephala	AA, AP	[1]/[4,5]	rec. / rec.	sparse
Chaenotheca ferruginea	AA	0/[4, unclear note]	rec. / rec.	sparse
Chaenotheca furfuracea	FS (dry bases of trunks)	0/[5]	rec. / rec.	sparse
Chaenotheca stemonea	AA	0/0	JM* / rec.	rare
Chaenotheca trichialis	AA (bark and dry wood of snags)	0/[4,5]	rec. / rec.	sparse
Chaenotheca xyloxena	wood of AA snags	0/[4,5]	JV / JV	frequent
***Chaenothecopsis debilis* (Sm.) Tibell**	wood of AA snags	0/0	non / JV	rare
Chaenothecopsis epithallina	?	0/[4,5]		not recorded
Chaenothecopsis pusilla	APlat	0/[4,5]		not recorded
Chaenothecopsis pusiola	AA (wood)	0/[4, unclear note]	JV / non	sparse
***Chaenothecopsis savonica* (Räsänen) Tibell**	AA, lichenicolous on Chaenotheca brunneola	0/0	JV / non	rare
Chrysothrix candelaris	AA, AP	0/[4,5]	non / JV	rare
Cladonia chlorophaea s.lat.	AP, FS, SC (trunk bases)	[1]/[4,5]	non / rec.	sparse
Cladonia coniocraea (incl. *C. ochrochlora*)	AA, BP, FS, PA, SA, SC (mossy bark and wood)	[1]/[4,5]	JV(2) / rec.	frequent
Cladonia digitata	AA, FS (wood and bark at trunk bases)	[1]/[4,5]	rec. / rec.	frequent
Cladonia fimbriata	AA, FE, FS, PA, SA (rotten wood and mossy bark)	[1]/[5]	rec. / rec.	frequent
Cladonia macilenta	mossy, rotten wood	0/0	non / JV	rare
Cladonia polydactyla	bark at base of FS	[1]/0		not confirmed
Cladonia pyxidata	AP (trunk bases)	[1, on soil]/[4,5]	rec. / JV(2)	sparse
Cladonia squamosa	AP (bark at trunk base)	[1]/0		not recorded; sparse in higher altitude [1]

Coenogonium luteum	FS	0/[4,5 sub *Dimerella lutea*]	non / JV	rare in lower altitudes
Coenogonium pineti	AA, AP, BP, FS, UG (usually bases of trunks), rotten wood	[1]/[4,5 sub *Dimerella p.*]	JV / rec.	frequent
Collema flaccidum	AP, FS, sandstone	[1]/[4,5]	rec. / rec.	rare
Cyphelium karelicum	AA	0/[8, coll. Hilitzer 1926]		not recorded
Dictyocatenulata alba	AA, AP, FS, SC, UG (bases of trunks), sandstone	[9]/0	JM, JV / JŠ	frequent in lowest parts in valleys
Diploschistes muscorum	AP (Cladonia squamules at trunk base)	[1]/0	non / JŠ	rare in higher altitudes (Kamenná Lúka)
***Diplotomma alboatrum* s.lat.**	AP	0/0	JV / non	rare
Eopyrenula leucoplaca	FS	0/[4,5]		not recorded
Evernia divaricata	PA	0/[7]		not recorded
Evernia prunastri	AP, FE	[1]/[4,5]	rec. / JV	sparse
Fellhanera gyrophorica	FS (also on bark mosses)	[3,10]/[4, sub *Fellhanera* sp.; 10]		rare
Felhanera cf. *subtilis*	FS	0/[4, possibly *F. ochracea*]		not recorded
Flavoparmelia caperata	FS	[1, sub Parmelia c.]/[4,5]	non / rec.	rare
Frutidella pullata	FS	[3, sub *Lecidea p.*]/0	non / JV	sparse in higher altitudes (at ridge)
Fuscidea arboricola	FS	0/[4,5]	JV / JV	rare
Fuscidea cyathoides var. *corticola* (Fr.) Kalb	(AP), FS (mostly canopies)	[1,3]/[5, outside Stuzhytsia]	JM, JV(3) / JV(2)	frequent
Fuscidea pusilla	SA	0/[4,5]	non / JV*	sparse in higher altitudes
***Graphis macrocarpa* (Pers.) Röhl.**	AA	0/0	JV / non	probably rare
Graphis pulverulenta (Pers.) Ach. (incl. older records of *Graphis scripta* s.lat.)	AA, AP, BP, CA, FE, FS, SC, UG	[1]/[4,5]	JV / JŠ, JV	frequent in lower altitudes, rare at ridge
Gyalecta carneola	FS	0/[4,5, outside Stuzhytsia]	JV / non	rare
Gyalecta flotowii	FS	[1,3]/[4,5]	JM(2) / JŠ, JV(2)	rare
Gyalecta truncigena	FS	0/[4,5]	JV / non	rare
Gyalecta ulmi	AP	0/[4,5]	JV / non	rare
Haematomma ochroleucum	AP, FS	0/[4,5]		not recorded
Heterodermia speciosa	AI, CB, FS	[1]/[6;7, sub *Anaptychia s.*]		extinct?; alt. 1150 m (Pišút 1966)
Hypocenomyce caradocensis	wood of snag	0/[4,5]	rec. / non	rare
Hypocenomyce scalaris	AA, (FS), wood of snags	[1]/[4,5]	rec. / rec.	frequent

Hypogymnia farinacea	AA	0/[4;7, sub *Parmelia bitteriana*]	rec. / rec.	sparse
Hypogymnia physodes	AA, AP, FS, SA, SC, PA	[1]/[4;7, sub *Parmelia p.*]	rec. / rec.	frequent
Hypogymnia tubulosa	AA, FS	0/[4;7, sub *Parmelia t.*]	rec. / rec.	sparse
Hypogymnia vittata	AA, FS	[1]/[7, sub *Parmelia v.*]	JV / rec.	rare in highest altitudes (one tree at 1100 m alt.)
Hypotrachyna revoluta	FS	0/[4,5]	non / JV(2) (possibly *H. afrorevoluta*)	sparse
Lecania croatica	AP, FE, FS, UG	0/[4, sub *Biatora punctiformis*, nom.ined.]	JM(3), JV(3) / JŠ, JV	frequent in lower altitudes
Lecania cyrtellina	UG	0/[4,5]		not recorded
Lecania naegelii	FE	0/0	non / JV	rare
Lecanora albella	AA, FS	0/0	non / JŠ, JV(2)	sparse
Lecanora allophana	?	0/[4,5]		not recorded
Lecanora argentata (incl. *L. subrugosa*)	AP, FE, FS	[1]/[4,5]	JM / rec.	frequent
Lecanora carpinea	AP, FS*	[1]/[4,5]		rare?
Lecanora chlarotera	AP, FE	0/[4,5]	JM / JV	rare
Lecanora cinereofusca	FS	[1, one specimen in SAV revised as *L. pulicaris*]/[4,5]		not recorded
Lecanora conizaeoides	AA, FS, PA, wood of snags	[1]/[4,5]	rec. / rec.	frequent
Lecanora expallens	AA, AP	0/[4,5]	JM / JV*	frequent
Lecanora* cf. *farinaria	AP	0/[5, *Lecanora farinaria*]	JM* / JV(2)*	sparse in higher altitudes, at ridge
Lecanora glabrata	FE, FS	0/[4,5]	rec. / JŠ	frequent in lower altitudes
Lecanora hagenii	AP, APlat	[1]/[5, sub *L. umbrina*]	JV / JV	sparse
Lecanora intumescens	AP, FS	[1]/0	JV / JV	sparse
Lecanora leptyrodes	AP, FE (twig), FS	0/[4,5,6]	JM(2) / JV	sparse
***Lecanora persimilis* (Th. Fr.) Arnold**	FE (twigs)	0/0	non / JV	rare
Lecanora pulicaris	AP, FS, SA, AA, wood of snags	[1]/[4,5]	JV(2) / JV	frequent (but usually in FS canopies)
Lecanora saligna	wood of snags	0/[4,5]	rec. / rec.	sparse
Lecanora sarcopidoides	AA	0/0	JM / non	rare
Lecanora subcarpinea	FS	[1, sub *L. nemoralis*]/0		?
Lecanora subintricata	AP	0/0	non / JV	sparse in higher altitudes, at ridge
Lecanora symmicta s.lat.	AP	[1]/[5]		?
Lecanora thysanophora	FS	0/0	non / JV*	frequent
Lecidea erythrophaea	AP, FE	0/[5]	JV / JV(2)	sparse
***Lecidea sanguineoatra* (Wulfen) Ach.**	FS (wood of twig on forest floor)	0/0	non / JV	rare

Lecidella elaeochroma (incl. *L. achristotera* and *L. euphorea*)	AP, FE, FS	[1]/[4,5]	JM / JV	frequent
Lecidella elaeochroma f. _soralifera_	AP	0/0	JV / non	rare
Lecidella flavosorediata	AP	0/[5]	JM* (fertile) / JV (fertile)	rare, in higher altitudes
Lepraria ecorticata (J.R. Laundon) Kukwa	FS	[Palice 12140, not published]*/0		sparse?
Lepraria incana	AA, AP, FS	[1]/[4,5]	non / JV	frequent
Lepraria lobificans	AP, FE, FS, UG	0/[4]	JM / JV(2)*	frequent
Lepraria rigidula	AP, FS	[3]/ [4,5]		not recorded
Leptogium cyanescens	FS (among mosses at trunk bases)	[1]/[4,5]	JV / JŠ	sparse
Leptogium gelatinosum	APlat, FE, FS	0/[4,5]		not recorded
Leptogium lichenoides s.str.	AP, FS (among mosses at trunk bases)	[1]/[4,5]	JM, JV / rec.	frequent
Leptogium saturninum	AP	0/[5]	non /JV	rare in uppermost altitude, at ridge (one record), 49°05'28"N, 22°32'47"E
Lobaria pulmonaria	AP, FS	[1]/[4,5]	rec. / rec.	frequent in higher altitudes
Lopadium disciforme	AP, FS	0/[4,5]	rec. / rec.	sparse
Loxospora elatina	AA (at base of trunk in brook valley)	0/[5, outside Stuzhytsia]	non / JV	rare
Megalaria laureri	AI, AP	0/[4,5]		not recorded
Megalaria pulverea	FS	0/[4,5]		not recorded
Melanelixia glabra	FS	0/[4,5, sub *Melanelia g.*]	non / JV	rare at higher altitude (collected at Polish side of ridge)
Melanelixia glabratula	AP, FS, SA, SC, UG	[1, sub *Parmelia g.*]/[4,5, sub *Melanelia g.*]	rec. / rec.	frequent
Melanelixia subaurifera	AP, FE, SC (usually canopies)	0/[4,5, sub *Melanelia s.*]	rec. / rec.	sparse
Melanohalea elegantula	AP	[1, sub *Parmelia e.*; specimens in BRA are *M. glabratula*]*/[5]		not recorded
Melanohalea exasperata	FS (canopy)	0/[4,5, sub *Melanelia e.*]	non / JV	rare
Melanohalea exasperatula	FS, FE	0/[4,5, sub *Melanelia e.*]	non / rec.	sparse
Melaspilea gibberulosa	AP, FS	0/[4,5]	JM(2), JV(3) / JV(2)	sparse
Menegazzia terebrata	AP, FS	[1]/[4,5;7, sub *Parmelia pertusa*]	JV / rec.	rare
Micarea adnata	wood of stump	0/[4,12]		not recorded
Micarea botryoides	AA (stump), FS (bark, wood)	0/[6]	JM / non	rare

Micarea denigrata	wood	0/[4,5]		not recorded
***Micarea micrococca* (incl. *M. byssacea*)**	FS, rotten wood	0/0	JV / JV(2)*	frequent
Micarea misella	rotten wood	0/0	JM / JV	sparse
***Micarea nigella* Coppins**	AA (rotten wood)	0/0	JV / JV	sparse
Micarea nitschkeana	?	0/[4, unclear note]		not recorded
Micarea peliocarpa	AA (bark at trunk base, rotten wood)	[1]/[4,5]	JM, JV / JV(2)	sparse
***Micarea prasina* s.str.**	AA (rotten wood)	0/[4,5, possibly *M. prasina* s.lat.]	JM*, JV / non	sparse
***Microcalicium disseminatum* (Ach.) Vain.**	AA	0/0	non / rec.	frequent
Multiclavula mucida	rotten wood of AA, FS	0/0	JM / rec.	sparse
Mycobilimbia carneoalbida	AP, APlat, FS	0/[4,5 sub *Biatora c.*]		not recorded
Mycobilimbia epixanthoides	FS	0/[4,5, sub *Biatora e.*]		not recorded
Mycobilimbia pilularis	AP, FS	0/[4,5, sub *Biatora sphaeroides*]		not recorded
Mycobilimbia tetramera	FS (on bark mosses)	[3]/0		rare
Nephroma bellum	AP, FS	[1]/0	non / JV	rare in uppermost altitudes (one record), 49°5'29"N,22°32'48"E
Nephroma parile	AP, FS, trunk bases close to brook	0/[4,5]	non / rec.	rare in valley bottoms (two records), 49°05'08"N, 22°32'09"E
Nephroma resupinatum	AP, FS	[1]/0	non / JV	rare in uppermost altitudes (two records), 49°05'15"N,22°33'29"E
Nephromopsis laureri	AA, FS	[1, sub *Cetraria l.*]/[5,6]		not recorded
Normandina pulchella	AP, FS	[1]/[4,5,7]	JV / rec.	sparse, more frequent in higher altitudes
Ochrolechia androgyna	AA, AP, FS	[1]/[4,5]	non / JV(3)	sparse, more frequent in higher altitudes
Ochrolechia arborea	AI, FS	0/[5 (Coppins 19529, det Kukwa)]		not recorded
Ochrolechia microstictoides	FE, FS	0/[5]		not recorded
Ochrolechia pallescens	AP	0/0	non / JV*	rare in higher altitudes, at ridge
Ochrolechia subviridis	FS	0/[5]		not recorded
Ochrolechia turneri	AP	0/0	non / JV*	rare in higher altitudes

Opegrapha niveoatra	AA, AP, FS	0/[4,5]	JV(3) / JV(2)	frequent
Opegrapha rufescens	AP, FS, FE	[1]/[4,5]	JV / JV	sparse
Opegrapha trochodes	AP (bark), FS (wood)	0/[5,13]	non / JV(2)	rare
Opegrapha varia	AA, AP, FS, wood of snags	[1, sub *O. lichenoides*, 3]/[4,5]	JM, JV / JV	frequent
Opegrapha vermicellifera	AP, FS	[3]/[4,5]	JV / non	sparse
Opegrapha viridis	FS	0/[4,5]	non / JV	frequent in lower altitudes
Opegrapha vulgata	FS	[3, specimen in PRA is *O. niveoatra*]/[5]		not recorded
Parmelia saxatilis	AP, FS, SA	[1]/[4,5]	rec. / JŠ*(s.str.)	frequent
Parmelia submontana	AP, FS, SA	[1]/[4,5]	JV / rec.	sparse
Parmelia sulcata	AP, FS, SA	[1]/[4,5]	rec. / JV	sparse; more frequent in higher altitudes
Parmeliella triptophylla	FS, FE	[1]/[4,5;7, sub *P. corallinoides*]	JV / JŠ, JV	sparse; in valleys and at ridge
Parmelina pastillifera	AP, FS	0/[4,5]	JM, JV / JŠ	sparse in higher altitudes
Parmelina quercina	FS	0/[5;7, sub *Parmelia q.*]		not recorded
Parmelina tiliacea	AP, FS	[1, sub *Parmelia t.*]/[4,5;7, sub *Parmelia scortea*]	rec. / rec.	frequent in higher altitudes
Parmeliopsis ambigua	AA, AP, BP, FS, SA	[1]/[4,5,7]	rec. / rec.	frequent; mostly in higher altitudes
Parmeliopsis hyperopta	AP, FS, SA	[1]/0	rec. / rec.	frequent in higher altitudes
Parmotrema arnoldii	FS, AP (canopy)	0/[6]	non / JV	rare
Parmotrema crinitum	FS	[1, sub *Parmelia c.*]/[4,5; 7, sub *Parmelia c.*]		several records, last in 1966
Parmotrema perlatum	CB	0/[4,5, sub *P.chinense*; 7, sub *Parmelia trichotera*]		not recorded
Peltigera collina	?	0/[5]		not recorded
Peltigera degenii	FS (mossy trunk bases), sandstone	0/[4,5, outside Stuzhytsia]	non / JV	rare in higher altitudes
Peltigera horizontalis	FS	0/[4,5]		not recorded
Peltigera hymenina	FS,AI	[1]/[5, outside Stuzhitsa]		not recorded
Peltigera polydactylon	FS	0/[4,5]		not recorded
Peltigera praetextata	AP, FS (at bases of trunks)	[1]/[4,5]	rec. / rec.	frequent
Pertusaria albescens	AP, FS, SA	[1]/[4,5]	non / JV	frequent in higher altitudes
Pertusaria alpina (incl. *P. constricta*)	AP, FS	[1]/[4,5]	JV / JV	sparse
Pertusaria amara	AP, FS, SC	[1]/[4,5]	rec. / JV	sparse

Pertusaria coccodes	AP, FS	[1]/[4,5]	non / JV(3)	sparse in higher altitudes, at ridge
Pertusaria coronata	AP, FS	[1]/[4,5]	JM, JV / non	sparse
Pertusaria flavida	AA, AP, FS	[1, specimens in BRA are other species]/0		not recorded
Pertusaria hymenea	FS	[1]/[4,5]	JV / non	sparse
Pertusaria leioplaca	FS	0/[4,5]	JM(2), JV(2) / non	frequent
Pertusaria pertusa	FS	[1]/[4,5]		?
Pertusaria pupillaris	AP	0/[4,5]	JM, JV / rec.	sparse
***Pertusaria waghornei* Hulting**	FS	0/0	non / JV	rare
Phaeophyscia ciliata	?	0/[4, unclear note]		not recorded
Phaeophyscia endococcina	FS	0/[5]		not recorded
Phaeophyscia endophoenicea	AP, FS	[1]/[4,5]	rec. / rec.	frequent
Phaeophyscia orbicularis	AP, FS	[1]/[4,5]	rec. / non	sparse
Phaeophyscia pusilloides	FS	[2,3]/0		rare, at Kamenná Lúka, alt. 1150 m
Phlyctis argena	AP, FE, FS, SA, UG	[1]/[4,5]	rec. / rec. (also fertile)	frequent
Physcia adscendens	AP, FE, FS	[1]/[4,5]	rec. / rec.	sparse, frequent only on Fraxinus
Physcia stellaris	FE	0/[4,5, outside Stuyhytsia]	rec. / JV	sparse
Physcia tenella	AP, FE	0/[4,5]	rec. / rec.	rare but frequent on Fraxinus
Physconia distorta	FS	0/[4,5]		not recorded
Physconia enteroxantha	FS	0/[4,5]		not recorded
Physconia grisea	AP, FS	0/[4,5]		not recorded
Physconia perisidiosa	FS	[1]/[4,5]	non / rec.	sparse in higher altitudes, at ridge
Piccolia ochrophora	AP, FS	0/0	JV / rec.	rare
Placynthiella* cf. *dasaea	(AP), FS	0/0	non / JŠ, JV(2)	frequent in higher altitudes (often in canopies)
Placynthiella dasaea	rotten wood, (FS)	0/[4,5, sub *Saccomorpha d.*]	rec. / non	sparse
Placynthiella icmalea	rotten wood	0/[4,5, sub *Saccomorpha i.*]	rec. / rec.	frequent
Platismatia glauca	AP, FS, SA	[1]/[4,5;7, sub *Cetraria g.*]	rec. / rec.	sparse in lower altitudes, frequent at ridge
Porina aenea	AP, FS	0/[4,5]	JV / JV	frequent
Porina leptalea	AP	0/[4,5, outside Stuzhytsia]	JV / non	rare
Porina pseudohibernica	CB, FS	0/[4,5, sub *Zamenhofia hibernica*; 14]		not recorded

Pseudevernia furfuracea	AA, AP, FS, SA	[1]/[4,5]	rec. / rec.	sparse in lower altitudes, frequent at ridge
Punctelia subrudecta (incl. *P. jeckeri*)	FS	[1, sub *Parmelia s.*]/[4,5]		recently not confirmed
Pycnora leucococca	AP	0/0	non / JV	rare in higher altitudes, at ridge
Pyrenula laevigata	AP, CB, FS	0/[4,5]		not recorded
Pyrenula nitida	AP, FS	[1]/[4,5]	rec. / JV	frequent
Pyrrhospora quernea	AP	0/[4,5]		not recorded
Ramalina farinacea	AP, FS	[1]/[4,5]	rec. / rec.	sparse
Ramalina fastigiata	AP	0/[4,5]		not recorded
Ramalina fraxinea	?	0/[4, unclear note]		not recorded
Ramalina pollinaria	AP, FS	[1]/[4,5]	rec. / rec.	sparse
Ramonia chrysophaea	AP, UG	0/[4,5]	non / JV(2)	sparse
Ramonia luteola	FS	0/[5, unclear note]	JV / non	rare
Reichlingia leopoldii	AP, CB	0/[4,5]		not recorded
Rinodina degeliana	AP	0/0	non / JV	rare
Rinodina efflorescens	AP, Al	0/[4,5]		not recorded
Rinodina griseosoralifera	FS, UG	0/[4,5]		not recorded
Rinodina septentrionalis (incl. *R. freyi*)	FE (twigs)	0/0	non / JV	rare
Ropalospora viridis	AP, FE, FS	0/[4,5, sub *Fuscidea v.*]	JM*, JV(3) / JV(2)*	frequent
***Sclerophora amabilis* (Tibell) Tibell**	FS	0/0	non / JŠ, JV	rare
Sclerophora coniophaea	AP	0/0	JV / JŠ	rare
Sclerophora farinacea	FS	0/0	non / JŠ, JV	rare
Sclerophora pallida	Aplat, FS	0/[4,5]	non / JŠ	rare
Sclerophora peronella	AP, FS (wood of snags)	0/0	JM / non	rare
Scoliciosporum chlorococcum	FS	[1]/[4,5]		rare?
Scoliciosporum sarothamni	FE, FS (canopy)	0/[4,5]	non / JV	sparse
Scoliciosporum umbrinum	FE, FS	0/[4,5]	JV(2) / JV	frequent in FS canopies
Sticta fuliginosa	mossy trees	0/[7]		not recorded
Strangospora pinicola	AA	0/0	non / JV	sparse in AA canopies
Strigula stigmatella	AP, FS, UG (mossy bark), sandstone	[3]/[4,5]	JM(3), JV / JŠ, JV	frequent
***Tetramelas chloroleucus* (Körb.) A. Nordin**	FS	0/0	non / JV	rare in higher altitudes, at ridge
Thelidium zwackhii	AG (exposed roots)	0/[6]		not recorded
Thelocarpon epibolum	rotten wood	0/0	JV / rec.	sparse

Thelotrema lepadinum	(AA), FS	[1,3]/[4,5]	JV / rec.	frequent in lower altitudes
Trapelia corticola	AA, FS, rotten wood	[3]/[4,5]	JV / JV	sparse
Trapeliopsis flexuosa	FS (bark), rotten wood	0/[4,5]	non / JV(2)	sparse
Trapeliopsis gelatinosa	rotten wood	0/0	JV / non	sparse
Trapeliopsis granulosa	rotten wood	0/0	rec. / non	sparse
Trapeliopsis pseudogranulosa	rotten wood	0/[4,5]	JM / non	rare
Trapeliopsis viridescens	AA (bark), rotten wood	0/[4,5]	rec. / JV	frequent
Tuckermannopsis chlorophylla	FS	0/0	rec. / rec.	sparse in higher altitudes
Usnea dasypoga	AA, FS	[1, sub *U. filipendula*]/[5, outside Stuzhytsia]	non / rec.	rare in uppermost altitude
Usnea hirta	?	0/[4, unclear note]		not recorded
Usnea subfloridana	FE	0/[5, outside Stuzhytsia]	non / rec.	rare
Usnocetraria oakesiana	AA, FS	[1, sub *Cetraria o.*]/[7, sub *Cetraria o.*]		not recorded
Varicellaria hemisphaerica	AA, AP, FS	[1,3]/[4] sub *Pertusaria h.*	JM, JV(2) / JV(2)	sparse
Verrucaria bryoctona	FS (on mosses at base of trunk)	0/0	non / JV	rare
Vezdaea aestivalis	AP, FS (on bark mosses)	[3]/[4,5]		rare
***Vezdaea* cf. *cobria* Giralt, Poelt & Suanjak**	FS	0/0	non / JV	rare
Violella fucata	AA, FS (bark), PA (wood of snag)	0/[4, sub *Mycoblastus sterilis*]	JM, JV / JV	sparse
Vulpicida pinastri	FS	[1, sub *Cetraria p.*]/[4;7, sub *Cetraria p.*]	rec. / rec.	frequent in uppermost altitudes, at ridge
Xanthoria parietina	AP, FS (canopy)	[1]/[4, unclear note]	rec. / rec.	rare
Xanthoria polycarpa	FS (canopy)	0/[5, outside Stuzhytsia]	non / rec.	rare

Lichenicolous fungi and epiphytic microfungi				
Anisomeridium macrocarpum (Körb.) V. Wirth	FS	0/0	non / JV(2)	sparse
Arthonia sp.	FS, lichenicolous on Melanelixia glabratula	[in sample BRA CR11713, unpublished]/0		rare?

Cornutispora lichenicola	?	0/[5]		not recorded
Dactylospora parasitica	FS, lichenicolous	0/[4,5]		not recorded
Dactylospora sp.	FE, not lichenicolous	0/0	JV / non	rare
Epigloea urosperma Döbbeler	on *Placynthiella icmalea*	0/0	JM / non	rare
Hysteropatella prostii	UG	0/[4]		not recorded
Kirschsteiniothelia (cf.) *aethiops*	AA, FS	0/[4,5, outside Stuzhytsia]	JV(4) / JV	frequent
Kirschsteiniothelia recessa (Cooke & Peck) D. Hawksw.	AA	0/0	non / JV	frequent
Lichenoconium erodens	on various epiphytic lichens	0/[5,6]		not recorded
Lichenoconium lecanorae	on *Hypogymnia physodes*	0/[5,6]		not recorded
Massarina corticola	AP	0/[5]		
Melaspilea proximella (Nyl.) Nyl.	AA	0/0	JV(2) / rec.	frequent
Muellerella hospitans	lichenicolous, AP, FS	0/[5]		not recorded
Mycocalicium subtile	dry wood of snags	0/[6]	rec. / JV	frequent
Peridiothellia fuliguncta	AP	0/[4]		not recorded
Phoma lobariae	on *Lobaria*	0/[5]		not recorded
Polydesmia lichenis	on *Peltigera*	0/[5]		not recorded
Rebentischia pomiformis	AP	0/[5]		not recorded
Sarea difformis (Fr.) Fr.	AA (resin)	0/0	non / JV	sparse
Sarea resinae	AA, PA (resin)	0/[5,6]	non / JV	sparse
Sphinctrina turbinata	FS, on *Pertusaria*	0/[4,5]		not recorded
Tremella cladoniae	on *Cladonia coniocraea*	0/[4,6]		not recorded
Tremella hypogymniae	on *Hypogymnia physodes*	0/[6]		not recorded
Tremella lichenicola	on *Violella fucata*	0/[4,5, probably outside Stuzhytsia]		not recorded

2.2. Ecology

In two papers included in this part, forest parameters in various forest types in the Czech Republic were compared with diversity of lichens, macrofungi and bryophytes. The cryptogam diversity was distinctly higher in unmanaged forests and on plots with large-diameter trees (of >80 cm DBH). A similar effect had large dead wood objects (as a parameter of old-growth or unmanaged forests). A distinct effect of large trees with a diameter >110 cm on species richness of red-listed lichens and fungi was observed. Additionally, positive effects of increasing elevation and varied tree composition were recorded (Hofmeister et al. 2015). As expected, lichen diversity was highest in unmanaged forests followed by heterogeneous stands and mature deciduous forests. Beech showed the greatest species richness per live tree individual, also the greatest contribution to the total lichen species pool as well as the most important substrate for red-listed lichens. Dead beeches, firs and large logs were other important substrate for rare species. *Opegrapha niveoatra*, *Thelotrema lepadinum*, *Biatora veteranorum* and *Lecanora thysanophora* were selected as bioindicators of unmanaged forests (Hofmeister et al. 2016).

Fig. 10. Salajka National Nature Reserve – a nice old-growth beech-silver fir forest in the Beskydy Mts (Czech Republic), one of the six studies areas by Hofmeister et al. (2015, 2016).

Another two, mostly taxonomical papers (Malíček 2014a; Malíček et al., in prep., P6), provide valuable information on ecology of several *Lecanora* species. One of the questions of the first publication was if any members of the *Lecanora subfusca* group in the Czech Republic are restricted to old-growth forests or a specific forest type.

A distinct preference for humid natural woodlands is known for *Lecanora cinereofusca*. *Lecanora argentata* and *L. glabrata* strongly prefer woodland areas and smooth bark (especially of beech and hornbeam). *Lecanora chlarotera* is a typical species of oak forests but it is common also in open landscape. The most common taxon, *L. pulicaris*, is an ubiquitous lichen common in various forest types (Malíček 2014a). Two rare sorediate species, *L. mughosphagneti* and *L. norvegica*, distinctly prefer boggy pine forests, at least in Central Europe. The centre of occurrence of the newly described *L. substerilis* is in old-growth beech forests in mountain regions (Malíček et al., in prep., P6).

Value of old forest attributes related to cryptogam species richness in temperate forests: A quantitative assessment

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Abstract: Changes in temperate forest ecosystems resulting from a long history of forest exploitation may severely impact current cryptogam diversity. We documented the distribution of cryptogams in representative forest types between 200 and 1000 m a.s.l. in central Europe, in managed and unmanaged stands. This survey included one-time inventories of lichens and bryophytes, 2 years of regular monitoring of macrofungi, and a detailed description of forest structure (live trees and dead woody debris) in 96 sampling plots (2500 m^2 each) in six study areas in the Czech Republic. On this basis, we attempted to identify the quantitative limits of forest structural attributes that affect cryptogam diversity along a gradient of forest management practices in central Europe. In total, we recorded 1387, 173 and 103 species of macrofungi, lichens and bryophytes, respectively, of which 149, 99 and 4 were red-listed species. Species richness was correlated among observed taxa at the plot scale, and rare and red-listed species made higher contributions in species-rich communities. Cryptogam species richness showed both common and taxa-specific patterns in relation to forest structure, tree species composition, age of the oldest tree strata and elevation. We found a positive influence of the largest-diameter tree classes (stem diameter >80 cm) on the species richness of all cryptogam taxa, whereas the contribution of dead wood to the fit of a linear mixed effect model was minimal. Nevertheless, the magnitude of total and red-listed species richness was remarkably high in plots in which at least one large tree or woody object occurred compared to plots lacking these attributes. The effect of large dead wood debris (diameter >80 cm and unit volume >1 m^3) was not replaced by total dead wood volume, even though it was relatively high (>40 $m^3.ha^{-1}$). Hence, both large live trees and woody debris compartments are probably important for the species richness of cryptogam communities. However, the spatial pattern of cryptogam communities at a given time point (i.e., the time of our survey) was associated with the spatial and temporal heterogeneity of live tree structures, but less with that of dead wood substrates. Large tree and woody debris characterize forests that have been unmanaged for at least several decades and occasionally occur in the oldest of moderately managed forests. The importance of these cryptogam refuges in managed forests should not be underestimated because their continuing disappearance will probably result in the impoverishment of cryptogam richness at regional scales.

Keywords: bryophytes, dead wood, forest structure, lichens, macrofungi, size-dependent coefficient model.

Introduction

The on-going debate concerning the loss of cryptogam diversity resulting from exploitation of temperate forests has produced a few conclusions that can provide a basis for effective changes in forest management practices (Brockerhoff et al., 2008; Brunet et al., 2010). Although clear negative effects of some management practices (e.g., clear-cutting) on cryptogam diversity have been demonstrated (e.g., Rosenvald and Lõhmus, 2008; Rudolphi et al., 2014), many foresters still ignore this evidence, arguing that large areas of temporarily unaffected, managed forests remain that provide a stable habitat for cryptogams. In central Europe, which has a long history of forest management, the discussion is further complicated by past modifications of forest ecosystems and biodiversity (Grove, 2002; Vrška et al., 2009). Thus, there is often poor evidence for, and differences in perception regarding, what is or what could be "natural" in this region (Lindenmayer and Laurance, 2012).

Despite such uncertainty, heterogeneity of forest structure in terms of tree species composition, age structure, and size distribution of live trees and dead wood has been identified as the most important stand-level factor affecting cryptogam diversity (Ódor et al., 2006; Ellis, 2012; Halme et al., 2013; Sverdrup-Thygeson et al., 2014). In particular, the effects of forest age, large old trees, and dead wood on cryptogam diversity have been repeatedly emphasized (e.g., Fritz et al., 2008; Ranius et al., 2008; Lindenmayer et al., 2012). However, little evidence is available as to which old forests are sufficiently old, what quantitative attributes make trees sufficiently large and old, and what size of dead wood objects is the most suitable for cryptogams.

In this study, we attempted to identify the distribution of cryptogam diversity (macrofungi, lichens, and bryophytes) and forest structural attributes that may be important for cryptogams in the most widespread forest types in the Czech Republic, in relation to environmental conditions and intensity of forest management. These forests represent prevailing conditions over a wide area of central Europe within altitudes from 200 to 1000 m a.s.l. Our main objective was to identify the quantitative limits of forest structural attributes that affect cryptogam diversity along a gradient of forest management practices in central Europe. We hypothesized that cryptogam diversity is related to forest structure at the stand scale and that suitable structures form the basis for the metapopulation structure of cryptogams in European forests (Löbel et al., 2006; Halme et al., 2013). Such studies are needed to develop recommendations for future forest management and for implementing these practices.

Materials and methods

Study areas

We selected six study areas (SA1–SA6) in the Czech Republic that included spatially important types of central European forest stands, with the exception of lowland floodplains and montane forests above 1000 m a.s.l. (Table 1 and Fig. 1). Each study area consisted of a continuous forest patch (1.4–10.0 km^2) that included stands representing spatiotemporal variability in tree species composition and forest management approach, i.e., nature reserves without regular forest management (referred to here as unmanaged forest); mature managed stands of deciduous, coniferous and eventually mixed tree species; immature managed forests aged 11 to 69 years; and heterogeneous unclassifiable managed stands (including internal ecotones).

Beech (*Fagus sylvatica*), spruce (*Picea abies*), and fir (*Abies alba*), the respective frequencies of which increase with elevation, were the dominant tree species in unmanaged forest stands, except for those at the lowest elevations, which were dominated by oak (*Quercus petraea*). Accordingly, beech and oak dominated the tree community in deciduous managed forest stands at higher and lower elevations, respectively. Coniferous stands generally consisted of monocultures of spruce or pine (*Pinus sylvestris*). The age of mature managed forests averaged approximately 100 years, but reached 160 years in deciduous stands. However, small remnants of old managed forest have survived for more than 200 years. Unmanaged forests were between 150 and 400 years old; most have been protected since the first half of the 20th century (the oldest since 1838 and the youngest since 1964).

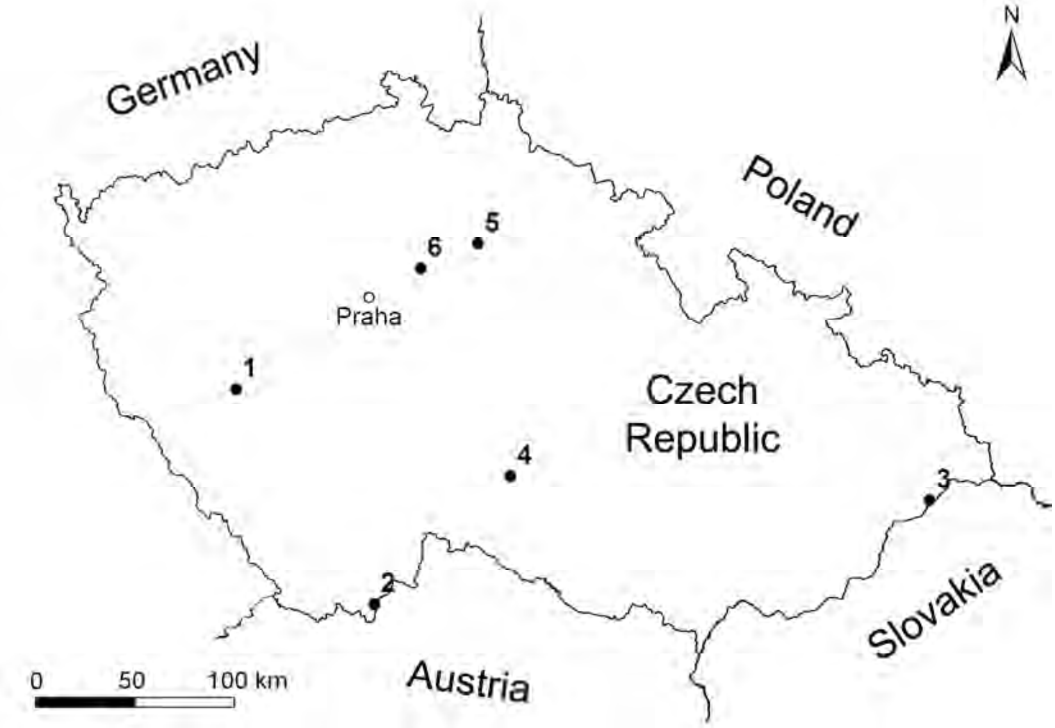


Fig. 1. Location of the six study areas.

Forest inventory

We established between one and four 2500-m^2 sampling plots in each forest management type within each study area. Eighteen plots were established in study area

(SA)1 to SA4, and 11 and 10 plots were established in SA5 and SA6, respectively (*n* = 96 sampling plots) (Table 1; for details, see Table S1, Supporting information). A forest inventory was conducted in each plot between 2009 and 2011. We measured the stem diameter of each tree at 1.3 m above the ground, excluding those with diameter <5 cm. The diameter and length of each dead wood object (standing and lying stems, branches, stumps and other materials) with diameter >5 cm were recorded to calculate their respective volumes. The volume of individual pieces of dead wood was calculated using geometric approximations or values of wood volume tables (Lesprojekt, 1952). The volume of irregularly shaped objects was estimated using approximate measurements.

SA	Area	Altitude	Mean temperature	Mean precipitation	Number of sampling plots	
	(km^2)	(m a.s.l.)	(°C)	(mm·year^{-1})	unmanaged forests	managed forests
1	6·75	436–585	6–7	600–650	4	14
2	9·95	732–935	4–5	700–800	4	14
3	4·60	635–880	4–5	1000–1200	4	14
4	7·39	590–730	5–6	600–650	4	14
5	10·00	250–280	7–8	550–600	0	11
6	1·36	180–210	7–8	550–600	3	10

Table 1. Description of study areas (SA) and distribution of sampling plots in unmanaged and managed forests. Data for mean temperature and precipitation (from 1961 to 2000) were taken from Tolasz (2007).

Sampling of macrofungi, lichens, and bryophytes

We surveyed the species composition of macrofungi, lichens, and bryophytes in the 96 sampling plots. Two-year inventories of macrofungal fruiting bodies (with a minimum of five visits each year) were conducted from early spring 2009 or 2010 to late autumn 2010 or 2011. A list of lichen and bryophyte species was compiled during a single visit in either 2009 or 2010.

All cryptogams were surveyed on all substrates (soil, stones, live trees, and dead wood objects) from the soil surface to 2 m above the ground throughout each plot. The only exception was the survey of lichens on live trees, which was limited to five selected trees representing the variability of tree species composition and stem diameter within each plot; other substrates (e.g., dead wood and stones) were examined exhaustively. Red-listed species were determined according to the current national red lists: Holec and Beran (2006) for macrofungi, Liška et al. (2008) for lichens and Kučera et al. (2012) for bryophytes. Fungi, lichens, and bryophytes that could not be readily identified in the field were sampled, dried, and identified by microscopy and chromatography, or by specialists in the respective genera.

Data analysis

The species richness of macrofungi, lichens, and bryophytes was analyzed separately using linear mixed effect models (LME) (Laird and Ware, 1982; Pinheiro and Bates, 2000). In these models, we sequentially increased the set of explanatory variables that were potentially important for cryptogam diversity and compared the model Akaike information criterion (AIC) values considering the principle of parsimony. The full set of explanatory variables obtained in the final model consisted of elevation, tree species composition, age of the oldest tree strata, sum of stem basal areas of all measured live trees, and volume of dead wood. Age effect was evaluated in the models as a parametric term having linear and quadratic term. Tree species composition was assigned to one of four classes according to the species that occupied >75% of the basal area in the plot: (i) beech-dominated forests, (ii) mixed deciduous species, (iii) mixture of deciduous and coniferous species, and (iv) monocultures or mixed coniferous species. The sums of the stem basal areas of living trees and volume of dead wood (excluding stumps) were divided into 18 categories according to the diameter of individual objects (details in Table S2 and S3, Supporting Information). The influence of the total stand basal area of live trees and total volume of dead wood on cryptogam species richness was size-dependent in the sense that the regression coefficient depended on the diameter of a particular tree or item of woody debris. Hence, the contribution of a given stand basal area or volume to species richness differed depending on the size of individual trees or pieces of dead wood. The functional form of the size dependence was not assumed *a priori*, but rather was inferred flexibly (nonparametrically) from the data. This enabled testing of the effect of size dependence. Size dependency (diameter of live stems and dead wood objects) was specified analogously to the parsimonious Almon parameterization (Almon, 1962; Johnston, 1984) to suppress collinearity. Therefore, the coefficients corresponding to the weights of individual stem diameter or dead wood diameter classes were forced to lie on a flexible B-spline curve (details in Appendix S1, Supporting Information). Two size-varying coefficients were used in all models: (a) a coefficient for the total stem basal area of live trees in 18 stem diameter classes, and (b) a coefficient for total dead wood volume in 18 object diameter classes. The parameters of each of the spline-basis functions were estimated from the data, together with other parameters of the LME. To address the spatial correlation among adjacent sampling plots, we allowed for spatial correlation in the residuals by using an exponential covariogram, the parameters of which were estimated via restricted maximum likelihood (REML) as part of the model identification.

The type of forest stand was not used as an explanatory variable in our models because our goal was to generate statistical models using data from first principles; we used data on the availability of growth substrates (live and dead wood) rather than prior classification of forest stands, which indirectly influences the substrate quantity. In addition to investigating direct influences, this approach is valuable in circumventing the effect of spatial and temporal variation in forest practices.

We first tested the total species richness of macrofungi, lichens, and bryophytes as response variables. Weighted species-richness models were also created, in which the presence of red-listed species in plots was weighted by a factor of 10 for extinct, critically endangered, and endangered macrofungi and lichens, and by 5 for the remaining red-list categories. For bryophytes, the group of red-listed species was extended by species included in the associated Attention List (Kučera et al., 2012). When we tested the numbers of red-listed species alone, the models failed because the response variables had zero or close to zero values in a large proportion of the sampling plots. Finally, we examined the species richness of lignicolous macrofungi only. All model analyses were based on data from 96 plots ranging in age from 14 to 315 years. Additional simple correlations were performed using the Pearson correlation coefficient (R) at $P < 0.05$. All computations were performed in R (R Development Core Team, 2013), using the 'nlme' (Pinheiro et al., 2013) package.

Results

Live trees and dead wood

The 96 surveyed sampling plots contained 15,599 living trees and shrubs (24 species), 618 standing dead stems, 9,647 lying dead stems and branches, 8,195 stumps, and 3,926 pieces of dead wood left by logging operations. The total volume of dead woody debris ranged from 1.6 to 352 $m^3.ha^{-1}$. Relatively fewer plots had live trees and dead woody objects in the large-diameter classes (Table S2 and S3, Supporting Information). All plots with dead woody objects with diameter and unit volume higher than 80 cm and 1 m^3, respectively, also had live trees with a diameter larger than 80 cm (11 sampling plots). However, there were 15 plots with large live trees (diameter >80 cm) but without large dead woody objects. Most plots with large trees (diameter >80 cm) were located in unmanaged forest reservations (54%), and this relationship was even stronger for large dead wood objects (diameter >80 cm and unit volume >1 m^3; 91 %).

Species richness of cryptogams

We recorded 1,387, 173, and 103 species of macrofungi, lichens, and bryophytes, respectively, in the 96 plots, of which 149, 99, and 4 were red-listed species. We found an average of 140, 18, and 17 species of macrofungi, lichens, and bryophytes per plot, respectively. The minimum (and maximum) numbers of macrofungal, lichen, and bryophyte species observed in individual plots were 65 (284), 4 (72) and 7 (38), respectively. At the plot scale, cryptogam species richness was significantly correlated between taxa groups: macrofungi vs. lichens ($R = 0.519$; $P < 0.001$), macrofungi vs. bryophytes ($R = 0.523$; $P < 0.001$) and lichens vs. bryophytes ($R = 0.485$; $P < 0.001$).

Unmanaged plots generally had higher species richness of cryptogam communities than in managed plots, and the lowest was found in mature coniferous forests. Uncommon, rare, and red-listed species mostly occurred in species-rich communities, while the opposite was true for widespread generalist species. As a result, the ratio of rare to common species (occupying <10 and >30 sampling plots, respectively) increased with species richness of macrofungi ($R = 0.608$; $P < 0.001$), lichens ($R = 0.630$; $P < 0.001$) and bryophytes ($R = 0.926$; $P < 0.001$). The contribution of lignicolous macrofungal species to the total macrofungal species richness in the sampling plot ranged from 15 to 64%, with an average of 38%.

Species richness vs. live tree diameter and dead wood volume

The generated linear mixed effect models showed mostly universal, but some taxa group-specific, patterns of cryptogam species richness in relation to the explanatory variables (Table 2). Regarding forest structure, cryptogam species richness was affected by tree diameter classes (Table 2; Fig. 2). A strong positive effect of the largest- and smallest-diameter tree classes (>80 and <20 cm, respectively) for living trees was found for macrofungi, especially for lignicolous fungi, and a moderate but still positive effect of the largest-diameter classes was observed for bryophytes providing that the weight of red-listed species was increased. When the analysis was weighted by red-listed species, an effect of large trees with a diameter > 110 cm on lichen species richness was observed (Fig. 2). If we neglect other significant explanation variables incorporated in the models, then the mean cryptogam and red-listed cryptogam species richness was significantly higher in sampling plots with large-diameter trees (>80 cm) than that in other plots (Table 3).

The AIC of the initially built model for macrofungal species richness did not decrease after addition of total dead wood volume or 18 diameter class parameters with class-varying coefficients. Nearly half of the 15 sampling plots with very high macrofungal species richness (>200 species) also had the absolutely highest dead wood volumes, ranging from 47 to 82 m^3 (without stumps), whereas four of the other plots had a dead wood volume of less than 5 m^3 (without stumps). Nevertheless, the use of dead wood as an explanation variable clearly improved the model for species richness of lignicolous fungi (Table 2; Fig. 3). A positive effect on species richness of lignicolous fungi was observed for finer (diameter <20 cm) and intermediate (40–80 cm) woody debris, whereas the effect of large woody debris appeared to be insignificant (Fig. 2). Despite lack of a significant effect in the model, cryptogam species richness was higher in the sampling plots with large dead wood objects, as in plots with large-diameter living trees (Table 3). There was no evidence that the effect of large-diameter logs or snags on richness could be attributed to a large volume of dead wood, as only a mean level of species richness of lichens (19 ± 9) and bryophytes (18 ± 8) and slightly above-mean species richness of macrofungi (177 ± 43) occurred in plots with large volumes of dead wood (11–42 m^3 without stumps), but without large woody debris.

Other factors relevant to cryptogam species richness

As expected, cryptogam species richness was positively correlated with age of the forest overstory (Table 2). Cryptogam species richness clearly increased with elevation, and species richness of macrofungi and lichens was further influenced by tree species composition. Species-rich communities of macrofungi and lichens were generally associated with either beech or mixed stands, whereas species-poor communities were associated with pure coniferous stands.

Discussion

Live trees and cryptogam diversity

We obtained clear evidence that the species richness of cryptogam communities in central European forests was higher in stands with the presence of large old trees, ideally in combination with abundant tree rejuvenation, such as that occurring in natural forests after the downfall of old trees in the canopy layer (resulting from natural death or external disturbance) as described, e.g., by Peterken (1996). The vital role played by large, old, slowly dying trees in supporting biodiversity has been revealed recently (Ranius et al., 2008; Winter and Möller, 2008), even at the global scale (Lindenmayer et al., 2012). In this study, cryptogam species richness was high in stands where stem diameter exceeded 80 cm, even when only one or a few large trees were present in a given forest habitat. Such trees are quite common in unmanaged forests (74% of plots in unmanaged forests in this study) and only occasionally present in moderately managed forests stands (18% of plots in managed forests in this study).

We confirmed the positive and negative effects of mixed deciduous tree species and spruce monocultures, respectively, on cryptogam species richness as previously reported (Vanderpoorten et al., 2004; Mežaka et al., 2012). Species-poor cryptogam communities were also found in oak-dominated forests at lower elevations, consistent with the observations by Heilmann-Clausen et al. (2005) for macrofungi, but contrasts with the report of Ódor et al. (2013) for lichens and bryophytes. Annual precipitation generally increases with elevation (Tolasz, 2007), which likely favors cryptogam communities at higher elevations, and some other environmental factors vary with elevation as well (e.g., geology). Moreover, the paucity of cryptogam species observed in oak-dominated lowland forests in our study may reflect the influence of several millennia of forest exploitation and fragmentation in the lowland region (Pokorný, 2005) more than an effect of the tree species currently present. Forests in the central European lowlands have been utilized and fragmented since the first half of the Holocene and extensively since the High Middle Ages. The historic duration and spatial extent of anthropogenic pressure decreases with elevation; permanently managed forests have dominated higher-elevation areas for a few centuries at most (Kaplan et al., 2009; Chytrý, 2012). Differences in the history of forest exploitation should be considered when searching for explanations for the generally low species richness of cryptogam communities in the present lowland forests.

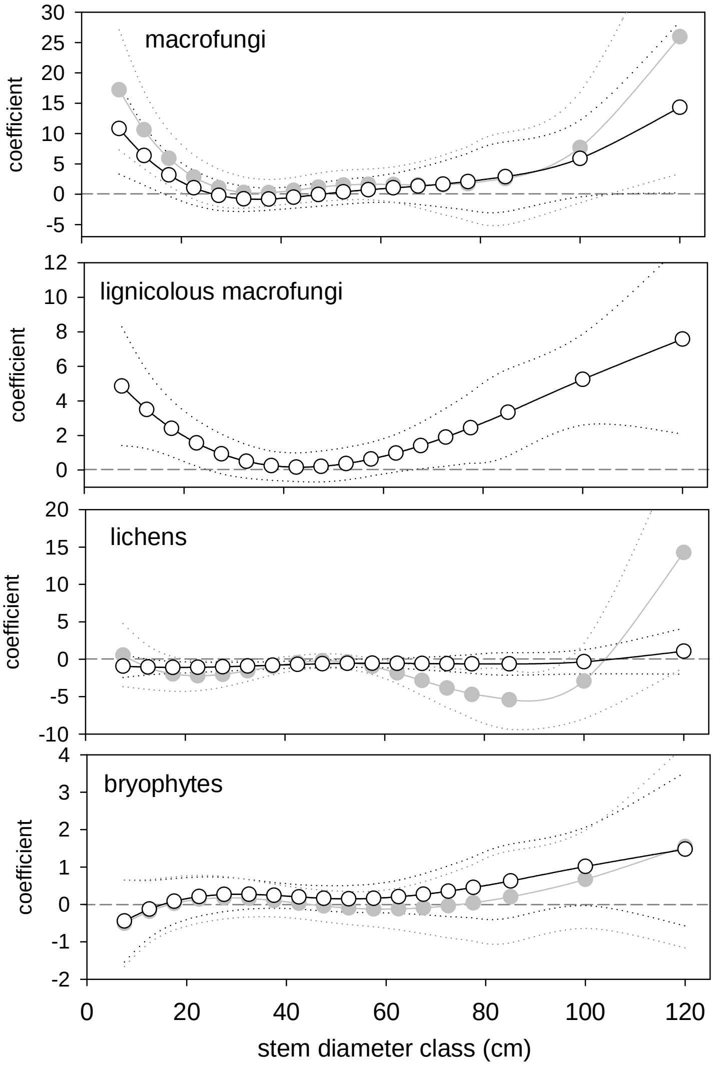


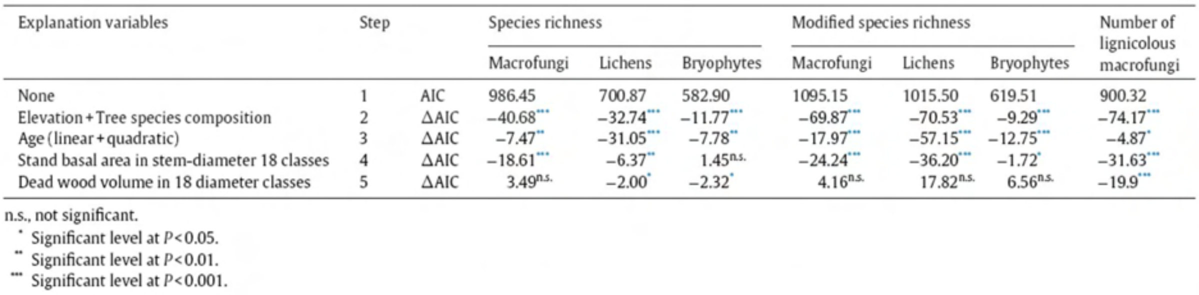
Fig. 2. Regression curves with 95% point-wise constructed confidence intervals for cryptogam species richness (black lines and open circles) and cryptogam species richness weighted by red-listed species (gray lines and gray circles) vs. the sum of the stem basal area for each stem diameter class of living trees. Circles indicate the median values of the class-varying coefficient for the total stem basal areas of living trees for each of 18 stem diameter classes. The estimated curves show how the contribution of total stem basal area to species richness changes with stem diameter.

Dead wood and cryptogam diversity

Similarly to live trees, but even more notably, there were relatively few plots with large-diameter dead wood objects (Table 3). The spatial pattern of large dead wood objects (logs and snags) corresponded with that of large live trees; large woody debris occurred only in a subset of plots occupied by large trees. This finding may explain why dead wood as a variable was redundant in most models built to explain cryptogam species richness and particularly why there was a lack of positive effect of large-diameter dead wood in these models. Moreover, both the appearance and disappearance of large dead wood objects are more variable in time than those of large live trees, which may result in less equilibrium between the actual species richness of cryptogam communities and dead wood availability at the particular time of the survey (Christensen et al., 2004; Jönsson et al., 2008).

The comparison of cryptogam species richness in plots with and without large logs or snags suggested that they were essential structures with positive effects on cryptogam species richness (Table 3). This result is consistent with previous findings that emphasized the importance of both coarse and fine woody debris (Nordén et al., 2004; Küffer et al., 2008) because large woody debris is generally accompanied by finer material. However, we documented that even relatively high total volumes of dead wood cannot guarantee high cryptogam diversity unless there is sufficient size variability in the woody debris, including large objects in particular.

The suitability of dead wood as a substrate for particular cryptogam species changes with the degree of decomposition (Heilmann-Clausen and Christensen, 2003) and differs among tree species (Heilmann-Clausen et al., 2005); we did not evaluate these effects separately. However, the variability of decay generally increases with the quantity of dead wood and is likely to be less important to species richness than the size of the woody debris (Küffer et al., 2008; Nordén et al., 2013). In our study, major differences in the species composition of dead wood corresponded to differences in the composition of live trees.



Explanation variables	Step		Species richness			Modified species richness			Number of lignicolous macrofungi
			Macrofungi	Lichens	Bryophytes	Macrofungi	Lichens	Bryophytes	
None	1	AIC	986.45	700.87	582.90	1095.15	1015.50	619.51	900.32
Elevation + Tree species composition	2	ΔAIC	-40.68^{***}	-32.74^{***}	-11.77^{***}	-69.87^{***}	-70.53^{***}	-9.29^{***}	-74.17^{***}
Age (linear + quadratic)	3	ΔAIC	-7.47^{**}	-31.05^{***}	-7.78^{**}	-17.97^{***}	-57.15^{***}	-12.75^{***}	-4.87^{*}
Stand basal area in stem-diameter 18 classes	4	ΔAIC	-18.61^{***}	-6.37^{**}	$1.45^{n.s.}$	-24.24^{***}	-36.20^{***}	-1.72^{*}	-31.63^{***}
Dead wood volume in 18 diameter classes	5	ΔAIC	$3.49^{n.s.}$	-2.00^{*}	-2.32^{*}	$4.16^{n.s.}$	$17.82^{n.s.}$	$6.56^{n.s.}$	-19.9^{***}

n.s., not significant.
* Significant level at $P<0.05$.
** Significant level at $P<0.01$.
*** Significant level at $P<0.001$.

Table 2. Results of linear mixed effects models (LME) predicting species richness of cryptogams and species richness weighted by red-listed species. In the models, the set of explanatory variables potentially important for cryptogam diversity was sequentially increased, and the model Akaike information criterion (AIC) was thus evaluated. Differences in the AIC (ΔAIC) and significance level (p) of added terms are given; ΔAIC is the difference in the AIC of a particular model with an added term compared to the AIC of the initial model without the term; significance levels are denoted as * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ and $^{n.s.}$ not significant.

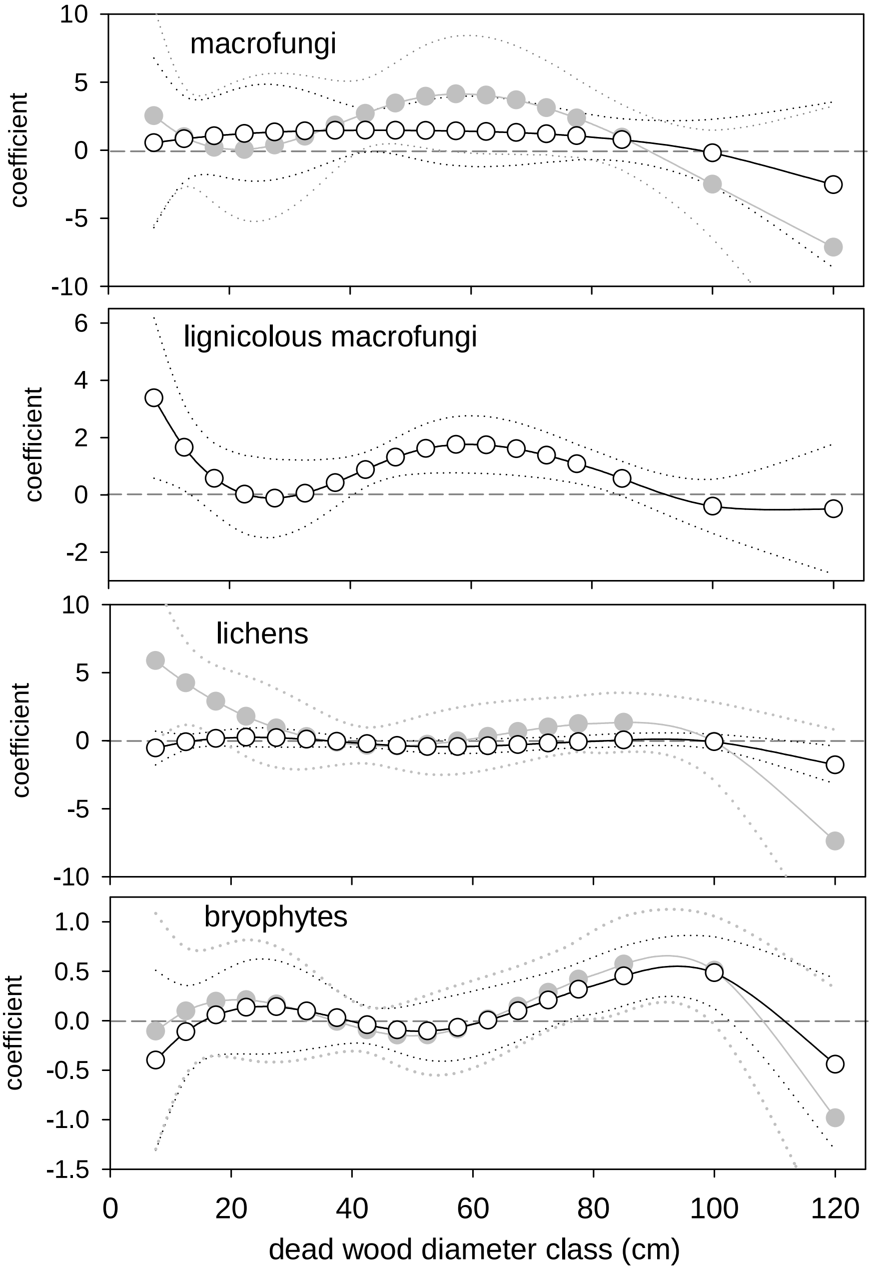


Fig. 3. Regression curves with 95% pointwise constructed confidence intervals for cryptogam species richness (black lines and open circles) and cryptogam species richness weighted by red-listed species (gray lines and gray circles) vs. dead wood volume in diameter classes. Circles indicate median values of the class-varying coefficient for total stem circumference of live trees in each stem-diameter class.

Forest age and cryptogam diversity

The increased cryptogam species richness with increasing forest age provided further evidence for the vital importance of old forests to cryptogam diversity, in agreement with previous evidence (Fritz et al., 2008). Forest age is associated with the time available for colonization but also contributes to the formation of forest structure and dead wood heterogeneity. These three attributes have synchronous effects on cryptogam diversity and it can be difficult to separate their individual influences. The concept of forest continuity, referring to the continuous presence of forest, is also relevant (Nordén and Appelqvist 2001), although different aspects of forest continuity may be important for different taxa. Continuity of forest land use (including clear-cut and intensive utilization) appears to be sufficient for the survival of several forest plant species (Graae and Sunde, 2000), whereas most cryptogams also require continuity of forest cover (clear-cutting in this case disrupts continuity) or even continuity of a dead wood supply (Westphal et al., 2004; but see Hofmeister et al., 2014).

	Trees with diameter (cm)			Dead woody objects with diameter (cm) and unit volume (m^3)		
	< 80 only	> 80		< 80 only	> 80 (>1 m^3)	
	(*70*)	(*26*)		(*85*)	(*11*)	
Macrofungi						
Species richness	122 ± 35	188 ± 48	***	130 ± 41	215 ± 35	***
Number of red-listed species	4 ± 3	13 ± 9	***	5 ± 4	19 ± 9	***
Lichens						
Species richness	16 ± 7	26 ± 16	***	16 ± 8	31 ± 20	***
Number of red-listed species	2 ± 3	10 ± 12	***	3 ± 4	13 ± 14	***
Bryophytes						
Species richness	16 ± 4	20 ± 7	**	17 ± 5	24 ± 3	***
Number of red-listed species	0.0 ± 0.2	0.1 ± 0.3		0.0 ± 0.2	0.2 ± 0.4	*

Table 3. Mean cryptogam species richness (± SD) in sampling plots that either included or did not include at least one live tree or dead woody object with a given stem diameter or object diameter and unit volume, respectively. The numbers of plots in each category are indicated in italics in parentheses. Significant differences between plots with and without trees with a stem diameter >80 cm and plots with or without dead woody objects with a diameter >80 cm and unit volume >1 m^3 are indicated by asterisks as $P < 0.05$ (*), $P < 0.01$ (**), and $P < 0.001$ (***).

Cryptogram diversity in the metapopulation context

As a result of previous management interventions conducted in limited areas of these presently unmanaged stands, suitable microhabitats may have disappeared along with their associated cryptogam species (Löbel et al., 2006; Halme et al., 2013). Species loss can continue long after the cessation of management operations as a result of extinction debt: the smaller the area of unmanaged stands and the longer the distance to the nearest refuge, the less likely species are to survive (Nordén et al., 2013). Regional metapopulation patterns also influence the probability of recolonization of cryptogam species that previously disappeared from the local species pool when the appropriate substrates are re-established (Ranius et al., 2008). Therefore, the low cryptogam species richness in some recently unmanaged and substrate-rich habitats in our study may reflect a delay in colonization from nearby refuges.

Alternatively, we questioned whether the presence of unmanaged forests closer to old and moderately managed forests could explain the remarkable diversity of red-listed macrofungi found in some of the latter habitats. One explanation is that unmanaged forests may provide a lasting source of cryptogam species for surrounding managed forests that allows only transient survival of these species (Malíček and Palice, 2013). A more likely explanation is based on the notion that neither small remnants of old managed forests nor limited areas of unmanaged forest can fulfill the habitat requirements of all potential cryptogam species (Lindenmayer and Laurence, 2012). This perspective is supported by our finding that cryptogam communities (particularly macrofungi) in the oldest managed forests did not consist of only a subset of the species observed in nearby unmanaged forests. We assume that the managed stands have the potential to expand the environmental conditions, microhabitats, and substrates covered by limited areas of unmanaged forests, which may help to maintain higher regional cryptogam diversity. Hence, the continuing disappearance of species-rich managed stands caused by logging will lead to impoverishment of cryptogam diversity not only at the local scale but also at the regional scale. Even maintenance of existing remnants of both unmanaged and managed old forests cannot prevent future reductions in species diversity as a result of extinction debt (Ranius et al., 2008).

Implications for conservation

We consider that heterogeneity of forest structure and dead woody substrates, such as that observed in unmanaged forests, is a necessary condition for the maintenance of cryptogam diversity. However, this habitat heterogeneity would probably encompass a larger area than is presently occupied by unmanaged forests in central Europe. Therefore, remnants of old forests adjacent to unmanaged forest areas should be protected (not logged) and expanded, and attributes of old-growth forests should be encouraged. Regeneration of cryptogam diversity will be less effective in large areas of managed forests that do not include remnants of old forests because of the long distances to the nearest cryptogam refuges (Nordén et al., 2013). Regardless, the characteristics of old growth (e.g., old trees with diameter >80 cm and large woody debris with diameter >80 cm and volume >1 m^3) should be encouraged or provided in managed forests in an effort to reduce the spatial isolation between refuges of rare cryptogams. Retention forestry is an appropriate approach for achieving inclusion of old growth attributes in managed forests in which significant forest structures are retained during logging operations (Lindenmayer et al., 2012). Adoption of this approach as a regular management practice is desirable as an alternative to traditional management practices based on clear cutting or recurrent selection harvesting, which systematically remove all large old trees and dead trees from forest stands. We caution against complacency, even if the principles of retention forestry are broadly implemented, because the requirements of highly sensitive species may remain unmet (Perhans et al., 2009; Löbel et al., 2012). Hence, an effective network of sufficiently large unmanaged forest stands probably represents an essential foundation for the protection of cryptogam diversity.

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Supporting information

Table S2. Stand basal areas (m^2) of living trees in sampling plots of 18 diameter classes (ranging from 5 to 150 cm).
Table S3. Total volume (m^3) of dead wood objects (excluding stumps) in sampling plots of 18 diameter classes (ranging from 5 to 150 cm).

Appendix S1. Specification of linear mixed effect models for Figs. 2 and 3.

The general form of the model for a dependent variable Y_{ij} (standing for species richness of macrofungi or lichens or bryophytes on j-th sampling plot and i-th study area) is:

$$Y_{ij} = \mu_{ij} + \varepsilon_{ij}$$

$$\mu_{ij} = \beta.altitude_{ij} + \sum_{k=1}^{K} \alpha_k.I\left(comp_{ij} = k\right) + \gamma_1.age_{ij} + \gamma_2.age_{ij}^2 + \sum_{l=1}^{L} \phi_l.P_{ij,l} + \sum_{m=1}^{M} \varphi_m.V_{ij,m}$$

$$\phi_l = \sum_{u=1}^{U} c_u.s_u(l),\ \varphi_m = \sum_{v=1}^{V} d_v.\tilde{s}_v(m)$$

$$\varepsilon_{ij} \sim N\left(\mu_{ij}, \sigma_{ij}^2\right) \qquad (1)$$

$$\sigma_{ij}^2 = \sigma^2.\mu_{ij}^{\theta}$$

$$\mathrm{cov}\left(\varepsilon_{ij}, \varepsilon_{rs}\right) = 0 \quad if\ i \neq r$$

$$= \sigma_{ij}.\sigma_{rs}.\exp\left(-\frac{\left|x_{ij} - x_{rs}\right|}{\rho}\right)$$

Where:

- $altitude_{ij}$ is the altitude of the j-th sampling plot from i-th study area
- $comp_{ij}$ is the tree species composition of the ij-th plot. $I(.)$ is the indicator function. It assumes value of 1 if the statement in its argument is true and value of 0 oterwise. Hence, the term $\sum_{k=1}^{K} \alpha_k.I\left(comp_{ij} = k\right)$ corresponds to the usual (ANOVA style factor) of tree composition with K = 4: i) beech-dominated forests,
  ii) mixture of deciduous species,
  iii) mixture of deciduous and coniferous species,
  iv) monocultures or mixtures of coniferous species.
- age_{ij} is the age of the oldest tree strata of the ij-th plot
- $P_{ij,l}$ is the sum of stem basal areas for the l-th stem diameter class (L = 18) (in cm):
  1) 5.0 – 9.9
  2) 10.0 – 14.9
  3) 15.0 – 19.9
  4) 20.0 – 24.9
  5) 25.0 – 29.9
  6) 30.0 – 34.9
  7) 35.0 – 39.9
  8) 40.0 – 44.9
  9) 45.0 – 49.9
  10) 50.0 – 54.9
  11) 55.0 – 59.9
  12) 60.0 – 64.9
  13) 65.0 – 69.9
  14) 70.0 – 74.9
  15) 75.0 – 79.9
  16) 80.0 – 89.9
  17) 90.0 – 109.9
  18) 110.0 – 150.0

- $V_{ij,m}$ is the dead wood volume for the m-th dead wood object diameter class (M = 18) (in m^3):

1) 5.0 – 9.9
2) 10.0 – 14.9
3) 15.0 – 19.9
4) 20.0 – 24.9
5) 25.0 – 29.9
6) 30.0 – 34.9
7) 35.0 – 39.9
8) 40.0 – 44.9
9) 45.0 – 49.9
10) 50.0 – 54.9
11) 55.0 – 59.9
12) 60.0 – 64.9
13) 65.0 – 69.9
14) 70.0 – 74.9
15) 75.0 – 79.9
16) 80.0 – 89.9
17) 90.0 – 109.9
18) 110.0 – 150.0

- $s_1(.),\ldots,s_U(.)$ and $\tilde{s}_1(.),\ldots,\tilde{s}_V(.)$ are B-spline functions. We use $U = V = 5$
- x_{ij} is the geographical location of the (centre of the) ij-th plot. $|x_{ij} - x_{rs}|$ is the (Eucleidian) distance between the centers of ij-th and rs-th plots.

$\beta,\alpha_1,\ldots,\alpha_K,\gamma_1,\gamma_2,c_1,\ldots c_U,d_v,\ldots d_V,\sigma^2,\theta,\rho$ are unknown parameters to be estimated from data via REML procedure.

Important feature of this model is that it enables one to estimate influence of individual stem-diameter and dead-wood-volume classes via class-varying coefficients (ϕ_l resp. φ_m). These coefficients are regularized in the functional data analysis (Ramsay & Silverman 2005) style, using the B-spline generalization of the (Almon 1962) idea.

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Table S1. Location (midpoint), forest description and cryptogam species richness in sampling plots (2500 m^2 each) in six study areas (SA) in the Czech Republic.

SA	Sampling plot (latitude/longitude)		Tree layer composition	Tree layer representation		Age	DBH	Height	Number of species					
									Macrofungi	Red-listed macrofungi	Lichens	Red-listed-lichens	Bryophytes	Red-listed bryophytes
				(number)	(%)	(year)	(cm)	(m)						
1	49°32'9'' N	13°33'22.6'' E	*Fagus sylvatica*	42	38.9	144	51	28.6	207	11	20	2	12	0
			Tilia cordata	30	27.8		16	18.6						
			Acer pseudoplatanus	19	17.6		21	22.0						
1	49°32'5.5'' N	13°33'26.7'' E	*Fagus sylvatica*	47	77.0	187	56	32.6	183	13	19	4	21	0
			Tilia cordata	10	16.4		43	31.3						
1	49°32'21.7'' N	13°33'27.8'' E	*Fagus sylvatica*	125	89.9	200	21	19.5	181	13	14	7	16	0
			Acer pseudoplatanus	10	7.2		36	24.8						
1	49°32'17'' N	13°33'30'' E	*Fagus sylvatica*	67	70.5	187	27	16.5	219	13	19	9	26	0
			Acer pseudoplatanus	16	16.8		31	22.0						
1	49°32'0.1'' N	13°32'12.9'' E	*Fagus sylvatica*	85	73.9	182	22	14.9	105	1	9	1	8	0
			Larix decidua	25	21.7		51	32.1						
1	49°32'3.9'' N	13°33'4.6'' E	*Fagus sylvatica*	62	96.9	122	43	31.3	145	5	13	0	16	0
1	49°32'21.9'' N	13°33'55.7'' E	*Acer pseudoplatanus*	198	83.5	117	10	12.4	204	16	12	0	14	0
			Ulmus glabra	18	7.6		16	14.2						
1	49°31'48'' N	13°35'11.5'' E	*Acer pseudoplatanus*	35	31.3	88	29	26.4	214	12	20	4	16	0
			Picea abies	34	30.4		15	11.2						
			Fagus sylvatica	18	16.1		52	27.0						
			Fraxinus excelsior	18	16.1		38	31.5						
1	49°32'33.8'' N	13°32'29.6'' E	*Picea abies*	133	94.3	90	33	26.9	101	2	13	0	17	0
1	49°31'52.4'' N	13°33'39.1'' E	*Picea abies*	156	98.1	76	33	25.7	102	2	8	0	18	0
1	49°32'38.7'' N	13°33'46.4'' E	*Picea abies*	103	100.0	79	38	29.8	113	2	7	0	20	0
1	49°31'43.2'' N	13°34'23.6'' E	*Picea abies*	160	100.0	80	32	28.8	139	2	7	0	13	0
1	49°32'1.1'' N	13°34'28.8'' E	*Picea abies*	453	100.0	29	16	10.6	164	4	7	0	14	0
1	49°32'0.8'' N	13°34'46.4'' E	*Larix decidua*	352	100.0	21	15	15.2	94	4	19	5	11	0
1	49°32'25.2'' N	13°32'24.6'' E	*Picea abies*	214	98.2	107	19	14.9	129	2	15	2	22	0
1	49°31'51'' N	13°33'26.2'' E	*Fraxinus excelsior*	147	78.2	99	12	14.3	224	8	13	0	21	0
			Picea abies	20	10.6		26	19.6						
1	49°32'7.3'' N	13°34'4'' E	*Fagus sylvatica*	46	47.9	169	44	24.3	233	20	25	6	18	1
			Fraxinus excelsior	36	37.5		12	13.0						
1	49°32'27.3'' N	13°34'41.9'' E	*Picea abies*	108	98.2	91	34	30.5	117	3	10	0	21	0
2	48°40'7.8'' N	14°42'21.8'' E	*Fagus sylvatica*	108	97.3	315	20	15.5	284	30	73	42	30	1
2	48°39'53.9'' N	14°42'30.7'' E	*Fagus sylvatica*	98	98.0	315	27	20.9	227	24	57	29	23	1
2	48°40'2.8'' N	14°42'35.8'' E	*Fagus sylvatica*	124	96.1	315	21	16.8	249	30	68	42	25	2
2	48°40'11.1'' N	14°42'34'' E	*Fagus sylvatica*	186	88.2	195	12	14.5	268	20	44	24	38	3
			Picea abies	21	10.0		72	38.1						
2	48°39'43.3'' N	14°40'50.3'' E	*Fagus sylvatica*	54	100.0	168	48	35.0	194	12	34	18	16	0
2	48°41'11.5'' N	14°41'16.2'' E	*Fagus sylvatica*	38	92.7	175	56	32.7	115	1	35	11	17	0
2	48°39'31.4'' N	14°41'36.6'' E	*Fagus sylvatica*	81	100.0	134	46	32.0	156	10	29	9	14	0
2	48°39'18.4'' N	14°41'56.7'' E	*Fagus sylvatica*	45	97.8	146	51	29.7	173	9	23	7	28	1
							7	4.8						
2	48°39'48.5'' N	14°40'22.4'' E	*Picea abies*	123	100.0	98	41	31.2	117	5	15	2	16	0
2	48°38'53'' N	14°42'3.8'' E	*Picea abies*	118	100.0	94	41	31.5	110	1	13	2	19	0
2	48°40'34.6'' N	14°42'26.2'' E	*Picea abies*	118	100.0	106	42	34.6	81	4	25	8	25	0
2	48°40'24.8'' N	14°42'39.7'' E	*Picea abies*	31	100.0	114	58	36.8	94	2	17	4	20	0
2	48°39'51.4'' N	14°41'19.2'' E	*Fagus sylvatica*	586	98.0	21	12	13.4	162	9	16	2	13	0
2	48°39'7.1'' N	14°42'31.1'' E	*Picea abies*	386	100.0	50	22	19.5	145	4	15	4	18	0
2	48°39'56.3'' N	14°40'51.7'' E	*Picea abies*	50	75.8	125	54	36.2	131	6	21	3	17	0
			Fagus sylvatica	16	24.2		13	9.4						
2	48°41'14.6'' N	14°41'36.3'' E	*Picea abies*	41	67.2	175	17	12.1	132	5	45	17	18	0
			Fagus sylvatica	19	31.1		62	35.8						
2	48°40'39.3'' N	14°41'58.4'' E	*Fagus sylvatica*	58	79.5	180	52	34.8	156	4	35	15	24	0
			Picea abies	15	20.5		41	32.8						
2	48°40'39.5'' N	14°43'8'' E	*Picea abies*	94	100.0	117	16	12.4	134	3	38	14	18	0
3	49°24'4.3'' N	18°24'53.7'' E	*Fagus sylvatica*	235	98.7	269	15	14.1	237	21	26	9	23	0
3	49°24'0.3'' N	18°25'0.7'' E	*Fagus sylvatica*	177	95.7	244	18	14.9	201	21	29	12	27	0
3	49°24'8.1'' N	18°25'2.6'' E	*Fagus sylvatica*	154	92.8	269	20	16.8	235	24	21	10	23	0
3	49°24'3.1'' N	18°25'10.7'' E	*Fagus sylvatica*	209	95.4	244	19	20.6	203	18	21	7	26	2
3	49°24'7.1'' N	18°24'21.7'' E	*Fagus sylvatica*	72	92.3	148	38	27.5	201	11	25	5	22	1
					7.7		34	21.6						
3	49°24'34.1'' N	18°25'0.9'' E	*Fagus sylvatica*	206	99.5	85	25	26.1	159	8	11	1	19	0
3	49°23'40.3'' N	18°26'12.4'' E	*Fagus sylvatica*	224	89.6	82	22	23.8	150	7	10	1	13	0
3	49°24'3.3'' N	18°26'51.8'' E	*Picea abies*	46	53.5	109	53	38.0	163	6	12	0	17	0
			Abies alba	25	29.1		45	33.5						
			Fagus sylvatica	15	17.4		21	17.7						
3	49°24'15'' N	18°25'16.1'' E	*Picea abies*	113	95.8	113	43	34.5	134	5	12	1	18	0
3	49°24'5.2'' N	18°25'34.1'' E	*Picea abies*	100	100.0	103	42	34.7	138	3	16	0	28	0
3	49°24'5.8'' N	18°26'19.7'' E	*Picea abies*	129	98.5	87	40	33.7	139	3	13	0	21	1
3	49°24'38.2'' N	18°26'20.7'' E	*Picea abies*	93	98.9	124	46	38.2	134	8	18	1	18	0
3	49°24'38.3'' N	18°25'36.4'' E	*Fagus sylvatica*	293	97.7	54	20	25.7	146	8	13	2	15	0
3	49°24'17.9'' N	18°26'29.9'' E	*Picea abies*	301	92.0	27	20	16.9	177	6	11	2	20	1
3	49°24'28.3'' N	18°25'34.7'' E	*Picea abies*	41	56.2	144	51	35.8	172	8	16	1	21	0
			Fagus sylvatica	32	43.8		26	14.6						
3	49°24'14'' N	18°25'50.8'' E	*Picea abies*	101	94.4	133	8	6.5	133	2	19	0	15	2
3	49°24'17.5'' N	18°26'6.3'' E	*Fagus sylvatica*	130	72.2	63	21	24.3	188	8	17	6	22	0
			Picea abies	49	27.2		39	30.6						
3	49°23'47.4'' N	18°26'48.2'' E	*Fagus sylvatica*	101	58.7	147	10	7.5	161	6	18	1	11	0
			Picea abies	67	39.0		44	32.8						
4	49°18'43.6'' N	15°30'31.5'' E	*Fagus sylvatica*	115	89.8	156	23	17.4	125	7	20	3	19	0
4	49°18'21.7'' N	15°30'51.5'' E	*Fagus sylvatica*	133	97.1	156	14	16.7	156	7	19	5	15	1
4	49°18'57.6'' N	15°31'23.7'' E	*Fagus sylvatica*	87	92.6	194	26	18.9	180	9	24	5	21	0
4	49°19'28.9'' N	15°30'45.9'' E	*Fagus sylvatica*	50	60.2	156	39	38.5	126	5	19	2	18	0
			Picea abies	23	27.7		58	40.1						
			Abies alba	10	12.0		55	37.2						
4	49°18'35.1'' N	15°31'5.5'' E	*Fagus sylvatica*	129	71.3	78	25	29.3	91	2	17	3	20	0
			Picea abies	28	15.5		40	31.3						
			Abies alba	14	7.7		34	29.4						

4	49°18'5.6'' N	15°31'11.7'' E	*Quercus robur*	75	91.5	106	36	27.9	84	1	23	3	13	0
4	49°18'19.7'' N	15°31'19'' E	*Fagus sylvatica*	89	100.0	111	41	37.9	141	5	21	4	21	0
4	49°18'44.2'' N	15°31'27.5'' E	*Fagus sylvatica*	180	88.7	194	15	15.8	182	5	13	3	13	0
			Fraxinus excelsior	14	6.9		21	25.2						
4	49°18'37,7'' N	15°31'11'' E	*Picea abies*	86	86.9	78	49	39.8	72	0	8	0	15	0
			Fagus sylvatica	13	13.1		20	25.1						
4	49°19'18.4'' N	15°31'5.2'' E	*Picea abies*	96	99.0	110	46	36.0	105	3	15	0	15	0
4	49°17'36.8'' N	15°32'44.1'' E	*Picea abies*	113	99.1	77	36	31.1	112	3	19	1	17	0
4	49°18'35.1'' N	15°30'13'' E	*Picea abies*	227	100.0	54	28	26.7	71	0	4	0	9	0
4	49°19'13.3'' N	15°30'50.2'' E	*Picea abies*	386	99.0	25	16	13.8	122	2	18	2	22	0
4	49°18'27.6'' N	15°30'23.9'' E	*Fagus sylvatica*	161	54.6	14	17	13.5	130	2	19	2	17	0
			Picea abies	81	27.5		13	9.6						
			Abies alba	43	14.6		14	11.7						
4	49°18'49.4'' N	15°31'6.5'' E	*Picea abies*	148	71.8	121	14	11.4	91	0	16	2	15	0
			Fagus sylvatica	42	20.4		14	11.8						
			Abies alba	16	7.8		19	17.8						
4	49°19'23.5'' N	15°31'12.5'' E	*Picea abies*	23	76.7	110	53	37.1	152	1	29	6	24	0
			Fagus sylvatica	5	16.7		95	37.0						
4	49°17'37.7'' N	15°31'34.2'' E	*Picea abies*	132	100.0	121	21	16.4	87	0	29	2	15	0
4	49°18'11.8'' N	15°31'32.5'' E	*Picea abies*	91	100.0	104	46	37.5	83	4	16	0	20	0
5	50°19'35.1'' N	15°5'1.8'' E	*Quercus robur*	83	96.5	132	33	22.9	65	1	25	2	12	0
5	50°19'33.9'' N	15°5'51.7'' E	*Pinus sylvestris*	38	48.7	173	28	26.9	135	4	14	0	9	0
			Fagus sylvatica	19	24.4		57	26.7						
			Quercus robur	15	19.2		21	20.5						
5	50°20'24.3'' N	15°7'14.5'' E	*Carpinus betulus*	83	51.6	133	9	11.2	125	6	23	5	11	0
			Quercus petraea	58	36.0		42	27.8						
			Acer pseudoplatanus	17	10.6		8	10.3						
5	50°19'37'' N	15°3'32.6'' E	*Picea abies*	161	88.5	78	25	25.5	78	2	9	0	17	0
			Larix decidua	15	8.2		36	29.0						
5	50°19'40.4'' N	15°4'40.2'' E	*Picea abies*	137	69.5	86	18	15.8	70	0	13	1	16	0
			Pinus sylvestris	59	29.9		38	22.8						
5	50°20'6.1'' N	15°5'1.5'' E	*Picea abies*	91	53.5	103	20	16.0	68	1	14	0	13	0
			Pinus sylvestris	76	44.7		35	23.3						
5	50°20'20.1'' N	15°4'54.9'' E	*Pinus sylvestris*	498	83.7	27	14	13.5	85	1	16	1	15	0
			Betula pendula	74	12.4		13	14.3						
5	50°20'14.9'' N	15°6'24.6'' E	*Picea abies*	424	97.5	29	15	14.6	118	0	13	2	17	0
5	50°20'0.9'' N	15°3'59.4'' E	*Picea abies*	77	44.5	133	14	12.2	88	2	19	3	17	0
			Pinus sylvestris	42	24.3		26	18.4						
			Quercus robur	29	16.8		40	22.8						
			Betula pendula	25	14.5		20	18.0						
5	50°20'11.1'' N	15°7'14.4'' E	*Carpinus betulus*	199	66.8	123	8	10.8	123	4	19	4	18	0
			Picea abies	41	13.8		24	18.1						
			Pinus sylvestris	35	11.7		40	26.1						
5	50°20'23.9'' N	15°8'1.9'' E	*Picea abies*	159	99.4	15	28	25.1	97	0	21	1	16	0
6	50°11'30.7'' N	14°43'5.1'' E	*Quercus robur*	42	79.2	182	52	33.9	138	3	26	6	9	0
			Tilia cordata	11	20.8		18	10.5						
6	50°11'31.7'' N	14°43'9.5'' E	*Quercus petraea*	46	74.2	182	44	25.3	116	2	12	1	9	0
			Quercus robur	12	19.4		55	30.2						
6	50°11'30.3'' N	14°43'13.6'' E	*Quercus robur*	121	100.0	182	25	16.9	123	4	15	2	12	0
6	50°11'17.9'' N	14°43'25.6'' E	*Quercus robur*	143	88.8	77	26	23.4	90	3	9	0	9	0
			Tilia cordata	17	10.6		10	9.1						
6	50°11'26.6'' N	14°43'49.3'' E	*Quercus robur*	102	82.9	92	32	27.0	89	0	14	1	17	0
			Tilia cordata	18	14.6		12	10.4						
6	50°11'14.4'' N	14°43'53.3'' E	*Quercus petraea*	86	49.1	122	34	25.5	121	5	13	0	15	0
			Tilia cordata	79	45.1		12	9.7						
6	50°11'43.3'' N	14°42'31.4'' E	*Pinus sylvestris*	146	48.0	92	27	22.3	90	2	14	0	15	0
			Pinus strobus	125	41.1		7	6.7						
6	50°11'38.3'' N	14°42'54'' E	*Picea abies*	105	75.0	92	27	23.8	75	1	6	0	15	0
			Pinus sylvestris	35	25.0		36	26.6						
6	50°11'17'' N	14°43'34.1'' E	*Quercus petraea*	188	52.5	83	10	9.4	106	0	12	0	17	0
			Pinus sylvestris	120	33.5		30	21.1						
			Betula pendula	42	11.7		9	10.8						
6	50°11'52.3'' N	14°42'25.4'' E	*Pinus sylvestris*	1075	96.6	21	9	11.1	129	2	11	0	10	0
6	50°11'40.2'' N	14°42'59.3'' E	*Pinus sylvestris*	34	40.5	52	28	22.0	103	0	22	1	13	0
			Larix decidua	19	22.6		25	23.5						
			Tilia cordata	17	20.2		12	10.2						
			Quercus robur	14	16.7		37	20.3						
6	50°11'29.8'' N	14°43'31.7'' E	*Picea abies*	50	39.4	92	11	8.9	116	1	18	2	16	0
			Quercus robur	38	29.9		33	19.6						
			Pinus sylvestris	37	29.1		33	23.3						
6	50°11'18.5'' N	14°43'40.9'' E	*Tilia cordata*	13	40.6	4	10	7.3	100	3	12	0	7	0
			Quercus robur	8	25.0		41	20.9						
			Larix decidua	6	18.8		43	29.1						

Table S2. Stand basal areas (m^2) of living trees in sampling plots of 18 diameter classes (ranging from 5 to 150 cm).

Longitude	Latitude	Tree diameter classes (cm)																		Total
N	E	5 - 10	10.1 - 15	15.1 - 20	20.1 - 25	25.1 - 30	30.1 - 35	35.1 - 40	40.1 - 45	45.1 - 50	50.1 - 55	55.1 - 60	60.1 - 65	65.1 - 70	70.1 - 75	75.1 - 80	80.1 - 90	90.1 - 110	110.1 - 150	
49°32'9" N	13°33'22.6" E	0.16	1.56	1.08	3.89	5.53	7.92	7.40	14.73	7.48	32.61	10.04	14.46	29.85	26.13	0.00	0.00	0.00	0.00	162.8
49°32'5.5" N	13°33'26.7" E	0.00	0.06	0.00	1.24	0.67	3.69	3.10	14.31	17.96	18.93	20.46	37.66	6.63	22.24	0.00	32.35	0.00	0.00	179.3
49°32'21.7" N	13°33'27.8" E	0.49	3.03	7.17	10.55	9.96	12.88	14.70	12.42	2.62	2.26	0.00	0.00	0.00	0.00	7.99	0.00	24.37	0.00	108.4
49°32'17" N	13°33'30" E	0.24	1.15	1.09	1.24	0.54	6.12	3.31	10.12	7.77	3.30	3.58	28.77	0.00	6.57	14.58	0.00	13.21	0.00	101.6
49°32'0.1" N	13°32'12.9" E	0.43	0.98	0.45	0.74	1.21	1.62	7.34	3.89	10.27	30.08	32.80	22.71	20.01	6.02	16.70	11.05	0.00	0.00	166.3
49°32'3.9" N	13°33'4.6" E	0.00	0.00	0.00	1.07	4.44	13.72	14.49	29.58	54.69	18.22	25.24	14.91	0.00	0.00	0.00	0.00	0.00	0.00	176.3
49°32'21.9" N	13°33'55.7" E	1.19	3.86	2.70	2.56	0.65	3.13	2.32	0.00	0.00	2.35	3.76	18.43	4.08	0.00	6.34	0.00	11.74	0.00	63.1
49°31'48" N	13°35'11.5" E	0.26	0.91	2.03	2.31	5.85	10.76	14.41	9.37	9.50	10.66	8.57	5.02	0.00	15.54	6.99	0.00	27.65	22.13	151.9
49°32'33.8" N	13°32'29.6" E	0.00	0.00	0.42	5.06	16.36	32.70	40.26	23.18	13.11	4.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	136.0
49°31'52.4" N	13°33'39.1" E	0.00	0.15	2.44	8.86	18.09	36.53	32.52	30.17	24.22	12.83	2.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	168.6
49°32'38.7" N	13°33'46.4" E	0.00	0.00	0.00	1.05	8.08	34.53	32.69	31.86	18.12	13.55	3.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	143.3
49°31'43.2" N	13°34'23.6" E	0.00	0.00	3.02	8.43	24.01	46.92	40.85	21.63	22.89	2.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	170.6
49°32'1.1" N	13°34'28.8" E	0.49	8.81	22.11	11.44	2.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	45.2
49°32'0.8" N	13°34'46.4" E	0.67	14.35	28.96	5.44	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	49.4
49°32'25.2" N	13°32'24.6" E	0.89	2.74	0.53	0.93	2.69	13.43	26.57	18.59	12.40	12.87	16.47	3.99	0.00	0.00	0.00	0.00	0.00	0.00	112.1
49°31'51" N	13°33'26.2" E	1.77	2.72	4.41	1.81	4.99	6.33	6.30	8.10	16.27	5.38	0.00	3.96	0.00	0.00	0.00	0.00	0.00	0.00	62.0
49°32'7.3" N	13°34'4" E	0.20	0.79	1.56	1.11	2.10	0.95	7.56	10.17	31.02	10.56	17.15	19.92	16.74	0.00	5.15	6.20	0.00	0.00	131.2
49°32'27.3" N	13°34'41.9" E	0.00	0.00	0.33	4.50	16.57	38.52	39.92	18.82	15.06	8.56	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	142.3
48°40'7.8" N	14°42'21.8" E	0.89	0.85	0.40	0.00	0.75	2.97	6.11	0.00	2.52	7.05	3.73	7.53	14.68	7.19	19.02	0.00	63.82	0.00	137.5
48°39'53.9" N	14°42'30.7" E	0.50	1.56	1.74	2.76	6.31	2.80	0.00	7.04	0.00	0.00	0.00	12.21	6.72	18.53	19.06	22.11	64.28	31.17	196.8
48°40'2.8" N	14°42'35.8" E	0.82	1.69	1.42	2.78	5.67	1.42	4.46	11.27	16.88	6.95	3.93	0.00	0.00	7.32	12.18	9.09	44.97	0.00	130.8
48°40'11.1" N	14°42'34" E	1.29	2.66	1.55	0.57	0.00	4.00	1.45	6.05	0.00	10.47	4.70	11.09	18.35	8.66	23.46	0.00	93.97	17.47	205.7
48°39'43.3" N	14°40'50.3" E	0.00	0.00	0.18	0.00	0.90	7.29	7.58	22.93	19.54	44.97	13.71	12.03	15.12	8.48	36.73	0.00	0.00	0.00	189.5
48°41'11.5" N	14°41'16.2" E	0.00	0.00	0.00	0.33	0.00	0.00	3.73	6.42	8.73	7.03	12.75	27.97	32.62	29.37	0.00	0.00	0.00	0.00	128.9
48°39'31.4" N	14°41'36.6" E	0.00	0.00	0.00	0.54	1.54	9.05	20.57	25.18	33.44	50.90	26.11	11.23	5.67	13.89	0.00	0.00	0.00	0.00	198.1
48°39'18.4" N	14°41'56.7" E	0.00	0.00	0.00	0.00	0.00	4.96	5.29	8.19	18.82	17.25	4.34	22.25	18.09	29.38	8.30	0.00	0.00	0.00	136.9
48°39'48.5" N	14°40'22.4" E	0.00	0.00	0.00	0.86	2.08	18.86	37.80	53.77	45.06	36.73	3.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	198.9
48°38'53" N	14°42'3.8" E	0.00	0.00	0.00	0.49	5.38	23.43	43.56	45.04	42.46	30.86	25.93	4.74	0.00	0.00	0.00	0.00	0.00	0.00	221.9
48°40'34.6" N	14°42'26.2" E	0.00	0.00	0.00	0.53	1.11	18.98	51.86	42.30	53.04	46.67	4.01	4.44	5.63	0.00	0.00	0.00	0.00	0.00	228.6
48°40'24.8" N	14°42'39.7" E	0.00	0.00	0.00	0.00	0.62	0.00	0.00	2.41	12.36	15.85	14.75	13.84	12.07	19.83	15.84	8.68	0.00	0.00	116.2
48°39'51.4" N	14°41'19.2" E	4.27	16.20	13.58	10.68	4.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	49.4
48°39'7.1" N	14°42'31.1" E	0.22	5.75	19.13	31.72	31.51	34.42	20.95	7.80	4.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	155.8
48°39'56.3" N	14°40'51.7" E	0.10	0.34	0.00	0.00	0.00	1.20	4.99	4.13	36.12	28.51	24.52	28.39	11.39	18.34	7.63	0.00	0.00	0.00	165.7
48°41'14.6" N	14°41'36.3" E	0.03	0.08	0.10	0.22	0.00	0.00	0.00	0.00	2.71	23.16	17.66	0.00	13.97	29.16	19.67	35.61	0.00	0.00	142.4
48°40'39.3" N	14°41'58.4" E	0.00	0.00	0.00	0.00	4.24	5.74	10.97	22.56	26.62	24.28	31.85	24.84	6.04	12.30	21.15	16.88	0.00	0.00	207.5
48°40'39.5" N	14°43'8" E	0.42	0.85	0.99	0.94	1.14	0.79	8.38	15.49	15.75	18.50	10.43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	73.7
49°24'4.3" N	18°24'53.7" E	1.44	4.71	4.64	5.99	6.04	1.13	4.38	2.47	3.40	4.39	7.17	0.00	12.43	7.24	0.00	18.02	15.07	0.00	98.5
49°24'0.3" N	18°25'0.7" E	0.85	2.74	3.05	2.46	1.71	5.72	1.48	4.56	11.48	3.78	15.43	4.39	17.26	7.48	17.73	53.73	14.18	0.00	168.0
49°24'8.1" N	18°25'2.6" E	1.13	3.53	4.47	3.29	2.58	1.66	2.06	3.75	6.12	6.69	0.00	0.00	12.95	12.86	9.70	0.00	59.67	67.44	197.9
49°24'3.1" N	18°25'10.7" E	0.92	4.00	11.64	10.52	12.63	12.01	14.83	5.85	0.00	6.15	12.40	15.71	0.00	7.84	9.08	10.21	15.28	0.00	149.1
49°24'7.1" N	18°24'21.7" E	0.08	0.03	0.21	1.02	4.38	13.12	15.58	24.74	15.67	28.01	20.93	0.00	5.65	0.00	7.98	0.00	0.00	0.00	137.4
49°24'34.1" N	18°25'0.9" E	0.19	2.23	9.54	21.78	33.74	33.29	24.62	13.28	6.02	3.55	0.00	4.66	0.00	0.00	0.00	0.00	0.00	0.00	152.9
49°23'40.3" N	18°26'12.4" E	0.08	4.57	15.52	18.73	39.46	18.68	9.33	16.34	16.78	8.57	3.69	3.92	5.14	0.00	0.00	0.00	0.00	0.00	160.8
49°24'3.3" N	18°26'51.8" E	0.00	0.34	0.91	1.38	5.00	2.06	14.02	11.04	33.49	44.74	38.52	5.35	29.60	20.35	0.00	0.00	0.00	0.00	206.8
49°24'15" N	18°25'16.1" E	0.03	0.02	0.38	3.74	3.62	11.41	29.69	56.40	50.04	59.88	23.91	4.54	0.00	0.00	0.00	0.00	0.00	0.00	243.7
49°24'5.2" N	18°25'34.1" E	0.00	0.00	0.00	1.86	7.57	15.14	27.04	32.81	37.04	41.56	7.90	29.51	0.00	0.00	0.00	0.00	0.00	0.00	200.4
49°24'5.8" N	18°26'19.7" E	0.02	0.00	0.00	1.18	3.26	22.18	48.32	73.12	29.49	26.63	4.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	208.3
49°24'38.2" N	18°26'20.7" E	0.00	0.00	0.00	0.00	1.08	4.66	19.31	44.04	77.60	55.76	31.62	5.33	12.00	7.26	0.00	0.00	0.00	0.00	258.7
49°24'38.3" N	18°25'36.4" E	0.19	8.41	24.47	40.10	33.12	18.20	8.60	4.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	137.4

Table S2. (finished)

Longitude	Latitude	Tree diameter classes (cm)																		Total
N	E	5 - 10	10.1 - 15	15.1 - 20	20. 1 - 25	25.1 - 30	30.1 - 35	35.1 - 40	40.1 - 45	45.1 - 50	50.1 - 55	55.1 - 60	60.1 - 65	65.1 - 70	70.1 - 75	75.1 - 80	80.1 - 90	90.1 - 110	110.1 - 145	
49°24'17.9" N	18°26'29.9" E	0.39	2.78	20.48	32.83	14.09	4.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	74.6
49°24'28.3" N	18°25'34.7" E	0.09	0.39	0.43	2.02	2.16	3.14	0.78	7.34	7.77	24.66	14.87	44.57	36.67	21.26	0.00	11.64	0.00	0.00	177.8
49°24'14" N	18°25'50.8" E	0.66	0.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.3
49°24'17.5" N	18°26'6.3" E	0.13	3.41	9.22	15.72	28.55	19.59	20.25	26.58	22.10	9.30	4.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	159.0
49°23'47.4" N	18°26'48.2" E	0.75	0.97	0.47	0.63	1.58	0.00	6.74	12.38	17.12	37.10	45.29	42.13	12.62	15.44	0.00	11.34	0.00	0.00	204.6
49°18'43.6" N	15°30'31.5" E	0.58	0.92	0.80	0.00	0.00	0.00	11.61	5.52	25.59	31.28	49.59	15.74	28.43	15.20	0.00	0.00	0.00	0.00	185.3
49°18'21.7" N	15°30'51.5" E	2.40	6.53	6.54	4.16	7.07	5.77	5.34	0.00	5.47	0.00	0.00	0.00	0.00	14.28	7.98	33.01	30.46	0.00	129.0
49°18'57.6" N	15°31'23.7" E	0.30	0.99	2.27	2.40	2.94	4.02	3.06	0.00	0.00	2.52	7.83	6.61	8.93	9.12	11.81	40.29	27.29	0.00	130.4
49°19'28.9" N	15°30'45.9" E	0.00	0.00	1.73	1.32	2.33	9.09	9.64	17.54	21.47	39.97	33.33	32.32	18.26	21.23	8.43	18.70	0.00	0.00	235.4
49°18'35.1" N	15°31'5.5" E	0.13	2.65	8.87	10.04	15.31	33.39	29.63	35.11	16.43	17.35	7.62	4.69	0.00	0.00	0.00	0.00	0.00	0.00	181.2
49°18'5.6" N	15°31'11.7" E	0.00	0.00	0.00	2.41	6.15	14.63	35.69	31.16	15.81	7.25	0.00	0.00	2.95	0.00	0.00	0.00	0.00	0.00	116.1
49°18'19.7" N	15°31'19" E	0.00	0.00	0.00	2.06	8.83	7.27	44.15	40.68	49.18	12.91	20.69	0.00	6.92	8.94	0.00	0.00	0.00	0.00	201.6
49°18'44.2" N	15°31'27.5" E	1.07	5.50	5.65	6.39	8.67	3.47	2.85	1.73	0.00	0.00	11.14	16.71	6.58	0.00	0.00	13.75	27.73	38.58	149.8
49°18'37.7" N	15°31'11" E	0.05	0.00	1.57	0.98	3.49	8.42	24.57	23.83	43.74	55.11	21.15	28.00	10.83	26.41	0.00	0.00	0.00	0.00	248.1
49°19'18.4" N	15°31'5.2" E	0.00	0.00	0.00	0.00	1.00	6.32	25.54	58.59	48.26	38.67	20.69	24.53	5.64	0.00	0.00	0.00	0.00	0.00	229.2
49°17'36.8" N	15°32'44.1" E	0.00	0.00	0.22	3.80	10.81	32.70	38.44	30.72	17.25	3.09	3.53	0.00	4.74	0.00	0.00	0.00	0.00	0.00	145.3
49°18'35.1" N	15°30'13" E	0.00	0.00	4.74	24.57	54.60	45.87	23.65	10.83	2.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	166.4
49°19'13.3" N	15°30'50.2" E	1.13	11.68	16.54	14.77	4.57	4.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	53.6
49°18'27.6" N	15°30'23.9" E	1.38	2.97	4.76	8.95	13.06	7.39	11.05	4.06	0.00	0.00	0.00	0.00	0.00	0.00	8.37	0.00	0.00	0.00	62.0
49°18'49.4" N	15°31'6.5" E	1.01	1.47	2.82	1.54	1.44	0.86	3.18	8.73	18.77	9.64	6.64	4.76	5.47	0.00	0.00	0.00	0.00	0.00	66.3
49°19'23.5" N	15°31'12.5" E	0.00	0.00	0.00	0.00	0.00	0.00	1.56	6.41	10.18	5.01	16.38	4.88	11.13	0.00	8.73	0.00	32.50	20.65	117.4
49°17'37.7" N	15°31'34.2" E	0.40	0.05	0.00	0.62	0.00	7.57	14.22	9.13	16.16	32.57	22.92	3.57	0.00	0.00	0.00	0.00	0.00	0.00	107.2
49°18'11.8" N	15°31'32.5" E	0.00	0.00	0.37	2.61	4.54	6.77	16.44	39.33	39.78	67.72	25.92	20.08	18.12	14.62	8.27	0.00	0.00	0.00	264.5
50°19'35.1" N	15°5'1.8" E	0.00	0.00	0.52	3.66	10.00	16.72	22.83	19.35	9.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	82.8
50°19'33.9" N	15°5'51.7" E	0.00	0.35	1.01	9.35	7.84	12.59	6.05	5.55	0.00	0.00	0.00	0.00	0.00	0.00	14.41	9.75	40.14	0.00	107.0
50°20'24.3" N	15°7'14.5" E	0.47	1.24	0.70	0.62	1.56	5.42	18.70	28.97	28.04	26.25	3.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	115.9
50°19'37" N	15°3'32.6" E	0.00	0.14	8.42	20.86	33.99	35.27	11.42	14.44	1.99	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	126.5
50°19'40.4" N	15°4'40.2" E	0.36	3.54	4.60	5.70	12.59	10.19	20.59	15.93	17.96	4.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	95.9
50°20'6.1" N	15°5'1.5" E	0.16	1.25	3.26	5.44	11.87	21.73	30.86	9.24	18.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	102.4
50°20'20.1" N	15°4'54.9" E	2.00	16.41	22.96	12.74	1.73	1.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	57.8
50°20'14.9" N	15°6'24.6" E	1.29	13.40	22.36	15.37	2.54	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55.8
50°20'0.9" N	15°3'59.4" E	0.28	3.19	6.15	5.06	4.29	6.24	8.34	15.59	6.42	8.39	2.70	11.55	0.00	0.00	0.00	0.00	0.00	0.00	78.2
50°20'11.1" N	15°7'14.4" E	1.52	1.94	2.74	1.93	2.92	11.08	5.88	16.33	22.42	18.14	7.65	5.08	3.38	0.00	0.00	0.00	0.00	0.00	101.0
50°20'23.9" N	15°8'1.9" E	0.04	0.37	2.98	14.29	29.20	33.36	19.11	8.26	6.71	4.81	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	119.1
50°11'30.7" N	14°43'5.1" E	0.00	0.00	0.00	0.11	0.56	1.78	2.24	6.38	17.24	37.69	23.03	29.39	18.04	0.00	0.00	0.00	0.00	0.00	136.5
50°11'31.7" N	14°43'9.5" E	0.00	0.06	0.00	0.00	0.00	2.60	8.72	9.00	21.42	26.15	21.39	48.85	7.27	0.00	0.00	0.00	0.00	0.00	145.4
50°11'30.3" N	14°43'13.6" E	0.69	0.54	0.16	0.00	0.00	0.00	4.52	12.91	22.39	30.55	31.58	14.08	5.41	0.00	0.00	0.00	0.00	0.00	122.8
50°11'17.9" N	14°43'25.6" E	0.04	0.51	5.58	15.32	28.26	28.41	10.27	5.88	0.00	3.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	97.6
50°11'26.6" N	14°43'49.3" E	0.03	0.30	0.41	7.60	21.87	22.81	24.25	12.46	7.52	6.28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	103.5
50°11'14.4" N	14°43'53.3" E	0.13	0.76	2.18	6.03	13.05	21.92	21.56	19.46	14.62	8.73	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	108.4
50°11'43.3" N	14°42'31.4" E	0.28	0.28	3.04	12.51	27.45	26.88	13.38	4.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	88.4
50°11'38.3" N	14°42'54" E	0.02	0.29	2.20	10.62	22.58	24.08	25.21	17.26	6.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	108.5
50°11'17" N	14°43'34.1" E	1.49	3.42	1.87	6.13	19.53	24.54	19.07	8.23	3.64	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	87.9
50°11'52.3" N	14°42'25.4" E	5.46	18.18	5.87	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.8
50°11'40.2" N	14°42'59.3" E	0.04	0.67	1.29	4.48	8.86	8.77	12.25	3.62	4.01	0.00	3.45	0.00	5.34	0.00	0.00	0.00	0.00	0.00	52.8
50°11'29.8" N	14°43'31.7" E	0.45	0.95	0.92	0.55	6.56	7.62	11.60	11.85	13.60	9.23	0.00	0.00	5.97	0.00	0.00	0.00	0.00	0.00	69.3
50°11'18.5" N	14°43'40.9" E	0.07	0.00	0.00	0.00	0.00	0.97	8.23	5.17	6.13	0.00	3.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24.3

Table S3. Total volume (m^3) of dead wood objects (excluding stumps) in sampling plots of 18 diameter classes (ranging from 5 to 150 cm).

Longitude	Latitude	Tree diameter classes (cm)																		Total
N	E	5 - 10	10.1 - 15	15.1 - 20	20.1 - 25	25.1 - 30	30.1 - 35	35.1 - 40	40.1 - 45	45.1 - 50	50.1 - 55	55.1 - 60	60.1 - 65	65.1 - 70	70.1 - 75	75.1 - 80	80.1 - 90	90.1 - 110	110.1 - 150	
49°32'9" N	13°33'22.6" E	0.67	0.95	0.53	0.41	0.64	0.00	2.13	3.53	3.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.66
49°32'5.5" N	13°33'26.7" E	0.67	0.61	0.74	0.76	0.49	1.10	0.44	2.89	0.00	0.00	4.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.50
49°32'21.7" N	13°33'27.8" E	0.64	1.01	1.65	0.84	0.71	2.69	1.16	3.04	2.10	0.00	2.10	0.00	0.00	0.00	0.00	1.32	4.66	0.00	21.91
49°32'17" N	13°33'30" E	1.11	1.76	2.12	1.31	2.86	1.49	2.22	0.00	1.24	2.20	3.52	0.00	3.50	0.00	4.96	9.29	9.43	0.00	47.00
49°32'0.1" N	13°32'12.9" E	0.49	0.14	0.07	0.25	0.03	0.00	0.00	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.61
49°32'3.9" N	13°33'4.6" E	0.33	0.05	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40
49°32'21.9" N	13°33'55.7" E	0.43	0.49	0.54	0.48	0.08	0.15	0.00	0.29	1.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4.19
49°31'48" N	13°35'11.5" E	1.62	1.74	1.46	0.65	0.89	1.26	0.00	1.28	0.00	0.00	0.00	2.26	0.00	0.00	0.00	0.00	0.00	0.00	11.17
49°32'33.8" N	13°32'29.6" E	0.20	0.07	0.01	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31
49°31'52.4" N	13°33'39.1" E	0.95	1.22	1.11	0.55	0.16	1.30	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.30
49°32'38.7" N	13°33'46.4" E	0.10	0.11	0.18	0.03	0.02	0.01	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61
49°31'43.2" N	13°34'23.6" E	1.16	1.00	1.30	0.80	0.47	0.04	0.02	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.68
49°32'1.1" N	13°34'28.8" E	0.23	0.15	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
49°32'0.8" N	13°34'46.4" E	2.33	1.55	0.39	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	4.41
49°32'25.2" N	13°32'24.6" E	0.50	0.27	0.17	0.96	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.90
49°31'51" N	13°33'26.2" E	0.21	0.34	0.18	0.91	1.08	0.34	0.87	0.40	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	4.75
49°32'7.3" N	13°34'4" E	0.37	0.64	0.08	0.15	0.36	0.27	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.37
49°32'27.3" N	13°34'41.9" E	0.14	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
48°40'7.8" N	14°42'21.8" E	1.03	1.63	1.54	2.00	2.04	1.87	3.24	0.00	2.44	0.00	1.16	3.09	5.55	10.32	1.86	10.81	7.31	0.00	55.89
48°39'53.9" N	14°42'30.7" E	0.95	0.99	0.96	0.47	1.09	0.94	1.38	1.16	1.63	2.24	1.32	0.00	0.00	0.00	7.73	1.72	0.00	0.00	22.57
48°40'2.8" N	14°42'35.8" E	0.93	1.10	0.85	1.33	1.10	1.06	2.00	1.66	3.21	4.20	1.91	0.00	10.63	5.74	5.59	16.57	10.23	0.00	68.11
48°40'11.1" N	14°42'34" E	0.32	0.14	0.16	0.73	1.66	1.49	1.33	0.87	1.18	1.71	0.00	0.00	7.63	1.88	0.00	0.00	0.00	0.00	19.10
48°39'43.3" N	14°40'50.3" E	0.66	0.47	0.40	0.00	0.89	0.00	0.00	0.78	0.68	0.00	1.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.41
48°41'11.5" N	14°41'16.2" E	0.17	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
48°39'31.4" N	14°41'36.6" E	1.54	0.94	0.48	0.49	0.73	0.00	0.62	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.04
48°39'18.4" N	14°41'56.7" E	0.18	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26
48°39'48.5" N	14°40'22.4" E	0.21	0.15	0.14	0.10	0.00	2.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.01
48°38'53" N	14°42'3.8" E	0.35	0.42	0.29	0.27	1.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.36
48°40'34.6" N	14°42'26.2" E	0.04	0.06	0.03	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16
48°40'24.8" N	14°42'39.7" E	0.09	0.30	0.16	0.03	0.00	0.96	0.00	0.00	0.05	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.64
48°39'51.4" N	14°41'19.2" E	0.67	0.54	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	1.36
48°39'7.1" N	14°42'31.1" E	1.90	1.83	1.96	0.74	0.00	0.84	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	7.79
48°39'56.3" N	14°40'51.7" E	0.06	0.16	0.04	0.06	0.23	0.00	0.27	0.08	0.37	0.00	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.74
48°41'14.6" N	14°41'36.3" E	0.29	0.24	0.36	0.13	0.08	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.18
48°40'39.3" N	14°41'58.4" E	0.73	0.67	0.64	0.37	0.00	0.67	2.45	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.52
48°40'39.5" N	14°43'8" E	0.08	0.13	0.05	0.07	0.04	0.00	0.14	1.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.60
49°24'4.3" N	18°24'53.7" E	0.85	1.00	1.36	1.96	2.42	1.39	5.06	2.88	5.39	0.32	4.37	3.06	8.24	6.53	0.00	15.01	11.78	10.71	82.33
49°24'0.3" N	18°25'0.7" E	0.58	0.72	0.47	1.18	1.62	2.06	1.86	4.57	0.35	1.00	0.00	8.85	2.43	2.38	0.00	13.79	19.46	0.00	61.32
49°24'8.1" N	18°25'2.6" E	1.31	1.92	2.11	2.02	1.25	1.45	0.38	3.31	2.76	1.65	3.15	2.06	4.49	6.32	1.43	0.00	14.70	11.01	61.31
49°24'3.1" N	18°25'10.7" E	0.85	0.58	0.30	1.51	1.21	0.64	0.95	1.17	2.26	4.99	4.42	2.46	0.00	6.72	5.65	2.54	8.43	2.58	47.28
49°24'7.1" N	18°24'21.7" E	0.22	0.13	0.04	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.56
49°24'34.1" N	18°25'0.9" E	0.61	0.52	0.24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.38
49°23'40.3" N	18°26'12.4" E	0.59	0.77	0.16	0.18	0.33	0.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.54
49°24'3.3" N	18°26'51.8" E	0.06	0.12	0.32	0.08	0.00	0.21	0.00	0.76	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05
49°24'15" N	18°25'16.1" E	0.31	0.12	0.02	0.01	0.06	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52
49°24'5.2" N	18°25'34.1" E	0.10	0.17	0.08	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.42
49°24'5.8" N	18°26'19.7" E	0.34	0.22	0.23	0.02	0.03	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.87

Table S3. (finished)

Longitude	Latitude	Tree diameter classes (cm)																		Total
N	E	5 - 10	10.1 - 15	15.1 - 20	20.1 - 25	25.1 - 30	30.1 - 35	35.1 - 40	40.1 - 45	45.1 - 50	50.1 - 55	55.1 - 60	60.1 - 65	65.1 - 70	70.1 - 75	75.1 - 80	80.1 - 90	90.1 - 110	110.1 - 150	
49°24'38.2" N	18°26'20.7" E	0.07	0.05	0.02	0.01	0.04	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22
49°24'38.3" N	18°25'36.4" E	0.41	0.28	0.60	0.25	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.91
49°24'17.9" N	18°26'29.9" E	3.67	6.70	2.86	0.91	0.28	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.36	0.00	0.00	0.00	15.02
49°24'28.3" N	18°25'34.7" E	0.17	0.05	0.08	0.02	0.03	0.23	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72
49°24'14" N	18°25'50.8" E	0.05	0.09	0.01	0.10	0.05	0.22	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62
49°24'17.5" N	18°26'6.3" E	0.69	0.72	1.43	0.33	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.57
49°23'47.4" N	18°26'48.2" E	0.16	0.06	0.01	0.03	0.28	0.03	0.00	0.00	0.00	0.65	0.00	0.59	0.00	0.00	0.00	0.00	0.00	0.00	1.80
49°18'43.6" N	15°30'31.5" E	0.29	0.09	0.63	1.52	1.89	9.65	8.51	3.01	9.38	4.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	39.36
49°18'21.7" N	15°30'51.5" E	0.74	2.22	2.33	1.06	1.73	0.00	1.47	2.74	0.00	2.86	6.22	0.00	0.00	2.50	0.00	0.00	0.00	0.00	23.86
49°18'57.6" N	15°31'23.7" E	0.16	0.06	0.48	0.50	0.56	1.07	4.32	1.25	8.08	3.15	12.01	4.44	0.81	0.00	0.66	1.22	7.63	0.00	46.39
49°19'28.9" N	15°30'45.9" E	0.14	0.12	0.06	0.02	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.59
49°18'35.1" N	15°31'5.5" E	0.52	0.42	0.33	0.41	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.05
49°18'5.6" N	15°31'11.7" E	0.27	0.03	0.31	0.00	1.28	1.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.78
49°18'19.7" N	15°31'19" E	0.48	0.18	0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.08
49°18'44.2" N	15°31'27.5" E	0.74	0.72	0.58	0.44	0.46	0.42	4.69	4.79	8.61	3.17	3.88	0.67	4.85	2.70	5.49	0.00	0.00	0.00	42.21
49°18'37.7" N	15°31'11" E	0.25	0.40	0.56	0.21	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.45
49°19'18.4" N	15°31'5.2" E	0.22	0.09	0.02	0.02	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.00	0.61
49°17'36.8" N	15°32'44.1" E	0.52	0.35	0.37	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.25
49°18'35.1" N	15°30'13" E	0.70	0.32	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.09
49°19'13.3" N	15°30'50.2" E	0.54	0.33	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91
49°18'27.6" N	15°30'23.9" E	0.40	0.21	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68
49°18'49.4" N	15°31'6.5" E	0.34	0.08	0.02	0.00	0.00	0.04	0.00	0.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57
49°19'23.5" N	15°31'12.5" E	0.10	0.05	0.04	0.07	0.15	0.19	0.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.61	0.00	4.34
49°17'37.7" N	15°31'34.2" E	0.12	0.11	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
49°18'11.8" N	15°31'32.5" E	0.09	0.06	0.06	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
50°19'35.1" N	15°5'1.8" E	0.05	0.15	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30
50°19'33.9" N	15°5'51.7" E	0.13	0.10	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91
50°20'24.3" N	15°7'14.5" E	0.30	0.15	0.23	0.04	1.65	0.03	0.14	0.00	0.14	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.76
50°19'37" N	15°3'32.6" E	0.17	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18
50°19'40.4" N	15°4'40.2" E	0.30	0.53	0.05	0.05	0.22	0.00	0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.84
50°20'6.1" N	15°5'1.5" E	0.12	0.07	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
50°20'20.1" N	15°4'54.9" E	0.52	0.46	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98
50°20'14.9" N	15°6'24.6" E	0.27	0.23	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80
50°20'0.9" N	15°3'59.4" E	0.54	0.47	0.30	0.84	0.04	0.00	0.00	0.00	1.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.59
50°20'11.1" N	15°7'14.4" E	0.24	0.08	0.29	0.08	0.40	0.00	0.00	0.00	2.13	0.00	0.00	0.00	0.00	0.96	0.00	0.00	0.00	0.00	4.18
50°20'23.9" N	15°8'1.9" E	0.17	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.21
50°11'30.7" N	14°43'5.1" E	0.53	0.87	1.07	1.14	0.35	0.49	1.09	4.23	0.00	0.00	4.41	0.00	0.00	0.00	0.00	0.66	0.00	0.00	14.84
50°11'31.7" N	14°43'9.5" E	0.20	0.29	0.22	0.59	0.00	0.38	0.99	0.00	2.58	0.00	2.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7.48
50°11'30.3" N	14°43'13.6" E	0.35	0.60	0.29	0.17	0.31	0.46	2.00	2.50	0.00	2.31	0.00	3.26	0.00	0.00	0.00	0.00	0.00	0.00	12.26
50°11'17.9" N	14°43'25.6" E	0.04	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
50°11'26.6" N	14°43'49.3" E	0.07	0.09	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.41
50°11'14.4" N	14°43'53.3" E	0.09	0.01	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.35
50°11'43.3" N	14°42'31.4" E	0.04	0.02	0.25	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43
50°11'38.3" N	14°42'54" E	0.08	0.22	0.33	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.69
50°11'17" N	14°43'34.1" E	0.08	0.14	0.56	0.73	0.14	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.65
50°11'52.3" N	14°42'25.4" E	0.57	0.20	0.02	0.00	0.00	0.20	1.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.38
50°11'40.2" N	14°42'59.3" E	0.13	0.13	0.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.53
50°11'29.8" N	14°43'31.7" E	0.14	0.25	0.29	0.95	0.30	0.30	0.00	0.00	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.56
50°11'18.5" N	14°43'40.9" E	0.07	0.10	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.22

Large beech (*Fagus sylvatica*) trees as 'lifeboats' for lichen diversity in central European forests

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Abstract: The forest management practices used in central Europe in the last several centuries have led to loss of lichen diversity that may be largely attributed to a loss of substrate variability and quantity. In an attempt to obtain information enabling us to mitigate this process, we surveyed affinity of lichen species to the substrates they currently occupy in six forest areas in the Czech Republic, located between 200 and 1000 m a.s.l. Tree bases and stems represented the most important substrate for lichen species, and especially so for threatened (i.e. red-listed) species. Lichen species richness per individual tree generally increased with stem diameter, especially for beech. Stems and tree bases of large-diameter beeches provide habitats that have enabled the survival of a crucial component of the red-listed lichen species in central Europe, far outweighing other tree species. The deciduous tree species that are commonly considered as favourable for lichen diversity (e.g. maples, ash, elms) were inhabited by only a few other lichen species additional to those associated with beech. This may be due to the low frequency of these tree species in most managed forests, and also some forest reserves, at the present time. Similarly, low incidence of dead wood in managed forests has likely limited its contribution to the lichen diversity, despite the high potential for lichen diversity associated with such substrates. It is thus apparent that bark of large-diameter live beech trees comprises a keystone habitat element in the provision of lichen diversity in central European forests.

Keywords: dead wood, forest management, red-listed species, tree species.

Introduction

Beech (*Fagus sylvatica*) dominated forest has been the prevalent type of vegetation in central Europe since the second half of the last post-glacial period, with the exception of land at elevations over 1000 m a.s.l. (Margi 2008; Chytrý et al. 2012). These forests have generally been enriched by many other deciduous tree species (e.g. *Acer platanoides*, *A. pseudoplatanus*, *Fraxinus excelsior*, *Ulmus glabra*), silver fir (*Abies alba*) and at higher altitudes also by Norway spruce (*Picea abies*) (Pott 2000; Chytrý et al. 2012). Although the expansion of beech-dominated forests was contemporaneous with human activity since its initial phase, it seems that the pattern of beech dominated forests in central Europe has been primarily shaped by natural processes (Tinner and Lotter 2006; Margi 2008). However, almost the entire current area of these forests has been patch fragmented and – at least temporarily – deforested during the most recent several centuries of forest exploitation in Europe (Jones 1945). Introduction of even-aged (mainly coniferous) plantations in the last two centuries has led to tree age structure simplification, disappearance of old and decaying trees and dominance of coniferous monocultures at the expense of tree species-rich deciduous and mixed forests (Bengtsson et al. 2000). Accordingly, all these processes have altered or completely degraded considerable areas of habitat suitable for forest dwelling taxa, including lichens (Hauck et al. 2013; Nascimbene et al. 2013).

The factors determining lichen species richness and composition in temperate forests have been repeatedly explored and described (e.g. Nascimbene et al. 2007, 2013; Fritz et al. 2008a; Moning and Müller 2009). High lichen diversity has been particularly associated with those deciduous tree species having less acidic bark surfaces, as for example stems of ash (*Fraxinus excelsior*), maples (*Acer* spp.) and elms (*Ulmus* spp.) (Thor et al. 2010; Mežaka et al. 2012) or stems of old beech with rot holes (Fritz and Heilmann-Clausen 2010). An association of large old trees with high lichen diversity has been often emphasized (Fritz et al. 2008b; Ranius et al. 2008; Dymytrova et al. 2014), but also sometimes questioned (Schei et al. 2013). Generally, lichen species richness is associated with high tree structural and compositional heterogeneity, and particularly the presence of dead trees, because some lichen species show strong preference for deadwood substrates (Ellis 2012; Nascimbene et al. 2013). Presence of exposed stone (such as pebbles, boulders and outcrops) on the forest floor allows for saxicolous lichen species, the diversity of which is again influenced by forest management (Boch et al. 2013b).

In northern Europe, some management measures have been even examined with a view to mitigating the negative effects of forest management on lichen diversity (e.g. retention forestry) (Rosenvald and Lõhmus 2008; Perhans et al. 2009; Ranius et al. 2014). If the effort to maintain lichen diversity in central European forests is to be successful, forest management must necessarily incorporate some measures that effectively support lichen diversity (Hauck et al. 2013). However, in central Europe we do not have suitable data on lichen species distribution and their substrate associations in either the small remnants of old unmanaged forests or the much larger areas of managed forests that surround them. Therefore, we do not know exactly where or how current lichen diversity could be effectively supported.

In an attempt to obtain the missing information, we surveyed lichen diversity in the most widespread types of both unmanaged and managed forests (including various temporal stages such as clearings and young forests) in six large forest complexes in the Czech Republic that covered a gradient of environmental conditions in central Europe between 200 and 1000 m a.s.l. The distribution of threatened (red-listed) lichen species was evaluated in relation to the occupied substrates. We aimed to find and demonstrate the most important substrates for current lichen diversity which should be supported by management measures.

Methods

Study areas and study plots

Each of the six forested areas (SA1-SA6) consisted of a continuous forest patch with an area of 1.4 km^2 to 10.0 km^2. They were distributed across the Czech Republic with the intention to cover environmental variability (e.g. geology, phytogeographical regions, climate) and include important types of central European forest stands, with the exception of lowland floodplains and montane forests above 1000 m a.s.l. (Table 1 and Fig. 1). Inside each study area, we established 20 (SA1-SA4) or 13 (SA5 and SA6) square sampling plots, each of 2500 m^2, categorized according to the forest age and forest management (Table 1; Appendix 1): a) nature reserves without regular forest management (referred to here as unmanaged forest), b) mature managed stands of deciduous, coniferous and eventually mixed tree species, c) immature managed forests from 11 to 69 years old, d) stands that were clear-cut between 2 and 10 years ago (clearings) and e) heterogeneous unclassifiable managed stands (including mosaics of different forest types, internal ecotones etc.). The size of sampling plots was chosen to reliably cover the tree layer structural and compositional variability in all forest management types including the most diverse in unmanaged beech-dominated forests. Distance among sampling plots of a certain forest management within the respective study area varied from 92 m to 5019 m (Appendix 2).

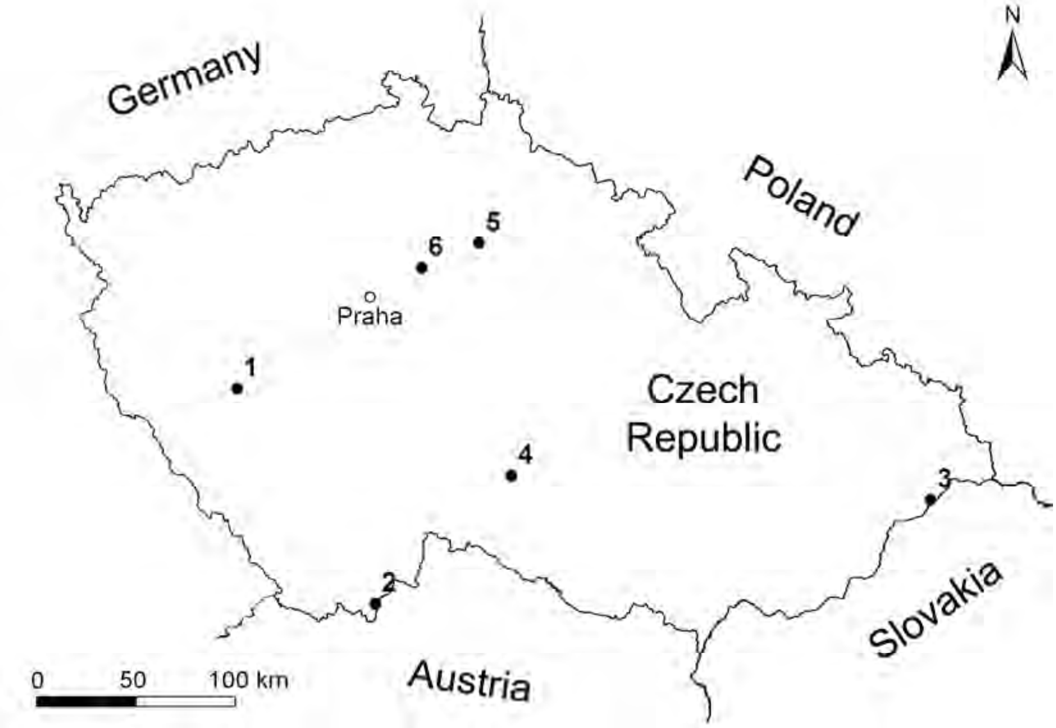

Fig. 1. Location of the six forest study sites to examine lichen diversity in the Czech Republic.

Beech (*Fagus sylvatica*) is the dominant tree species in unmanaged forest stands, with exception of those at the lowest elevations, which are dominated by oak (*Quercus petraea*). Spruce (*Picea abies*) and silver fir (*Abies alba*) are also present in the beech-dominated unmanaged forests, both increasing at higher elevations. Beech and oak dominate the tree community in deciduous managed forests at higher and lower elevations, respectively. Spruce and pine (*Pinus sylvestris*) are dominant species of coniferous stands. Other deciduous tree species, such as *Acer platanoides*, *A. pseudoplatanus*, *Fraxinus excelsior*, *Tilia cordata*, *T. platyphyllos* and *Ulmus glabra*, occur rarely in both unmanaged and managed forests. The age of mature managed forests was around 100 years, but reached up to 180 years in deciduous stands. The age of currently unmanaged forests ranges between 150 and 400 years; most have been protected since the first half of the 20th century (the oldest since 1838 and the youngest since 1964). However, protection does not necessarily mean immediate exclusion of all management interventions, so that some large tree or fallen logs were likely removed even after several decades of protection.

Lichen survey

In each of 106 sampling plots, we surveyed lichen species on all substrates (soil, stones, living trees, and dead wood) from the soil surface to 2 m above ground. We examined all substrates within the plots comprehensively except for living trees, where we sampled five stems per plot. Stems were selected to be representative of the species and diameter class composition of the tree population within each plot. Observations were made from two zones defined on each sampled stem: 'tree base', from ground level to 50 cm above ground level, and 'stem', from 50 to 200 cm above ground level. All trees (live and standing dead) were classified into two groups according to diameter (< 40 cm and ≥ 40 cm) measured at breast height (1.3 m).

Samples that could not be determined in the field were collected and identified in the laboratory and eventually referred to the relevant specialist for identification if needed. The voucher specimens are housed in herbaria PRA, PRC and the private herbarium of J. Malíček. Species nomenclature and conservation status were taken from the Checklist and Red List of lichens of the Czech Republic (Liška et al. 2008). Conservation status of the species not included in Checklist and Red List of lichens of the Czech Republic were classified as 'data deficient'. The substrate was specified for each lichen record according to the list of 32 primary substrates, which were subsequently grouped into the 12 categories (Fig. 2).

Study area	Size	Altitude range	Mean temperature	Mean precipitation	Number of sampling plots in particular types of forest stands					
	(km^2)	(m a.s.l.)	(°C)	(mm.year^{-1})	A	B	C	D	E	F
1	6.75	436–585	6–7	600-650	4	4	4	2	2	4
2	9.95	732–935	4–5	700-800	4	4	4	2	2	4
3	4.60	635–880	4–5	1000-1200	4	4	4	2	2	4
4	7.39	590–730	5–6	600-650	4	4	4	2	2	4
5	10.00	250–280	7–8	550-600	0	3	3	2	2	3
6	1.36	180–210	7–8	550-600	3	3	3	1	0	3

Table 1. Description of study areas and number of sampling plots in different types of forest stands to examine lichen diversity across the Czech Republic: A – unmanaged forest, B – mature deciduous forests (>70 years old), C – mature coniferous forests (>70 years old), D – immature managed forests from 11 to 69 years old, E – clearings, F – other heterogeneous forest stands. Data of mean temperature and precipitation (from 1961 to 2000) were taken from Tolasz (2007).

Data analysis

A relationship between lichen species richness and stem-diameter of particular tree species was assessed by Pearson's correlation at a significance level of $P < 0.05$. Species accumulation curves were built for determination of total lichen species pools associated with the particular tree species (sensu Gotelli and Colwell 2001). We used the randomisation curves computed with 100 000 permutations of the data that show the mean lichen species number with conditional standard deviation (standard deviation for all trees = 0).

Indicator values of lichen species were computed for both tree species and forest stand types according to the procedure designed by De Cácerés and Legendre (2009) according to the equation:

$$\sqrt{\mathrm{IndVal}_{pi}^{g}} = \sqrt{\mathrm{A}_{pi}^{g} * \mathrm{B}_{pi}} = \sqrt{\frac{n_p/N_p}{\sum_{k=1}^{K} n_k/N_k} * \frac{n_p}{n}}$$

where A_{pi}^{g} is the positive predictive value, B_{pi} is the sensitivity of the species, N is the total number of sites, N_p is the number of sites belonging to the target site group, n is the number of occurrences of the species among all sites, n_p is the number of occurrences of the species within the target site group, K is the number of site groups, N_k is the number of sites belonging to the kth site group and n_k is the number of occurrences of the species in the kth site group.

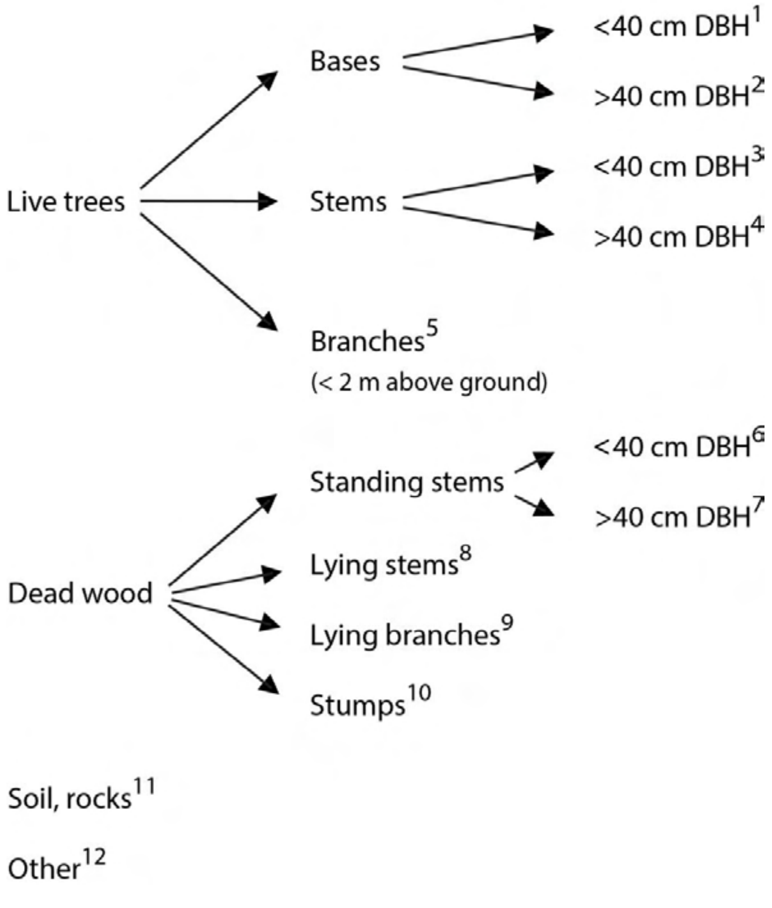

Fig. 2. List of 12 substrate categories on which lichens were recorded in six representative forest sites across the Czech Republic.

The indicator value is combined from two components: positive predictive value (specifity) and sensitivity of the species (fidelity). Specifity is the number of occurrences of particular lichen species within sampling plots (or trees) belonging to the target forest stand type (or tree species), divided by the number of occurrences of that lichen species across all sites. Fidelity is expressed as the relative frequency of particular lichen species in sampling plots (or trees) belonging to the target forest stand type (or tree species). The procedure equalized both specifity and fidelity values of different numbers of sampling plots and tree species individuals, respectively. Statistical significance of indicator values was assessed by 999 permutations at $P < 0.05$.

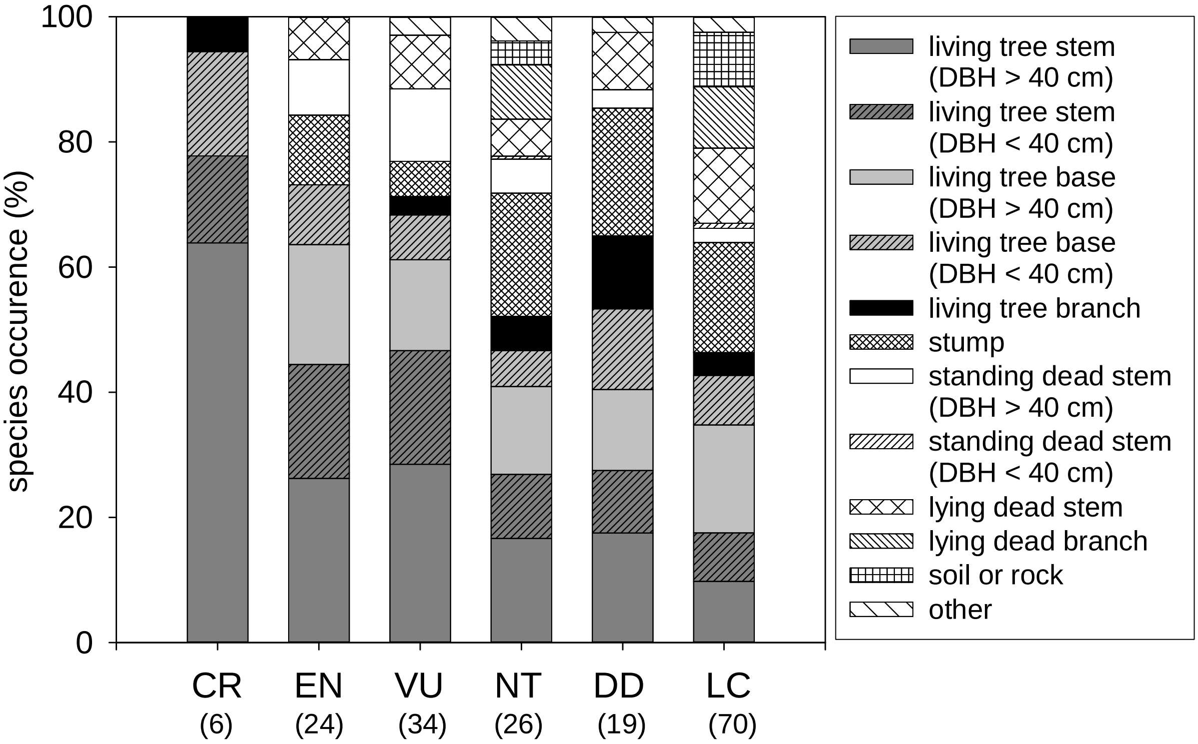

Fig. 3. Affinity of the lichen species of respective Red List categories to the substrates in six representative forest sites of the Czech Republic. Abbreviations of Red List categories (Liška et al. 2008): CR – critically endangered species, EN – endangered species, VU – vulnerable species, NT – near-threatened species, DD – species with data deficient and unclassified in Red List, LC – species of least concern. DBH means diameter at breast height. Numbers of lichen species in the Red List categories are indicated beneath respective category in parenthesis.

Differences in species richness and environmental conditions among forest stand types were assessed by one-way analysis of variance (ANOVA) followed by Tukey HSD test to denote different means at $P < 0.05$. Additionally, we counted correlations between dissimilarities in mutual distances and lichen species composition among sampling plots within each study area to detect eventual distance-based effects on patterning of lichen species composition. We used a Mantel test based on Pearson's correlation, in which significance was evaluated by 9999 permutations at $P < 0.05$. Differences in lichen species composition were assessed by Jaccard dissimilarity index. All computations were performed in R (R Development Core Team 2014), using the "vegan" (Oksanen et al. 2012) and "indicspecies" packages (De Cácerés and Jansen 2015).

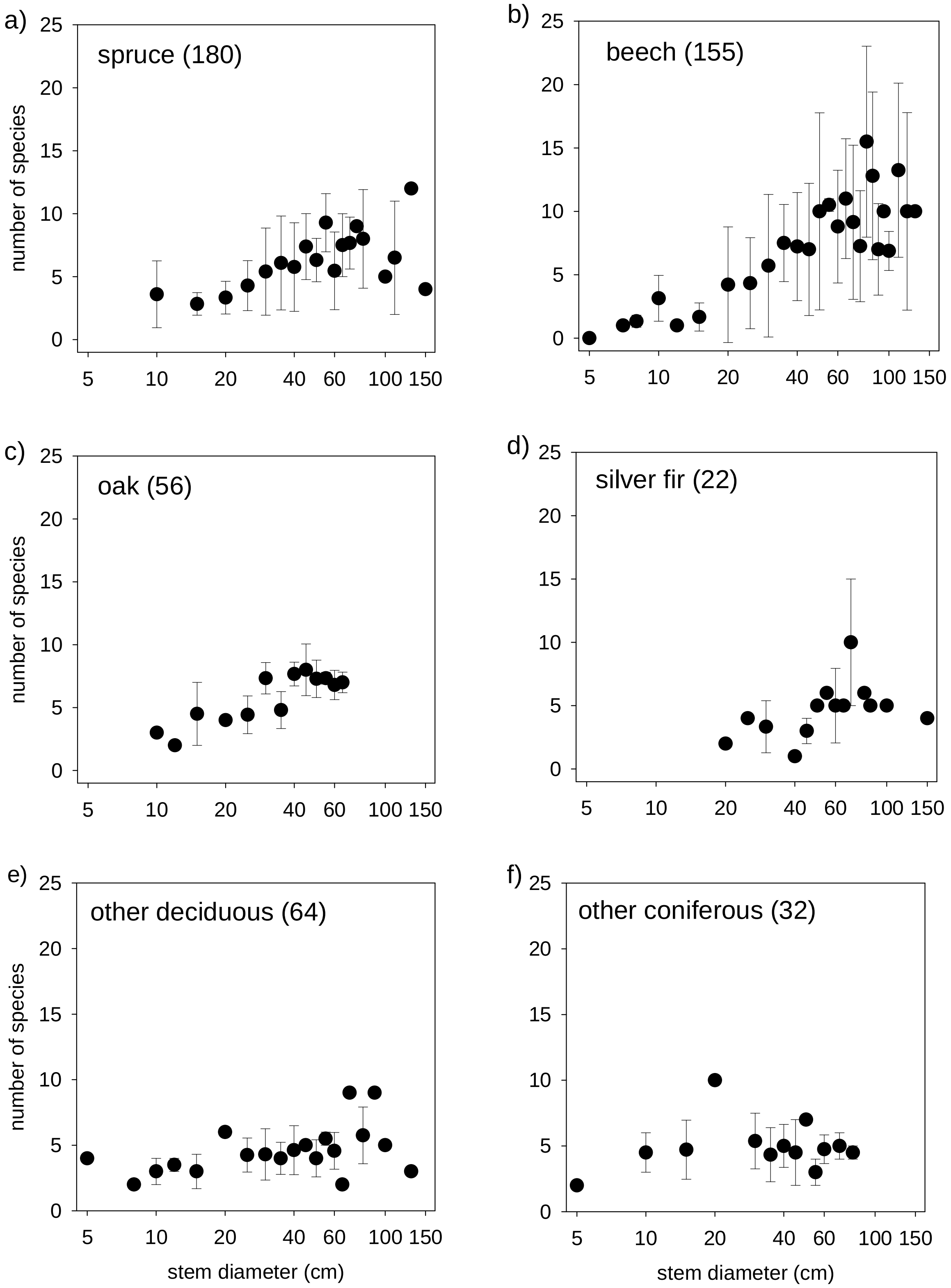

Fig. 4. Relationship between tree stem diameter (log-transformed) and mean lichen species richness per tree individual (± s.d.) in the respective stem diameter classes in six representative forest sites across the Czech Republic. Number of surveyed stems of respective tree species is indicated in parenthesis.

Differences in species richness and environmental conditions among forest stand types were assessed by one-way analysis of variance (ANOVA) followed by Tukey HSD test to denote different means at $P < 0.05$. Additionally, we counted correlations between dissimilarities in mutual distances and lichen species composition among sampling plots within each study area to detect eventual distance-based effects on patterning of lichen species composition. We used a Mantel test based on Pearson's correlation, in which significance was evaluated by 9999 permutations at $P < 0.05$. Differences in lichen species composition were assessed by Jaccard dissimilarity index. All computations were performed in R (R Development Core Team 2014), using the "vegan" (Oksanen et al. 2012) and "indicspecies" packages (De Cácerés and Jansen 2015).

The importance of the substrates for lichen species occurrence was expressed as the proportion of the respective species assemblage recorded on particular substrates. The contribution of each lichen species was equal regardless of differences in species frequency, which was either ascribed to one or proportionally divided among more substrates, according to the occupation frequency of respective species.

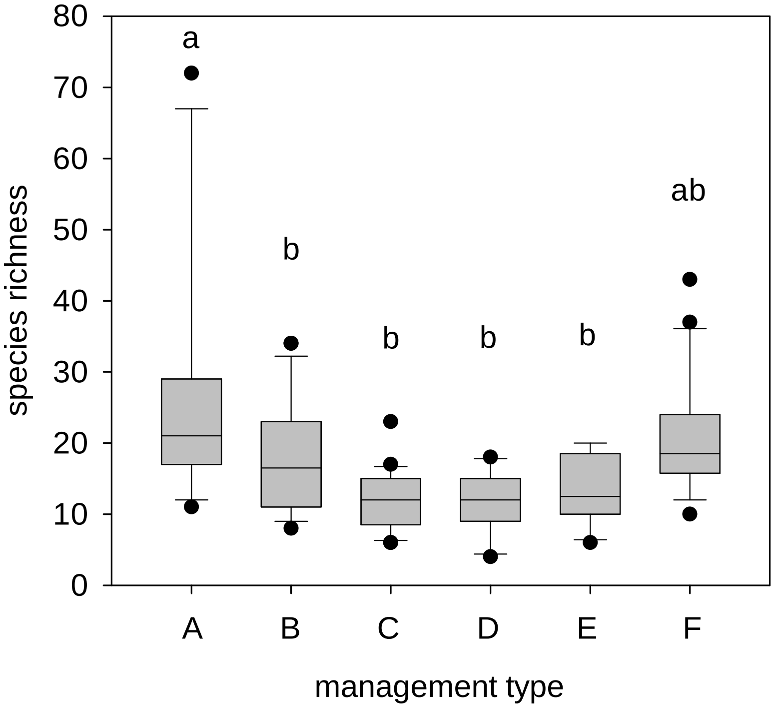

Fig. 5. Lichen species richness in plots in a given type of forest stand across six representative forest sites in the Czech Republic: A – unmanaged forest, B – mature deciduous forests (>70 years old), C – mature coniferous forests (>70 years old), D – immature managed forests from 11 to 69 years old, E – clearings, F – other heterogeneous forest stands. Median, lower, and upper quartiles, and deciles and outliers of species richness are depicted. Different letters indicate differences in species richness (ANOVA followed by Tukey HSD test ; $P < 0.05$).

Results

In total, we found 179 lichen species, of which 136 (76 %) occupied living trees (up to a height of 2 m), 34 (19 %) standing dead stems, 60 (34 %) lying dead wood, 66 (37 %) stumps, 17 (9 %) soil and rocks and 14 (8 %) other substrates (Appendix 3). More than one third of total lichen diversity was recorded exclusively on the surfaces of live trees (65), whereas smaller numbers of lichen species were associated strictly with dead wood substrates (35 species) and only 6 species were associated with the remaining substrates. Moreover, the importance of bases and stems of living trees as substrates for lichen species increased according to their conservation status. The higher category of Red List we evaluated, the greater proportion of lichen species were recorded on the bark (tree bases and stems) of the living trees (Fig. 3). The threatened species occurred more frequently on the trees with stem diameters greater than 40 cm (Fig. 3). Lichen species richness per tree individual increased with stem diameter for deciduous tree species: beech (Pearson's correlation, r = 0.424, $P < 0.001$), oak (r = 0.519, $P < 0.001$), all other deciduous species together (r = 0.306, $P = 0.014$), but also spruce (r = 0.349, $P < 0.001$) (Fig. 4). Unmanaged forests had the greatest species richness compared to all other stands in managed forests (Fig. 5). Differences in lichen species composition were not significantly correlated with mutual distances among sampling plots in any of the six study areas (Mantel test, $P > 0.05$).

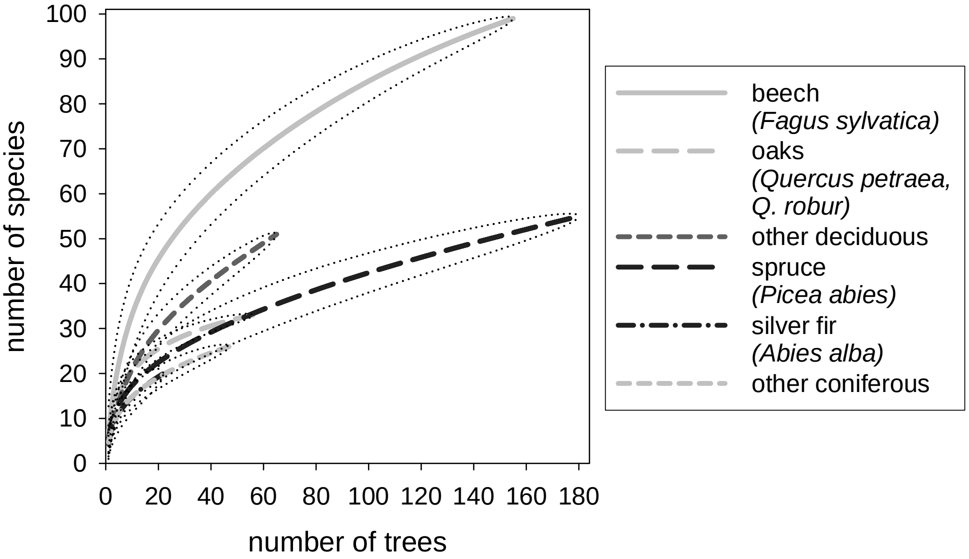

Fig. 6. Random species accumulation curves (based on 100 000 permutations) and their standard deviations of lichen species associated with either particular tree species or groups of other less frequent deciduous and coniferous tree species in six representative forest sites across the Czech Republic.

Beech showed the greatest lichen species richness per live tree individual with the maximum reaching 33 species and also the greatest contribution to the total lichen species pool (Fig. 6). Live beeches were one of the most important substrates for red-listed species because they were occupied by 69 % of all critically endangered, endangered and vulnerable lichen species found in this study. Twelve of these lichen species (e.g. *Biatora chrysantha*, *Lopadium disciforme*) were found on two or more beeches, but they were not recorded from other tree species (Table 2). If we summed all species recorded exclusively on the particular tree species, dead wood or soil, stones and other ground substrates, the major role of live beech was again revealed (Fig. 7). Although several lichen species showed high specifity to beech, they occupied only a minor subset of observed beeches (i.e. they lack fidelity) (Table 2). The most frequent lichens associated with beech were *Graphis scripta*, *Ropalospora viridis* and *Pyrenula* *nitida* (Table 2); *Graphis scripta* represented the most abundant red-listed species in studied forests.

The coniferous trees hosted usually ubiquitous acidophilic lichens and only a few less frequent boreal-montane or poorly known species (e.g. *Fellhanera gyrophorica*, *Lecanora sarcopidoides*, *Lecidea leprarioides*) were observed exclusively on spruces. Some other lichens had high specifity either to oaks (e.g. *Chaenotheca chrysocephala*) or maple, including some threatened species (Table 2), but many of them were recorded only once or twice. The most widespread lichens regardless of substrate were *Lepraria* spp. (mostly *L. finkii*), *Micarea prasina* agg. (mainly *M. micrococca*), *Cladonia coniocraea*, *Coenogonium pineti*, *Hypogymnia physodes*, and *Lecanora conizaeoides*. In coniferous forests, *Hypocenomyce scalaris* was another very common lichen, *Porina aenea* predominated in deciduous (mainly beech) woodlands, and *Lecanora expallens* was a characteristic species of oak stands.

The contribution of dead wood substrates to the total lichen diversity was less than that of living trees (Fig. 3 and 6). However, the greater fraction of critically endangered, endangered and vulnerable lichen species on standing dead firs and beeches (7 of 14 and 10 of 21 species, respectively) is noteworthy. Many rare lichens were concentrated on large logs as well. Moreover, these results may not reliably show the importance of dead wood substrates because of the low frequency or even complete lack of these forest components in central European forests. Stumps, which were by far the most common type of dead wood object in managed forests, hosted a substantial fraction of lichen species of less conservation concern as well as a very small fraction of threatened species (Fig. 3 and 7). The same evidence was found for lichen diversity on soil, stones and other forest floor substrates (Fig. 3 and 7).

The frequency of rare and red-listed lichens was greatest in unmanaged forest reserves, in accordance with far greater occurrence of both large living trees and large standing and lying woody debris (Table 3). According to the analysis of indicator values, 29 lichen species were determined as indicators of unmanaged forest stands (Table 3). The best indicators (lichens with the highest specifity and fidelity) of unmanaged forests were *Opegrapha niveoatra*, *Thelotrema lepadinum*, *Biatora veteranorum* and *Lecanora thysanophora*. However, the species indicators of unmanaged forests included also some widespread and ubiquitous taxa (e.g. *Anisomeridium polypori*, *Parmelia saxatilis*, *Petrusaria amara, Phlyctis argena*). Lichen species composition was uniform and showed little species-specificity in all other forest stand types in comparison with the unmanaged forests. The stems of large trees were also generally species rich in the managed forests (if they were present), but the number of red-listed lichen species associated with these trees rarely matched that of unmanaged forests.

Table 2. List of lichen species associated to the live stems of respective tree species, the number of occupied individuals of respective tree species, and specifity, fidelity and indicators value for given tree species in six representative forest sites across the Czech Republic.. The indicator values indicated by * are significant at $P < 0.05$. The total number of individuals of respective tree species is associated with name of tree species in parenthesis. Species with either one record or specifity < 0.5 were excluded from the table except lichens with significant indicator value. Tree species with only one record were not evaluated. Red-list categories (Liška et al. 2008): CR – critically endangered species, EN – endangered, VU – vulnerable, NT – near threatened, DD – data deficient and unclassified in Red List, LC – species of least concern.

Table 2

Tree species	Lichen species	Red List	Number of trees	Specifity	Fidelity	Indicator values
Beech (155)	*Graphis scripta*	VU	50	1.000	0.323	0.568
	Ropalospora viridis	LC	30	0.972	0.194	0.434
	Pyrenula nitida	EN	33	0.744	0.213	0.398
	Agonimia repleta	DD	20	1.000	0.129	0.359
	Mycoblastus fucatus	LC	34	0.584	0.219	0.358
	Buellia griseovirens	LC	16	1.000	0.103	0.321
	Lecanora pulicaris	LC	23	0.622	0.148	0.304
	Parmelia saxatilis agg.	LC	14	1.000	0.090	0.301
	Parmeliopsis ambigua	LC	24	0.566	0.155	0.296
	Biatora chrysantha	VU	12	1.000	0.077	0.278
	Lopadium disciforme	EN	9	1.000	0.058	0.241
	Pertusaria leioplaca	VU	12	0.582	0.077	0.212
	Biatora efflorescens	VU	10	0.644	0.065	0.204
	Pertusaria amara	NT	11	0.561	0.071	0.200
	Lecanora thysanophora	DD	6	1.000	0.039	0.197
	Arthonia radiata	VU	9	0.511	0.058	0.172
	Fellhaneropsis vezdae	VU	4	1.000	0.026	0.161
	Ochrolechia androgyna	VU	5	0.745	0.032	0.155
	Dictyocatenulata alba	DD	3	1.000	0.019	0.139
	Lecanora albella	EN	3	1.000	0.019	0.139
	Pertusaria coronata	VU	3	1.000	0.019	0.139
	Phaeophyscia endophoenicea	EN	3	1.000	0.019	0.139
	Trapelia corticola	EN	3	0.778	0.019	0.123
	Bacidina phacodes	EN	2	1.000	0.013	0.114
	Biatora helvola	EN	2	1.000	0.013	0.114
	Buellia disciformis	VU	2	1.000	0.013	0.114
	Buellia erubescens	CR	2	1.000	0.013	0.114
	Calicium salicinum	VU	2	1.000	0.013	0.114
	Peltigera praetextata	NT	2	1.000	0.013	0.114
	Pertusaria coccodes	VU	2	1.000	0.013	0.114
	Pertusaria pertusa	EN	2	1.000	0.013	0.114
	Arthonia leucopellaea	EN	2	0.700	0.013	0.095
	Micarea prasina s.str.	LC	2	0.700	0.013	0.095
Larch (19)	*Usnea scabrata*	CR	2	0.864	0.105	0.302
N. maple (3)	*Arthonia excipienda*	LC	1	1.000	0.333	0.577 *
	Opegrapha vermicellifera	VU	1	1.000	0.333	0.577 *
	Bacidia rubella	VU	1	0.963	0.333	0.566 *
	Gyalecta flotowii	CR	1	0.963	0.333	0.566 *
	Opegrapha varia	NT	1	0.945	0.333	0.561 *
Oaks (56)	*Chaenotheca chrysocephala*	NT	9	0.967	0.161	0.394
	Chaenotheca ferruginea	LC	23	0.334	0.411	0.370
	Chaenotheca stemonea	VU	9	0.659	0.161	0.325
	Parmelia sulcata	LC	4	1.000	0.071	0.267
	Chaenotheca trichialis	NT	4	0.928	0.071	0.257
	Scoliosporum schadeanum	VU	4	0.787	0.071	0.237
Spruce (180)	*Hypocenomyce caradocensis*	LC	42	0.592	0.232	0.371
	Cladonia norvegica	VU	7	0.857	0.039	0.182
	Cladonia cenotea	LC	3	1.000	0.017	0.129
	Micarea peliocarpa	LC	3	1.000	0.017	0.129
	Lecanactis abietina	EN	3	0.720	0.017	0.109

Discussion

Similarly to our study, species-rich lichen communities have been recently found in the oldest beech-dominated forests in Bavaria, Germany (Moning and Müller 2009) and southern Sweden (Fritz et al. 2008a; Fritz and Brunet 2010), while rather species-poor lichen communities were found on beech in north-eastern Germany (Friedel et al. 2006) and Hungary (Nascimbene et al. 2012; Ódor et al. 2013). A regional difference was revealed when beech-dominated forests were compared in three areas in Germany (Boch et al. 2013b). Extraordinarily species-rich lichen communities are associated with beech in the largest old-growth beech forest reserve in Europe in the Ukrainian Carpathians (Dymytrova et al. 2014). As with all lichen communities in general, epiphytic lichen communities associated with beech became impoverished in central Europe due to long lasting negative effects of acid deposition and unfavourable forest management (Hauck et al. 2013). The effects of acid deposition on maintaining bark surface acidity can be still important despite substantial declines in sulphur emission in recent decades (Vestreng et al. 2007). Therefore, the importance of tree species with more acidic bark for survival of lichen diversity has been emphasized (Thor et al. 2010; Mežaka et al. 2012). Regional differences in lichen diversity are further attributed to differences in climate characteristics (e.g. precipitation and humidity) (Marini et al. 2011) or acid deposition (Svoboda et al. 2010).

In our study, no other tree species matched the lichen diversity recorded on beech. Tree species such as maples (*Acer platanoides*, *A. pseudoplatanus*), limes (*Tilia cordata, T. platyphyllos*), elms (*Ulmus glabra, U. minor*) and ash (*Fraxinus excelsior*) did not exceed the lichen species richness of adjacent beeches. Distribution of these admixtured deciduous tree species is scarce across central European forests. Only a few individuals of these tree species were found within a limited area of unmanaged forests as well as over wide areas of managed forests. Occurrence of infrequent tree species may not meet optimal habitat conditions regarding the canopy closure, humidity and other factor important for lichen diversity. For trees meeting suitable environmental conditions, the establishment of a species-rich lichen assemblage depends on successful dispersal of lichen propagules from surrounding populations (Scheidegger and Werth 2009; Sverdrup-Thygeson et al. 2014). All these factors may seriously affect population viability and maintenance of the lichen species associated with scarcely distributed tree species. As a result, lichen diversity associated with the admixtured deciduous trees in the forests of the Czech Republic was not as high as expected. Some rare taxa – 'niche specialists' (e.g. *Bacidia rosella*, *Sclerophora pallida*) that were not encountered on beech were recorded on one single old maple (*Acer platanoides*) growing outside of sampling plots included in this study (Malíček and Palice 2013). On the other hand, beech also appeared to be the most important tree species for lichen diversity in large old-growth forest in the Ukrainian Carpathians with greater admixture of *Acer platanoides* and *A. pseudoplatanus* (Dymytrova et al. 2014). The greatest species richness in this old-growth forest was recorded on beech stems, with figures exceeding 30 lichen species per tree (which is comparable with results from our study). Accordingly, the majority of rare lichen species were restricted to old beeches in this old-growth forest (Dymytrova et al. 2014).

Table 3. List of lichen species associated with respective type or two types of forest stand, the number of occupied sampling plots of the respective stand type(s), and specifity, fidelity and indicators value for given forest stand type(s) in six representative forest sites across the Czech Republic.: A – unmanaged forest, B – mature deciduous forests (>70 years old), C – mature coniferous forests (>70 years old), D – immature managed forests from 11 to 69 years old, E – clearings, F – other heterogeneous forest stands. The indicator values indicated by * are significant at $P < 0.05$; ** at $P < 0.01$ and *** at $P < 0.001$. Red List categories (Liška et al. 2008): CR – critically endangered species, EN – endangered, VU – vulnerable, NT – near threatened, DD – data deficient and unclassified in Red List, LC – species of least concern.

Forest stand type	Lichen species	Red List	Number of occupied sampling plots	Specifity	Fidelity	Indicator values
A	*Opegrapha niveoatra*	NT	9	0.839	0.473	0.630 ***
A	*Anisomeridium polypori*	LC	12	0.558	0.631	0.594 **
A	*Thelotrema lepadinum*	EN	7	0.890	0.368	0.573 ***
A	*Chaenotheca xyloxena*	VU	8	0.755	0.421	0.564 ***
A	*Biatora veteranorum*	EN	6	1.000	0.315	0.562 ***
A	*Lecanora thysanophora*	DD	5	1.000	0.263	0.513 ***
A	*Agonimia repleta*	DD	8	0.606	0.421	0.506 **
A	*Phlyctis argena*	LC	7	0.618	0.368	0.477 **
A	*Pertusaria amara*	NT	5	0.852	0.263	0.474 **
A	*Arthonia vinosa*	VU	4	1.000	0.210	0.459 **
A	*Fellhaneropsis vezdae*	VU	4	1.000	0.210	0.459 **
A	*Lopadium disciforme*	EN	4	1.000	0.210	0.459 **
A	*Ochrolechia androgyna*	VU	4	1.000	0.210	0.459 **
A	*Parmelia saxatilis* agg.	LC	5	0.743	0.263	0.442 **
A	*Chaenotheca chrysocephala*	NT	5	0.658	0.263	0.416 *
A	*Micarea prasina* s.str.	LC	5	0.658	0.263	0.416 *
A	*Trapelia corticola*	EN	4	0.822	0.210	0.416 *
A	*Lecanactis abietina*	EN	3	1.000	0.157	0.397 *
A	*Arthonia leucopellaea*	EN	3	1.000	0.157	0.397 *
A	*Bacidia rubella*	VU	3	1.000	0.157	0.397 *
A	*Dictyocatenulata alba*	DD	3	1.000	0.157	0.397 *
A	*Opegrapha varia*	NT	3	1.000	0.157	0.397 *
A	*Biatora efflorescens*	VU	4	0.698	0.210	0.383 *
A	*Biatora chrysantha*	VU	4	0.698	0.210	0.383 *
A	*Bacidina phacodes*	EN	2	1.000	0.105	0.324 *
A	*Gyalecta flotowii*	CR	2	1.000	0.105	0.324 *
A	*Chaenotheca brachypoda*	VU	2	1.000	0.105	0.324 *
A	*Chaenotheca furfuracea*	LC	2	1.000	0.105	0.324 *
A	*Chaenotheca chlorella*	EN	2	1.000	0.105	0.324 *
D	*Micarea viridileprosa*	NT	4	0.787	0.363	0.535 ***
E	*Placynthiella oligotropha*	LC	4	0.814	0.400	0.571 ***
E	*Trapeliopsis flexuosa*	LC	5	0.492	0.500	0.496 **
E	*Lecanora saligna*	LC	2	0.687	0.200	0.371 *
A + B	*Pyrenula nitida*	EN	17	0.824	0.414	0.585 **
A + B	*Arthonia spadicea*	NT	17	0.822	0.414	0.584 ***
A + E	*Bacidia subincompta*	VU	7	1.000	0.241	0,491 ***
A + F	*Buellia griseovirens*	LC	8	0.897	0.195	0.419 *
B + F	*Arthonia radiata*	VU	9	0.886	0.204	0.426 *
C + F	*Hypocenomyce caradocensis*	LC	16	0.793	0.363	0.537 **
D + F	*Micarea misella*	LC	15	0.656	0.468	0.555 *

Dispersal limitation may not constrain lichen diversity only on deciduous tree species with a sparse distribution as we mentioned above, but also on beech as the most abundant deciduous tree species. A likely explanation is that even beech frequency considerably decreased in central European forests during recent centuries. Beech-dominated stands probably represent a dominant type of 'natural' vegetation from the lowlands to 1000 m a.s.l. (Bolte et al. 2011; Chytrý 2012). Instead, they occupy less than 8 % of the present forested area in the Czech Republic (Vašíček 2007), of which only a negligible part is represented by mature and old-growth stands. The continuity of these fragmented and isolated mature stands has been impaired by forest management with the exception of some small areas in unmanaged forest reserves. The preference for large old beech by red-listed lichens as well as the lichen diversity as a whole may arise from formation of age-related microhabitats (e.g. rough bark, rot holes etc.) and longer periods of time available for colonization (Ranius et al. 2008; Ellis 2012). For instance, bark pH is less acidic below rot holes in beech due to exudates from the rotting wood and these microhabitats are favourable for many epiphytic lichens of conservation concern (Fritz and Heilmann-Clausen 2010). The unique role of beech as a lichen substrate is largely due to the variability of bark surface characteristics from acidic and smooth in young and middle aged trees, to less acidic and rough with many suitable microhabitats in old trees. This range can even be covered by a single beech tree (Fritz and Heilmann-Clausen 2010).

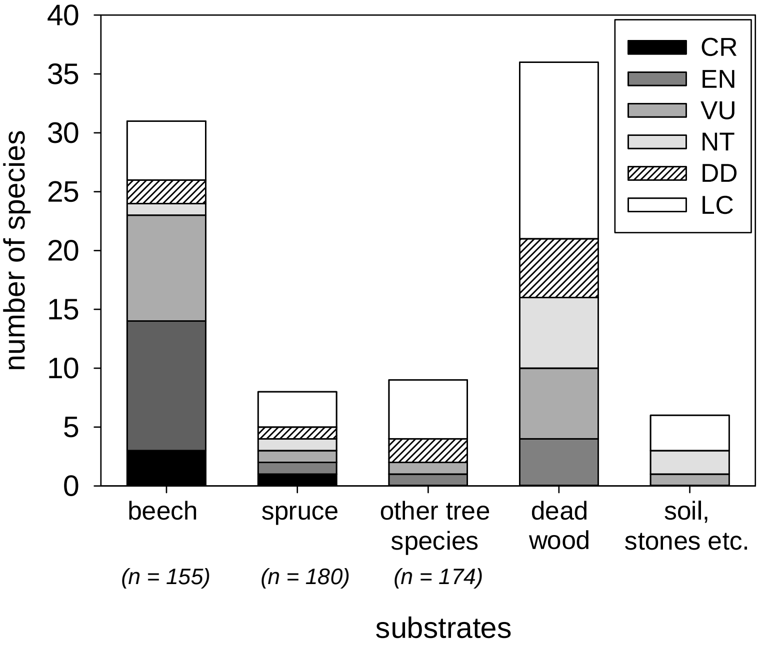

Fig. 7. Subsets of lichen species assemblages associated exclusively to living trees of beech, spruce and other tree species, and dead wood, soil, stones and other ground substrates in six representative forest sites across the Czech Republic. Red-listed status of the species (sensu Liška et al. 2008) is indicated: CR – critically endangered species, EN – endangered, VU – vulnerable, NT – near threatened, DD – data deficient and unclassified in Red List, LC – species of least concern. The total numbers of surveyed trees (*n*) are indicated beneath respective category in parenthesis.

Old large trees would be commonly colonized by lichens not only at the base and lower part of stem, but also higher in the canopy. Age-related substrates expand higher to the tree canopy in old trees as well as containing suitable microclimate conditions in old forest stands (Fritz 2009; Boch et al. 2013a). Moreover, branches in the canopy are less shaded than the stems and bases of trees and light availability may also be a contributing factor in lichen diversity (Dymytrova et al. 2014). Therefore, we suppose that we might have recorded higher values of lichen diversity on the old beeches if we had also surveyed the bark surfaces above 2 m. Accordingly, the superiority of old large beeches for lichen diversity would had been even more impressive (see Boch et al. 2013a). On the other hand, lichen indicators of unmanaged forests include some widespread and ubiquitous species that we rarely found beneath dense tree canopies in managed forests (up to 2 m above the soil surface), but which could be commonly present in less shaded conditions. Moreover, some extremely small taxa could be easily overlooked when growing in small quantities in suboptimal conditions (e.g. *Anisomeridium polypori*). Hence, the strength and reliability of indicator species shall be further tested in future studies.

Microhabitats suitable for rare lichen species are surfaces of damaged, slowly-dying and recently dead trees of large stem diameter. Unfortunately, such trees are preferably removed from stands in managed forests. On the other hand, substrates left in clear-cut and young replanted stands – such as stumps, bare soil and stones - may serve as niches for common lichen species, but only exceptionally for lichens of higher red-list categories (Fig. 3). The negative effect of plantation forestry has been already documented (Humphrey et al. 2000; Rosenvald and Lõhmus 2008), but not much reflected by changes in forest management practices. The implementation of such management measures such as retention of patches occupied by old large trees in forest harvesting procedure does have a positive effect (Rosenvald and Lõhmus 2008; Gustafsson et al. 2012); however, the size of retention patches as they have been typically made (up to 0.5 ha) is likely to be too small for preservation of sensitive lichen species (Perhans et al. 2009). Suitable size of retention patches as well as the form of retention forestry practices is still little explored and probably differs in relation to the tree species composition, forest history and forest fragmentation in a broader landscape context (Lindenmayer et al. 2012). It can be assumed that even a generously applied retention forestry approach may not assure preservation of the most sensitive lichen species, which may require strict protection with a complete absence of timber harvesting (Baker and Read 2011; Lindenmayer et al. 2012).

Centuries of forest management and decades of acid deposition have adversely affected lichen diversity in the whole central Europe, however the patterns of these effects are neither spatially nor temporally uniform (Svoboda et al. 2010). In our study, the greatest species richness and the highest contribution of red-listed species was found in study area 2, which was characterized by a relatively low acid deposition and relatively short history of regular forest management (probably not exceeding three centuries). Moreover, study area 2 includes the largest area of unmanaged forests (100 ha) with the longest period of protection (since 1838). A detailed description of lichen diversity in study area 2 has been already carried out in a separate study (Malíček and Palice 2013). In contrast, lichen diversity is generally low in traditionally inhabited landscape of central Bohemia (study areas 5 and 6) in which extensive disruption of forest continuity began at least a millennium ago (Pokorný 2005). Consequently, oaks as dominant tree species of human inhabited lowland landscape in central Europe may host lower lichen diversity than their potential, as suggested by the results of previous studies in other regions (Ranius et al. 2008; Ódor et al. 2013). For the same reason, the superiority of beech as a tree species for lichen diversity may be partly attributable to the fact that beech has dominated in those forest stands that have been least affected by forest management and atmospheric pollution.

Within the area of extant forest in central Europe, these large-stemmed beeches appear to play a unique and crucial role in supporting lichen diversity, in terms of both extent and variability of substrate, and sometimes even outside the forest reserves. Therefore, future efforts should focus on providing conditions for the increasing the presence of critical substrates (such as deadwood, including snags and logs, and large stems of subdominant deciduous tree species) in managed forests, but also prevent the decline of abundance of large old beeches resulting from harvesting of the oldest managed forest stands. Hence, we argue that the retention of all small, mutually isolated and lichen-rich refuges of old beech-dominated forests within large areas of managed forests is strongly justified, regardless of whether they previously belonged to managed forests or not.

Conclusions

We have outlined the crucial role of large-diameter beech trees for maintaining lichen diversity in extant central European forests. However, the contribution of other potentially important substrates associated with some other deciduous trees (e.g. maples, elms, ash), as well as standing and lying dead trees may be underestimated due to the rarity of these components in most managed forests. In attempting to maintain (and enhance) the lichen diversity in central European forests, we strongly recommend: (a) complete cessation of forest management in the most valuable fragments of old beech-dominated managed forests, and (b) substitution of traditional clear-felling interventions by nature-based forestry to assure a continual presence of old large-diameter live, dying and dead trees. These old trees should be both dispersed individually and aggregated into old-forest patches across the entire area of managed forests in order to effectively maintain lichen diversity.

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Supplementary Material

Appendix 1. Location (midpoint) of sampling plots (2500 m^2 each), including assigned forest habitat type, tree layer composition and observed species richness in six representative forest sites across the Czech Republic. SA - study area, DBH – diameter at breast height, types of forest management: A – unmanaged forest, B – mature deciduous forests (>70 years old), C – mature coniferous forests (>70 years old), D – immature managed forests from 11 to 69 years old, E – clearings, F – other heterogeneous forest stands. Lichen species richness and number of red-listed species (RD) are given.

SA	Sampling plot (latitude/longitude)		Forest habitat type	Tree layer composition	Tree layer representation		Age	DBH	Height	Species richness	RD
					(n)	(%)	(year)	(cm)	(m)		
1	49°32'9"	13°33'22.6"	A	*Fagus sylvatica*	42	39	144	51	29	20	2
				Tilia cordata	30	28		16	19		
				Acer pseudoplatanus	19	18		21	22		
1	49°32'5.5"	13°33'26.7"	A	*Fagus sylvatica*	47	77	187	56	33	19	4
				Tilia cordata	10	16		43	31		
1	49°32'21.7"	13°33'27.8"	A	*Fagus sylvatica*	125	90	200	21	20	14	7
				Acer pseudoplatanus	10	7		36	25		
1	49°32'17"	13°33'30"	A	*Fagus sylvatica*	67	71	187	27	17	19	9
				Acer pseudoplatanus	16	17		31	22		
1	49°32'0.1"	13°32'12.9"	B	*Fagus sylvatica*	85	74	182	22	15	9	1
				Larix decidua	25	22		51	32		
1	49°32'3.9"	13°33'4.6"	B	*Fagus sylvatica*	62	97	122	43	31	13	
1	49°32'21.9"	13°33'55.7"	B	*Acer pseudoplatanus*	198	84	117	10	12	12	
				Ulmus glabra	18	8		16	14		
1	49°31'48"	13°35'11.5"	B	*Acer pseudoplatanus*	35	31	88	29	26	20	4
				Picea abies	34	30		15	11		
				Fagus sylvatica	18	16		52	27		
				Fraxinus excelsior	18	16		38	32		
1	49°32'33.8"	13°32'29.6"	C	*Picea abies*	133	94	90	33	27	13	
1	49°31'52.4"	13°33'39.1"	C	*Picea abies*	156	98	76	33	26	8	
1	49°32'38.7"	13°33'46.4"	C	*Picea abies*	103	100	79	38	30	7	
1	49°31'43.2"	13°34'23.6"	C	*Picea abies*	160	100	80	32	29	7	
1	49°32'1.1"	13°34'28.8"	D	*Picea abies*	453	100	29	16	11	7	
1	49°32'0.8"	13°34'46.4"	D	*Larix decidua*	352	100	21	15	15	19	
1	49°32'12.2"	13°32'3.9"	E				5			7	
1	49°32'0.7"	13°32'36.9"	E	*Fagus sylvatica*	1	100	5	83	33	11	1
1	49°32'25.2"	13°32'24.6"	F	*Picea abies*	214	98	107	19	15	15	2
1	49°31'51"	13°33'26.2"	F	*Fraxinus excelsior*	147	78	99	12	14	13	
				Picea abies	20	11		26	20		
1	49°32'.3"	13°34'4"	F	*Fagus sylvatica*	46	48	169	44	24	25	
				Fraxinus excelsior	36	38		12	13		
1	49°32'.3"	13°34'41.9"	F	*Picea abies*	108	98	91	34	31	10	
2	48°40'.8"	14°42'21.8"	A	*Fagus sylvatica*	108	97	315	20	16	73	42
2	48°39'.9"	14°42'30.7"	A	*Fagus sylvatica*	98	98	315	27	21	57	29
2	48°40'2.8"	14°42'35.8"	A	*Fagus sylvatica*	124	96	315	21	17	68	42
2	48°40'11.1"	14°42'34"	A	*Fagus sylvatica*	186	88	195	12	15	44	24
				Picea abies	21	10		72	38		
2	48°39'43.3"	14°40'50.3"	B	*Fagus sylvatica*	54	100	168	48	35	34	18
2	48°41'11.5"	14°41'16.2"	B	*Fagus sylvatica*	38	93	175	56	33	35	11
2	48°39'31.4"	14°41'36.6"	B	*Fagus sylvatica*	81	100	134	46	32	29	9
2	48°39'18.4"	14°41'56.7"	B	*Fagus sylvatica*	45	98	146	51	30	23	7
2	48°39'48.5"	14°40'22.4"	C	*Picea abies*	123	100	98	41	31	15	2
2	48°38'53"	14°42'3.8"	C	*Picea abies*	118	100	94	41	32	13	2
2	48°40'34.6"	14°42'26.2"	C	*Picea abies*	118	100	106	42	35	25	8
2	48°40'24.8"	14°42'39.7"	C	*Picea abies*	31	100	114	58	37	17	4
2	48°39'51.4"	14°41'19.2"	D	*Fagus sylvatica*	586	98	21	12	13	16	2
2	48°39'7.1"	14°42'31.1"	D	*Picea abies*	386	100	50	22	20	15	4
2	48°39'34.5"	14°40'45.7"	E				5			14	2
2	48°40'56.6"	14°41'58.1"	E				5			18	5

Appendix 1. (continued)

SA	Sampling plot (latitude/longitude)		Forest habitat type	Tree layer composition	Tree layer representation		Age	DBH	Height	Species richness	RD
					(n)	(%)	(year)	(cm)	(m)		
2	48°39'56.3"	14°40'51.7"	F	*Picea abies*	50	76	125	54	36	21	3
				Fagus sylvatica	16	24		13	10		
2	48°41'14.6"	14°41'36.3"	F	*Picea abies*	41	67	175	17	12	45	17
				Fagus sylvatica	19	31		62	36		
2	48°40'39.3"	14°41'58.4"	F	*Fagus sylvatica*	58	80	180	52	35	35	15
				Picea abies	15	21		41	33		
2	48°40'39.5"	14°43'8"	F	*Picea abies*	94	100	117	16	12	38	14
3	49°24'4.3"	18°24'53.7"	A	*Fagus sylvatica*	235	99	269	15	14	26	9
3	49°24'0.3"	18°25'0.7v	A	*Fagus sylvatica*	177	96	244	18	15	29	12
3	49°24'8.1"	18°25'2.6"	A	*Fagus sylvatica*	154	93	269	20	17	21	10
3	49°24'3.1"	18°25'10.7"	A	*Fagus sylvatica*	209	95	244	19	21	21	7
3	49°24'7.1"	18°24'21.7"	B	*Fagus sylvatica*	72	92	148	38	28	25	5
3	49°24'34.1"	18°25'0.9"	B	*Fagus sylvatica*	206	100	85	25	26	11	1
3	49°23'40.3"	18°26'12.4"	B	*Fagus sylvatica*	224	90	82	22	24	10	1
3	49°24'3.3"	18°26'51.8"	B	*Picea abies*	46	54	109	53	38	12	
				Abies alba	25	29		45	34		
				Fagus sylvatica	15	17		21	18		
3	49°24'15"	18°25'16.1"	C	*Picea abies*	113	96	113	43	35	12	1
3	49°24'5.2"	18°25'34.1"	C	*Picea abies*	100	100	103	42	35	16	
3	49°24'5.8"	18°26'19.7"	C	*Picea abies*	129	99	87	40	34	13	
3	49°24'38.2"	18°26'20.7"	C	*Picea abies*	93	99	124	46	38	18	1
3	49°24'38.3"	18°25'36.4"	D	*Fagus sylvatica*	293	98	54	20	26	13	2
3	49°24'17.9"	18°26'29.9"	D	*Picea abies*	301	92	27	20	17	11	2
3	49°24'7.2"	18°26'10.7"	E				5			13	
3	49°24'28"	18°26'19.6"	E				5			10	
3	49°24'28.3"	18°25'34.7"	F	*Picea abies*	41	56	144	51	36	16	1
				Fagus sylvatica	32	44		26	15		
3	49°24'14"	18°25'50.8"	F	*Picea abies*	101	94	133	8	7	19	
3	49°24'17.5"	18°26'6.3"	F	*Fagus sylvatica*	130	72	63	21	24	17	6
				Picea abies	49	27		39	31		
3	49°23'47.4"	18°26'48.2"	F	*Fagus sylvatica*	101	59	147	10	8	18	1
				Picea abies	67	39		44	33		
4	49°18'43.6"	15°30'31.5"	A	*Fagus sylvatica*	115	90	156	23	17	20	3
4	49°18'21.7"	15°30'51.5"	A	*Fagus sylvatica*	133	97	156	14	17	19	5
4	49°18'57.6"	15°31'23.7"	A	*Fagus sylvatica*	87	93	194	26	19	24	5
4	49°18'44.2"	15°31'27.5"	A	*Fagus sylvatica*	180	89	194	15	16	13	3
				Fraxinus excelsior	14	7		21	25		
4	49°19'28.9"	15°30'45.9"	B	*Fagus sylvatica*	50	60	156	39	39	19	2
				Picea abies	23	28		58	40		
				Abies alba	10	12		55	37		
4	49°18'35.1"	15°31'5.5"	B	*Fagus sylvatica*	129	71	78	25	29	17	3
				Picea abies	28	16		40	31		
				Abies alba	14	8		34	29		
4	49°18'5.6"	15°31'11.7"	B	*Quercus robur*	75	92	106	36	28	23	3
4	49°18'19.7"	15°31'19"	B	*Fagus sylvatica*	89	100	111	41	38	21	4
4	49°18'37.7"	15°31'11"	C	*Picea abies*	86	87	78	49	40	8	
				Fagus sylvatica	13	13		20	25		
4	49°19'18.4"	15°31'5.2"	C	*Picea abies*	96	99	110	46	36	15	
4	49°17'36.8"	15°32'44.1"	C	*Picea abies*	113	99	77	36	31	19	1
4	49°18'11.8"	15°31'32.5"	C	*Picea abies*	91	100	104	46	38	16	
4	49°18'35.1"	15°30'13"	D	*Picea abies*	227	100	54	28	27	4	
4	49°19'13.3"	15°30'50.2"	D	*Picea abies*	386	99	25	16	14	18	2
4	49°17'28.1"	15°31'40.2"	E	*Picea abies*	46	69	5	7	5	20	1
				Betula pendula	20	30		10	8		
4	49°18'45.7"	15°31'47.8"	E	*Picea abies*	57	92	5	7	5	20	1
4	49°18'27.6"	15°30'23.9"	F	*Fagus sylvatica*	161	55	14	17	14	19	2
				Picea abies	81	28		13	10		
				Abies alba	43	15		14	12		

Appendix 1. (continued)

SA	Sampling plot (latitude/longitude)		Forest habitat type	Tree layer composition	Tree layer representation		Age	DBH	Height	Species richness	RD
					(n)	(%)	(year)	(cm)	(m)		
4	49°18'49.4"	15°31'6.5"	F	*Picea abies*	148	72	121	14	12	16	2
				Fagus sylvatica	42	20		14	12		
				Abies alba	16	8		19	18		
4	49°19'23.5"	15°31'12.5"	F	*Picea abies*	23	77	110	53	37	29	6
				Fagus sylvatica	5	17		95	37		
4	49°17'37.7"	15°31'34.2"	F	*Picea abies*	132	100	121	21	16	29	2
5	50°19'35.1"	15°5'1.8"	B	*Quercus robur*	83	97	132	33	23	25	2
5	50°19'33.9“	15°5'51.7“	B	*Pinus sylvestris*	38	48	173	28	27	14	
				Fagus sylvatica	19	24		57	27		
				Quercus robur	15	19		21	21		
5	50°20'24.3“	15°7'14.5“	B	*Carpinus betulus*	83	52	133	9	11	23	5
				Quercus petraea	58	36		42	28		
				Acer pseudoplatanus	17	11		8	10		
5	50°19'37“	15°3'32.6“	C	*Picea abies*	161	89	78	25	26	9	
				Larix decidua	15	8		36	29		
5	50°19'40.4“	15°4'40.2“	C	*Picea abies*	137	70	86	18	16	13	1
				Pinus sylvestris	59	30		38	23		
5	50°20'6.1“	15°5'1.5“	C	*Picea abies*	91	54	103	20	16	14	
				Pinus sylvestris	76	45		35	23		
5	50°20'20.1“	15°4'54.9“	D	*Pinus sylvestris*	498	84	27	14	14	16	1
				Betula pendula	74	12		13	14		
5	50°20'14.9“	15°6'24.6“	D	*Picea abies*	424	98	29	15	15	13	2
5	50°19'38.2“	15°3'53.5“	E				5			12	1
5	50°20'35.6“	15°7'50.8“	E	*Quercus petraea*	16	94	5	7	7	14	2
5	50°20'0.9“	15°3'59.4“	F	*Picea abies*	77	45	133	14	12	19	3
				Pinus sylvestris	42	24		26	18		
				Quercus robur	29	17		40	23		
				Betula pendula	25	15		20	18		
5	50°20'11.1“	15°7'14.4“	F	*Carpinus betulus*	199	67	123	8	11	19	4
				Picea abies	41	14		24	18		
				Pinus sylvestris	35	12		40	26		
5	50°20'23.9“	15°8'1.9“	F	*Picea abies*	159	99	15	28	25	21	1
6	50°11'30.7“	14°43'5.1“	A	*Quercus robur*	42	79	182	52	34	26	6
				Tilia cordata	11	21		18	11		
6	50°11'31.7“	14°43'9.5“	A	*Quercus petraea*	46	74	182	44	25	12	1
				Quercus robur	12	19		55	30		
6	50°11'30.3“	14°43'13.6“	A	*Quercus robur*	121	100	182	25	17	15	2
6	50°11'17.9“	14°43'25.6“	B	*Quercus robur*	143	89	77	26	23	9	
				Tilia cordata	17	11		10	9		
6	50°11'26.6“	14°43'49.3“	B	*Quercus robur*	102	83	92	32	27	14	1
				Tilia cordata	18	15		12	10		
6	50°11'14.4“	14°43'53.3“	B	*Quercus petraea*	86	50	122	34	26	13	
				Tilia cordata	79	45		12	10		
6	50°11'43.3“	14°42'31.4“	C	*Pinus sylvestris*	146	48	92	27	22	14	
				Pinus strobus	125	41		7	7		
6	50°11'38.3“	14°42'54“	C	*Picea abies*	105	75	92	27	24	6	
				Pinus sylvestris	35	25		36	27		
6	50°11'17“	14°43'34.1“	C	*Quercus petraea*	188	53	83	10	10	12	
				Pinus sylvestris	120	34		30	21		
				Betula pendula	42	12		9	11		
6	50°11'52.3“	14°42'25.4“	D	*Pinus sylvestris*	1075	97	21	9	11	11	
6	50°11'40.2“	14°42'59.3“	F	*Pinus sylvestris*	34	41	52	28	22	22	1
				Larix decidua	19	23		25	24		
				Tilia cordata	17	20		12	10		
				Quercus robur	14	17		37	20		
6	50°11’29.8“	14°43'31.7“	F	*Picea abies*	50	39	92	11	9	18	2
				Quercus robur	38	30		33	20		
				Pinus sylvestris	37	29		33	23		
6	50°11’18.5“	14°43'40.9“	F	*Tilia cordata*	13	41	4	10	7	12	
				Quercus robur	8	25		41	21		

Appendix 2. Environmental variables for 106 sampling plots showing mean and standard deviation (and range in parenthesis) for all sampling plots, and types of forest stands in six representative forest sites across the Czech Republic: A – unmanaged forest, B – mature deciduous forests (≥70 years old), C – mature coniferous forests (≥70 years old), D – immature managed forests from 11 to 69 years old, E – clearings, F – other heterogeneous forest stands. Lichen species richness and number of red-listed species (RD) are given. Different letters indicate differences in variable (ANOVA followed by Tukey HSD test at $P < 0.05$). Data of mean annual temperature and mean annual precipitation (from 1961 to 2000) were taken from Tolasz (2007).

	All sites	A	B	C	D	E	F
Elevation (m a.s.l.)	576 ± 226	619 ± 209	586 ± 253	560 ± 234	546 ± 230	588 ± 200	557 ± 235
	(177 - 915)	(178 - 796)	(179 - 915)	(177 - 895)	(177 - 842)	(232 - 856)	(181 - 850)
Aspect (°)	162 ± 108	119 ± 95	193 ± 114	193 ± 122	174 ± 108	157 ± 83	134 ± 103
	(3 - 357)	(3 - 305)	(18 - 347)	(7 - 357)	(49 - 339)	(15 - 311)	(5 - 337)
Slope (°)	7.1 ± 5.5	8.2 ± 4.7	9.0 ± 6.0	5.6 ± 5.7	6.1 ± 5.3	6.3 ± 4.6	6.8 ± 5.6
	(0.3 - 24.9)	(1.2 - 16.5)	(0.5 - 20.7)	(0.3 - 24.4)	(0.4 - 15.8)	(0.6 - 16.7)	(0.4 - 24.9)
Mean annual temperature (°C)	6.9 ± 1.4	6.7 ± 1.4	7.0 ± 1.5	7.0 ± 1.5	7.0 ± 1.4	6.7 ± 1.2	7.0 ± 1.5
	(5.5 - 9.5)	(5.5 - 9.5)	(5.5 - 9.5)	(5.5 - 9.5)	(5.5 - 9.5)	(5.5 - 8.5)	(5.5 - 9.5)
Mean annual precipitation (mm)	723 ± 193	736 ± 206	717 ± 196	717 ± 196	720 ± 198	740 ± 198	717 ± 196
	(525 - 1100)	(525 - 1100)	(525 - 1100)	(525 - 1100)	(525 - 1100)	(600 - 1100)	(525 - 1100)
Longitude (°)	15.39 ± 1.59	15.42 ± 1.72	15.38 ± 1.60	15.37 ± 1.60	15.39 ± 1.64	15.46 ± 1.72	15.38 ± 1.60
	(13.53 - 18.44)	(13.56 - 18.44)	(13.54 - 18.44)	(13.54 - 18.44)	(13.57 - 18.44)	(13.57 - 18.44)	(13.54 - 18.45)
Latitude (°)	49.48 ± 0.53	49.38 ± 0.48	49.51 ± 0.48	49.51 ± 0.56	49.51 ± 0.58	49.45 ± 0.56	49.51 ± 0.55
	(48.64 - 50.34)	(48.66 - 50.19)	(48.66 - 50.19)	(48.65 - 50.34)	(48.65 - 50.34)	(48.66 - 50.34)	(48.67 - 50.34)
Mutual distance (m)		428 ± 334^{a}	1787 ± 983^{b}	1729 ± 878^{b}	1359 ± 570^{b}	2355 ± 1603^{b}	1751 ± 1037^{b}
		(92 – 1287)	(384 – 3610)	(410 – 3721)	(355 – 2011)	(668 – 5019)	(331 – 4848)

Appendix 3. List of lichen species with indication of substrates occupied in in six representative forest sites across the Czech Republic. The numbers indicate the rank of respective study areas (SA1-SA6) (details in Table 1, Figure 1 and Appendix 1). Common names of living trees are abbreviated: AS – ash, BE – beech, BI – birch, EL – elms, HR – hornbeam, LA – larch, LI – limes, NM – Norway maple, OA – oaks, PI – pine, SF – silver fir, SM – sycamore maple, SP – spruce, RC – other coniferous species and RD – other deciduous species; Latin names are given in Table 2. Red-listed species (Liška et al. 2008) are given in categories: CR – critically endangered, EN – endangered; VU – vulnerable; NT – near-threatened; DD – data deficient and LC – least concerned. Nomenclature follows updated version of Czech Redlist and Checklist of lichens (Liška and Palice 2010) with few amendments (Malíček and Palice 2013).

species	**Red-list category**	**living trees**	**standin g dead trees**	**lying dead wood**	**stump s**	**soil, stones**	**others**
Absconditella celata	DD				2		
Absconditella delutula	NT					5	
Absconditella lignicola	LC			2346	2345		
Agonimia repleta	DD	BE1234	24		23		
Amandinea punctata	LC	OA46 HR5			6		
Anisomeridium polypori	LC	BE1234 SM1234 SF34 AS4 LI4 OA5 SP4			4		
Arthonia didyma	VU	BE2 LI4					
Arthonia excipienda		NM2					
Arthonia leucopellaea	EN	BE2 SP2	2				
Arthonia mediella	VU	BE2					
Arthonia radiata	VU	BE1234 NM4	4				
Arthonia spadicea	NT	BE1234 SM1234 SP24 AS4 LI4 OA5 SF4			2		
Arthonia vinosa	VU	BE2 EL2			2		
Bacidia circumspecta	CR	BE2					
Bacidia incompta	CR	BE2					
Bacidia rubella	VU	BE23 NM1					
Bacidia subincompta	VU	SM134 BE12 EL1 NM1					
Bacidina chloroticula	LC				24		
Bacidina phacodes	EN	BE23					
Bacidina sulphurella	LC	BE24 RE5	2	2	2		
Baeomyces rufus	LC					24	2
Biatora albohyalina	EN	BE2					
Biatora chrysantha	VU	BE2					
Biatora efflorescens	VU	BE2 OA4					
Biatora fallax	EN	BE2			2		
Biatora helvola	EN	BE2					
Biatora ocelliformis	EN	BE2					
Biatora veteranorum	EN	SF2 SP2	23		23		
Biatoridium monasteriense	VU	BE2					
Bryoria fuscescens	VU	SP2					

Appendix 3.
(continued)

species	Red-list category	living trees	standing dead trees	lying dead wood	stumps	soil, stones	others
Buellia disciformis	VU	BE2					
Buellia erubescens	CR	BE2					
Buellia griseovirens	LC	BE24	3	6			
Calicium salicinum	VU	BE2	2		4		
Caloplaca chrysodeta	NT	BE2					
Candelariella efflorescens agg.	NT	AS1 BE1 OA4		2			
Candelariella xanthostigma	LC	OA6					
Cetrelia monachorum	DD			2			
Chaenotheca brachypoda	VU		2				
Chaenotheca brunneola	NT		234		4		
Chaenotheca chlorella	EN		2				
Chaenotheca chrysocephala	NT	OA56 SP2	2				
Chaenotheca ferruginea	LC	SP1234 SF234 OA56 BE2 LA1 LI6	14		12356		
Chaenotheca furfuracea	LC	BE3 EL2 SP2					
Chaenotheca stemonea	VU	OA56 LI6	2				
Chaenotheca trichialis	NT	OA56 SP2	4	2	3		
Chaenotheca xyloxena	VU		1234	1			
Cladonia cenotea	LC	SP3			3	5	
Cladonia chlorophaea	LC	BE3 SP5			2	25	
Cladonia coniocraea	LC	SP12345 BE1234 OA1456 BI156 PI156 LA16 AS1 LI4 SM1		123456	2	123456	
Cladonia digitata	LC	SP1234 BE123 SF234 BI15 OA45 PI15 LA1		245	12345	235	
Cladonia fimbriata	LC	SP12345 BE234 OA456 BI15 PI15 SM4		12456	123456	2456	1
Cladonia floerkeana	LC	SP2					
Cladonia macilenta	LC	SP23 PI1				4	
Cladonia merochlorophaea	DD				2		
Cladonia norvegica	VU	BE2 SP2		23	2		
Cladonia polydactyla	NT	LA1 SP1		12	2		
Cladonia pyxidata	LC	BE2 SP2				2	
Coenogonium pineti	LC	SP123456 BE12345 OA1234 LA145 LI146 PI156 SM134 BI15 SF34 AS4 EL1 HR5 ER1	1234	123456	123456		1
Dictyocatenulata alba	DD	BE2					
Evernia prunastri	NT	BE2 LA1					
Fellhanera gyrophorica		SP2					
Fellhaneropsis vezdae	VU	BE2					
Fuscidea pusilla		SF2 SP2					
Graphis scripta	VU	BE1234	2	2			
Gyalecta flotowii	CR	BE23 NM2					

Appendix 3.
(continued)

species	Red-list category	living trees	standing dead trees	lying dead wood	stumps	soil, stones	others
Gyalideopsis helvetica	DD	BE2	2		2		
Halecania viridescens	DD	OA4					
Hypocenomyce caradocensis	LC	SP2345 LA4 OA5 PI5			234		
Hypocenomyce scalaris	LC	SP12345 OA456 PI156 BI15 SF34	2	14			
Hypogymnia physodes	LC	SP12345 OA1456 LA146 SF234 BE23 BI15 PI56 AS1 HR5 RE6	3	123456	245		24
Jamesiella anastomosans	DD	BE2 SP4		2			
Lecanactis abietina	EN	BE2 SP2	2				
Lecania cyrtella	LC	RE5			4		
Lecania naegelii	NT				2		
Lecanora albella	EN	BE2					
Lecanora albellula	VU			6			
Lecanora argentata	NT	BE12 AS1 SM1	2				
Lecanora compallens	DD	BE2					
Lecanora conizaeoides	LC	SP123456 BE1234 LA1456 OA1456 PI156 SF234 BI15 AS1 EL1 LI6 ER6	34	2456	123456		2
Lecanora expallens	LC	OA56 BE2 EL2 LA1 LI6					
Lecanora filamentosa	VU						2
Lecanora intumescens	LC	BE2					
Lecanora phaeostigma	DD				5		
Lecanora pulicaris	LC	BE1234 SP24 OA4 SM3		12			2
Lecanora saligna	LC				45		
Lecanora sarcopidoides	DD	SP2					2
Lecanora subfusca group	LC	BE4 SM1					
Lecanora symmicta	NT						2
Lecanora thysanophora		BE23					
Lecanora varia	LC			1			
Lecidea leprarioides	EN	SP2					
Lecidea nylanderi	VU	BE2 SF2 SP2					
Lecidea pullata	NT	BE2			2		
Lecidella elaeochroma	NT	BE12 NM1 SM1					
Lecidella subviridis		BE2					
Lepraria incana	LC				2		
Lepraria lobificans auct.	LC	BE2			2		
Lepraria sp.	LC	SP123456 BE12345 OA1456 SM1234 BI156 LI146 NM124 PI156 SF234 AS14 EL12 LA16 HR5 ER16	123	12456	123456	2	2
Lichenomphalia umbellifera	LC				23	3	
Lopadium disciforme	EN	BE2					
Macentina abscondita	LC	SM4					

Appendix 3.

species	Red-list category	living trees	standing dead trees	lying dead wood	stumps	soil, stones	others
Macentina dictyospora	LC			2			
Melanelixia fuliginosa	LC	BE1234 AS14 LI14 BI6 EL1 OA6 SM1		126	6		
Micarea adnata	CR	SP2					
Micarea botryoides	LC	PI1 SP3					
Micarea denigrata	LC	BE2		45	45		2
Micarea hedlundii	EN				2		
Micarea melaena	LC	SP3					
Micarea misella	LC			246	123456		
Micarea nigella	DD			6	234		
Micarea peliocarpa	LC	SP3		2	34		
Micarea prasina agg. (incl. *M. micrococca*)	LC	SP123456 BE12345 LA1456 OA456 PI156 SF234 AS14 SM14 BI5 HR5 ER6 RE6	4	123456	123456		
Micarea prasina s.str.	LC	BE2 SP2		3	23		
Micarea sylvicola	LC	BE2					
Micarea viridileprosa	NT			2456	5		
Multiclavula mucida	EN			2	2		
Mycoblastus fucatus	LC	BE234 SM34 SF2		3			
Ochrolechia androgyna	VU	BE2 SP2					
Ochrolechia microstictoides	VU	BE2 SP2					
Opegrapha niveoatra	NT	BE123 EL2 LI4 NM4 SM1					
Opegrapha varia	NT	BE2 NM2	2				
Opegrapha vermicellifera	VU	NM4	2				
Opegrapha viridis	EN	BE2					
Parmelia saxatilis agg.	LC	BE2		23			
Parmelia submontana	EN			2			
Parmelia sulcata	LC	OA46		1256			
Parmeliopsis ambigua	LC	BE234 OA45 SP24 SM1		1	5		
Parmeliopsis hyperopta	NT			2			
Peltigera didactyla	LC					2	
Peltigera horizontalis	EN	BE2					
Peltigera praetextata	NT	BE2			2		
Pertusaria amara	NT	BE2 SM1					
Pertusaria coccodes	VU	BE2					
Pertusaria coronata	VU	BE2					
Pertusaria hemisphaerica	EN	BE2					
Pertusaria leioplaca	VU	BE12 SM1	4				
Pertusaria pertusa	EN	BE2					
Pertusaria pupillaris	VU	BE3					
Phaeophyscia endophoenicea	EN	BE2					
Phaeophyscia orbicularis	LC			1			

Appendix 3.

species	Red-list category	living trees	standing dead trees	lying dead wood	stumps	soil, stones	others
Phlyctis argena	LC	BE23 NM12 SM12 AS1 EL2					
Physcia adscendens (incl. *P. tenella*)	LC	OA46 BE1 EL1 LI6 PI5		16			
Placynthiella dasaea	LC	SP1234 SF234LA1 LI1 PI5		123456	123456	2345	12
Placynthiella icmalea	LC	SP12345 LA146 PI156 SF23 LI6 ER6		123456	123456	23456	123
Placynthiella oligotropha	LC					246	
Placynthiella uliginosa	LC					25	
Platismatia glauca	NT	BE2 OA6 SP2		3			
Porina aenea	LC	BE12345 SM134 AS4 HR5ER1		1			
Porina leptalea	EN	SM3					
Pseudevernia furfuracea	NT	SP2345 BE23 LA1 SF2		234			
Pyrenula nitida	EN	BE1234 OA1 SM2	24	1	2		
Ramalina farinacea	VU			2			
Ramonia interjecta	DD	RE5					
Rhaphidicyrtis trichosporella		BE2					
Ropalospora viridis	LC	BE123 SP2		23			
Sarcosagium campestre	LC		2		4		
Scoliciosporum chlorococcum	LC	BE1245 OA1456 SP1246 BI56 AS1 EL1 HR5 LA1 LI6 PI6	1	156	346		2
Scoliciosporum sarothamni	LC	BE234 LA145 SP124 OA46 PI56 AS1 BI6 HR5 LI6 SF4 RE6		146			
Scoliciosporum umbrinum	LC			3			
Scoliosporum schadeanum	VU	OA45 BE2					
Steinia geophana	LC			24	4		
Thelocarpon epibolum	LC				24		
Thelocarpon intermediellum	NT			26	456		
Thelotrema lepadinum	EN	BE23 EL2 SM2 SP2	2				
Trapelia corticola	EN	BE3 SP2			3		
Trapeliopsis flexuosa	LC	BE2 LA6		126	12456		
Trapeliopsis glaucolepidea	NT	SF2		2	25		
Trapeliopsis granulosa	LC	BE2 PI5 SP4		2456	23456	2	
Trapeliopsis pseudogranulosa	LC				2		
Trapeliopsis viridescens	VU				23		
Tuckermannopsis chlorophylla	NT	SP2					
Usnea hirta	VU	LA1					
Usnea scabrata	CR	LA1 SP2					
Usnea substerilis		LA1					
Vulpicida pinastri	NT				2		
Xanthoria candelaria	LC	LI6		16	4		
Xanthoria parietina	LC			14			
Xylographa parallela	VU		2				

2.3. Taxonomy of woodland lichens

Although papers included in this thesis are mostly of ecological, methodological or diversity character, taxonomical problems accompany the research at every step. The correct identification quite often requires consultation with specialists or confirmation by molecular methods. In some cases, this is still insufficient and additional studies are required. I focused especially on one of the largest lichen genus in Europe – the genus *Lecanora*. A large infraspecific morphological variability, poorly known chemotaxonomy and ecology as well as frequent misinterpretation of identification characters led to many species misidentifications. I specialize on epiphytic taxa, mainly from the *Lecanora subfusca* group and related species. Material from old-growth forests was a keynote source of samples for taxonomical studies because all of them occur in woodlands and some of them distinctly prefer old-growth forests.

The two taxonomic papers about *Lecanora* contain new data on chemistry, ecology, distribution, identification keys, one new species (*L. substerilis*) from beech forests and many comments on poorly known taxa. Molecular data and phylogenetic trees are included as well.

A revision of epiphytic species of the *Lecanora subfusca* group (*Lecanoraceae*, Ascomycota) in the Czech Republic

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Abstract: During a revision of epiphytic species of the *Lecanora subfusca* group in the Czech Republic, nine taxa were recorded. *L. cinereofusca*, although reported for the first time from the country here, is considered to be extinct, as is *L. horiza. L. circumborealis* has been excluded from the list of Czech lichens. *L. rugosella* and *L. subrugosa* respectively are regarded as extreme morphological forms of *L. chlarotera* and *L. argentata* ecologically derived through nutrient enrichment (eutrophication). *L. laevis* is regarded as a morphotype of *L. horiza*. An identification key is provided. The importance of the amphithecium and cortex type as a taxonomic character is discussed in detail. Several new secondary metabolites belonging to the terpenoids, discovered during an investigation of lichen compounds, proved to be taxonomically important. The abundance of *L. allophana* and *L. chlarotera* has decreased during the second half of the 20th century, but *L. pulicaris* has expanded. The main reasons for these changes are air pollution and acidification of substrates; *L. pulicaris*, for example, formerly a predominant lichen on acid-barked trees, today grows mainly on trees with slightly acidic or subneutral bark.

Key words: chemotaxonomy, extreme morphological forms, *Lecanora laevis*, terpenoids, substrate acidification

Introduction

Lecanora, one of the most diversified and taxonomically complicated lichen genera comprises 75 species in the Czech Republic (Liška *et al.* 2008). One of the most poorly understood group is the *L. subfusca* group. It is characterized by apothecia with generally reddish-brown discs, the presence of calcium oxalate crystals in the apothecial margin, and the presence of atranorin in the greyish-white to grey thallus; almost all species have ellipsoid to broadly ellipsoid spores c. 10–20 × 6–9 µm (Brodo 1984). This group is considered here in a narrow sense (sensu Brodo 1984), but some authors (e.g. Magnusson 1932, Poelt 1952, Ibáñez & Burgaz 1998, Edwards *et al.* 2009), also include the *L. albella* group, which is characterized by the absence of an apothecial cortex (except *L. carpinea*), strongly pruinose discs, and contains some species with xanthones (Kofler 1956, Imshaug & Brodo 1966).

The name of the group is derived from the taxon described by Linnaeus – *Lichen subfuscus* L. Acharius (1810) created the genus *Lecanora* and established the combination *Lecanora subfusca* (L.) Ach. with eight varieties, most of which are now regarded as species (Brodo & Vitikainen 1984). Taxonomic revisions of the *L. subfusca* group were undertaken by Stizenberger (1868) and Hue (1903). A further revision by Magnusson (1932) has proved useful in the present study, as he described several taxa and studied the anatomy with emphasis on the epihymenial granules, amphithecial crystals, and cortex characters. Another important work by Kofler (1956) used polarized light to study crystals in the apothecia. Contributions by Poelt (1952), Clauzade (1953), Makarevich (1971) and Motyka (1977) added to our regional knowledge. The typification of many collections mainly from Acharius Herbarium in Helsinki was made by Brodo & Vitikainen (1984). In a very valuable and critical monograph of North American species Brodo (1984) revised in detail the morphology, anatomy and chemistry of all taxa. His work was followed by several other monographs from Japan (Miyawaki 1988), Australasien (Lumbsch 1994), India (Upreti 1997), South and Central America (Guderley 1999), and Thailand (Papong & Lumbsch 2011). In Europe, Estonian taxa were investigated by Jüriado (1998), Iberian species by Ibáñez & Burgaz (1998), and *Lecanora* growing on *Rhododendron* in the Alps by Hinteregger (1994). Two new epiphytic species (*L. barkmaniana*, *L. sinuosa*) from Western Europe have been described (Aptroot & van Herk 1999, van Herk & Aptroot 1999). Guderley & Lumbsch (1999) studied taxa with polysporous asci. Useful data on the selected groups are present in several determination keys (Poelt & Vězda 1981, Clauzade & Roux 1985, Tønsberg 1992, Nimis & Bolognini 1993, Wirth 1995, Ryan *et al*. 2004, Edwards *et al*. 2009, Wirth *et al.* 2013), and important chemical data are provided by Lumbsch & Feige (1992, 1994, 1996), Elix *et al*. (1994), and Elix & Lumbsch (1996). Several other papers on the *L. subfusca* group deal mainly with saxicolous species (e.g. Brodo *et al.* 1994) or non-European species (e.g. Lumbsch 1995, Lü *et al.* 2011, Papong *et al.* 2011).

Members of the *Lecanora subfusca* group were usually overlooked or misidentified in the Czech Republic, and many published records are dubious. This study provides detailed observations of the ecology and distribution of all epiphytic species in the Czech Republic, a critical revision of secondary metabolites, and numerous taxonomic notes, including comments on some traditionally used and problematic characters. Several synonymisations are proposed. Historical as well as recent collections have been used for the study.

Material and methods

Observations are based on material collected by the author from the Czech Republic and on specimens housed in BRNM, BRNU, CBFS, HOMP, OLM, PL, PRA, PRC, PRM and the personal herbaria of F. Bouda, J. P. Halda, J. Kocourková, A. Müller, Z. Palice, O. Peksa, D. Svoboda and L. Syrovátková. All specimens collected by the author are retained in his personal herbarium (abbreviation JM). Type and comparative specimens were studied from GZU, H, L, PRM and UPS.

Microscopic descriptions are based on observations made of hand-cut sections mounted in water. The solubility of epihymenial crystals was studied in 50% HNO_3. The amphithecium and apothecial cortex were observed in KOH. Crystals and granules in apothecia were observed in polarized light (using two polarized filters). For the terminology of anatomical characters, the work of Brodo (1984) was followed. The presence of fumarprotocetraric acid or pannarin was primarily detected by a fresh ethanol solution of paraphenylenediamine (Pd), which was applied on the apothecial margin. Thin-layer chromatography (TLC), with a few minor modifications, follows the methods of Orange *et al*. (2001). Lichen compounds were applied on a set of three glass plates and placed into A, B and C solvents. A distance between starting and finishing line was usually c. 100 mm. A volume of added acetone into the test tube was two or three drops (according the quantity of testing material). Fatty acids were detected by dipping each of these into water tanks. Chloratranorin was not distinguished from atranorin.

Selected samples were analysed by HPLC following the methods of Feige *et al*. (1993). In the description of species only total numbers of analysed samples from the Czech Republic are mentioned. Specimens of rare or floristically interesting species are presented as "Selected specimens examined".

Statistical analyses were carried out in R. 2.9.2. using the application R Commander. Rare species were excluded since they were data deficient. Only *L. argentata*, *L. chlarotera* and *L. pulicaris* were used for analyses. For graphs, *L. allophana* was also included. Altitude and bark pH preferences were tested according to the negative binomial linear model of Haldane (1945) with interaction. This technique was used instead of the model with a Poisson structure of errors due to a high overdispersion (Crawley 2007). The normality of resulting residuals was verified by the Shapiro-Wilk (1965) test. A dispersed parameter theta for altitude was 7.7517, and for bark pH 676. Altitude data were acquired from herbarium labels or subsequently found via a map. Average bark pH values for all common phorophytes, determined from several sources (Barkman 1958, Bates & Brown 1981, Bibinger 1967, Wirth 1995, and Marmor & Randlane 2007), were as follows: *Acer platanoides* (5.75), *A. pseudoplatanus* (6.1), *Alnus* sp. (4.5), *Betula pendula* (4.3), *Carpinus betulus* (5.6), *Fagus sylvatica* (5.3), *Fraxinus excelsior* (5.3), *Picea abies* (3.65), *Pinus sylvestris* (3.4), *Populus tremula* (5.9), *Quercus* sp. (4.5), *Sorbus aucuparia* (4.9), *Tilia* sp. (5.1), etc. This procedure was employed for the following reasons: (1) to prevent destruction of the herbarium material during the measurements, (2) pH of old samples could change over time, and (3) for a comparison of preferred substrates in the past against recent ones it is better to use standardized values from more independent sources.

Distribution maps were created in ArcGIS, with recent (black circles) and historical (white circles) records indicated; 1990 has been selected as the boundary since it is the period (1) after the strong impact of acid rain, (2) with a stabilized system of agricultural farming, and (3) with a high probability that the record still exists. Photographs of species including type specimens and apothecial sections are available on www.jjh.cz/foto.

Results and discussion

Morphology – extreme forms

The main problem in the identification of single species within the *L. subfusca* group is the large morphological variability, especially in the size and shape of apothecia. The morphology of thallus and apothecia is the main character differentiating *L. rugosella* and *L. subrugosa* from *L. chlarotera* and *L. argentata* respectively. In Europe, I regard the former taxa as extreme morphological forms of *L. chlarotera* and *L. argentata* following Lumbch & Feige (1994, 1996). The extreme morphotypes are characterized by (1) a thick, coarse and verrucose thallus, (2) constricted base of apothecia, (3) thick, coarse, frequently flexuose, crenulate or verrucose apothecial margin, and (4) slightly larger ascospores with thick walls (more than 1 µm). Such morphotypes are conditioned ecologically, in most cases, dependent upon the availability of nutrients. Typical habitats for them are eutrophicated sites along roads and fields, dusty places, dying trees, subneutral and decaying bark. The occurrence of typical form together with the extreme one was frequently observed in the field, e.g. typical *L. argentata* gradually develops into

"*L. subrugosa*", which was growing on old or partly decaying bark of the same tree. On roadside trees, *L. chlarotera* and *L. pulicaris* frequently develop into extreme morphotypes on the bark of trees facing the road due to their exposure to nitrogen compounds derived from vehicle emissions, whereas bark on the reverse sides of such trees support typical forms.
The large morphological variability of *L. argentata* has been confirmed by ITS molecular data, where several samples with different morphology including typical "*L. subrugosa*" have formed one well supported clade (Malíček, unpublished data). The lectotype of *L. subrugosa* is a typical extreme form of *L. argentata* with all characters (see above), which is relatively common in, for example, the Alps, but rare in the Czech Republic. In case of *L. rugosella*, the type material is quite poor and represents an untypical form of *L. chlarotera* with very thick apothecial margin and constricted basis of apothecia.

Separation of *L. rugosella*, *L. subrugosa* or both former species is traditionally kept by many authors, e.g. Poelt & Vězda (1981), Nimis & Bolognini (1993), Wirth (1995), Thomson (1997), Jüriado (1998), Diederich & Sérusiaux (2000), Ryan *et al.* (2004), Santesson *et al.* (2004), Liška *et al*. (2008), Roux (2012) and Wirth et al. (2013). An ecologically derived morphology of *L. argentata* was studied more in detail by Lumbsch & Feige (1996), who emphasized the influence of the substrate in the creation of extreme forms and regarded *L. subrugosa* as a synonym of *L. argentata*.

Anatomy

Taxa known from the Czech Republic are characterized by the well developed thalline margin, colourless hymenium and hypothecium, orange, red-brown to brown epihymenium, presence of apothecial cortex, and 8-spored asci of *Lecanora* s. str. type. Pycnidia were rarely found and no differences in the conidium size were observed. As an important taxonomic character, three types of epihymenia sensu Brodo (1984) were distinguished. The *chlarotera*-type epihymenium is usually brown due to the mass of coarse (slowly soluble in HNO_3) granules [1–2.5 (–4.0) µm], which are concentrated at the tips of paraphyses. The red-brown pigment is absent or present. The *pulicaris*-type is mostly reddish-brown with fine (insoluble in HNO_3) granules of size 0.5–1.0 µm, which are dispersed in the upper part of the hymenium. In the *glabrata*-type, the granules are absent and the pigment is orange to orange-red. Oil droplets are rarely present. In contrast to the former types, the pigment usually persists in KOH or changes to (reddish-) brown.

The second important character is the type of amphithecium. The *pulicaris*-type has large crystals (>10 µm) and the *allophana/campestris*-type has small crystals (<10 µm). Rarely the crystals are in the *pulicaris*-type absent, but they may be broken into small and middle sized crystals in very old apothecia. Brodo's (1984) concept in distinguishing the *allophana*-type and from the *campestris*-type of amphithecium was not adopted in this study since the character of amphithecium is extremely variable and problematic in case of European epiphytic taxa. Hundreds of thin sections from apothecia of different age and shape were examined in water and KOH, but the differences between the two types of amphithecium were usually difficult or impossible to see, and it probably changes during apothecial development. Nevertheless, the typical *campestris*-type of amphithecium is usually possible to observe in saxicolous *L. campestris*, which has a well delimited cortex without entering amphithecial crystals.

However, Brodo (1984) noted the taxonomic importance of the different type of amphithecium for distinguishing the *L. horiza* from *L. allophana* and *L. glabrata*. According to my observations, the *allophana*-type is usually well developed in *L. allophana*, but in *L. glabrata* and *L. horiza* intermediate forms or more or less typical *allophana*-type predominate.

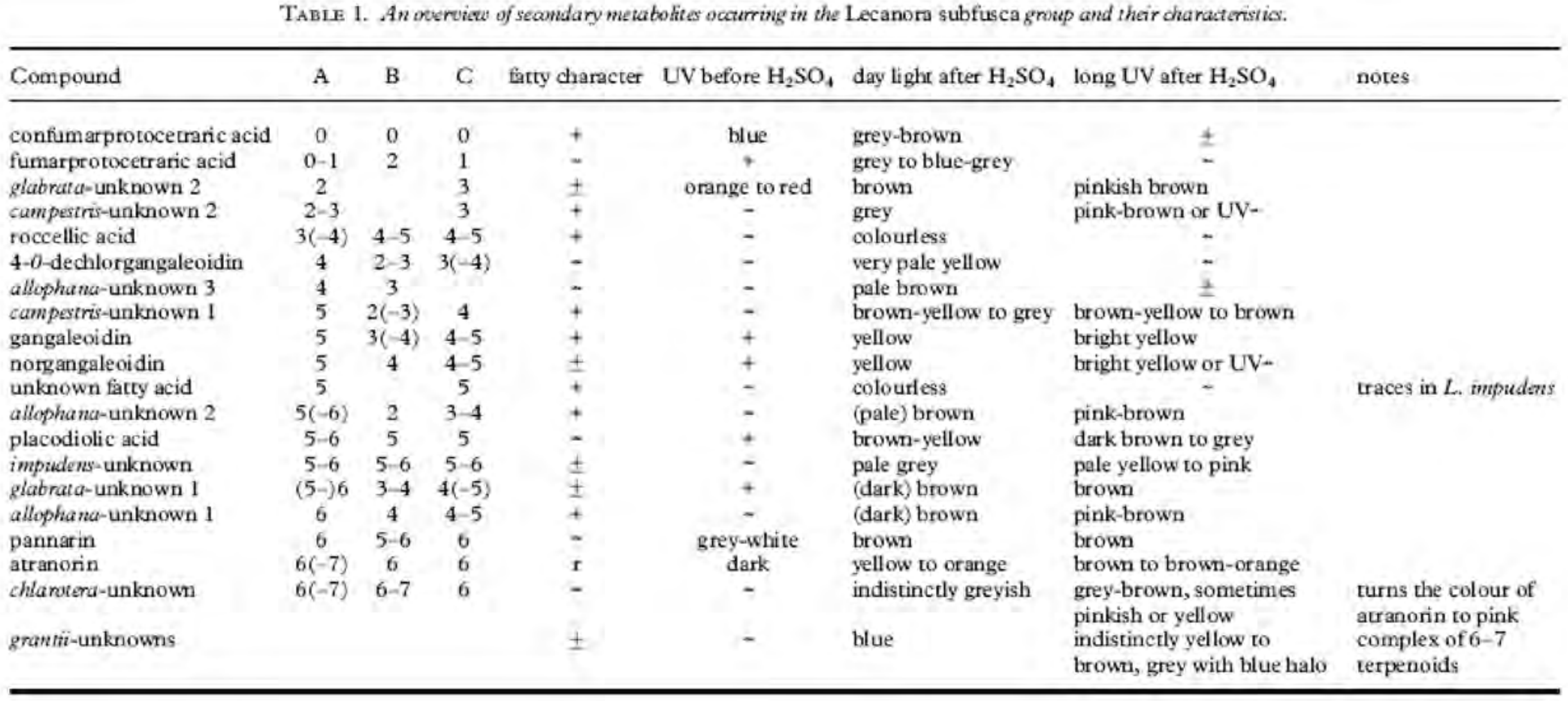

TABLE 1. *An overview of secondary metabolites occurring in the* Lecanora subfusca *group and their characteristics.*

Compound	A	B	C	fatty character	UV before H_2SO_4	day light after H_2SO_4	long UV after H_2SO_4	notes
confumarprotocetraric acid	0	0	0	+	blue	grey-brown	±	
fumarprotocetraric acid	0–1	2	1	–	+	grey to blue-grey	–	
glabrata-unknown 2	2		3	±	orange to red	brown	pinkish brown	
campestris-unknown 2	2–3		3	+	–	grey	pink-brown or UV–	
roccellic acid	3(–4)	4–5	4–5	+	–	colourless	–	
4-*0*-dechlorgangaleoidin	4	2–3	3(–4)	–	–	very pale yellow	–	
allophana-unknown 3	4	3		–	–	pale brown	±	
campestris-unknown 1	5	2(–3)	4	+	–	brown-yellow to grey	brown-yellow to brown	
gangaleoidin	5	3(–4)	4–5	+	+	yellow	bright yellow	
norgangaleoidin	5	4	4–5	±	+	yellow	bright yellow or UV–	
unknown fatty acid	5		5	+	–	colourless	–	traces in *L. impudens*
allophana-unknown 2	5(–6)	2	3–4	+	–	(pale) brown	pink-brown	
placodiolic acid	5–6	5	5	–	+	brown-yellow	dark brown to grey	
impudens-unknown	5–6	5–6	5–6	±	–	pale grey	pale yellow to pink	
glabrata-unknown 1	(5–)6	3–4	4(–5)	±	+	(dark) brown	brown	
allophana-unknown 1	6	4	4–5	+	–	(dark) brown	pink-brown	
pannarin	6	5–6	6	–	grey-white	brown	brown	
atranorin	6(–7)	6	6	r	dark	yellow to orange	brown to brown-orange	
chlarotera-unknown	6(–7)	6–7	6	–	–	indistinctly greyish	grey-brown, sometimes pinkish or yellow	turns the colour of atranorin to pink
grantii-unknowns				±	–	blue	indistinctly yellow to brown, grey with blue halo	complex of 6–7 terpenoids

TABLE 1. An overview of secondary metabolites and their characters.

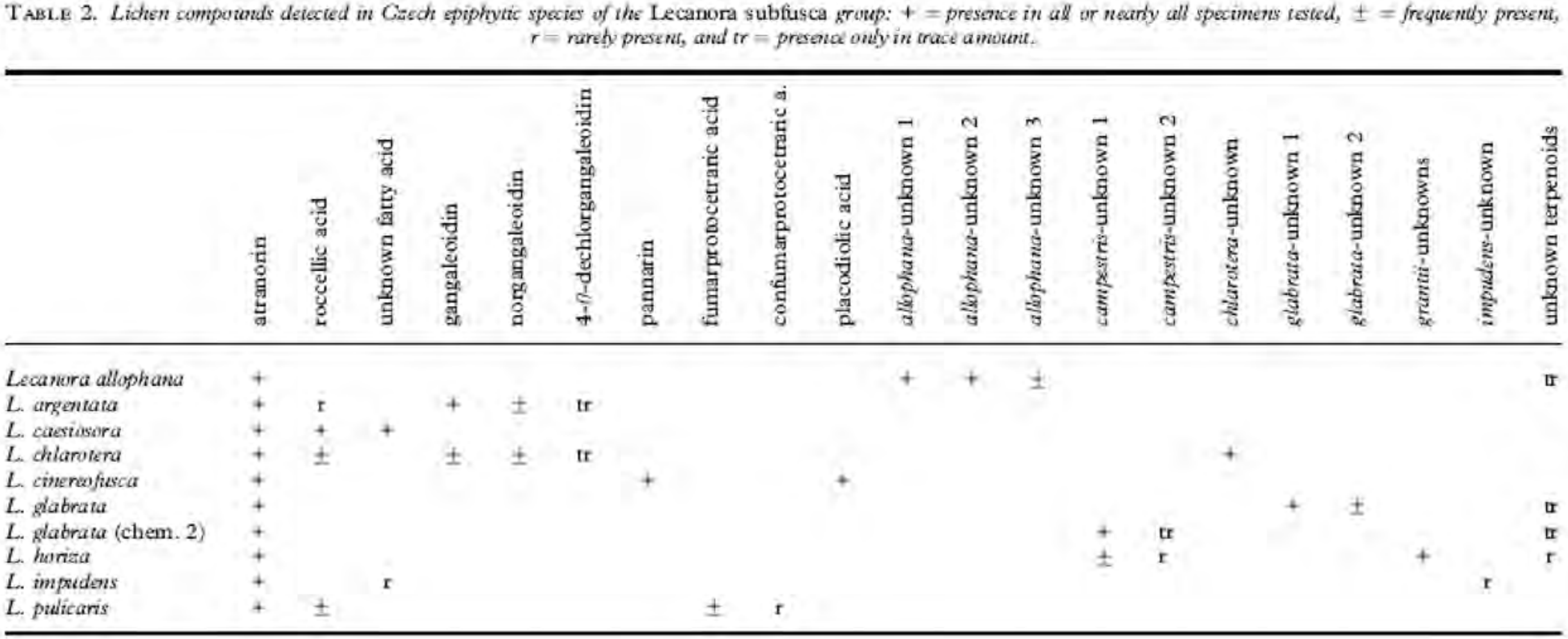

TABLE 2. *Lichen compounds detected in Czech epiphytic species of the* Lecanora subfusca *group: + = presence in all or nearly all specimens tested, ± = frequently present, r = rarely present, and tr = presence only in trace amount.*

	atranorin	roccellic acid	unknown fatty acid	gangaleoidin	norgangaleoidin	4-*0*-dechlorgangaleoidin	pannarin	fumarprotocetraric acid	confumarprotocetraric a.	placodiolic acid	*allophana*-unknown 1	*allophana*-unknown 2	*allophana*-unknown 3	*campestris*-unknown 1	*campestris*-unknown 2	*chlarotera*-unknown	*glabrata*-unknown 1	*glabrata*-unknown 2	*grantii*-unknowns	*impudens*-unknown	unknown terpenoids
Lecanora allophana	+										+	+	±								tr
L. argentata	+	r		+	±	tr															
L. caesiosora	+	+	+																		
L. chlarotera	+	±		±	±	tr										+					
L. cinereofusca	+						+			+											
L. glabrata	+																+	±			tr
L. glabrata (chem. 2)	+													+	tr						tr
L. horiza	+													±	r				+		r
L. impudens	+		r																	r	
L. pulicaris	+	±						±	r												

TABLE 2. Lichen compounds detected in Czech epiphytic species: + = presence in all or nearly all tested specimens, ± = frequently present, r = rarely present, and tr = presence only in trace amount.

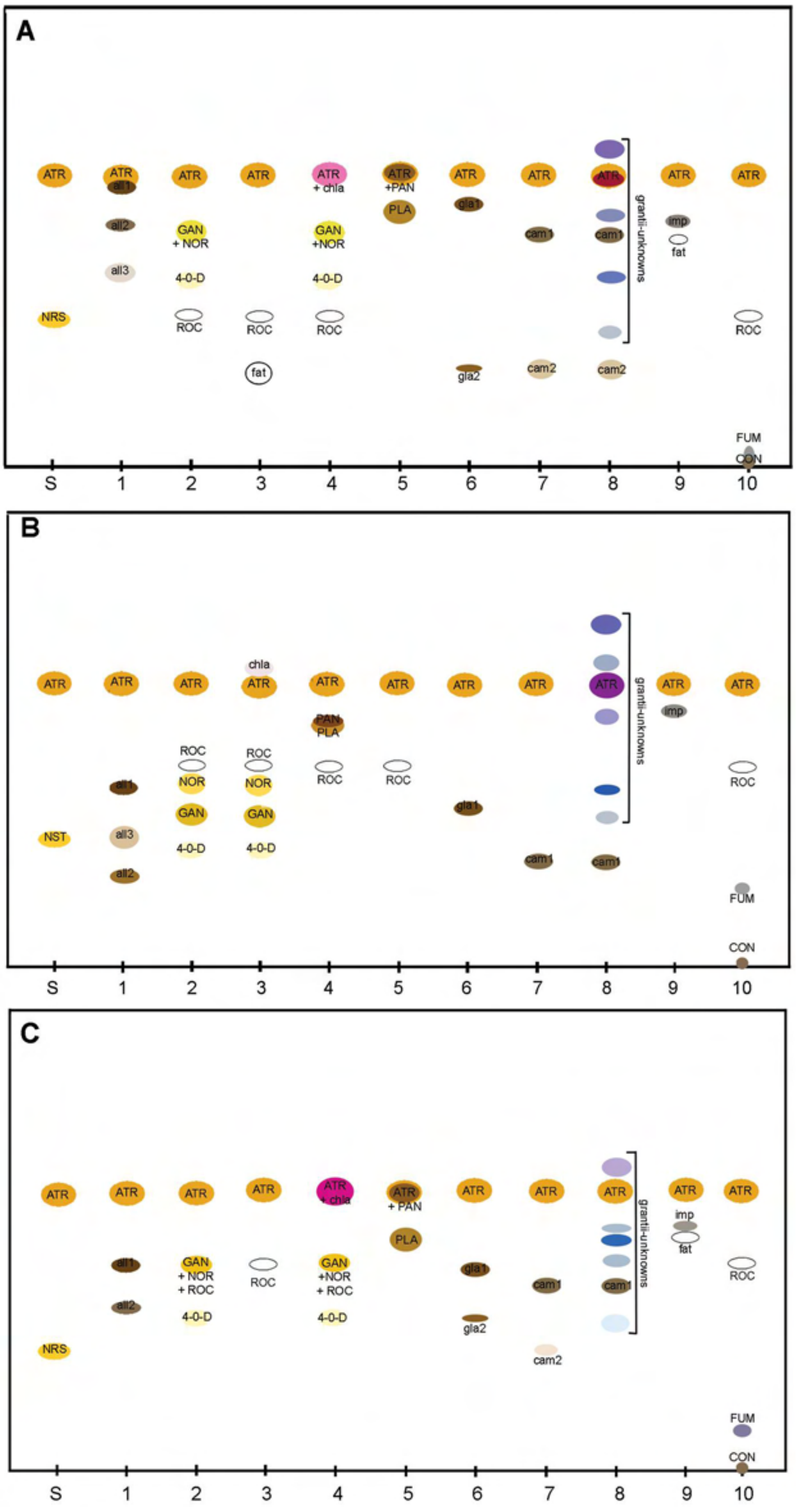

FIG. 1. TLC chromathograms in A, B and C solutions: S – standard, 1 – *L. allophana*, 2 – *L. argentata*, 3 – *L. caesiosora*, 4 – *L. chlarotera*, 5 – *L. cinereofusca*, 6 – *L. glabrata*, 7 – *L. glabrata* (chemotype 2), 8 – *L. horiza*, 9 – *L. impudens*, and 10 – *L. pulicaris*.
ATR – atranorin, NRS – norstictic acid, all1, 2 & 3 – *allophana*-unknowns 1, 2 & 3, GAN – gangaleoidin, NOR – norgangaleoidin, ROC – roccellic acid, fat – unidentified fatty acid, 4-0-D – 4-0-dechlorgangaleoidin, chla – *chlarotera*-unknown, PAN – pannarin, PLA – placodiolic acid, gla1 & 2 – *glabrata*-unknowns 1 & 2, cam1 & 2 – *campestris*-unknowns 1 & 2, imp – *impudens*-unknown, FUM – fumarprotocetraric acid, CON – confumarprotocetraric acid.

The third important character is the type of cortex. Brodo (1984) distinguished three types: (1) *allophana*-type, which is gelatinous, indistinctly delimited from the medulla and contains crystals which are insoluble in KOH, (2) *pulicaris*-type, which is also gelatinous, distinctly delimited from the medulla and contains only crystals (granules) which are soluble in KOH, and (3) *cinereofusca*-type, which is non-gelatinous, usually indistinct and 0–15 (–20) µm thick. The separation of an *allophana* and *pulicaris*-type of cortex can be problematic, especially in species with the *allophana/campestris* type of amphithecium (see above).

Chemistry

TLC analyses of secondary metabolites are very helpful in the identification of members of the *L. subfusca* group. In the case of sorediate species and poorly developed samples, analysis of lichen compounds is necessary. Czech epiphytic taxa have a more or less unique chemistry (see Table 2). Terpenoids are the most diversified group of metabolites, being produced mainly by species with small amphithecial crystals. Several terpenoids were unknown and are reported here for the first time (e.g. *glabrata*-unknowns). Taxa with large crystals contain the gangaleoidin chemosyndrome, roccellic acid, depsidones (fumarprotocetraric acid, rarely with related compounds, pannarin) or placodiolic acid. An overview of secondary products and spot characters is presented in Table 1 and graphically depicted in Fig. 1.

Individual Rf values are highly variable (±10%) and depend on many factors, such as atmospheric conditions, age of solvents, and probably on the amount of lichen compounds. The concentration of secondary metabolites on the plate strongly influences the fatty character and final colour of the spot. Differences in TLC analyses between recent and historical collections were not found. During analyses, photosynthetic pigments and terpenoids from the bark frequently accompanied lichen metabolites, so special care is necessary since terpenoids from bark can be very similar to lichen terpenoids on TLC plates. Bark terpenoids usually surround atranorin; the bark of *Abies*, *Alnus*, *Juglans* and *Rhododendron* is particularly rich in these compounds. TLC is optimal for routine identification of *L. subfusca* metabolites in order to distinguish all taxonomically important compounds. In comparison with HPLC, TLC does not separate, for example, gangaleoidin, from all of its related substances. On the other hand, according to the standardized HPLC method (Feige *et al.* 1993), it is impossible to detect several common metabolites, including fatty acids.

Ecological and substrate preferences

The epiphytic members of the *L. subfusca* group are characterized by a reasonably distinctive ecology, as summarized in species descriptions below (see also Fig. 2). According to field observations, some taxa are noticeably more abundant in higher altitudes on acid bark (e.g. *L. pulicaris*), others in lower altitudes on more basic bark (e.g. *L. chlarotera*). A data set acquired from herbarium labels was used for the statistical comparison of altitude and bark pH preferences of three common species (*L. argentata*, *L. chlarotera* and *L. pulicaris*). Firstly, an interaction of altitude and bark pH was verified by the model of linear regression and shown to be very strong (p-value < 0.0001, Fig. 3). Therefore the dependence of bark pH on the altitude was filtered out from the final analyses, which confirmed a higher altitudinal preference for *L. pulicaris* in comparison to *L. argentata* and *L. chlarotera* (p-value = 0.0061). *Lecanora chlarotera* probably prefers higher altitudes compared to *L. argentata* (p-value = 0.0429) with a preferred altitude of 700–800 m (see Fig. 4), but this is strongly influenced by a preference for beech which is more frequent in mountainous areas.

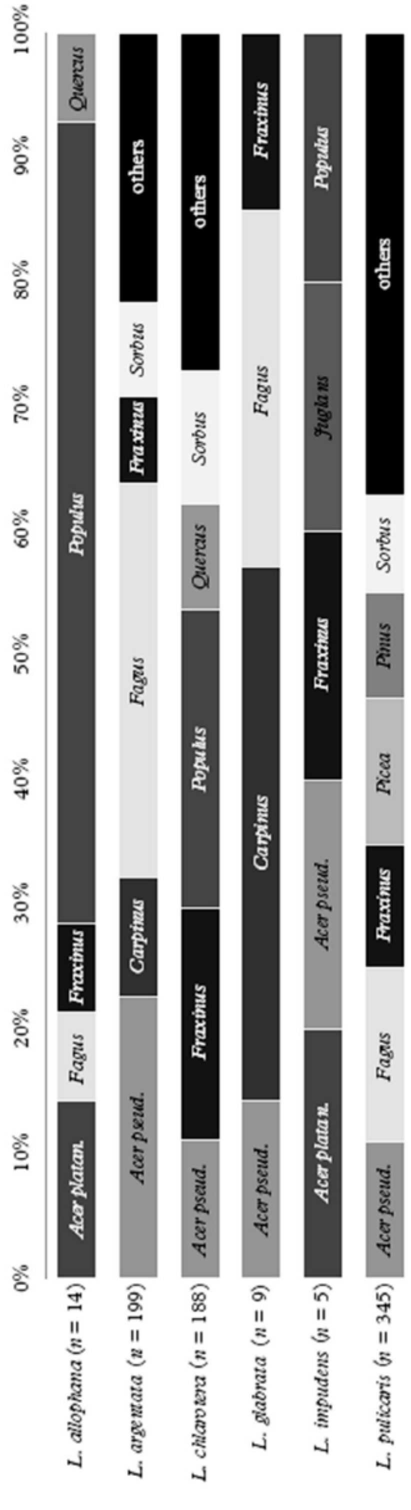

FIG. 2. The most frequent substrates of selected epiphytic species (based on data from Czech collections).

In the case of bark pH, *L. pulicaris* has a distinct preference for more acid bark (p-value = 0.0093, Fig. 5a). However, it is actually much more complicated due to the acidification of substrates during the period of acid rain, which affected the whole country, more particularly in the north (Moldan 1990). The shift of preferred bark pH of *L. pulicaris* before and after acidification (the boundary is 1970) was statistically significant (p-value < 0.0001, compare Figs 5A & 7B). Historical specimens come mostly from acid-barked trees (median of bark pH = 3.65; average = 4.12), whereas collections after 1970 were usually from slightly acid bark (median of bark pH = 5.30; average = 5.20). Slightly larger differences were observed when areas of low impact of acid rain were excluded from the analysis. The primarily acidophilous *L. pulicaris* colonized a very wide range of substrates including phorophytes with normally slightly acid to subneutral bark despite of acidification; this has increased during the last several decades. However, acid rain had the opposite effect on the distribution of *L. chlarotera*, which used to be the commonest member of the group and occupied a wide range of substrates (except strongly acidic bark). Recently, it has become restricted to the subneutral bark in the northern half of the country.

A decrease of bark pH from 5.0 to 3.0 caused by sulphur content in the bark was observed by Johnsen & Søchting (1973) and the occurrence of acidophilous lichens on subneutral bark caused by pollution is mentioned by Türk & Wirth (1975). In the Czech Republic, a similar observation was made by Liška *et al.* (1996), who recorded a shift of rare epiphytes from conifers to the bark of deciduous trees. However, substrate acidification in the country was very uneven; mountain regions such as Krušné and Jizerské hory on the northern border of the Czech Republic were subjected to an extremely strong impact of acid rain, resulting in the death of thousands of hectares of forest, but to the south part of the country (especially the Šumava Mts) such influence was relatively slight (Moldan 1990).

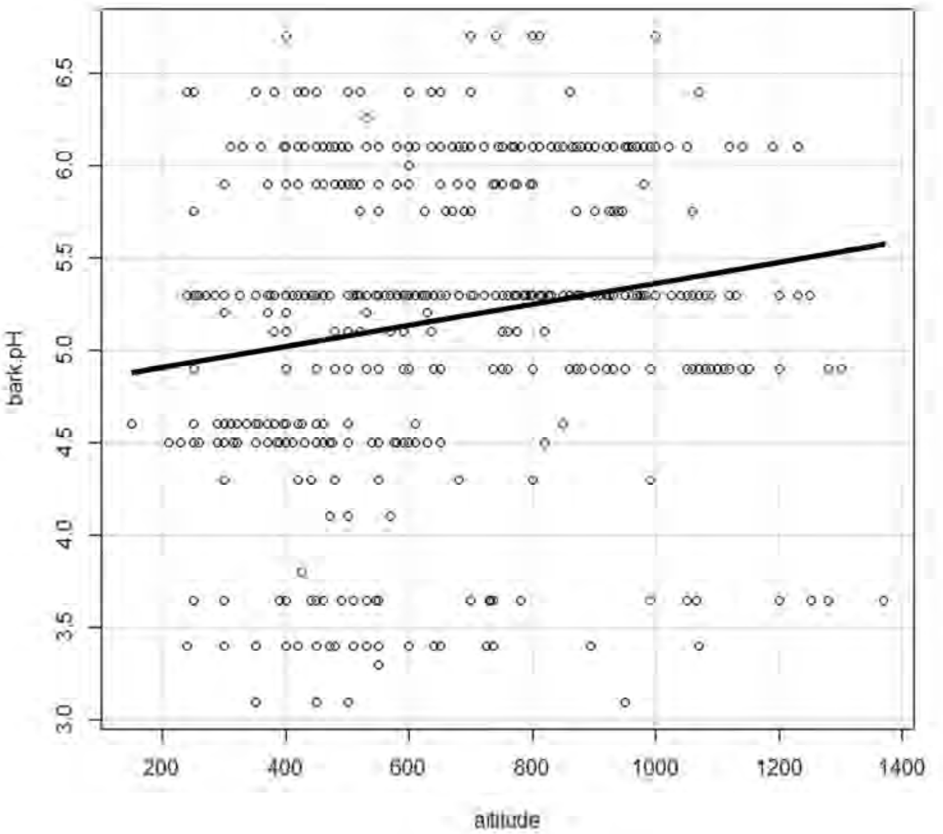

FIG. 3. Scatterplot of the dependence of bark pH on the altitude (black line) with marked local average (grey dashed line); data from substrates of all examined specimens.

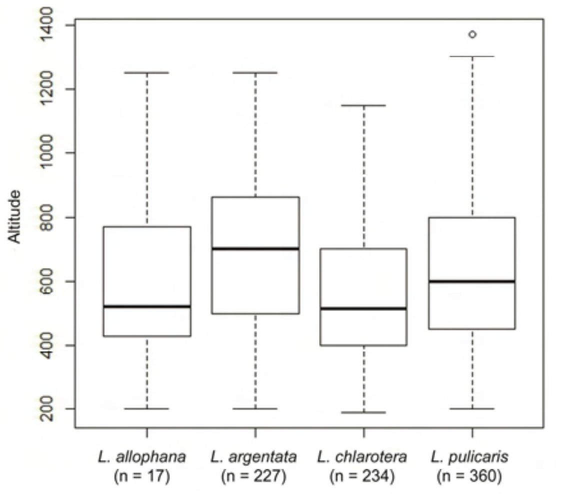

FIG. 4. Boxplot of altitude preferences: thick line = median; lower and upper side of boxes = quartiles; marginal values = maximum and minimum of data.

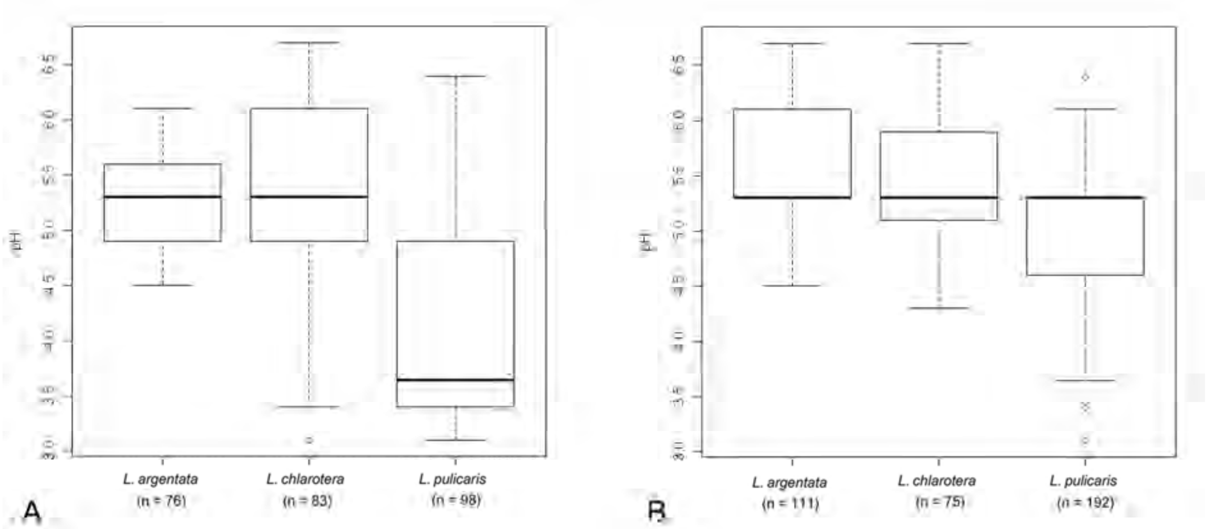

FIG. 5. Bark pH preferences of the three commonest species A, before 1970, and B, after 1970 (thick line = median; lower and upper side of boxes = quartiles; marginal values = maximum and minimum of data).

Identification and diversity of epiphytic taxa in the Czech Republic

During this study, 877 specimens were examined, a quarter of which were collected by the author from different parts of the Czech Republic. 71% of herbarium examined specimens had been misidentified or identified in a broad sense. Most herbarium material was identified without major difficulties; only untypically developed, very poor or strongly infected samples remained unidentified. The large variability of single species is the main problem in identification.

Nine taxa were recorded from the country. The rare species *L. cinereofusca*, published here as a new for the Czech Republic, is known only from a single historical collection from an old-growth beech forest. *Lecanora horiza* is regarded as extinct and *L. caesiosora* was recorded only once growing as an epiphyte. The boreal *L. circumborealis* is excluded from the list of Czech lichens because it was reported from the country based on misidentified specimens.

By comparison, eight epiphytic species are known from Slovakia (Guttová *et al.* 2013), 16 from Austria (Hafellner & Türk 2001, Tønsberg et al. 2001), 15 from Germany (Wirth *et al.* 2013), and nine from Poland (Fałtynowicz 2003, Kukwa & Kubiak 2007).

The species

Lecanora allophana (Ach.) Nyl.

Flora **55**: 250 (1872); *Lecanora subfusca* var. *allophana* Ach., *Lichenogr. Univers.*, p. 395 (1810); type: Suecia, (H-ACH 1143a! – lectotype).
Lichen subfuscus L., *Spec. plant.* **2**: 1142 (1753), nom. rejic.

(Figs 6A, 7A)

Thallus smooth to coarse, rarely verrucose; *apothecia* large, 0.6–2.0 mm in diam., constricted at base, rarely sessile; *discs* distinctly reddish-brown, in young apothecia sometimes slightly pruinose; *thalline margin* medium thick, smooth to slightly crenulate, often flexuose.
Epihymenium glabrata-type, clearly orange to orange-red, oil droplets (POL-) rarely present; *amphithecium allophana/campestris*-type, crystals occasionally sparse or partly overlapped by the algal layer; *cortex* often indistinctly delimited from medulla ("pseudocortex"), with abundant amphithecial crystals insoluble in KOH, 15–40 µm at margin, 50–100 µm at base; *ascospores* 14.0–20.0(–22.0) × 8.0–11.0 µm.
L. allophana f. *sorediata* (Schaer.) Vain. produces delimited, plane to convex soralia. Apothecia are often present.

Chemistry: Specific terpenoids, *allophana*-unknowns 1 and 2, were detected in most specimens (absent in only two samples). *Allophana*-unknown 3 is present in low concentrations and produces a pale inconspicuous spot on TLC plates. It was recorded in 69% of the samples (n = 16). Traces of other terpenoids, probably from bark, were rarely detected.

Ecology: *L. allophana* prefers slightly acid to subneutral bark and *Populus tremula* was its commonest substrate in the Czech Republic, but it also occurs on *Acer platanoides*, *Fraxinus excelsior*, *Fagus sylvatica* and *Quercus* sp. In Central Europe, it frequently occurs also on *Juglans regia*. It is a lichen of open and extensively farmed landscape, and is very sensitive to substrate acidification, air pollution and eutrophication.

Distribution: *L. allophana* has been collected at 18 localities in various parts of the country. The population decreased significantly due to the acid rain, and is now known from only four localities in Southern Bohemia and Northern Moravia. The sorediate form has been collected once in the south of Moravia. The species is more frequent in neighbouring countries, such as Slovakia, Austria and in some parts of Germany.

Remarks: A very distinctive and easily recognizable species because of its large apothecia with constricted bases, the largest ascospores in the group, and specific terpenoids. Separation of *L. impudens* from the sterile sorediate form of *L. allophana* is

very problematic (see under that species), but *L. allophana* is more often found with apothecia.
No. of specimens examined =18.

Selected specimens examined. **Southern Bohemia:** Šumava Mts, Stožec Mt., c. 1060 m, *Acer platanoides*, 1993, Z. Palice (PRA); Šumava Mts, Pěkná, edge of boggy spruce forest, 735 m, c. 48°51'10–15''N, 13°55'E, *Populus tremula*, Z. Palice 5507c (PRA); Novohradské hory Mts, Pohoří na Šumavě, *Acer platanoides*, 2004, D. Svoboda, O. Peksa & M. Zahradníková (PRC); ––**Northern Moravia:** montes Králický Sněžník, ad ripam rivi "Kopřivák", 800 m, *Fagus sylvatica*, 2001, J. Halda 4868 & M. Zmrhalová (hb. Halda); ––**Southern Moravia:** Kotelná, Pavlovské Kopce, c. 400 m, quercicola in colle, 1922, J. Suza (PRM; *L. allophana* f. *sorediata*!).

Lecanora argentata (Ach.) Röhl.

Deutsch. Flora, Abth. 2 (Frankfurt): 82 (1813); *Parmelia subfusca* var. *argentata* Ach., *Method. Lich.*, 169 (1803); type: Suecia (H-ACH 1189a! – lectotype).
Lecanora subfuscata H. Magn., *Acta horti Gothob*. **7**: 79 (1932); type: Sweden, Dalsland, Bäcke sn, Hjulserud á träd, 1914, S. & C. Bergström (UPS – lectotype).
Lecanora subrugosa Nyl., *Flora* **58**: 15 (1875); type: Fennia. Tavastia australis: Hollola, Tiirismaa, sorbicola, 1873, E. Lang (H-NYL 27600! – lectotype).

(Figs 6B, 7B & C)

Thallus thick, smooth, rarely verrucose, frequently rimose; *apothecia* sessile, crowded, 0.5–1.0 (–1.5) mm in diam.; *discs* reddish-brown to dark reddish brown; *margin* slightly crenulate, in extreme forms thick, strongly crenulate or verrucose.
Epihymenium glabrata-type, distinctly orange to brownish-red; *amphithecium pulicaris*-type with numerous large crystals; *cortex* usually distinctly developed, 10–20 µm at margin, 25–30 µm at base, degrading in old apothecia and in extreme forms; *ascospores* 11–15 × 6.5–9 µm.

Chemistry: Gangaleoidin is usually present (96% of specimens). Norgangaleoidin (= californin) and 4-0-dechlorgangaleoidin accompany gangaleoidin. However, 4-0-dechlorgangaleoidin is present in very low concentrations and usually indistinct on TLC plates. Roccellic acid has been detected in 9% of the samples (n = 69), and norstictic acid has been found in several samples as a contaminant from *Phlyctis argena* or other lichens associated with *L. argentata*.

Ecology: *L. argentata* clearly prefers smooth and slightly acid bark, being dominant, mainly on *Fagus sylvatica*, *Acer pseudoplatanus* and *Carpinus betulus*. It is also found on other phorophytes (e.g. *Fraxinus excelsior*, *Acer platanoides*), but only in regions where these species are abundant. In the Czech Republic, it is concentrated in forested areas, mainly at higher altitudes (above 500 m). At lower altitudes, it is rare, occurring at riverside sites and stream valleys, and is absent in intensively farmed regions and in regions with low precipitation. In Europe it is a characteristic species of natural beech forests.

Distribution: Currently, *L. argentata* is concentrated mainly in southern and western Bohemia, being very common in the Šumava Mts. In the past it was collected at many places in different parts of the country, but now it is absent in northern Bohemia due to acid rain.

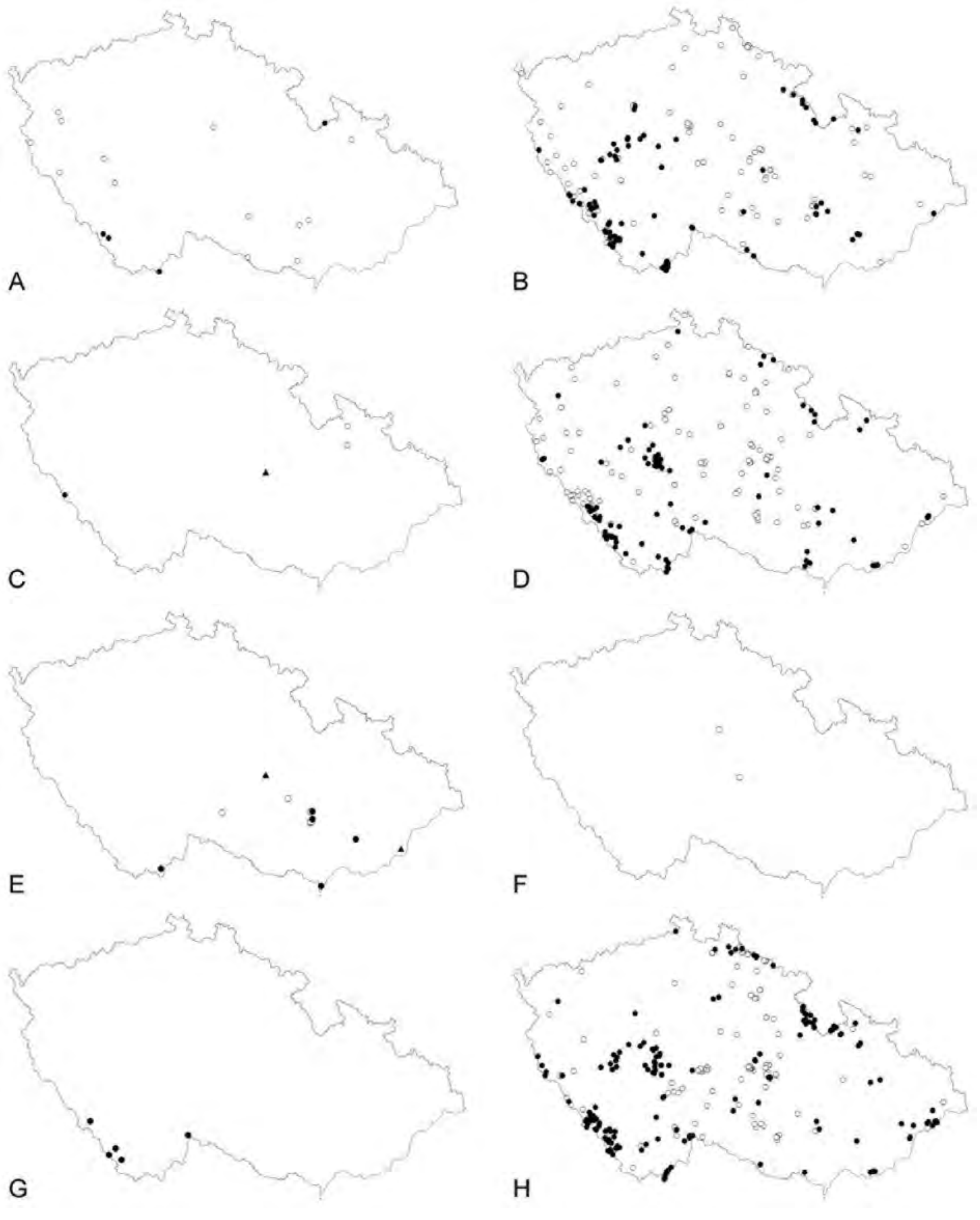

FIG. 6. Distribution of studied species in the Czech Republic (ŏ = recent localities after 1990; ○ = historical localities). A, *L. allophana*; B, *L. argentata*; C, *L. caesiosora* and *L. cinereofusca* (ƶ); D, *L. chlarotera*; E, *L. glabrata*, chemotype 2 (ƶ); F, *L. horiza*; G, *L. impudens*; H, *L. pulicaris*.

Remarks: This species is relatively easily recognized by the combination of non-granulose epihymenium, large crystals in amphithecium and its ecology. It grows in

similar places to *L. glabrata*, which has smaller apothecia, an *allophana*-type of amphithecium, and contains specific terpenoids.
No. of specimens examined = 233.

Lecanora caesiosora Poelt

Denkschr. Regensb. bot. Ges. **26**: 82 (1966) nom. nov.; *Lecanora soralifera* H. Magn., *Bot. Notiser* 1937: 135 (1937); type: Magnusson: Lich. sel. Scand. exs. 270b, Sweden, Västergötland: Partille, northwest of Tultered, 1936, A. H. Magnusson (UPS – holotype).
Lecanora cenisia var. *soredians* Suza, *Sb. Klubu Přírodovědeckého v Brně* **11**: 152 (1929); type: Moravia, Sudeti or., Jeseníky, in monte Vozka (Fuhrmannstein), ad saxo schistosi in fissis subumbrosis, 1370 m, 1928, J. Suza, TLC: atranorin, roccellic acid, trace of unidentified fatty acid (PRM 639535! – holotype).

(Fig. 6C)

Thallus thick, verrucose; *soralia* large (0.5–1.0 mm in diam.), convex, rounded, flat to convex, ± delimited, later partly confluent; *apothecia* as in *L. cenisia*, not found in the Czech epiphytic material, 1.0–2.0 mm in diam., constricted at base; *discs* reddish-brown to black, often lightly pruinose; *margin* crenulate to flexuose.
Epihymenium: *chlarotera*-type, orange, reddish-brown to olivaceous-brown (then HNO_3+ red); *amphithecium*: *pulicaris*-type; *cortex* (20–)25–35 µm thick; *ascospores*: 10.5–15 × 7.5–8.5 µm (Brodo *et al.* 1994).

Chemistry: Roccellic acid and probably rangiformic acid (minor) have been found in the only epiphytic specimen from the country. Additionally, traces of stictic acid as a contaminant has been detected. According to Brodo *et al.* (1994), 89% of collections contain roccellic acid (sometimes with unidentified fatty acids) and 11% nephrosteranic acid.

Ecology: *L. caesiosora* has been collected from bark of *Sorbus aucuparia* at an altitude of c. 1150 m. In the Alps it also occurs on twigs of *Rhododendron* (Hinteregger 1994). It is primarily a saxicolous species growing mainly on shaded siliceous rocks and overhangs in mountainous regions (Brodo *et al.* 1994). Saxicolous collections from the Czech Republic come from schistose rocks.

Distribution: The epiphytic population is currently known from a glacial cirque of the Černé jezero Lake in the Šumava Mts. It is very rare species in the country, being reported from only two localities on rocks in the Jeseníky Mts (Suza 1929, Vězda 1961, as *L. cenisia* var. *soredians*).

Remarks: This taxon is probably a sorediate form of *L. cenisia*. However, following the concept of Brodo *et al.* (1994), the sorediate form at the species level is recognized in terms of the slightly different morphological variation, presence of nephrosteranic acid-chemotype, which is absent in *L. cenisia*, and differences in habitat preferences. The type specimen of *L. cenisia* var. *soredians* resembles a diminutive form of *L. cenisia*. It is characterized by its distinctly grey thallus, apothecia 1.0–1.2 mm in diam., slightly crenulate margin, dark brown discs, reddish-brown pigment in epihymenium (pale brown in KOH), and a cortex expanded at the base up to 60 µm. Other characters correspond with the description published by Brodo *et al.* (1994). The epiphytic *L. exspersa* is very similar to *L. caesiosora*, but differs in its thinner, non-verrucose thallus

and the soralia which are distinctly smaller in *L. exspersa*, concave to flat and usually bordered by a thin thalline rim.
No. of epiphytic specimens examined = 1.

Selected specimens examined. **Western Bohemia:** Šumava Mts, Železná Ruda: glacial cirque or Černé jezero lake, 49°10'35''N, 13°11'10''E, c. 1150 m, *Sorbus aucuparia*, 1995, Z. Palice 232 (PRA).

Lecanora chlarotera Nyl.

Bull. Soc. linn. Normandie, sér. 2, **6**: 274 (1872); type: In Germania prope Jenam, 1797, C. Steven (H-NYL 27347! – lectotype).
Lecanora crassula H. Magn., *Meddn Göteb. Bot. Trädg.* **7**: 80 (1932).
Lecanora rugosa Nyl., *Flora* **55**: 250 (1872).
Lecanora rugosella Zahlbr., *Cat. Lich. Univers.* **5**: 524 (1928); type: Gallia (H-ACH 1193h! – lectotype).

(Figs 6D, 7D)

Thallus medium thick to thick, smooth to slightly verrucose; *apothecia* sessile, usually crowded, 0.5–1.0 mm in diam.; *discs* pale brown, pink-brown, rarely dark brown or red-brown, sometimes slightly pruinose (especially in old collections); *margin* relatively thick, smooth to crenulate.
Epihymenium chlarotera-type, brown due to the abundant presence of coarse granules, rarely with reddish-brown pigment, granules slowly soluble in HNO_3; *amphithecium*: *pulicaris*-type; *cortex* 10–25 µm at margin, up to 40 µm at base; *ascospores* 11.0–15.0 × 7.0–8.5 µm.

Chemistry: The species is well characterized by the presence of the compound "*chlarotera*-unknown", which is probably related to a terpenoid and is present in the form of coarse epihymenial granules. In the case of sparse granules, the characteristic spot turning atranorin to pink is absent or almost absent on TLC plates. Roccellic acid has been detected in 56% of samples. Gangaleoidin and norgangaleoidin are present in 54% of specimens (n = 57). Traces of 4-0-dechlorgangaleoidin have been found in one collection. Roccellic acid is usually present in specimens without gangaleoidin, but commonly both substances occur together.

Ecology: *L. chlarotera* distinctly prefers slightly acid to subneutral bark, mainly occurring on *Populus* sp., *Fraxinus excelsior*, *Acer pseudoplatanus*, *Sorbus aucuparia*, *Quercus* sp. and *Juglans regia*, and rarely grows on wood. It occurs in open landscape (in avenues, solitary trees, borders of forests, gardens) and in young and light deciduous forests; it is very rare in woodlands. *L. chlarotera* is very sensitive to bark acidification. It has been recorded from lowlands to submontane areas, but is rare in mountains (above 1000 m). It is sparse in agricultural landscapes and along the less frequently used roadsides. It appears to tolerate continental climatic conditions in the Czech Republic, being the commonest member of the *L. subfusca* group in warm and dry areas.

Distribution: In the past, *L. chlarotera* was the most abundant species of the *L. subfusca* group in the country, but today it is common only in Southern Bohemia and Moravia, which have not been so strongly affected by acid rain and air pollution. It is rare in the northern half of the Czech Republic, where it is concentrated on suitable habitats such as old avenue trees with subneutral-bark.

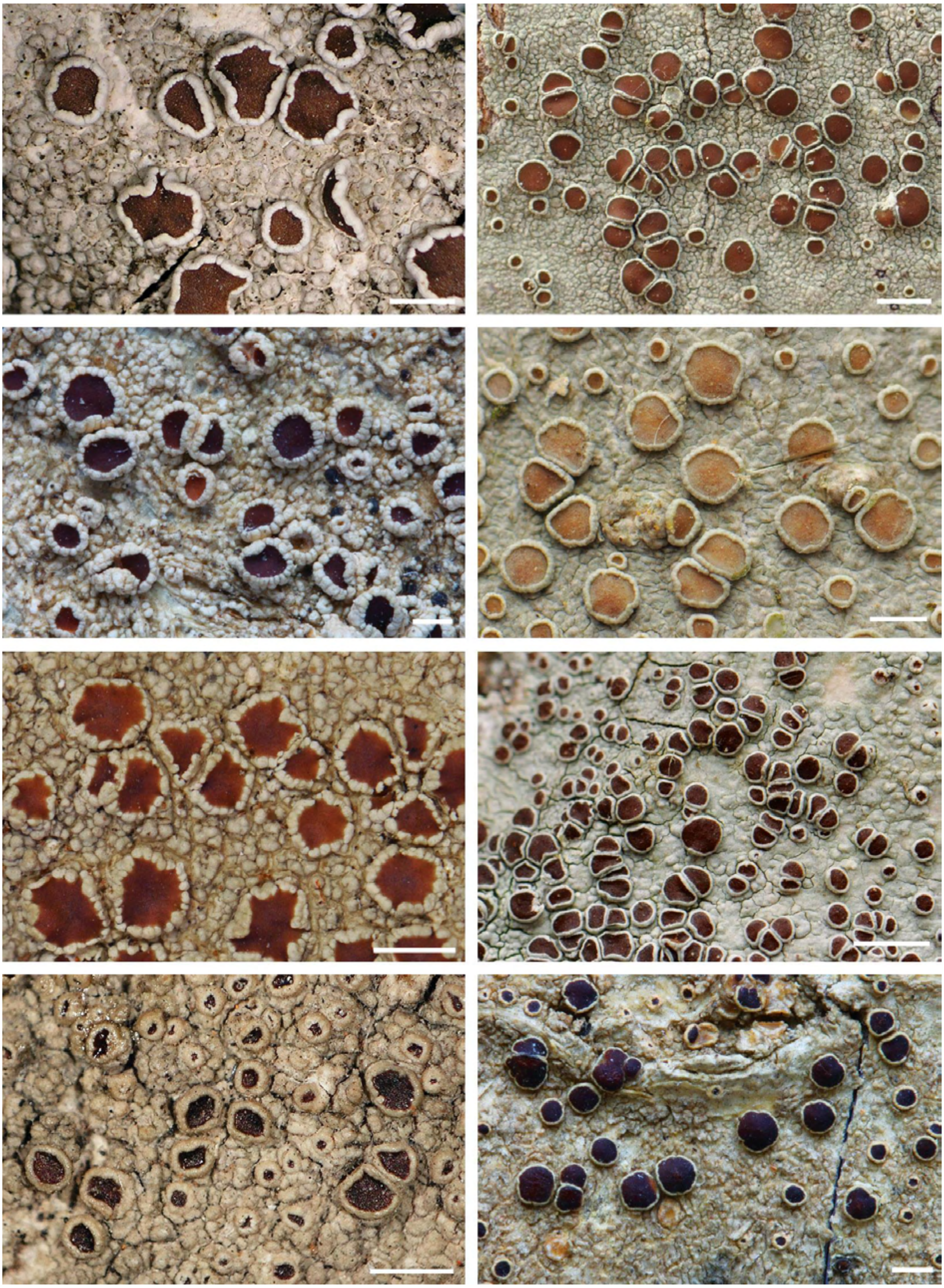

FIG. 7. Habitus of selected species. A, *Lecanora allophana*; B, *L. argentata* – lectotype; C, *L. argentata* – extreme form, the lectotype of *L. subrugosa*; D, *L. chlarotera* – typical form; E, *L. cinereofusca*; F, *L. glabrata* – lectotype; G, *L. horiza* – type material (H-ACH 1193c); H, *L. horiza* – isosyntype of *L. laevis*. Scales = 1 mm.

Remarks: *L. chlarotera* is very variable taxon in Europe (especially in southern Europe) and probably comprises more taxa. Czech populations are relatively uniform. Very similar species are, for example, *L. salicicola* (high mountain element differing in the thin apothecial margin and complete absence of gangaleoidin), *L. rubicunda* (southern element containing norstictic acid), and *L. meridionalis* (southern element with dark pigmented discs and dark green to olive epihymenial pigment).

The coarse epihymenial granules ("*chlarotera*-unkown") present on tips of paraphyses are a very effective anti-herbivory mechanism. Species with fine granules in the epihymenium or without them frequently have a hymenium damaged by snails. It is very common especially in *L. argentata*, but in *L. chlarotera* the hymenium usually remains without traces of such grazing. Coarse epihymenial granules have a similar anti-herbivorous effect as a pruina on apothecial discs (Nimis & Skert 2006). On the other hand, *L. chlarotera* is frequently parasitized by lichenicolous fungi such *Stigmidium congestum*, *Lichenoconium lecanorae* and *Vouauxiella lichenicola*.

No. of specimens examined = 237.

Lecanora cinereofusca H. Magn.

Meddn Göteb. Bot. Trädg. **7**: 86 (1932); type: [U.S.A.] Maryland, Benfield, On *Magnolia glauca*, 1907, C. C. Plitt (UPS – lectotype).

Lecanora degelii Schauer & Brodo, *Nova Hedw.* **11**: 528 (1966).

(Figs 6C, 7E)

Thallus smooth to coarse; *apothecia* immersed in thallus when young, later sessile, 0.6–1.5 mm (up to 1.0 mm in the Czech collection) in diam.; *discs* red to brown-red; *margin* relatively thick, distinctly crenulate to discontinuous.

Epihymenium chlarotera-type, orange-red, Pd+ red with the formation of clusters of crystals, granules often sparse; *amphithecium pulicaris*-type, but crystals frequently rare, eventually absent; *cortex* indistinct or 10–15 µm thick; *ascospores* 10.0–14.0 × 7.0–9.0 µm, thin walled.

Chemistry: The epihymenium, and sometimes also the apothecial margin, react Pd+ orange to red due to the presence of pannarin, which is characteristic for this species. Placodiolic acid has also been detected in the Czech specimen. Brodo (1984) mentioned roccellic acid in *L. cinereofusca*, but this has not been recorded in analysed material, including reference collections from Austria and Germany.

Ecology: The only collection from the Czech Republic is from bark of *Fagus sylvatica*. In the Alps, it grows on *Acer pseudoplatanus*, *Abies alba*, *Alnus* sp. and *Salix* sp. (Schauer & Brodo 1966). *L. cinereofusca* clearly prefers natural humid woodlands in oceanic and suboceanic areas. It also occurs on trees on the banks of lakes and rivers surrounded by natural forest vegetation. The Czech collection comes from an old-growth beech forest reservation at an altitude of c. 800 m.

Distribution: This species was collected in 1904 from the forest reservation on the top of Žákova hora Mt. in the Žďárské vrchy Mts. Despite intensive research in this locality in recent years, *L. cinereofusca* has not been refound. Žákova hora Mt. was formerly a very important locality for many rare lichens, but the forest has been greatly influenced by acid rain and the lichen flora has changed significantly. *L. cinereofusca* is considered to be extinct in the country. In Europe, it is reported from the Alps, Scandinavia, Scotland

(Edwards *et al*. 2009) and Slovakia, where it is regarded as a taxon indicating ecological forest continuity (Pišút 1997).

Remarks: *L. cinereofusca* is a very distinctive species characterized by the presence of pannarin, immersed young apothecia, reddish discs and strongly crenulate to partly disappearing apothecial margin. It resembles the very rare species *L. insignis*, which differs in its larger, thick walled ascospores (16–21 × 8–12 µm), absence of placodiolic acid and a preference for conifers (*Abies*, *Picea*).

Specimen examined. **Western Moravia:** Na buku na vrcholu Žákové hory, leg. F. Kovář 1904 (OLM 7062).

Lecanora glabrata (Ach.) Malme

Svensk Bot. Tidskr. **6**: 100 (1912); *Lecanora subfusca* var. *glabrata* Ach., *Lich. univ.*, 1–696 (1810); type: Helvetia (H-ACH 1192a! – lectotype).
Lecanora subfuscata f. *glabrata* (Ach.) Poelt, *Ber. bayer. bot. Ges.* **29**: 61 (1952).

(Figs 6E, 7F)

Thallus thin to medium thick, usually smooth; *apothecia* sessile, typically small, 0.4–0.8 mm in diam.; *discs* reddish-brown to dark brown, plane to later convex; *margin* thin, smooth, disappearing in some specimens.
Epihymenium glabrata-type, orange to red-orange; *amphithecium allophana/campestris*-type, small crystals abundant; *cortex* in KOH ± distinctly delimited form the medulla, 15–25 µm at margin, expanded up to 60 µm at base, with or without amphithecial crystals; *ascospores*: 11.0–14.0(–16.0) × 6.0–8.0 µm.

Chemistry: Two chemotypes have been found by a critical examination. The common strain is characterized by the specific terpenoid *glabrata*-unknown 1, usually accompanied by *glabrata*-unknown 2, which has been recorded in four samples (n = 11). Probably both terpenoids are usually present, but sometimes in very low concentrations. Occasionally, traces of other terpenoids have also been found. Three collections (from OLM) belong to chemotype 2, which contains *campestris*-unknowns and often traces of several additional terpenoids. This chemotype has been detected in many specimens, especially from Slovenia, but also from several other South-European countries. The terpenoids *grantii*-unknowns published by Brodo (1984) have not been recorded in European material.

Ecology: *L. glabrata* is ecologically very similar to *L. argentata*, and both species frequently occur at the same site. It grows mainly on bark of *Fagus* and *Carpinus*, and rarely on *Acer pseudoplatanus* and *Fraxinus excelsior*. *L. glabrata* is a characteristic lichen of beech forests, but prefers humid sites such as valleys of streams and rivers. Most of the Czech records come from lowlands, but it is frequently recorded in the mountain areas of surrounding countries.

Distribution: The chemotype with *glabrata*-unknowns (alternatively without terpenoids) has been recorded from 11 localities in the country, mostly in southern Moravia. It is a rare species, but more frequently found in deep valleys in the area of Moravian Karst. The second chemotype is only known from two historical localities.

Remarks: *L. glabrata* is very similar to *L. horiza*, which differs in the chemistry and usually larger apothecia; *L. horiza* also prefers different phorophytes in open habitats. Extremely developed morphological forms of *L. glabrata* can be confused with poorly developed *L. allophana*. In the Czech Republic, both former species are distinct in their chemistry, so in such cases TLC is necessary for correct identification. In the field, *L. glabrata* is often associated with *L. argentata*, which has larger apothecia, paler plane discs, and a thicker crenulate margin.
No. of specimens examined = 13.

Selected specimens examined. **Southern Bohemia:** Novohradské hory Mts, Pohorská ves, Smrčina Mt. 48°39'44''N, 14°40'38''E, 900 m, *Fagus sylvatica*, 2010, J. Malíček 2965, I. Černajová & Z. Palice (herb. JM); ––**Southern Moravia:** Břeclav, nature reserve Ranšpurk, a flood-plain forest S of Lanžhot, 150 m, *Carpinus*, 2001, Z. Palice 8707 (PRA); Chřiby Mts, Salaš, valley of Bunčovský brook 2 km ENE of village, 49°08'45''N, 17°22'13''E, 260 m, *Fagus sylvatica*, 2010, J. Malíček 2600 (herb. JM); Moravský kras, Lažánky, Suchý žleb valley, near Kateřinská jeskyně cave, *Carpinus betulus*, 2007, J. Malíček 568 (herb. JM); ––**Western Moravia:** Fagicola, Roštýn prope, Třešť, J. Suza (BRNM); Vrchol Žákovy hory, F. Kovář? (chemotype 2, OLM); ––**Eastern Moravia:** U Brumova, 1909, J. Mastný (chemotype 2; two specimens in OLM).

Lecanora horiza (Ach.) Röhl.

Deutschl. Fl., Abth. 2 (Frankfurt), **3**: 82 (1813); *Lecanora subfusca* var. *horiza* Ach., *Lich. univ.*: 394 (1810); type: Gallia (H-ACH 1193d! – lectotype).
Lecanora laevis Poelt, *Ber. dt. bot. Ges.* **29**: 64 (1952); type: C. Flagey: Lichenes Algerienses no. 113, C. sur les jeunes frênes près de l'hôpital civil de Constantine, C. Flagey (H! – isosyntype).
Lecanora parisiensis Nyl., *Bull. Soc. bot. Fr.* **13**: 368 (1866); type: Paris. Bagneaux, ad juglandem, W. Nylander (H-NYL 27674! – lectotype).

(Figs 6F, 7G & H)

Thallus smooth to coarse or verrucose; *apothecia* sessile to slightly constricted at base, 0.5–1.2 µm in diam.; *discs* deeply reddish-brown to brown, glossy when young, in sunny sites usually glossy also in later stages of development, rarely with thin pruina on young apothecia; *margin* thin to medium thick, smooth.
Epihymenium glabrata-type; *amphithecium allophana/campestris*-type; *cortex* usually distinctly delimited (better seen in KOH), 10–25 µm thick, at base expanding up to 40–60(–80) µm, composed of branched hyphae (2–3 µm thick), with fine granules soluble in KOH, amphithecial crystals usually not entering into the cortex, but sometimes interspersed in the basal part; *ascospores* 12.0–15.0 × 7.0–9.0 µm.

Chemistry: A complex of terpenoids "*grantii*-unknowns" is characteristic for this species. These substances are typical for the bright blue colour on TLC plates; it is a complex of six to seven spots, some of which overlap atranorin, which is violet in colour. In the case of low concentrations, at least one or two spots are present on the plates. The former two compounds correspond to lgr-1 and lgr-2 in Brodo (1984) for North-American *L. grantii*, as well as populations of *L. horiza*. Minor terpenoid *campestris*-unknown 1 frequently accompanies *grantii*-unknowns, but very rarely *campestris*-unknown 2 is also present. Occasionally traces of several other unknown terpenoids have been detected. The two analysed Czech samples contained 2 or 3 *grantii*-unknowns and no *campestris*-unknowns.

Ecology: Both Czech collections are from wood; elsewhere, *L. horiza* grows on various phorophytes with slightly acid to subneutral bark, especially *Juglans*, *Aesculus*, *Populus*, *Fraxinus*, *Acer* and *Ulmus* (Brodo 1984, Edwards *et al*. 2009). In Great Britain, it is also known from gravestones and bricks of churches. It prefers open landscape and tolerates eutrophication.

Distribution: It has been collected only two times in the Czech Republic (from Kolín in 1853 and Havlíčkův Brod at the end of 19th century). It is also recorded from nearby Mt Falkenstein on the German side of the Šumava-Bayerischer Wald Mts (Poelt 1952, as *L. laevis*). All literature records (Vězda & Liška 1999, see under *L. allophana*) are erroneous. *L. horiza* has an Atlantic-Mediterranean distribution (Ibáñez & Burgaz 1998), and is extremely rare in Central Europe.

Remarks: *Lecanora horiza* is a taxonomically problematic species and requires a detailed molecular study. The Mediterranean populations are variable and possibly include more taxa. *Lecanora laevis* Poelt is regarded here as a morphological form of *L. horiza*; it differs from typical *L. horiza* in its larger apothecia (0.8–1.2 mm) with more constricted bases, and generally paler thallus and apothecial margin. However, it seems to be only a morphotype from ± shady sites. *L. horiza* is anatomically congruent with saxicolous *L. campestris*. Brodo (1984) mentioned chemical differences between these taxa, but the author has observed no important characters in the chemistry of European populations. Preliminary molecular results show both lichens as genetically distinct species (Malíček & Powell 2013). The Mediterranean *L. sienae* B. de Lesd. may be a well defined taxon from the *L. horiza* complex, but it needs further investigation.
No. of specimens examined = 2.

Selected specimens examined. **Central Bohemia:** Kolín, 1853, Veselský (PRM); ––**Eastern Bohemia:** Německý Brod, J. Novák (PRM).

Lecanora impudens Degel.

Svensk bot. Tidskr. **38**: 50 (1944); nom. nov. for *Pertusaria farinacea* H. Magn., *Bot. Not.* 1942: 15 (1942); type: Sweden, Södermanland: Botkyrka, Tullinge gård. On *Ulmus* in an avenue, 1938, A. H. Magnusson 16125 (UPS 65900! – holotype).
Lecanora maculata (Erichs.) Almb., *Bot. Not.* 1952: 251 (1952); *Pertusaria maculata*
Erichs., *Rabenh. Kryptog. Flora Deutsch.*, **5**: 646 (1936).

(Figs 6G, 8A)

Thallus thin to medium thick, usually smooth; *soralia* more or less delimited, 0.3–0.6(–1.0) mm in diam., sometimes slightly confluent, rounded, concave or flat when young, later convex, thin thalline rim along the base of soralia often present, mainly in young soralia; *soredia* finely granulose, greyish to more often yellowish; *apothecia* not recorded in the Czech material, but according to Brodo (1984) are sessile to slightly constricted at base, 0.5–1.0 mm in diam.; *discs* reddish-brown; *margin* smooth, later sorediate.
Epihymenium *glabrata*-type; *amphithecium* *allophana/campestris*-type; *cortex* indistinctly delimited from the medulla, c. 20 µm laterally, (35–)47–85 µm at base; *ascospores* 10.0–14.0(–15.5) × 5.5–8.0 µm (Brodo 1984).

Chemistry: Three Czech samples contained only atranorin (n = 5). The terpenoid *impudens*-unknown and trace of fatty acid reported by Tønsberg (1992) and both detected also in the type material, has only been detected in one collection from the Czech Republic (JM 5071). Another specimen (JM 4736) contained traces of 2 or 3 unknown terpenoids (possibly from bark, but one of them could be *impudens*-unknown in a very low concentration). The higher concentration of *impudens*-unknown is very probably situated in apothecia and their primordia. Norstictic acid is occasionally present in trace amounts in European material (including the holotype). It is not clear if this substance is only a contaminant from associated lichens or the minor product of *L. impudens*. No. of tested specimens = 5.

Ecology: *L. impudens* is ecologically similar to *L. allophana*. It prefers open landscape and light natural deciduous forests, and occurs on slightly acid to subneutral bark. In the Czech Republic it was collected on *Acer platanoides*, *A. pseudoplatanus*, *Fraxinus excelsior*, *Juglans regia* and *Populus* sp. *L. impudens* is intolerant of eutrophicated sites and areas with a strong impact of acid rain. According to Poelt & Vězda (1981) it prefers mountain regions.

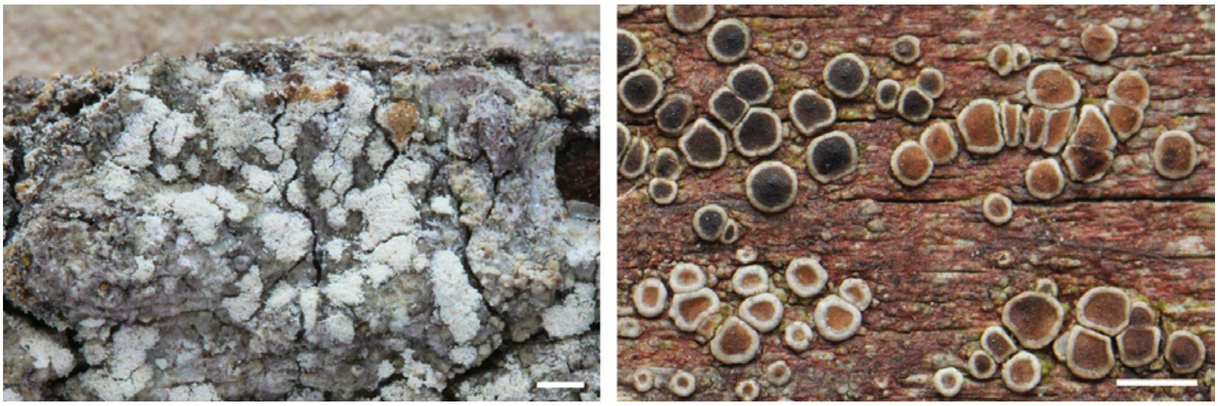

FIG. 8. Habitus of selected species. A, *Lecanora impudens* and B, *L. pulicaris*. Scales = 1 mm.

Distribution: It is known from only five localities in the Czech Republic, four of which are situated in the Šumava Mts. Historical specimens of *L. impudens* reported by Erichsen (1936, 1940) as *Pertusaria maculata* belong to different species (*Biatora chrysantha*, *Buellia griseovirens* and *Pertusaria pupillaris*). *L. impudens* seems to be a rare taxon in the Czech Republic, but is very probably overlooked or misidentified.

Remarks: *L. impudens* is easily confused with sterile *L. allophana* f. *sorediata*. Several authors (e.g. Poelt & Vězda 1981, Clauzade & Roux 1985, Schreiner & Hafellner 1992, Wirth 1995) regarded both species as identical. Here, based on chemistry, both taxa have been distinguished. Brodo (1984) separated them on the basis of soredia size and nature of soralia. Here, no differences in the morphology of thallus and soralia in European material have been found. The chemotypes with only atranorin seem to be very problematic; theoretically, they can belong to *L. allophana*, which very rarely contains no terpenoids according to TLC or the terpenoids are produced in very low concentrations.
No. of specimens examined = 5.

Selected specimens examined. **Southern Bohemia:** Šumava National Park, Nová Pec, virgin spruce-beech forest on Hraničník Mt., 48°45'02''N, 13°54'43''E, 1200 m, *Acer pseudoplatanus*, 2012, J. Malíček *et al.* 4736 (herb. JM); Šumava Mts, Bližná, along road at E border of village, 48°43'17''N, 14°05'48''E, 760 m, *Fraxinus excelsior*, 2012, J. Malíček 5071 (herb. JM); Šumava Mts, Želnava, a scree-forest c. 1.5 km NE of village, 48°49'06"N, 13°59'13"E, 945 m, *Acer platanoides*, 2010, J. Malíček & Z. Palice 13581 (PRA); Šumava Mts, Kvilda, at road-side direction to Horská Kvilda, 49°02' N, 13°35' E, 1065–1070 m, *Populus* sp., 2003, Z.

Palice 8179 (PRA); Jindřichův Hradec, Fabián, "Lesovna v Dubovnici", 49°02'N, 14°58'50''E, 540 m, *Juglans*, 2002, M. Kukwa & Z. Palice 6800 (PRA).

Lecanora pulicaris (Pers.) Ach.

Syn. meth. lich., p. 336 (1814); *Patellaria pulicaris* Pers., *Ann. Wetter. Gesellsch. Ges. Naturk.* **2**: 13 (1811) [1810]; type: Hercynia [Germany, Harz] (L – holotype?).
Lecanora chlarona (Ach.) Nyl., *Flora* **55**: 250 (1872).
Lecanora coilocarpa (Ach.) Nyl., in Norrlin, *Not. Sällsk. Fauna et Fl. Fenn. Förh.* **13**: 330 (1873) [1871–1874]. *Lecanora pinastri* (Schaer.) H. Magn., *Meddn Göteb. Bot. Trädg.* **7**: 82 (1932).

(Figs 6H, 8B)

Thallus mostly thin and smooth, rarely thick and verrucose; *apothecia* sessile or with slightly constricted bases; 0.4–1.2 mm in diam.; *discs* pale brown to black; *margin* smooth, rarely coarse, usually thin.
Epihymenium pulicaris-type, reddish-brown, in dark coloured discs occasionally with olive-black pigment, numerous fine granules dispersed mostly between paraphyses in upper part of the hymenium; *amphithecium pulicaris*-type, especially in poorly developed apothecia crystals are sparse or absent; *cortex* 15–25 µm at margin, 25–45 µm at base; *ascospores* 11.0–15.0 × 6.5–10.0 µm.

Chemistry: Fumarprotocetraric acid is present in 68% of the specimens (tested by Pd+ red spot reaction). In case of lower concentrations, the spot reaction is yellow-orange. In 15% of specimens no Pd-reaction was observed. The remaining specimens (17%) were mixed populations of both chemotypes. According to Brodo (1984), fumarprotocetraric acid is present in all specimens, but only in low concentrations. However, preliminary HPLC results show a complete absence of this substance in selected samples, as also noted by Lumbsch & Feige (1994). However, many publications and determination keys (e.g. Ibáñez & Burgaz 1998, Edwards *et al*. 2009) present this lichen metabolite as constant in all specimens. The reason(s) for the presence or absence of fumarprotocetraric acid are very interesting. Surely, it does not depend on ecological conditions and distributional patterns, since thalli of both chemotypes are commonly intermixed on one piece of bark. The most probable reason is genetic differences or the presence of a closely related chemical compound impossible to detect by TLC. In 58% of specimens (n = 60), roccellic acid has been found, mostly in samples without fumarprotocetraric acid. As a rare minor substance, confumarprotocetraric acid was detected in two specimens.

Ecology: The ecological amplitude of *L. pulicaris* is very wide. Primarily it is an acidophilous species, but it frequently grows on slightly acid, or more rarely on subneutral, bark especially in areas influenced by acid rain. In regions with no or minimal impact of substrate acidification, it prefers *Picea abies*, *Pinus sylvestris*, *Fagus sylvatica* and *Sorbus aucuparia*. In the northern part of the Czech Republic, it is common on phorophytes such as *Fraxinus excelsior*, *Acer platanoides* and *A. pseudoplatanus*. It avoids strongly eutrophicated and dusty sites. *L. pulicaris* is the most frequent Czech member of the *L. subfusca* group growing on wood. On one occasion it was collected from serpentinite rock. This taxon occurs in open landscapes as well as woodlands from the lowlands to the alpine belt, but its distribution is centred in mountainous areas.

Distribution: It is the most frequent member of the *L. subfusca* group, being distributed all over the country, especially in the northern part. *L. pulicaris* is relatively rare in warm and lowland areas.

Remarks: *L. pulicaris* is an extremely variable taxon, making identification difficult. The presence of fumarprotocetraric acid is unique for this species, and it is the only Czech species with fine epihymenial granules insoluble in HNO_3. Additionally, the thin thallus seems to be a distinctive character. The boreal species, *L. circumborealis*, differs in the markedly thickened amphithecial cortex, which reaches 22–38 µm at the margin and 35–65 (90) µm at the base, and has larger ascospores (13.0–17.5 × 8.0–11.0 µm) with thicker walls, and usually dark coloured discs (Brodo 1984). The similar *L. hybocarpa* reported from Western Europe (Ryan *et al.* 2004) has a thicker crenulate apothecial margin and usually pinkish-brown discs. The Western European *L. sinuosa* resembles an extreme form of *L. pulicaris* or *L. hybocarpa*, but differs from *L. pulicaris* in its thick verrucose thallus, very thick, flexuose, coarse to crenulate apothecial margin, which is distinctly elevated above pink-brown discs, and, according to Herk & Aptroot (1999), also in the presence of gangaleoidin in some collections.
No. of specimens examined = 367.

Key to corticolous species of the *Lecanora subfusca* in the Czech Republic

1a. Thallus sorediate **2**
1b. Thallus without soralia **4**
2a. Thallus thick, verrucose, soralia large, 0.5–1.0 mm in diam., rounded, flat to convex, indistinctly delimited; contains fatty acid(s) as major compounds .... ***L. caesiosora***
2b. Thallus thin to medium thick, soralia smaller, 0.3–0.6(–1.0) mm, concave to slightly convex, delimited by thin thalline rim or later confluent; terpenoids as major compounds or without lichen substances **3**
3a. Terpenoids *allophana*-uknowns present; apothecia frequently developed, larger then 1.0 mm, ascospores 14.0–20.0 × 8.0–11.0 µm .... ***L. allophana* f. *sorediata***
3b. Terpenoid *impudens*-unknown present or containing atranorin alone; thallus very rarely with apothecia, ascospores 10.0–14.0 × 5.5–8.0 µm .... ***L. impudens***
4a. Apothecial margin Pd+ orange to red **5**
4b. Apothecial margin Pd– **6**
5a. Apothecial margin smooth, apothecia sessile, epihymenium of *pulicaris*-type, Pd– in section, with fumarprotocetraric acid; widely distributed species .... ***L. pulicaris***
5b. Apothecial margin strongly crenulate, young apothecia immersed in thallus, epihymenium of *chlarotera*-type, Pd+ red in section, with pannarin; very rare species of light forest in humid areas .... ***L. cinereofusca***
6a. Amphithecium with small crystals (*allophana* or *campestris*-type), thallus with specific terpenoids **7**
6b. Amphithecium with large crystals (*pulicaris*-type), terpenoids usually absent **9**
7a. Apothecia large, 1.0–2.0 mm in diam., constricted at base, margin relatively thick, ± flexuose, ascospores 14–20 × 8–11 µm, terpenoids *allophana*-unknowns present .... ***L. allophana***
7b. Apothecia 0.4–1.2 mm in diam., sessile or with slightly constricted base, margin usually thin, ascospores 11–15 × 6–9 µm, terpenoids *allophana*-unknowns absent... **8**
8a. Apothecia 0.4–0.8 mm in diam.; terpenoids *glabrata*-unknowns present or rarely with *campestris*-unknowns; woodland species of smooth acid bark .... ***L. glabrata***

8b. Apothecia 0.5–1.2 mm in diam.; terpenoids *grantii*-unknowns present; in Central Europe, a very rare lichen preferring an open landscape and nutrient-rich bark ***L. horiza***

9a. Epihymenial granules absent, pigment orange to orange-red, in KOH reddish-brown, apothecial margin slightly crenulate; gangaleoidin usually present........... ***L. argentata***

9b. Epihymenial granules present, epihymenium red-brown to brown, pigment and granules soluble in KOH... **10**

10a. Epihymenium red-brown, with fine granules dispersed between paraphyses (*pulicaris*-type), granules insoluble in HNO_3, apothecial margin usually smooth, thallus mostly thin; gangaleoidin absent... ***L. pulicaris***

10b. Epihymenium with coarse granules on paraphyses tips (*chlarotera*-type), granules slowly soluble in concentrated HNO_3, apothecial margin at least slightly crenulate, thallus medium thick; gangaleoidin absent or present.. **11**

11a. Apothecia immersed when young, discs red-tinged, margin distinctly crenulate, epihymenium red to reddish-brown, Pd+ red in section, epihymenial granules usually sparse ....***L. cinereofusca***

11b. Apothecia sessile, discs pale brown or pinkish-brown, margin slightly crenulate, epihymenium brown due to the layer of granules, Pd–; the substance *chlarotera*-unknown always present.. ***L. chlarotera***

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Corticolous sorediate *Lecanora* species (Lecanoraceae, Ascomycota) containing atranorin in Europe

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Abstract: Sixteen sorediate epiphytic species with atranorin from Europe are reported here. *Lecanora substerilis* is described as a new species from beech forests in Slovakia, Romania and Ukraine; it belongs to the *L. subfusca* group in its strict sense and produces atranorin and fatty acid(s). A new yellow chemotype of *L. barkmaniana* containing pulvinic acid derivatives is recognized from Austria. Morphological, ecological and chemical variation in *L. exspersa, L. farinaria* and *L. variolascens* is discussed in detail; other eleven species are shortly commented. Evaluation of the type material and molecular data indicate that the predominantly saxicolous *L. caesiosora* is a sorediate form of *L. cenisia*. Molecular data confirmed the identities of sorediate forms of *L. albella* and *L. allophana* that are conspecific with their fertile counterparts. New Central European localities are listed for rare *L. exspersa*, *L. mughosphagneti*, *L. norvegica* and *L. variolascens*. Positions in ITS and mtSSU phylogenies are outlined for most species. Identification keys to fertile as well as sterile populations are provided.

Key words: epiphytic lichens, *Lecanora subfusca* group, *Lecanora substerilis*, old-growth beech forests, pulvinic acid.

Introduction

Members of the genus *Lecanora*, as currently recognized, are characterized by mostly lecanorine apothecia and a crustose or rarely placodioid thallus. Sexual reproduction predominates, but vegetative reproduction by soredia is also quite common. Sorediate European species usually have a crustose thallus; leprose (e.g. *L. expallens*, *L. rouxii*) and placodioid (only in saxicolous *L. lisbonensis* and *L. lojkaeana*) growth forms are rare. Soralia vary from small delimited ones (e.g. *L. exspersa*, *L. impudens*) to those covering almost the entire thallus (e.g. *L. barkmaniana*, *L. thysanophora*). It is difficult to identify many predominantly sterile species and thus chemotaxonomic methods, mainly spot tests or thin layer chromatography, are necessary for the correct identification (e.g. Brodo et al. 1994, Malíček 2014, Zduńczyk & Kukwa 2014).

In this study, we focused on sorediate taxa occurring on tree bark or wood and containing atranorin or chloratranorin as a major secondary metabolite. Some sterile specimens cannot be unambiguously identified without DNA sequence data owing to the large within-species variabilities and a limited amount of phenotypic characters. In contrast, our sequence data of mtSSU and ITS loci did not distinguish some closely related species that we still regard as "good species" with respect to their differences in anatomical, chemical and ecological characters.

We collected several unidentifiable sorediate lichen crusts in the last years, during our research of forest lichen diversity in Central Europe. Some of the unidentified specimens could belong to new taxa of *Lecanora* or to new chemotypes (e.g. with gangaleoidin) of already known species. One crust, prooved to be *Lecanora* by the DNA sequence data, was distinct and collected at more localities and it is described here as new. Five other taxa are treated in detail, the others are shortly commented. We provide identification keys (for specimens with apothecia and for sterile specimens) to all sixteen species known from Europe. Generally, this group of lichens is taxonomically very difficult and detailed TLC and DNA analyses are recommended for the correct identification.

Material and methods

This study is based on material collected by the authors and deposited either in private or public herbaria (FB – hb. F. Berger; JM – hb. J. Malíček; PRA). In addition, other specimens, including the type material, were studied in B, BG, BM, BRA, E (collections of B. J. Coppins), GZU, H, L, M, PRA (collections of Z. Palice and J. Vondrák), PRA-V, S, SZU and UPS,. Type material of *L. farinaria* and the *L. inversa* was examined only via Jstor Global Plants.

Anatomical and chemical examination

Microscopic descriptions are based on hand-cut sections mounted in water. The solubility of epihymenial crystals was studied in 50% HNO_3. The amphithecium and apothecial cortex were observed in KOH. Crystals and granules in apothecia were observed in polarized light (POL). For the terminology of anatomical characters, the work of Brodo (1984) was followed. Thin-layer chromatography (TLC), with a few minor modifications, follows the methods of Orange *et al.* (2010). Lichen compounds were applied on a set of three glass plates and placed into A, B' and C solvents. The distance between starting and finishing lines was c. 100 mm. Two or three drops (according to the quantity of tested material) of acetone were added to each test tube. Fatty acids were detected by dipping each of these plates into water tanks. Chloratranorin was not distinguished from atranorin; their mutual presence is constant in all involved species, but we do not mention it again in species descriptions.

DNA extraction, amplification and sequencing

At the beginning, the simple NaOH extraction (Werner *et al.* 2002) was used for DNA isolations. We can recommend this method for quick isolations of non-problematic loci, e.g. for nrITS and mtSSU regions in some richly fertile taxa (*L. argentata*, *L. chlarotera*). Then, the Invisorb Spin Plant Mini Kit (Invitek) and CTAB protocol (Cubero *et al.* 1999) were used with better results. The fungal nuclear ITS region and mitochondrial SSU were amplified with the following primers: ITS1F (Gardes & Bruns 1993) and ITS4 (White *et al.* 1990), mrSSU1, mrSSU2 and mrSSU3R (Zoller *et al.* 1999). We tested also nuclear IGS, Mcm7, LSU, SSU and protein-coding β-tubulin, RPB2 and TEF; they were used mainly in problematic sterile samples where no or only one-locus data were avaiable. However, the amplification was unsuccessful in almost all cases.

PCR reactions of nrITS and mtSSU were prepared for a 20 µl final volume containing 14 µl double-distilled water, 4 µl MyTaq polymerase reaction buffer, 0.2 µl MyTaq DNA polymerase, 0.4 µl of each of the 25 mM primers and 1 µl of the sample. Amplifications of both loci consisted of an initial 1 min denaturation at 95 °C, followed by 35 cycles of 1 min at 95 °C, 1 min at 55–56 °C, 1 min at 72 °C, and a final extension of 7 min at 72 °C. The PCR products were quantified on a 0.8% agarose gel stained with ethidium bromide and cleaned with GenElute PCR Clean-Up Kit (Sigma), according to the manufacturer's protocols, or with the sodium acetate/ethanol purification method. In total 22 new nuclear ITS and 52 mtSSU sequences were generated (Table 1).

Unfortunately, we were unable to get sequences from five species. The reasons are the lack of fresh material (*L. viridissima*, epiphytic *L. cenisia* f. *soredians*) and difficulties with gene amplification (*L. jamesii*, *L. mughosphagneti*, *L. norvegica*). The sequence acquiring of many sterile species was very problematic and often with very low success. For example the ITS region from *L. impudens, L. thysanophora* and *L. allophana* was unsuccessfully amplified in most attempts, despite of employing various troubleshootings (touch-down PCR, nested PCR, tunning PCR settings, application of specific primers etc.). We also had to use only short mtSSU region (SSU2 × SSU3R) of c. 400 BP in many cases because of higher efficiency than for the long one (SSU1 × SSU3R) of c. 700 BP. Some species are only represented by one or two sequences (*L. allophana* f. *sorediata*, *L. farinaria*) due to a limited amount of fresh collections and the amplification problems discussed above.

Alignment and phylogenetic analysis

Sequences were edited in BioEdit 7.2.5 free software (Hall 1999) and then aligned by the on-line application MAFFT version 7 (Katoh & Standley 2013) with L-INS-i method (Katoh et al. 2005). The alignments were manually revised. The final ITS alignment contained 639 positions and 41 sequences; the mtSSU alignment had 894 positions and 63 sequences. Gaps were coded in SeqState by simple coding (Simmons & Ochoterena 2000). Molecular phylogenies were reconstructed by Bayesian inference as incorporated inMrBayes 3.1.2 (Huelsenbeck & Ronquist 2001; Ronquist & Huelsenbeck 2003). The general time reversible model using a gamma shaped distribution and proportion of invariant sites (GTR+G+I) was suggested as the best DNA substitution model for both loci. This was evaluated with the help of the program Modeltest (Posada & Crandall 1998). Each analysis was performed using a run with four MCMC chains. Trees were sampled after every 500th generation. The analyses were stopped when the average standard deviation of the split frequencies between the simultaneous chains was below 0.01. To eliminate trees sampled before reaching apparent stationarity, the first 25% of entries were discarded as burn-in and the rest were used to compute majority-rule consensus, where the relative occurrences of nodes are identified with the Bayesian posterior probabilities (Figs 1–2). Final trees were modified in Adobe Illustrator CS3.

Taxon	**Source - Specimen**	**ITS**	**mtSSU**
Lecanora albella	Austria, Niederösterreich, *J. Malíček* 5855 (hb. JM)	**JM 368**	n/a
Lecanora albella	Austria, Styria, *J. Hafellner* 51518 (GZU)	AY541241	n/a
Lecanora albella	Czech Republic, Šumava Mts, *J. Malíček* 7336 (hb. JM)	**JM 367**	**JM 367**
Lecanora albella f. *sorediata*	Austria, Salzburg, *F. Berger* 29362 (hb. FB)	**JM 355**	**JM 355**
Lecanora alboflavida	Great Britain, Scotland, *B. J. Coppins* s.n. (E)	**JM 356**	**JM 356**
Lecanora alboflavida	Great Britain, Scotland, *B. J. Coppins* s.n. (E)	n/a	**JM 357**
Lecanora alboflavida	Great Britain, Scotland, *B. J. Coppins* s.n. (E)	n/a	**JM 358**
Lecanora allophana	Albania, Valbona, *J. Malíček* 4226 (hb. JM)	n/a	**JM 183**
Lecanora allophana	Austria, Styria, *U. Arup* L98005 (hb. Arup)	AF159939	n/a
Lecanora allophana	Germany, Oberammergau, *J. Malíček* 7009 (hb. JM)	**KT630248**	**KT630256**

Taxon	**Source - Specimen**	**ITS**	**mtSSU**
Lecanora allophana	Slovakia, Muránska planina, *J. Malíček* 3775 (hb. JM)	n/a	**JM 182**
Lecanora allophana f. *sorediata*	Albania, Drenove, *J. Malíček* 4198 (hb. JM)	n/a	**JM 176**
Lecanora allophana f. *sorediata*	Germany, Saldenburg, *R. Cezanne & M. Eichler* 8311 (M)	n/a	**JM 348**
Lecanora argentata	Czech Republic, Pohorská Ves, *J. Malíček* 1963 (hb. JM)	**KT630245**	**KT630264**
Lecanora argopholis	Austria, *U. Arup* L97504 (LD)	n/a	DQ787358
Lecanora barkmaniana	Austria, Niederranna, *F. Berger & J. Malíček* 7352 (hb. JM)	**KT630247**	**KT630257**
Lecanora barkmaniana	Austria, Niederranna, *F. Berger & J. Malíček* 7353 (hb. JM)	**KT630246**	**KT630258**
Lecanora barkmaniana	Czech Republic, Třeboň, *Z. Palice* 17448 (PRA)	n/a	**JM 273**
Lecanora barkmaniana	Germany, Bodensee, *R. Cezanne & M. Eichler* 7806 (M)	n/a	**JM 347**
Lecanora barkmaniana	Great Britain, Cambridgeshire, *M. Powell* (hb. JM)	n/a	**JM 271**
Lecanora barkmaniana	Netherlands, Nieuweroord, *J. Malíček* 6960 & *L. Syrovátková* (hb. JM)	n/a	**KT630259**
Lecanora bicincta	Australia, Australian Capital Territory, *U. Trinkaus* 109 (GZU)	AY541263	n/a
Lecanora campestris	Sweden, *U. Arup* (hb. Arup)	AF159930	n/a
Lecanora campestris	Sweden, *U. Arup* L97370 (hb. Arup)	n/a	DQ787362
Lecanora carpinea	Slovenia, Vojsko, *J. Prügger* 62808 (GZU)	AY398710	n/a
Lecanora carpinea	Sweden, *U. Arup* L03192 (hb. Arup)	n/a	DQ787364
Lecanora cateilea	Canada, British Columbia, *T. Goward & J. Poelt* (GZU)	AY541250	n/a
Lecanora cenisia	Austria, Steiermark, *J. Malíček* 5869 (hb. JM)	**JM 363**	**JM 363**
Lecanora cenisia	Czech Republic, Český les Mts, *J. Malíček* 5953 (hb. JM)	n/a	**JM 277**
Lecanora cenisia	Czech Republic, Hrubý Jeseník Mts, *J. Malíček* 8702 (hb. JM)	**JM 304**	**JM 304**
Lecanora cenisia	Germany, Schwarzwald Mts, *J. Malíček* 5903 (hb. JM)	n/a	**JM 364**
Lecanora cenisia	Romania, Cindrel Mts, *J. Malíček* 6714 (hb. JM)	**JM 360**	**JM 360**
Lecanora cenisia f. *soredians*	Czech Republic, Hrubý Jeseník Mts, *J. Malíček* 8703 (hb. JM)	n/a	**JM 278**
Lecanora cinereofusca	U.S.A., North Carolina, Dare Co., *J. Lendemer* 34415 (NY)	KP224470	KP224465
Lecanora exspersa	Austria, Gerlos, *J. Malíček* 5391 (hb. JM)	**KT630244**	**KT630255**
Lecanora exspersa	Slovakia, Nová Sedlica, *J. Šoun* & *J. Vondrák* 12339 (PRA)	**JM 214**	**JM 214**
Lecanora exspersa	Ukraine, Uholka, J. Malíček 8235 (hb. JM)	**JM 248**	**JM 248**
Lecanora exspersa	Ukraine, Uholka, *J. Vondrák* 14118 (PRA)	**JV 586**	n/a
Lecanora farinaria	Norway, Selje, *T. Tønsberg & Z. Palice* 20106 (PRA)	**JM 321**	**JM 321**
Lecanora farinaria	Norway, Selje, *T. Tønsberg* 46170 & *Z. Palice* (BG)	**JM 324**	**JM 324**
Lecanora farinaria	Scotland, Island of Islay, *M. Powell* 1777 (hb. JM)	n/a	**KT630261**
Lecanora glabrata	Sweden, Skåne, *U. Arup* L011003 (LD)	n/a	DQ787360
Lecanora hybocarpa	Spain, Guadalajara, *H.T. Lumbsch* s.n. (F)	EF105412	n/a
Lecanora hybocarpa	U.S.A., Tennessee, *F. Lutzoni et al.* 03.07.04-2 (DUKE)	n/a	DQ912273
Lecanora chlarotera	Germany, Hinterzarten, *J. Malíček* 5890 (hb. JM)	n/a	**KT630263**
Lecanora chlarotera	U.K., Scotland, *C.J. Ellis & B.J. Coppins L642: 25* (E)	FR799206	n/a
Lecanora impudens	Austria, Steiermark, *J. Hafellner* 76555 (GZU)	n/a	**JM 199**
Lecanora impudens	Austria, Tirol, *J. Malíček* 7005 (hb. JM)	n/a	**JM 201**
Lecanora impudens	Czech Republic, Šumava Mts, *J. Malíček* 5071 (hb. JM)	n/a	**JM 177**
Lecanora impudens	Romania, Fagaras Mts, *J. Malíček* 6618 (hb. JM)	n/a	**JM 175**
Lecanora impudens	Serbia, Suva Planina Mts, *J. Malíček* 7757 (hb. JM)	n/a	**JM 217**
Lecanora impudens	Slovakia, Muránska planina, *J. Malíček* 2413 (hb. JM)	n/a	**JM 181**
Lecanora intumescens	Austria, Styria, *J. Hafellner* 51153 (GZU)	AY541254	n/a
Lecanora intumescens	Czech Republic, Hrubý Jeseník Mts, *J. Malíček* 8480 (hb. JM)	**JM 261**	**JM 261**
Lecanora intumescens	Norway, Hordaland, *S. Ekman* 3162 (BG)	n/a	AY300892

Taxon	Source - Specimen	ITS	mtSSU
Lecanora intumescens	Ukraine, Uholka, *J. Malíček* 8203 (hb. JM)	**JM 259**	**JM 259**
Lecanora leptyrodes	Slovenia, Trnovski gozd, *J. Prügger* 65224 (GZU)	AY541255	n/a
Lecanora paramerae	Spain, Guadalajara, *H.T. Lumbsch* s.n. (F)	EF105413	n/a
Lecanora pulicaris	(BCC-Lich 13258)	AF101274	n/a
Lecanora pulicaris	Slovakia, Nová Sedlica, J. Malíček & J. Vondrák 6486 (hb. JM)	n/a	**KT630262**
Lecanora pulicaris	Ukraine, Uholka, J. Vondrák s.n. (PRA)	n/a	**JM 305**
Lecanora rupicola subsp. *sulphurata*	Turkey, prov. Izmir, *H.T. Lumbsch* s.n. (GZU)	AY541260	n/a
Lecanora sorediomarginata	Portugal	GU480121	n/a
Lecanora sorediomarginata	Portugal	GU480122	n/a
Lecanora subcarnea	Sweden, Västergötland, *U. Arup* L97580 (hb. Arup)	AY541267	n/a
Lecanora substerilis	Romania, Paring Mts, *J. Malíček* 6690 (hb. JM)	n/a	**KT630252**
Lecanora substerilis	Slovakia, Stužica, *J. Vondrák* 12294 (CBFS)	**KT630243**	**KT630254**
Lecanora substerilis	Slovakia, Stužica, *J. Vondrák* 12387 (CBFS)	n/a	**KT630253**
Lecanora substerilis	Ukraine, Uholka, *J. Malíček* 8111 (hb. JM)	n/a	**JM 251**
Lecanora substerilis	Ukraine, Uholka, *J. Malíček* 8162 (hb. JM)	n/a	**JM 252**
Lecanora substerilis	Ukraine, Uholka, *J. Malíček* 8209 (hb. JM)	**JM 250**	**JM 250**
Lecanora thysanophora	Czech Republic, Šumava Mts, *J. Malíček* 8656 (hb. JM)	n/a	**JM 262**
Lecanora thysanophora	Germany, Bayern, *J. Malíček* 7020 (hb. JM)	n/a	**JM 258**
Lecanora thysanophora	U.S.A., Pennsylvania, *J. Lendemer* 16933 (NY)	n/a	KC184024
Lecanora thysanophora	Ukraine, Uholka, *J. Malíček* 8272 (hb. JM)	n/a	**JM 260**
Lecanora variolascens	Austria, Ybbstaler Alpen Mts, *J. Malíček* 8422 (hb. JM)	**JM 257**	**JM 257**
Lecanora variolascens	Slovakia, Muránska planina, *J. Malíček* 3100 (hb. JM)	n/a	**JM 256**
Lecanora variolascens	Slovakia, Muránska planina, *A. Guttová, J. Halda & Z. Palice 11380* (PRA)	n/a	**KT630260**
Protoparmelia badia	Spain, Guadalajara, H.T. Lumbsch s.n. (F)	n/a	EF105420
Protoparmelia badia	U.S.A., Montana, *T. Spribille* s.n. (GZU)	JN009728	n/a
Protoparmelia ochrococca	USA, Oregon, *B. McCune* 31673 (OSU)	KP822293	KP822489

TABLE 1. GenBank accession numbers and voucher information for sequenced specimens used in this paper. Sequences in bold are newly produced.

Results and Discussion

Phylogeny

Nuclear ITS and mitochondrial SSU trees are presented separately because the gapped sequence dataset (see Table 1). As expected, ITS region was more variable than mtSSU. Almost all species were represented by highly supported clades, but phylogeny at higher taxonomical levels remained unresolved in both loci.

According to ITS, members of the *Lecanora subfusca* group in its strict sense (Brodo 1984) were placed in three clades: 1) a group with small amphithecial crystals and terpenoids represented by *L. allophana* and *L. campestris*; 2) with large amphithecial crystals and fatty acids or gangaleoidin chemosyndrome and 3) the clade of *L. farinaria* (Fig. 1).

MtSSU phylogeny indicated a monophyly of the *L. subfusca* group (Fig. 2). Species with small and large amphithecial crystals were again distinguished; *L. farinaria* and *L. pulicaris* formed isolated clades. Due to a lower variability of this region, some closely related species were not separated from each other (e.g. *L. cenisia* and *L. exspersa*) although they differ well in many characters.

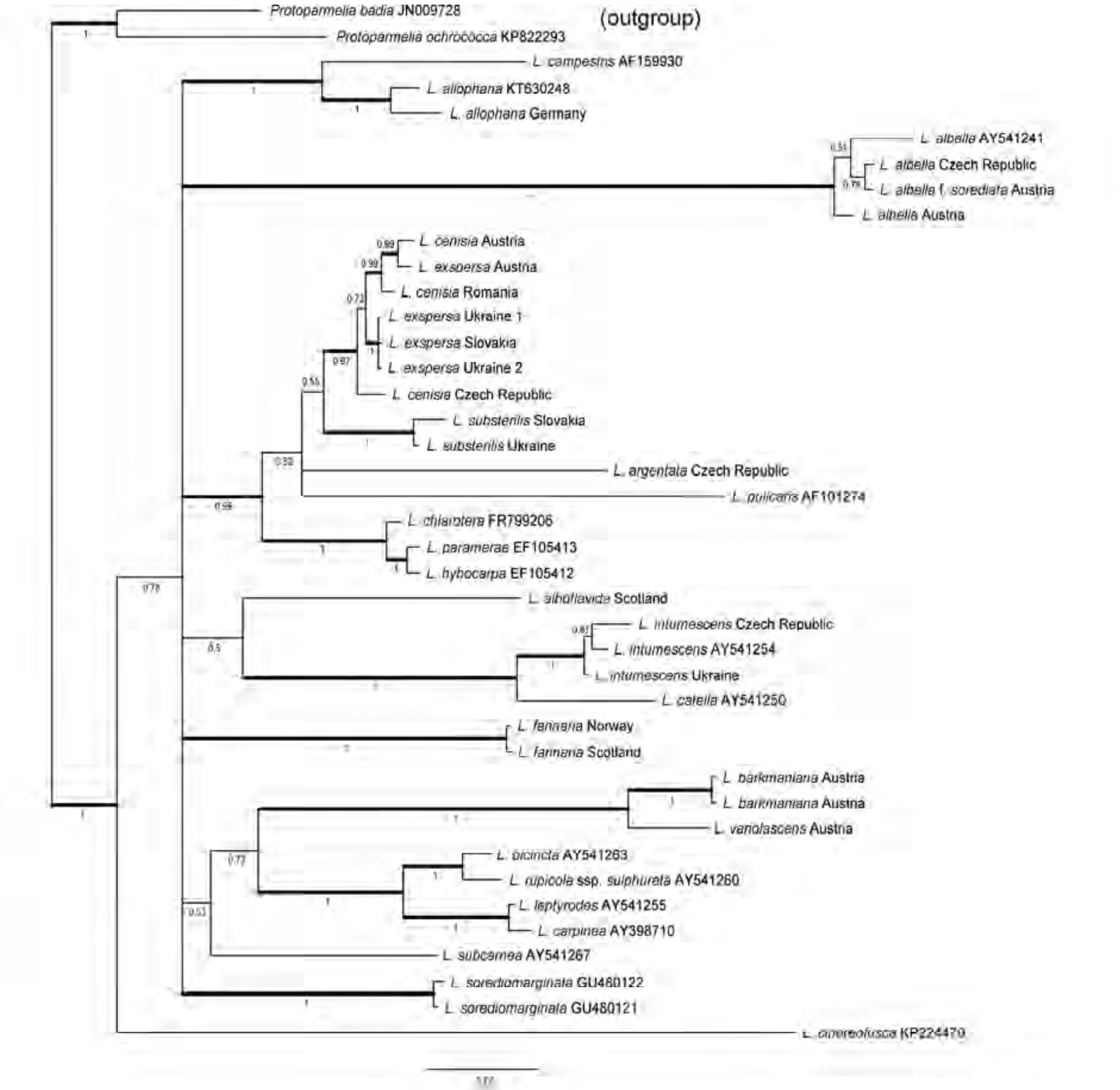

FIG. 1. Bayesian phylogenetic reconstruction (75% majority-rule consensus) of the nrITS showing positions of sorediate epiphytic *Lecanora* specimens containing atranorin. Branches with >0.95 Bayesian posterior probability values are indicated by thicker lines.

Species

Lecanora albella f. sorediata (Schaer.) H. Olivier

Expo. Syst. Descr. Lich. Ouest Fr. **1**: 277 (1897); type: not seen.
Lecanora pallida f. *sorediata* Schaer., *Enum. critic. lich. europ. (Bern)*: 78 (1850).

L. albella is characterized by strongly pruinose apothecia and the presence of protocetraric acid in apothecia giving a distinct Pd+ red reaction. The sorediate form is characterized by greenish, rounded, flat to convex, well delimited soralia of c. 0.5–2.0 mm in diam. and smooth and thin thallus. Soralia and thallus contain roccellic acid. In the ITS and mtSSU phylogenetic reconstructions, sorediate and non-sorediate populations are closely related and form together supported clades distant from all other included species (Figs 1 & 2). The species prefers old-growth beech forests, but it is occassionaly found on other phorophytes and in other forest types.

Specimens examined: **Austria:** *Salzburg*: Obersulzbachtal, 47°11'41''N, 12°15'43''E, alt. 1300 m, *Alnus*, 2015, *F. Berger* 29362 (hb. Berger).

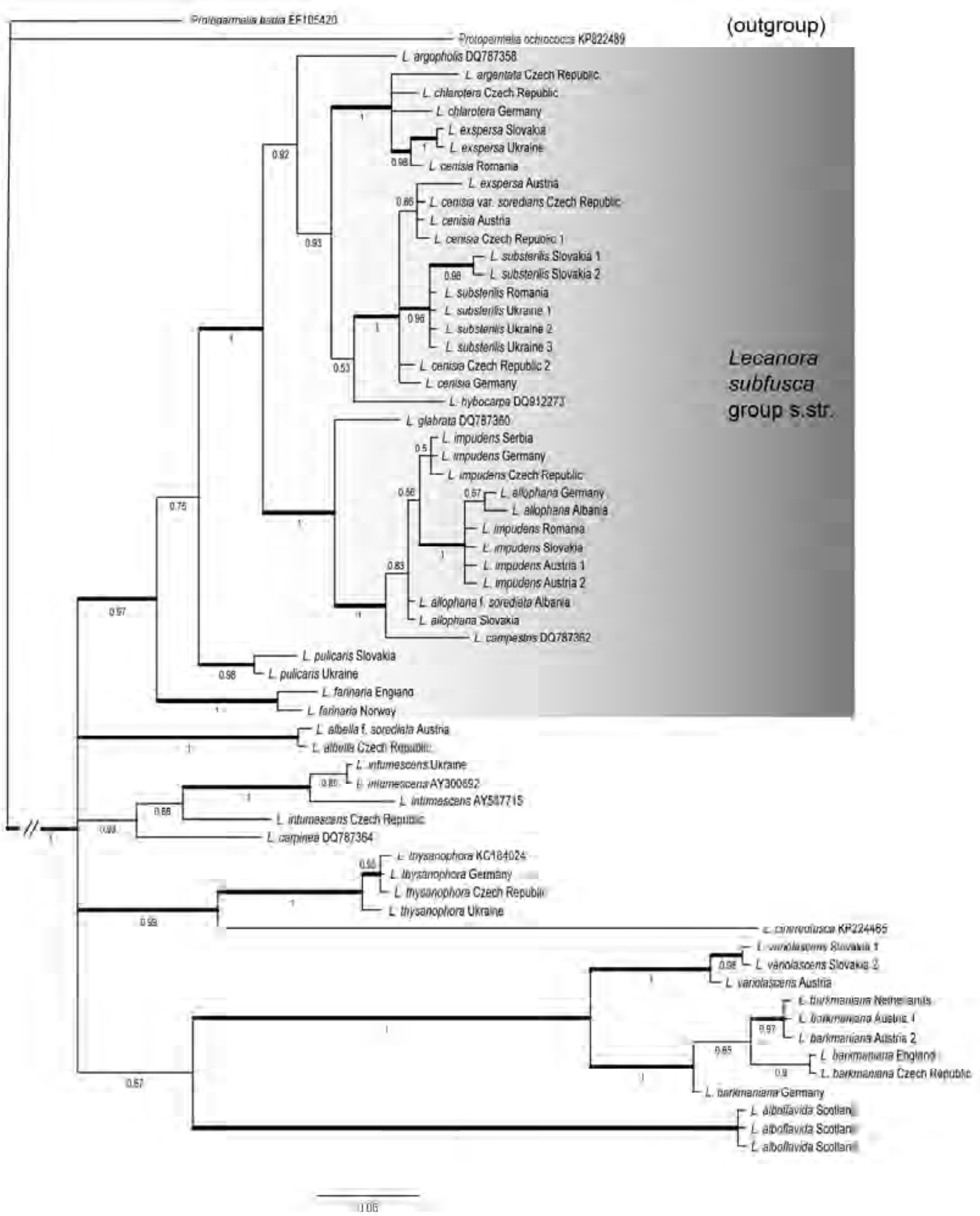

FIG. 2. Bayesian phylogenetic reconstruction (75% majority-rule consensus) of the mitochondrial SSU showing positions of sorediate epiphytic *Lecanora* specimens containing atranorin. Branches with >0.95 Bayesian posterior probability values are indicated by thicker lines.

Lecanora alboflavida Taylor

Fl. Hibern. **2**: 260 (1836); type: not seen.
Lecanora inversa Nyl., *Flora, Regensburg* **62**: 361 (1879), type: [Ireland], on furze [*Ulex europaeus*], Finnihy River, Co. Kerry, [*Taylor*], (BM975547 – lectotype?).
Ochrolechia inversa (Nyl.) J.R. Laundon, *Lichenologist* **2**: 130 (1963).

The species is characterized by the thick, smooth to more often pustulate thallus and rounded soralia which tend to be confluent later. Apothecia are rare and ascospores unknown. Based on anastomosing paraphyses, Laundon (1963) transferred the species into the genus *Ochrolechia*. It produces xanthones (arthothelin, thiophanininic acid and sometimes others). *L. alboflavida* has an isolated position among *Lecanora* species included in both trees (Figs 1 & 2). It is a very distinct taxon among the other sorediate *Lecanora* species containing atranorin due to its yellowish thallus and soralia that are UV+ as well as C+ orange. The thallus colour reflects the xanthone concentration and may vary from the grey to yellow. It can be misidentified for saxicolous *Pertusaria flavicans*, lacking atranorin, and *Lecidella subviridis* with very similar chemistry, but that species has a much thinner thallus with usually confluent and never rounded soralia.

Lecanora alboflavida is a poorly known and very rare oceanic species. It occurs on old acidic bark, rarely on slate and sandstone rocks. Most of its localities are known from the British Isles. It has been reported also from Norway, France and Macaronesia (Edwards et al. 2009), but the material have not been examined. Nevertheless, the Norwegian record is absent from the checklist of Fennoscandian lichens (http://130.238.83.220/santesson/home).

The species was described from transition rocks (Taylor 1836). According to Laundon (1963), the only one saxicolous Tyalor's specimen, i.e. the holotype, is *L. epanora* in the fact. Therefore, the right name should be *L. inversa*, which was described by Nylander (1879) based on epiphytic Taylor's material. However, we follow the concept of British authors (Edwards et al. 2009) because we haven't studied the Taylor's collections yet.

Specimens examined: **Great Britain:** *Scotland*: Kirkendbrightshire, Glen Trool, Caldons wood, 55°4'36–39''N, 4°30'40–51''E, alt. 80 m, *Betula* and *Quercus*, 2016, *B. J. Coppins* (E, dupl. hb. JM). **Ireland:** North Kerry, Cahnicaun Wood, Killarney Lakes, *Quercus*, 1982, *P. W. James* (BM); Derrycunihy, Woods above Galway's bridge, 1982, *P. W. James* (BM).

Lecanora allophana f. sorediata Vain.

Meddn Soc. Fauna Flora fenn. **3**: 103 (1878); type: not seen.

The sorediate morphotype of *L. allophana* produces delimited, white to yellowish soralia. Apothecia are frequently present as well. The sorediate form quite commonly accompanies non-sorediate populations. The presence of terpenoids *allophana*-unknowns distinguishes this species from all other European corticolous *Lecanora*. For a detailed description see Tønsberg (1992) and Malíček (2014).

The species strongly resembles *L. impudens*, which is not recognized from *L. allophana* in the mtSSU phylogeny (Fig. 2); an amplification of nrITS was unsuccessful. However, both taxa differ in secondary metabolites and ascospore size and we tend to keep them at the species level at this time.

Selected specimens examined. **Austria**: *Tirol*: Heiterwang, 47°27'18''N, 10°45'32''E, alt. 980 m, 2014, *Fraxinus excelsior*, *J. Malíček* 7005 & 7006 (hb. JM). **Albania**: *Korcë County*: Drenove National Park, Korča

[Korcë], 40°35'02''N, 20°50'43''E, alt. 1400 m, *Populus tremula*, 2011, *J. Malíček* 4198 & *F. Bouda* (hb. JM). **Germany**: *Bayern*: Allgäu, am Bannwaldsee nördl. Füssen, 800 m, *Fraxinus excelsior*, 1956, *An. & Ad. Schröppel & J. Poelt* (PRA-V 14603); Niederbayern, Burganlage oberhald von Saldenburg, alt. 560 m, Esche, 2011, *R. Cezanne* & *M. Eichler* 8311 (M). **Slovakia**: Muránská planina National Park, Cigánka Reserve, 48°45'34.8"N, 20°03'37.8"E, alt. 920–925 m, *Acer pseudoplatanus*, 2010, *J. Malíček* 3081 & *Z. Palice* 13483 et al. (hb. JM, PRA).

Lecanora barkmaniana Aptroot & Herk

As *L. barkmaneana* in *Lichenologist* **31**: 3 (1999); type: Netherlands, prov. Friesland, De Blesse, 7 km. south of Wolvega, 6°05'E, 52°50'N, young wayside *Quercus robur* tree, at the base of the trunk, *C.M. van Herk* 1996 (B – holotype, L 0064338 – isotype!).

(Figs 3A–E)

Thallus white to pale grey, matt, up to 8 cm in diam. or exceptionally covering large areas, thin to rarely strongly verrucose or pustulose (up to 0.25 mm thick), pustules frequently fissured, filled by large calcium oxalate crystals (POL+); *prothallus* absent or indistinct, whitish-grey, visible in some collections, especially from smooth bark; *photobiont* trebouxioud, cells globose to subglobose, 7–13 µm in diam.; *soralia* more or less delimited when young, later confluent or forming a continuous leprose crust covering the whole thallus, but the thallus remains still visible at least in the marginal zone; *soredia* whitish-grey with a yellow tinge, rarely greenish-yellow to golden-yellow, farinose, 25–35(–40) µm in diam. *Apothecia* rare, lecanorine, sessile, 0.5–0.9 mm in diam.; *margin* slightly to strongly crenulate or flexuose, medium thick (c. 0.1 mm), grey to rarely yellow, often partly sorediate; *discs* yellow to pale brown, matt, usually with very small and scattered pruina-like granules.

Thalline exciple with numerous photobiont cells; *amphithecium* ±paraplectenchymatous, with large crystals, often forming clusters; *cortex* indistinct; *hypothecium* colourless, yellowish in K; *hymenium* colourless, 50–75 µm high, composed of unbranched paraphyses 1.5–2.0 µm thick, conglutinated, very slightly swollen at tips, K/I-; *epihymenium* with pale brownish granules (POL-), rarely with golden-orange pigment and granules, granules at paraphyses tips, soluble or partly insoluble in K; *asci Lecanora*-type, 35–50 × 9–15 µm, 8-spored but usually less spores observed; *ascospores* simple, colourless, broadly ellipsoid to rarely subglobose, 12–15 × 8.5–10 µm. *Conidiomata* unknown.

Chemistry. Atranorin/chloratranorin and zeorin as major substances (8 specimens including the isotype analyzed by TLC). According to HPLC, atranorin is only a minor compound (Aptroot & Herk 1999). A new yellow chemotype with pulvinic acid complex is reported here from Austria (specimens marked by *). An unidentified yellow pigment (visible in A, B’, C solvents by TLC) is produced as a major compound, trace of calycin is visible in C solvent. We suppose the pigment is closely related to pulvinic acid due to its presence in tested material of *Candelariella* species together with pulvinic acid. This pulvinic acid derivative is characterized as a yellow spot (UV+ orange before heating) on TLC plates. In the B’ solvent, the spot is below the level of pulvinic acid and in the same position as norstictic acid. The common chemotype of *L. barkmaniana* sometimes accompanies the yellow form in Austria. The pulvinic acid derivatives are often unevenly distributed on the thallus and apothecia: some parts are vivid lemon yellow, others have the common tinge. Spot reactions of thallus and soralia: Pd- or Pd+ yellow (in the yellow chemotype), K+ yellow, C-, KC-, UV-.

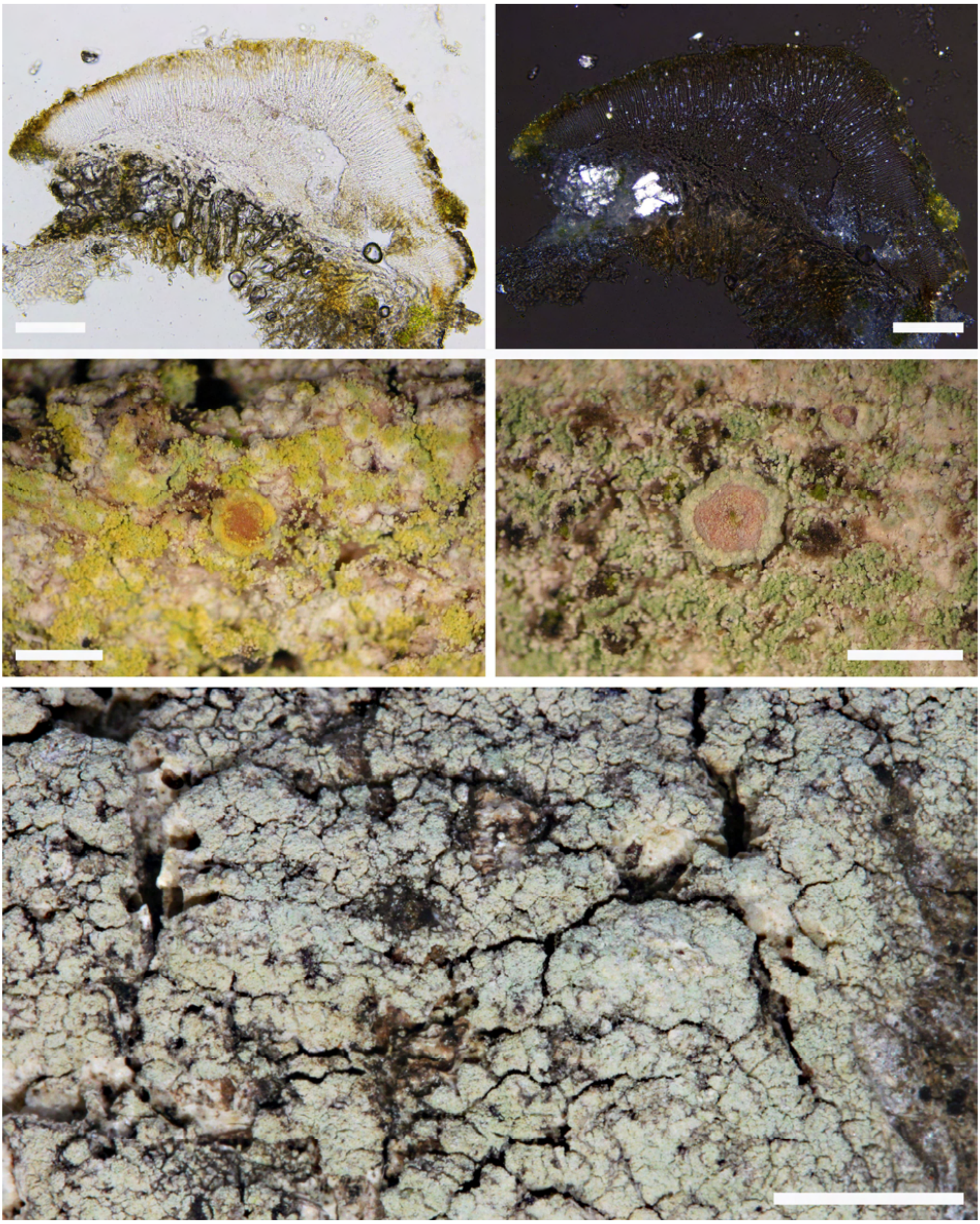

FIG. 3. Habitus of *Lecanora barkmaniana*. A, apothecial section of the chemotype with pulvinic acid derivatives; B, the same in polarized light; C, apothecium with high concentration of pulvinic acid derivatives; D, Austrian collection without the yellow pigment; E, isotype of *L. barkmaniana* (L64338). Scales A, B = 100 µm, C, D = 1 mm, E = 1 cm.

Phylogeny. Based on ITS and mtSSU sequences, *L. barkmaniana* does not belong to the *L. subfusca* group in a narrow sense as suggested by Aptroot & van Herk (1999), but forms an isolated clade with *L. variolascens* (Figs 1 & 2).

Ecology. In Western Europe, it occurs mainly on wayside deciduous trees (e.g. *Quercus robur*), usually at eutrophicated sites (Aptroot & Herk 1999). Central European localities are characterized by natural deciduous woodlands with *Quercus robur*, *Alnus glutinosa*, *Fraxinus excelsior* etc. The Austrian populations are concentrated mainly at the bottom of wind- and sun-protected river gorges; this area gets c. 1000 mm of precipitation a year and has an average annual temperature of c. 9 °C. These sites are interesting due to the occurrence of several species with suboceanic distribution (e.g. *Coniocarpon cinnabarinum* and *Micarea coppinsii*).

Distribution. The species has a subatlantic distribution; it occurs mainly in Western Europe (Great Britain, Netherlands, Germany, France etc.). Scattered localities are reported from Central Europe: Austria and the Czech Republic – new records for both countries. Surprisingly no occurrences are known from Scandinavia. A dubious record has been published from Korea (Kondratyuk *et al.* 2013). The yellow chemotype is known only from the Danube valley and some of its tributaries in Upper Austria, very close to the north-west border with Germany, in the Bayerischer Wald Foothills region.

Remarks. Despite of the species can resemble several other sorediate crusts (e.g. *Lecanora compallens*, *Lecidella elaeochroma* f. *sorediata*, *L. subviridis*), it is well characterized by the grey-white thallus, ±continuously covered by yellowish confluent soralia, and its chemistry. The yellow variety of *L. barkmaniana* is one of a few species in the genus producing pulvinic acid derivatives (see Lumbsch 1994). The morph with golden-yellow soralia resembles *Chrysothrix candelaris* or *Candelariella efflorescens* agg.

Specimens examined. **Austria:** *Upper Austria*: Schärding, Waldkirchen, Kleiner Keßlbach, 290 m, *Fraxinus*, 2004, *F. Berger* *19451 (hb. Berger); Ibid.: 48°27'51"N, 13°47'20"E, 2014, *J. Malíček* *7352 & *F. Berger* (hb. JM); Rohrbach, Neustift, valley of the river Ranna, alt. 340 m, 48°29'28''N, 13°46'52''E, *Alnus glutinosa*, 2004, *F. Berger* *19437 (hb. Berger, BG); Ibid.:, 48°28'46"N, 13°46'37"E, alt. 300 m, *J. Malíček* *7353 & *F. Berger* (hb. JM); Braunau, Salzachtal, Auwald W St. Radegund, 365 m, *Alnus glutinosa*, 2004, *F. Berger* *19718 (hb. Berger); Engelhartszell, Kronschlag, 48°28'42''N, 13°45'43''E, alt. 340 m, *Juglans regia*, 2014, *J. Malíček* 6981, 7350, 7351 & *F. Berger* (hb. JM). **Czech Republic:** *S Bohemia*: Třeboň, nature reserve Stará řeka, alluvial oak forest, 48°59'00''N, 14°50'39''E, alt. 435 m, *Quercus robur*, 2014, *Z. Palice* 17448 (PRA). **Germany:** *Bayern*: Bodensee, Weißenberg, alt. 530 m, Linde, *R. Cezanne & M. Eichler* 7806 (M). **Great Britain:** *England*: Cambridgeshire, Gamlingay Wood, *Populus tremula*, 2013, *M. Powell* (hb. JM). **Netherlands:** *Drente*: 7 km W of Diever, Vledder, *Quercus robur*, 1993, *P. v.d. Boom* 15075 (PRA-V); Hoogeveen, Nieuweroord, 52°43'28''N, 6°34'30''E, alt. 0–50 m, *Quercus robur*, *J. Malíček* 6960 & *L. Syrovátková* (hb. JM).

Lecanora cenisia f. sorediaus (Suza) Malíček comb. nov.

Lecanora cenisia var. *soredians* Suza, *Sb. Klubu Přírodovědeckého v Brně* **11**: 152 (1929); type: Moravia, Sudeti or., Jeseníky, in monte Vozka (Fuhrmannstein), ad saxa schistosa in fissis subumbrosis, 1370 m, 1928, *J. Suza* (PRM 639535! – holotype).

Lecanora caesiosora Poelt, *Denkschr. Regensb. bot. Ges.* **26**: 82 (1966) nom. nov. – *Lecanora soralifera* H. Magn., Bot. Notiser **1937**: 135 (1937); type: Magnusson: *Lich. sel. Scand. exs.* 270b, Sweden, Västergötland: Partille, northwest of Tultered, on stone fence, open situation, 1936, *A. H. Magnusson* (UPS – holotype; B!, BRA! – isotypes).

(Fig. 4A)

The sorediate form of *L. cenisia* is characterized by a thick verrucose thallus and large, flat to convex, rounded soralia. It produces roccellic acid, rarely replaced by nephrosteranic acid. For a detailed describtion see Brodo *et al.* (1994) and Malíček (2014). *L. cenisia* is predominantly a saxicolous species occurring on siliceous rocks in montane areas. The sorediate form prefers overhanging rocks. The epiphytic growth is rare and most records are from twigs of *Rhododendron* in subalpine zone (Hinteregger 1994). There, the species can be easily misidentified for *L. exspersa*.

In contrast to Brodo *et al.* (1994) and Malíček (2014), we prefer to regard *L. caesiosora* as a sorediate form of *L. cenisia*. Both "species" are morphologically and chemically identical, they share ecological preferences, apothecial anatomy and often grow together. Synonymization of *L. caesiosora* with *L. cenisia* is supported by mtSSU data (Fig. 2); sorediate form shares the same sequence as the typical *L. cenisia* co-occurring at the type locality of var. *soredians*. Nevertheless, the taxonomy of *L. caesiosora* sensu Brodo *et al.* (1994) remains still partially unclear because of its large variation. The rare chemotype with nephrosteranic acid may potentially represent a saxicolous form of *L. exspersa*, but no molecular data are available.

Epiphytic specimens examined. **Austria:** *Tirol*: Ötztaler Alpen, S von Obergurgl, Gurgler-Heide, Gaisberglift, 1950 m, *Rhododendron ferrugineum*, 1986, *E. Hinterreger* (GZU). **Czech Republic:** *Šumava Mts*: cirque of the Černé jezero lake, 49°10'35''N, 13°11'10''E, 1150 m, *Sorbus aucuparia*, 1995, *Z. Palice 232* (PRA).

Lecanora exspersa Nyl.

Flora, Regensburg **58**: 443 (1875); type: [Romania], ad ramulos abietum in regione "Aragyes" infra alpem Retyezát, com. Hunyad in Trassylvania, 1873, *Lojka* (H-NYL 27610! – holotype, M 207003! – isotype).

Lecanora coilocarpa var. *sorediata* Räsänen, *Medd. Soc. Fauna Flora fenn.* **43**: 118 (1917); type: Ob. Simo. Pahnila, huoneen semalla, [on wood], 1913 & 1915, *V. Räsänen* (H! – lectotype).

Lecanora elisa Nyl., *Flora, Regensburg* **64**: 178 (1881); type: Ad ramulos Pini Cembrae in regione "Arágyes" infra alpem Retyezát com. Hunyad in Transsylvania, 1874, *Lojka* (H-NYL 27609! – holotype, M 207005! – isotype).

Lecanora raesaenenii Gyeln. [as 'räsenii'], *Acta Faun. Fl. Univers., Ser. 2, Bot.* **1** (no. 5–6): 10 (1933).

(Figs 4B–D)

Thallus whitish-grey, thin, usually slightly pustulate to areolate-cracked, rarely ±smooth; *prothallus* absent or black when adjacent to other lichens; *photobiont*: trebouxioud, cells globose, 7–12 (–15) µm in diam.; *soralia* whitish, distinctly paler than thallus, rarely yellowish (in populations from beech forests), flat or concave when young, 0.2–0.8 mm in diam., rounded, delimited by a thalline rime which can be missing in large or old soralia, only locally confluent; *soredia* farinose, 20–50 µm in diam.

Apothecia usually absent or poorly developed, sessile or immersed when young, up to 0.5 mm in diam.; *margin* flexuose, uneven, later disappearing or discontinuous; *discs* brown to brownish-black, sometimes slightly pruinose, flat to convex.

Amphithecium with large crystals (*pulicaris*-type), but these usually absent; *cortex* indistinct or if present, up to 40 µm at base; *hypothecium* colourless; *hymenium* 40–100 µm high; *epihymenium* reddish-brown to brown, granules usually sparse to rarely almost absent, coarse, at paraphyses tips (*chlarotera*-type), soluble in HNO_3; *asci* and *ascospores* not developed in the studied material, but according to Hinteregger (1994) asci 8-spored and ascospores 7–11 × 4–6 um. Pycnidia according to Hinteregger (1994) brown to brown-grey; *conidia* filiform, straight to curved, 15–25 × 1.0–1.2 µm.

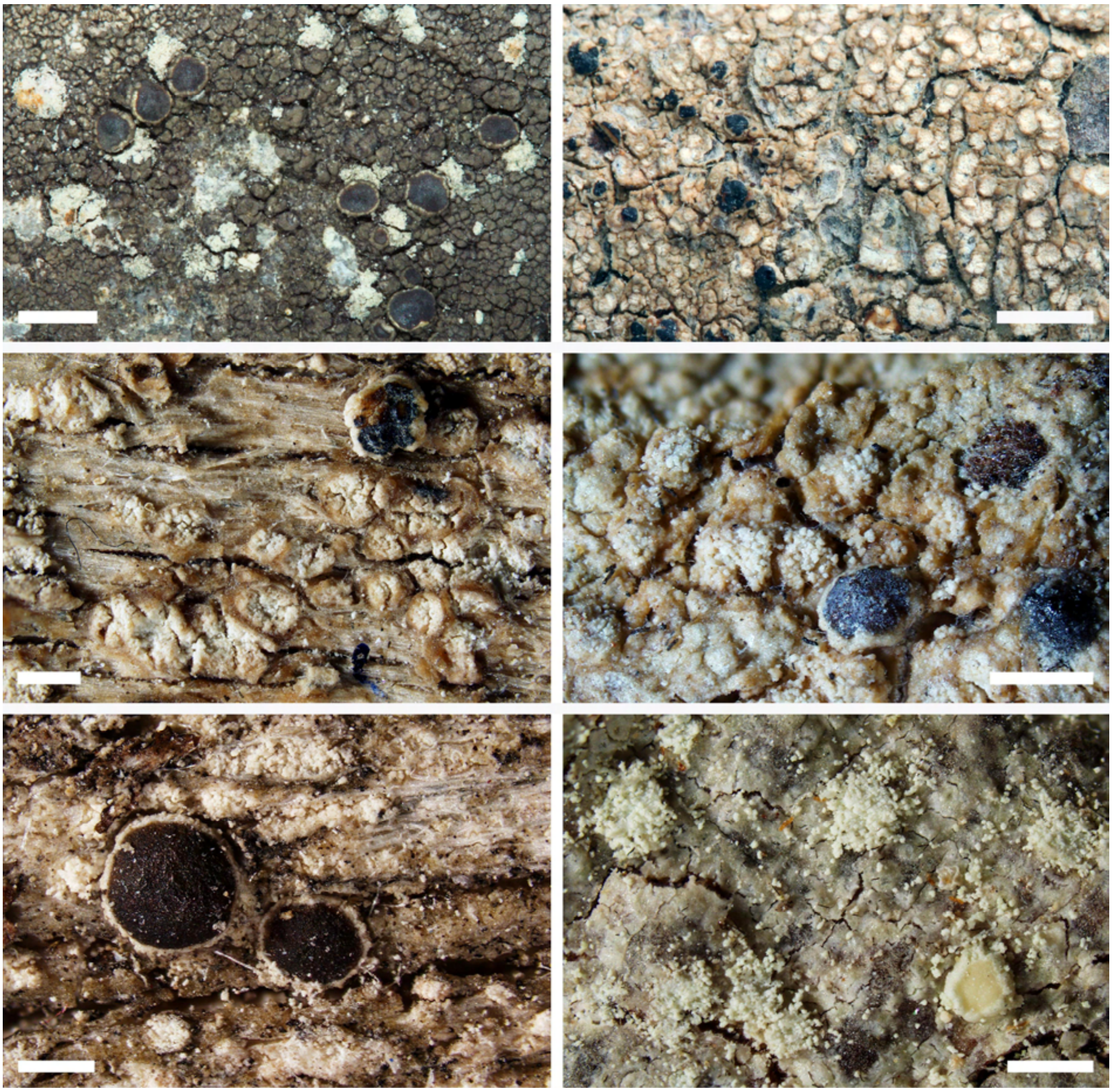

FIG. 4. A, holotype of *Lecanora cenisia* var. *soredians* (PRM); B & C, type collection of *L. elisa* (= *L. exspersa*), H-NYL 27609 & M; D, type material of *L. exspersa* (M); E, habitus of *L. farinaria* (B); F, fertile specimen of *L. jamesii* (JM 9007). Scales A, B = 2 mm, C, D, E, F = 0.5 mm.

Chemistry. Nephrosteranic acid as a major secondary compound; a trace amount of 1–2 unknown fatty acids (under nephrosteranic a.) found in 9 samples (n = 28). In one collection (GZU/Poelt 11706), roccellic acid instead of nephrosteranic acid was detected. Hinteregger (1994) reported the roccellic acid from several specimens, but according to our result, the nephrosteranic acid is the prevailing substance and the roccellic acid is more typical for some similar species, e.g. *L. cenisia* f. *soredians*, *L. farinaria* and *L. substerilis*. The bark of *Rhododendron*, the most common substrate of this species, is rich in various terpenoids that form very distinct spots on TLC plates.

Ecology. It is quite common on *Rhododendron ferrugineum*, especially on old twigs and stems in the subalpine belt, from 1080 m to 2500 m. Rarely, it occurs on bark of *Alnus incana*, hard coniferous wood and decorticated twigs, as in the case of type material collected on wood of dry fir twigs. Some populations are reported here for the first time from old-growth beech forests, on stems of old *Fagus sylvatica* and *Acer pseudoplatanus* at a tree line in the elevation of 1150–1200 m. The tree line is artificially lowered for summer grazing there, the habitat is very light and old trees with a very rich lichen biota are present. At the Ukrainian locality, *L. exspersa* is accompanied also by species known mostly from stems of *Rhododendron* in the Alps, e.g. *Caloplaca sorocarpa* and *Rinodina malangica*.

Distribution. The species has been reported only from Europe so far: most of its localities are known from the Alps. Single records are from Finland (Räsänen 1917, as *L. coilocarpa* var. *sorediata*), Romania (Nylander 1875) and Montenegro (Vězda 2000). It is reported here for the first time from Slovakia, Ukraine and Russia. The previous record from Slovakia (Palice et al. 2006) is erroneous, based on stunted specimens of *Lecanora pulicaris* with partly eroding, 'sorediate' thalli. The Slovakian and Ukrainian localities are situated in old-growth forests Stužica and Uholka-Shyrokyi Luh in the Carpathians.

Phylogeny. ITS and mtSSU phylogenies are not congruent in relationships between *L. cenisia*, *L. expersa* and some other species in the *Lecanora subfusca* group. In the ITS phylogeny, *Lecanora expersa* is not distinguished from *L. cenisia*, but they form a well supported clade distinct from other taxa. In the mtSSU, a single sequence of *L. expersa* from the Alps is in the clade together with *L. substerilis* and most of *L. cenisia* sequences, whereas sequences of *L. expersa* from the Carpathians form a supported clade together with *L. argentata*, *L. chlarotera* and one *L. cenisia* from Romania. We decided to maintain the "classical" phenotypic delimitation of *L. expersa*, although it does not correspond with mtSSU (and partly with ITS). Our decision might be temporary, but an establishing any other taxonomical alternative needs stronger support.

Except the ecology and yellowish soralia in the Carpathian samples, no additional characters have been found.

Remarks. *L. exspersa* growing on wood can be easily misidentified for *Ochrolechia microstictoides* or *O. alboflavescens* in the field, but the soralia delimited by a thalline rim are characteristic. Very similar morphotypes can be sometimes formed by *L. farinaria*, but the overall distribution and ecology of these species are different. The predominantly saxicolous *L. cenisia* f. *soredians* occurs sometimes on *Rhododendron ferrugineum* as well (Hinteregger 1994); its thallus is thicker, verrucose, soralia are large (up to 1 mm in diam.), usually convex, delimited for a long time and the roccellic acid is produced as the major secondary compound. The beech forest populations occur together with *L. substerilis* which has greyish-white soralia without a thalline rim and produces roccellic acid.

Selected specimens examined. **Austria:** *Salzburg*: Hohe Tauern, Krimml, 47°12'33''N, 12°10'21''E, alt. 1080 m, *Alnus incana*, 2012, *J. Malíček* 5417, 5551 (hb. JM); Ibid.: Gerlos, 47°10'57''N, 12°06'45''E, alt. 1740 m, *Rhododendron ferrugineum*, 2012, *J. Malíček* 5391 (hb. JM); Ibid.: Mt Hoher Sonnblick, N47°03'41.2", E12°59'26.0", *Pinus mugo*, 2014, *F. Bouda*, *Z. Palice* 18558 & *O. Peksa* (PRA); *Tirol*: Rhätische Alpen, Samnaun-Gruppe, südlich des Asches Hütte, 2250 m, *Rhododendron*, 1972, *J. Poelt* 11706 (GZU). **Montenegro:** Montes Durmitor, silva virginea supra lacum "Zminje jezero", loco Surdup dicto, alt. 1500–1700 m, 1984, *A. Vězda* (GZU). **Russia:** *Republic of Bashkortostan*: Yuryuzan', vill. Tyulyuk, alt. 1200–1300 m, 54°33'51''N, 58°50'37''E, wood of *Picea obovata*, 2011, *J. Vondrák* 13214 (PRA). **Slovakia:** *Poloniny Mts*: Nová Sedlica, Stužica, 49°5'24''N, 22°32'57''E, alt. 1150 m, 2014, *Acer pseudoplatanus*, *J. Šoun & J. Vondrák* 12339 (PRA). **Ukraine:** *Zakarpattia Oblast*: Velyka Uhol'ka, Mt Manchul, 48°17'52"N 23°39'59"E, alt. 1200 m, *Fagus sylvatica*, 2015, *F. Berger* , *J. Malíček* 8235, *Z. Palice* 19165, 19235 & *J. Vondrák* 14117, 14118 (hb. Berger, JM, PRA).

Lecanora farinaria Borrer

Suppl. Engl. Bot. **2**: tab. 2727 (1834); type: England, Sussex, Hurstpierpoint, Danny sandfields, on wood, Borrer (BM – holotype & possible isotype 1089246!).

(Fig. 4E)

Thallus immersed to thin (up to 0.1 mm thick), grey-white, smooth; *prothallus* indistinct or black; *photobiont* trebouxioid, 6–11 µm in diam., *soralia* white, greenish- or yellowish-white, delimited to confluent, rounded to ellipsoid, 0.2–1.0 mm, sometimes covering the whole thallus surface (e.g. in the holotype), flat to more rarely convex, often bordered by a thin thalline rim; *soredia* farinose, 20–50 µm in diam.
Apothecia rare, sessile or with constricted bases, 0.4–1. (–1.5) mm; *margin* sorediate, up to 0.1 mm thick, often becoming exluded, white, regular to more often flexuose; *discs* brown to black, matt, unpruinose, flat to slightly convex.
Amphithecium with large crystals or crystals absent (*pulicaris*-type), with abundant algal cells; *cortex* absent; *hypothecium* colourless; *hymenium* 50–80(–100) µm; *epihymenium* pale brown to reddish-brown, rarely with green pigment, K+ olive, HNO_3+ brownish-red to red, interspersed with fine granules (POL+) soluble in K, insoluble in N (*pulicaris*-type); *paraphyses* 1.5–2.0 µm, up to 3.0 µm at apices; *asci* 8-spored; *ascospores* broadly ellipsoid to subglobose, 14–18(–20) × (9–)10–13(–15) µm, thick-walled (1.0–1.5 µm). *Conidiomata* unknown.

Chemistry: Roccellic acid (major) with traces of 1–2 fatty acids.

Ecology: It prefers humid forests in lower elevation, especially close to the coast. The most common substrata are *Alnus incana*, *Sorbus aucuparia* (Tønsberg 1992) and wood.

Distribution: *L. farinaria* has been reported from many European countries, North America and Asia (see Kukwa & Kubiak 2007), but some of these records could be based on the misidentification. It is an oceanic species known mainly from Great Britain (Edwards et al. 2009) and Norway (Tønsberg 1992). It very probably occurs in other Western European and Scandinavian countries (material not seen). A record from Ukraine by Kondratyuk & Coppins (1999) belongs to *L. substerilis*, the Italian specimen from Sardinia by Zedda (2002) to *L. impudens*. In Central Europe, the species has been reported from humid parts of the Austrian Alps (Tønsberg *et al.* 2001) and Poland (Kukwa & Kubiak 2007).

Phylogeny. Bayesian analyses of ITS and mtSSU regions demonstrated a quite isolated position within the *L. subfusca* group (Figs 1 & 2).

Remarks: *L. farinaria* is a very variable species, especially in the soralia and thallus character. Tønsberg (1992) mentioned morphotypes with areolate or tuberculate thallus containing oxatale. This is a quite common feature in several other sorediate *Lecanora*, but probably very rare in *L. farinaria*. Sterile material can be easily confused with several similar taxa (*L. exspersa*, *L. impudens*, *L. substerilis* etc.). However, its ecology and distribution are more or less different. Apothecial anatomy is very similar to *L. pulicaris*.

Selected specimens examined. **Austria:** Hohe Tauern, Krimml, 47°12'44''N, 12°10'09''E, alt. 1050 m, *Alnus incana*, 2012, *J. Malíček* 5417 (hb. JM); *Tyrol*: Brandenberg, Kaiserklamm, 47°33'N, 11°54'E, alt. 730–760 m, *Salix*, *T. Tønsberg* 24270 (BG). **Great Britain:** *Scotland*: East Inverness, Glen Affric, SW shore of the lake Loch Beinn a Mhea, N57°15.99', W004°57.77', *Vaccinium*, alt. 235 m, 2004, *Z. Palice* 9831 (PRA); Island of Islay, on fence post, 2011, *M. Powell* 1777 (hb. JM). **Norway:** *Norland:* Vefsn, W of lake Fustvatnet, alt. 40–60 m, *Alnus incana*, 1982, *T. Tønsberg* 7615a (GZU); Møre og Romsdal, Rauma, W of Innfjorden, 40 m, *Corylus avellana*, 1979, *T. Tønsberg* 3817 (GZU); Selje, 62.0562°N 5.3912°E, alt. 270–280 m, *Sorbus aucuparia*, 2015, *T. Tønsberg* 46170 & Z. Palice 20106 (BG).

Lecanora impudens Degel.

Svensk bot. Tidskr. **38**: 50 (1944); nom. nov. for *Pertusaria farinacea* H. Magn., Bot. Not. 1942: 15 (1942); type: Sweden, Södermanland: Botkyrka, Tullinge gård. On *Ulmus* in an avenue, 1938, A. H. Magnusson 16125 (UPS 65900! – holotype).
Lecanora maculata (Erichsen) Almb., Bot. Not. 1952: 251 (1952); *Pertusaria maculata* Erichsen, Rabenh. Kryptog. Flora Deutsch., 5: 646 (1936).

L. impudens is morphologically identical with *L. allophana* f. *sorediata*. These taxa are separated by chemistry and ascospore size (up to 14 µm in *L. impudens*). *L. impudens* produces an unknown fatty acid and the terpenoid *impudens*-unknown or atranorin alone. For a detailed description see Tønsberg (1992) and Malíček (2014).

L. impudens prefers trees with a higher bark pH (e.g. *Fraxinus excelsior*) in open landscape. It has a mostly continental distribution in Europe; it is completely absent from Western Europe, but occurs in more continental part of Norway (Tønsberg 1992). The record from Sardinia is phytogeographically interesting. Generally, it is not a very common lichen, but it can be locally widespread, e.g. in some regions of Scandinavia, in the Alps and Carpathians.

Some authors (e.g. Poelt & Vězda 1981; Clauzade & Roux 1985; Schreiner & Hafellner 1992; Wirth 1995) regarded *L. impudens* and *L. allophana* f. *sorediata* as conspecific. Both taxa are very similar, share almost the same ecology and they are not resolved by mtSSU phylogeny (Fig. 2). Although, we separate them at the species level based on the different chemistry and ascospore size.

Selected specimens examined. **Austria:** *Steiermark*: Grazer Bergland, Straßegg Sattel ca. 8 km E von St. Jakob-Breitenau, 47°23'20''N, 15°31'50''E, 1180 m, *Fraxinus*, 1999, *J. Hafellner* 49623 (GZU). **Italy:** [*Sardinia*:] Illorai, Monte Artu, alt. 900 m, old *Quercus pubescens*, 1996, *L. Zedda* (B). **Macedonia:** *Galichica National Park*: Stenje, Mt Magaro, 40°56'46''N, 20°52'16''E, alt. 1150 m, old *Quercus cerris*, 2014, *J. Malíček* 7964 (hb. JM). **Serbia:** *Suva Planina Mts: Sopotnica*: 43°10'00''N, 22°08'59''E, alt. 690 m, old *Quercus cerris*, 2014, *J. Malíček* 7757 (hb. JM). **Slovakia:** *Strážovské vrchy*: prope pg. Briestenné, 500 m, ad cort. Juglandis, 1976, *I. Pišút* (BRA).

Lecanora jamesii J. R. Laundon

Lichenologist **2**: 122 (1963); type: U.K., Pembroke, near Pontfaen, Afon Gwaun. V.C. 45, on rotting branches of *Salix* over stream, 350 ft., 1958, *P.W. James* (BM – holotype).

(Fig. 4F)

This species is well characterized by its yellow delimited soralia containing usnic acid and the production of 2-O-methylsulphurellin as a diagnostic substance. Apothecia are rare, containing large crystals in the amphithecium and with a granular, pale yellowish-brown epihymenium

(Laundon 1963). In Europe, the species is reported from oceanic parts of Western Europe and humid regions of the Austrian Alps (e.g. Brodo & Elix 1993, Tønsberg *et al.* 2001). For a detailed description see Laundon (1963) and Edwards *et al.* (2009).

Selected specimens examined. **Austria:** Wildnisgebiet Dürrenstein, Lunz am See, primeval beech-silver fir forest "Grosser Urwald", 47°46'56''N, 15°05'02''E, alt. 1200 m, *Fagus sylvatica*, 2015, *J. Malíček* 8471, *F. Berger*, *O. Breuss* & *R. Türk* (hb. JM); Ibid.: See bei Oisklause, 47°46'33''N, 15°08'54''E, alt. 1010–1020 m, Holz von *Picea abies*, *F. Berger*, *O. Breuss J. Malíček* & *R. Türk* 56240 (SZU). **Canada:** *British Columbia*: Hyphocus Island, 48°55.808'N, 125° 31.679'W, alt. 2–10 m, *Alnus rubra*, 2011, *T. Tønsberg* 41348 (BG). **France:** *Bretagne*: Monts d'Arrée, St. Herbot, alt. 250 m, *Salix atrocinerea*, 1984, *P. Clerc* 6298 (S). **Great Britain:** *S-Devon*: Slapton bei Start, *Salix*, 1971, *J. Poelt* 10545 (GZU); *Scotland:* Lochgilphead, Kilmartin, 56°08'43''N, 5°32'04''W, alt. 50 m, *Salix aurita*, 2014, *J. Malíček* 9005, *B. J. Coppins* & *J. Vondrák* (hb. JM); Argyllshire, Mull, Salen, *Salix aurita*, 1968, *P. W. James* (S – Vězda: Lich. Sel. Exs. 789); **U.S.A.:** *Washington*: Olympic Nat. Park, Ozette Lake, 48°07.2'N, 124°36.1'W, alt. 10 m, Salix, 1999, *T. Tønsberg 28040 & C. Printzen* (M).

Lecanora mughosphagneti Poelt & Vězda

Biblioth. Lichenol. **16**: 364 (1981); type: Bavaria, Allmannshauser Filz, *Arnold* in Lich. exs. 1832 (M! – holotype).

Thin, whitish to pale grey thallus, early coalescent soralia with fine, whitish to pale yellowish soredia covering almost the whole thallus are typical for this species. Whitish pruinose apothecia of the *L. albella* type are known only from the type material (Poelt & Vězda 1981). The species produces caperatic and roccellic acids as major secondary metabolites. Protocetraric acid was detected in apothecia only (Lumbsch *et al.* 1997). For a detailed description see Poelt & Vězda (1981) and Lumbsch *et al.* (1997).

L. mughosphagneti has been published from Germany, Austria (Lumbsch *et al.* 1997) and Switzerland (Bürgi-Meyer et al. 2014) up to now. It is reported here as new for the Czech Republic. The species grows mainly on trunks of *Pinus* spp. in boggy pine forests. It can be found at the same sites like the very similar *L. norvegica*, which differs in Pd+ red reaction of soralia (protocetraric acid). A detailed study of both species will be published elsewhere (Palice & Tønsberg, in prep.).

Selected specimens examined. **Czech Republic:** *Southern Bohemia:* Šumava Mts, Smolná Pec: waterlogged spruce forest with *Pinus rotundata*, 48°51'03''N, 13°53'05''E, alt. 815 m, *Pinus rotundata*, 2010, *J. Malíček* 2736 & *Z. Palice* (hb. JM). Třeboň region, Suchdol nad Lužnicí, Červené blato, alt. 470 m, *Pinus rotundata*, 2010, *J. Malíček* 2953 (hb. JM). **Germany:** *Bayern*: Föhrenrinden in der Pupplinger Au im Isarthale bei Wolfratshausen, 1893, *Arnold* (M – Lich. Monac. Exs. 297); Spirkenfilz zw. Bernried u. Bern. Filz, Spirke, 1955, *J. Poelt* (M); Spirkenfilz südlich Rohrmoos, Gemeinde Forst, *Pinus uncinata*, 1964, *J. Poelt* (M).

Lecanora norvegica Tønsberg

Sommerfeltia **14**: 165 (1992); type: Norway, Oppland, Sel, Sjoa, UTM grid ref.: 32V, NP 2839, alt. 280–300 m, on *Pinus sylvestris*, 1990, *T. Tønsberg* 13145 (BG – holotype, E – isotype).

This species is very similar to *L. mughosphagneti*, from which differs in Pd+ red soralia due to the presence of protocetraric acid. We detected the roccellic acid as a minor compound in one specimen (Tønsberg 17746). According to Tønsberg (1992), soralia are green to grey-green and discrete at first, but these characters are probably not reliable for a differentiation of these species. For a detailed description see Tønsberg (1992).

It has been reported from Norway (Tønsberg 1992), Sweden (Santesson *et al.* 2004), Switzerland (Dietrich & Scheidegger 1996), Estonia (Jüriado 2000), Lithuania (Motiejūnaitė *et al.* 2007) and European Russia (Stepanchikova *et al.* 2010). Here, we present *L. norvegica* as new for the Czech Republic. The species prefers humid pine mire forests.
Cliostomum leprosum, *Loxospora elatina*, *Megalaria pulverea* and *Ochrolechia microstictoides* are other sorediate species with similar ecology, therefore the TLC is necessary for the correct identification.

Selected specimens examined. **Czech Republic:** *Northern Moravia*: Jeseníky Mts, Rejvíz, 50°13'13"N, 17°17'13"E, alt. 760 m, *Pinus rotundata*, 2012, *J. Malíček* 5131 & *L. Syrovátková* (hb. JM); *Southern Bohemia*: Novohradské hory Mts, Pohoří na Šumavě, Stodůlecký vrch, 48°35'09''N, 14°42'20''E, alt. 955 m, *Pinus sylvestris*, 2012, *J. Malíček* 5707, *J. Kocourková, Z. Palice & J. Vondrák* (hb. JM). **Norway:** *Oppland*: Sel, Sjoa, 61°41'N, 9°33''E, alt. 300 m, *Pinus sylvestris*, 1992, *T. Tønsberg* 17746 (M).

Lecanora sorediomarginata Rodrigues, Terrón & Elix

Lichenologist **43**: 102 (2011); type: Portugal, Beira Litoral, Figueira da Foz, Dunas de Quiaios, alt. 49 m, *Pinus pinaster* in a pine forest on sand dunes, 2006, *S. A. Rodrigues* (AVE-L – holotypus; LEB-Lichenes 7581– isotypus).

This recently described species (Rodrigues *et al.* 2011) is characterized by the endosubstratal or very thin thallus, coalescent soredia, sorediate apothecial margin and C+ red reaction due to the presence of 3,5-dichloro-2'-O-methylnorstenosporic acid as a major compound. Atranorin and chloratranorin are present only as minor substances. It has been reported so far from bark of pines in coastal regions in Portugal. *Lecanora sorediomarginata* is well distinguishable by its chemistry and specific ecology. For a detailed description see Rodrigues *et al.* (2011).

Lecanora substerilis Malíček & Vondrák sp. nov.

MycoBank No.: MB 813677

Diagnosis: a member of the *L. subfusca* group in a strict sense, macroscopically similar to *L. farinaria*, but the thallus often thick and verrucose; thalline apothecial margin sorediate; epihymenium with coarse granules at paraphyses tips; amphithecium with large crystals; roccellic acid alone or together with an unknown fatty acid as major secondary metabolites; on bark of beeches in old-growth beech forests.
Type: **Slovakia:** *Poloniny Mts:* Nová Sedlica, protected area Stužica, in a valley, alt. 600–800 m, 49°04'24''N, 22°32'35''E, *Fagus sylvatica*, 2014, *J. Šoun* & *J. Vondrák* (PRA JV12294 – holotype, 12303 – isotype). Sequences of the holotypus: KT630243 (ITS) and KT630254 (mtSSU).

(Figs 5A–E)

Thallus crustose, grey, matt, forming patches up to 5 cm in diam., sterile specimens usually with a thin thallus up to 0.1 mm thick, in fertile material thallus well developed and strongly pustulose (> 0.5 mm thick); *pustules* low and almost indistinct to strongly developed and globose to clavate with constricted bases, filled with large calcium oxalate crystals (POL+); *prothallus* indistinct or whitish-grey; *photobiont* trebouxioid; *soralia* pale grey to grey-green, punctiform to rarely confluent, flat, 0.2–0.6 mm in diam.; *soredia* farinose to granulose, simple or in consoredia, 25–75 µm in diam., coarser in fertile collections. *Apothecia* lecanorine, known from the holotype only, c. 1 mm in diam., with a constricted base, probably arising from pustules; *margin* 0.2 mm thick, uneven and slightly pustulate when young, later sorediate; *discs* brown, matt, pruina absent.

Amphithecium with abundant large crystals (*pulicaris*-type), filled with numerous trebouxioid photobiont cells (5–14 µm in diam.) surrounded by 2.5–3.5 µm thick and branched hyphae, lower part without algae and crystals ± paraplectenchymatous; *cortex* not observed; *hypothecium* colourless, prosoplectenchymatous; *hymenium* colourless, 60–80 µm high; *paraphyses* 1.5–2.0 µm thick, not or very slightly broadening at tips; *epihymenium chlarotera*-type, red-brown (K+ pale brown), with coarse, brown, irregular granules (POL+) abundantly at paraphyse tips, 1–2(–5) µm in diam., soluble in KOH; *asci* 8-spored, *Lecanora*-type, c. 45–55 × 12 µm; *ascospores* well developed, simple, colourless, broadly ellipsoid to subglobose, 10–14 × 7–11(ï 12) µm. *Conidiomata* unknown.

Chemistry. Atranorin, roccellic acid alone or together with an unknown fatty acid. In three of eleven specimens, traces of several terpenoids (probably from bark) detected by TLC. Soralia: K+ yellow, Pd-, C-, UV-.

Etymology. This species is mostly collected sterile, fertile material is very rare.

Phylogeny. *L. substerilis* belongs to the *L. subfusca* group. In the nrITS phylogeny, it forms a supported clade that is well resolved from the closest outgroup including *L. cenisia* and *L. exspersa* (Fig. 1). It also forms a supported clade in mtSSU that is in polytomy with the latter taxa.

Ecology and Distribution. The new species is known from Carpathian beech forests so far, especially from old-growth woodlands in the elevation of 450–1050 m. It has been published from Stužica beech-silver fir forest in Slovakia as *Lecanora* cf. *farinaria* (Vondrák *et al.* 2015). It is quite common on *Fagus sylvatica* in this reserve; one collection is also from *Abies alba*. The most frequently associated species are *Lecanora argentata*, *Candelariella xanthostigma*, *Hypogymnia physodes*, *Lecanora pulicaris*, *Porina aenea* and *Scoliciosporum umbrinum.* The second site from Slovakia is situated in the Muránska planina National Park.

L. substerilis is a common species in the Ukrainian beech virgin forest Uholka-Shyrokyi Luh, here together with *Buellia griseovirens*, *Rinodina efflorescens* etc. It is also known from a humid beech forest in 1050 m a.s.l. in Paring Mts (Muntii Parâng) in Romania.

Remarks. *Lecanora substerilis* strongly resembles the western *L. farinaria*. The latter species differs in the smooth, immersed to thin thallus and the *pulicaris*-type of epihymenium (with fine granules). Sterile specimens are hardly distinguishable from e.g. *L. allophana* f. *sorediata*, *L. impudens*, *L. exspersa*, *L. variolascens* and *L. cenisia* f. *soredians*. These taxa are absent or very rare in beech forests. The first three species do not contain roccellic acid in the thallus. *L. exspersa* usually occurs in higher elevation and its soralia have a distinct thalline rim; *L. cenisia* f. *soredians* has larger (at least 0.5–1.0 mm in diam.) and convex soralia.

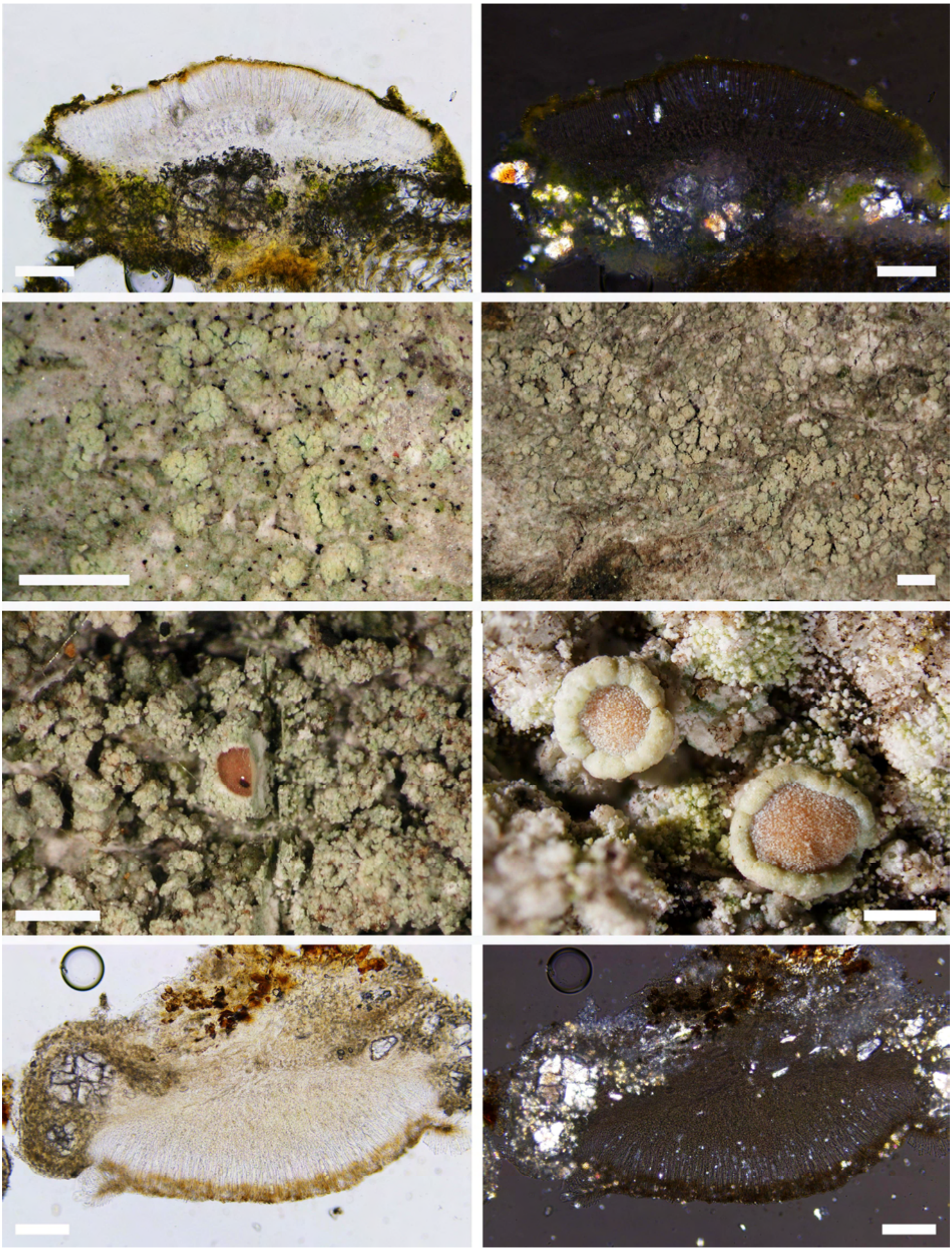

FIG. 5. A & B, apothecial sections of holotype of *Lecanora substerilis* in ordinary and polarized light; C & D, sorediate thallus of *L. substerilis*; E, apothecium of the holotype specimen (PRA JV12294); F, habitus of *L. variolascens* (JM 8422); G & H, apothecial sections of *L. variolascens* in ordinary and polarized light. Scales A, B, G, H = 100 µm, C, D, E = 1 mm, F = 0.5 mm.

Additional specimens examined. **Romania**: *Paring Mts*: Petrosani, 100 m E of Cabana Mija, 45°24'24''N, 23°30'22''E, 1050 m, *Fagus sylvatica*, 2013, *J. Malíček* 6690 & *F. Bouda* (hb. Malíček). **Slovakia**: *Bukovské vrchy Mts*: Nová Sedlica, Stužica, S-facing slopes between Mt Kamenná lúka (1201 m) and Mt Kremenec (1221 m), 49°05'10''N, 22°33'09''E, 1050 m, *Fagus sylvatica*, 2013, *J. Malíček* 6541 & *J. Vondrák* (hb. JM). Ibid.: 800 m, 49°04'20"N, 22°32'06"E, *Fagus sylvatica*, 2014, *J. Šoun* & *J. Vondrák* (CBFS JV12387). Ibid.: in valley, 600–800 m, 49°04'24''N, 22°32'35''E, *Abies alba*, 2014, *J. Šoun* & *J. Vondrák* (CBFS JV12293); *Muránska planina National Park*: Čertova dolina protected area, 48°44'22''N, 19°52'00''E, alt. 950 m, *Fagus sylvatica*, 2012, *J. Malíček* 5269, *A. Guttová* & *Z. Palice* (hb. JM). **Ukraine:** *Zakarpattia Oblast Region:* Khust, Velyka Uhol'ka, at many sites in the Uholka old-growth forest, 48°14–15'N, 23°39–41'E, alt. 460–820 m, *Fagus sylvatica* and *Acer pseudoplatanus*, 2015, *F. Berger* 29182, 29183, *J. Malíček* 8111, 8162, 8209, 8294, *Z. Palice* 19223, 19611 & *J. Vondrák* (hb. FB, JM, PRA).

Lecanora thysanophora R.C. Harris

Bryologist **103**: 790 (2000); type: U.S.A, New York, Clinton Co., Town of Mooers, trail to The Gulf Unique Area, 1.5 mi. (2.4 km) NW of Cannon Corners Road (Co. Rd. 10) on Rock Road, 1 mi. [1.6 km] N of Davison Road at Cannon Corners, 448599 N, 73846.59 W, conifer-red maple woods, 1996, *Buck* 30804 (NY – holotype).

L. thysanophora differs from all species included in this paper by its continuously sorediate, yellow to blue-yellow thallus and the arachnoid prothallus which can be absent or poorly developed in young thalli. Apothecia are unknown in European populations. Apart from atranorin, it produces usnic acid, zeorin and specific terpenoid(s) *thysanophora*-unknowns visible only as UV+ blue spots after sulpuric acid spraying and heating. It belongs to a more or less isolated lineage according to mtSSU (Fig. 2.).

In Europe, the species is quite common in beech forests in some parts of the Alps and Carpathians, scattered in some other mountains in Central Europe (e.g. Šumava/Bavarian Forest Mts). Surprisingly, it is widely distributed in Northern Poland, commonly also on *Carpinus betulus* and *Quercus* (Zduńczyk & Kukwa 2014), and some surrounding countries (Motiejūnaitė *et al.* 2006, Golubkov & Kukwa 2006). For a detailed description see Harris *et al.* (2000). It can be confused with *Haematomma ochroleucum*, containing the porphyrilic acid.

Selected specimens examined. **Austria:** *Tirol*: Brandenberg, NW of Kaiserklamm, 47°32'48''N, 11°54'39''E, alt. 750 m, *Salix elaeagnos*, 2012, *J. Malíček* 5538 (hb. JM). **Czech Republic:** *Šumava Mts*: Mt Smrčina, 48°43'59''N, 13°56'17''E, alt. 1105 m, *Fagus*, 2015, *J. Malíček* 8656 & *J. Vondrák* (hb. JM). **Germany:** *Bayern*: Oberammergau, Graswang, 47°33'44''N, 11°02'15''E, alt. 920 m, *Fagus*, 2014, *J. Malíček* 7020 (hb. JM). **Ukraine:** *Zakarpattia Oblast Province*: Kvasovo, flood-plain forest Otok, 48°12'35''N, 22°46'08''E, alt. 120 m, *Populus nigra*, 2013, *J. Malíček* 6445 & *J. Vondrák* (hb. JM).

Lecanora variolascens Nyl.

Flora, Regensburg **64**: 183 (1881); type: [Germany, Baden-Württemberg], Heidelberg, an *Carp.* et *Sorbus* rar., *v. Zwackh* 252 (H-NYL 27851! – holotype).

Lecanora bavarica Poelt, *Ber. Bayer. Bot. Ges.* **29**: 68 (1952). Type: [Germany], Oberbayern, Ldks. Starnberg u. Bernried, Obere Hochebene, Ulme an der Straße nach Unterzeismering, ziemlich am Grunde des Stammes, 1951, *J. Poelt* (M! – holotype).

(Figs 5F–H)

Thallus quite variable, smooth to rough, often verrucose especially in the middle, greyish, thin to medium thick (up to 0.2 mm), filled by large calcium oxalate crystals; *photobiont* trebouxioid;

soralia flat to slightly convex, concolorous with the thallus, at first delimited (0.3–1.0 mm in diam.), later more or less confluent and rarely forming a sorediate crust covering the thallus; *soredia* farinose. *Apothecia* frequently present, 0.5–1.0(–1.5) mm in diam., sessile or rarely with constricted bases, plane; *discs* reddish-brown to dark brown, medium to strongly whitish to bluish pruinose, rarely non-pruinose; *margin* smooth to coarse, matt, thick, partly flexuose, elevated, sometimes slightly crenulate.

Epihymenium reddish-brown, in K ±colourless to pale orange-brown, pigment more or less intensifying in HNO_3, with coarse brown granules of 3–5(–8) µm in diam. on the surface of paraphyses tips, soluble in K, very slowly soluble in HNO_3, POL-; *amphithecium* of *pulicaris*-type, with very large crystals of calcium oxalate (up to 100 µm in diam.), soluble in HNO_3; *true cortex* absent; *hypothecium* colourless to yellowish; *hymenium* 60–80 µm high; *paraphyses* (1.0–) 1.5–2.0 µm thick; at tips slightly swollen (up to 3.0 µm); *asci* 8-spored; *ascospores* broadly ellipsoid, (9–)10–12.5 × 6–8(–9) µm. *Conidiomata* unknown.

Chemistry. Atranorin and zeorin detected by TLC as major compounds. In two specimens (from 14 analysed) including the holotype, a trace of an unknown colourless spot (C4, UV-) with fatty character was recorded. Discs C-; soralia K+ yellow, Pd+ yellow, C-. Crystals of zeorin are usually visible on old collections.

Phylogeny. The species is not closely related to the morphologically similar *L. intumescens* but it forms an isolated clade with *L. barkmaniana* (Figs 1 & 2).

Ecology. *L. variolascens* occurs on ±acidic bark (mainly of oaks and pines) but usually at slightly eutrophicated places as noted by Lumbsch et al. (1997). *Candelariella efflorescens* agg., *C. reflexa* s.str., *C. xanthostigma*, *Catillaria nigroclavata*, *Opegrapha rufescens*, *Phlyctis argena*, *Physcia adscendens*, *Physconia distorta* and *Lecidella albida* were closely associated lichens. It prefers well-lit forests in middle elevations.

Distribution. The species is rare and only known from several European countries: Austria, France, Germany, Italy, Poland and Switzerland (Lumbsch *et al.* 1997, Nimis & Martellos 2003, Roux *et al.* 2015). Here it is reported as new for Slovakia.

Remarks. *Lecanora variolascens* is a distinctive species, although it has been very rarely reported. Many specimens have been found in herbaria by chance as unidentified or incorrectly identified specimens. These confusions might have arisen by a vague and an ambiguous description of the taxon by earlier authors. Apothecia of some morphotypes (e.g. the holotype) can resemble *L. intumescens* which differs mainly in the apothecial anatomy (e.g. tiny crystals in amphithecium). Indeed, Nylander (1881) and Brodo (1984) suggested that this sorediate taxon is closely related to *L. intumescens* if not conspecific. Lumbsch *et al.* (1997) distinguished it from *L. intumescens*, included the Central European *L. bavarica* Poelt as its synonym, and provided its more detailed description. Unfortunately, the authors characterized *L. variolascens* as a species with psoromic acid and relatively small crystals in amphithecium (nevertheless of *pulicaris*-type according to the mentioned size). The Pd+ yellow reaction of the soralia suggesting the presence of psoromic acid could be caused by a high concentration of atranorin; no psoromic acid was detected by TLC in examined material, including two specimens studied by Lumbsch *et al.* (1997). Nevertheless, we didn’t use HPLC for chemical analysis like Lumbsch *et al.* (1997). Although we applied large pieces of sorediate thallus for TLC, we can't definitely exclude the presence of psoromic and 2'-O-demethylpsoromic acids in a very low concentration.

The sorediate thallus strongly resembles *L. impudens*, *L. allophana* f. *sorediata*, *L. farinaria* and several *Ochrolechia* species. In such cases, TLC or spot reactions are necessary for the certain identification. *Lecanora variolascens* is chemically concordant with *L. barkmaniana*. The latter taxon is usually sterile with yellowish, very early confluent soralia. When the apothecia are present, ascospores of *L. barkmaniana* are distinctly larger than in *L. variolascens*.

The species *L. carneolutescens* regarded as endemic to southwestern North America shares chemical and anatomical characters with *L. variolascens*. It differs in non-pruinose apothecia and larger ascospores, 12.5–16 × 8.5–10.5 µm (Ryan *et al.* 2004).

Specimens examined. **Austria**: *Steiermark*: Kalvarienberg SW oberhalb vom Landeskrankenhaus Feldbach, Umgebung eines alten Lehmabbaus, 340 m, *Malus domestica*, 1993, *B. Wieser* 642 (GZU); *Oberösterreich*: Rading (nw. Windischgarsten), an Föhrenstämmen im Radinger Moor, 600 m, 1986, *S. Wagner* (GZU, dupl. ex SZU 10491); Haiden bei Ischl, 1867, *H. Lojka* (GZU); *Lower Austria:* Ybbstaler Alpen Mts, Langau, Maierhöfen, 47°51'36.9"N 15°06'46.2"E, alt. 680 m, *Pyrus communis*, 2015, *J. Malíček* 8422 (hb. JM). **France:** *Aquitaine*: Pyrénées Atlantiques, St. Engrâce, 47°46.83'N, 3°29.67'W, 600 m, *Acacia*, 1992, *J. L. Spier* 4898 (L). **Germany**: *Oberbayern*: Starnberg, Moorsinger Schlucht, *Quercus*, 1952, *A. Schreppel* (GZU); *Bayern*: Allgäu, an *Acer* am Forggensee nördlich Füssen, 785 m, 1956, *J. Poelt* (B, S, Lich. Alp. 4). **Slovakia:** *Muránska planina plateau:* nature reserve Poludnica, well-lit oak forest, N48°45.44', E20°01.72', alt. 660 m, *Quercus*, 2007, *A. Guttová, J. Halda & Z. Palice* 11380 (PRA, BG); Ibid.: c. 48°45'33''N, 20°02'01''E, alt. 700–750 m, *Quercus petraea* agg., 2010, *J. Malíček* 3100, *A. Guttová & Z. Palice* (hb. JM); Ibid.: 48°45'19"N, 20°01'46"E, alt. 565 m, 2014, *A. Guttová, Z. Fačkovcová & Z. Palice* 18379 (PRA); Ibid.: nature reserve Šiance, 48°45'55"N, 20°03'55"E, alt. 886 m, *Quercus*, 2012, *A. Guttová & Z. Palice* 17959 (PRA).

Lecanora viridissima Nordin, Sundin & Thor

Nordic Journal of Botany **15**: 555 (1995); type: Sweden, Gotland, Lummelunda parish, Ellstädaränget wooded meadow, c. 1 km NW Bunge and c. 1 km E of Lummelunda church, 57°46'N, 18°28'E, *Quercus robur*, 1990, *A. Nordin, R. Sundin & G. Thor* 1300 (S! – holotype).

The species is characterized by a yellow to green sorediate thallus forming small patches up to 1 cm; apothecia are unknown. This small lichen can be very easily overlooked in the mosaic with other species. It resembles for example young *L. expallens*. Based on herbarium material from S, it often occurs together with morphologically very similar *Lecidella subviridis* and *Pyrrhospora quernea*. Some specimens identified as *L. viridissima* represent in fact these taxa; including the holotype, which is a mixture of *Lecidella subviridis* and *L. viridissima*. All these lichens differ chemically and a careful TLC/HPLC analysis is necessary for the right identification. *L. viridissima* produces, apart from atranorin, an unknown substance in position B'5 and C5. This compound is recognized in TLC as a yellow spot with a huge pale halo and fatty character; it is pale yellow-green to brown in long UV after charring (not observed in low concentrations). It is very probably related to 2-O-methylsulphurellin and some planaic acid derivates due the very characteristic spots on TLC plates. From the 2-O-methylsulphurellin, it differs in the lower position on TLC plates and typical double yellow spot in B' solvent.

L. viridissima is a poorly known species so far reported from Gotland in Sweden. It occurs on bark of *Quercus robur* and *Fraxinus excelsior* mainly in wooded meadows (Nordin *et al.* 1995). *Lecanora argentata* and *Phlyctis argena* were the most common closely associated species in the studied material.

Selected specimens examined. Sweden: Gotland: Träkumla, Tjängdarve, 59°33'N, 18°19'E, *Fraxinus*, 1989, *A. Nordin, R. Sundin & G. Thor* 49 (S); Rone, Oggesänget, 57°12'N, 18°25'E, *Quercus*, 1990, *A. Nordin, R. Sundin & G. Thor* 1186 (S); Lojsta, 57°18'N, 18°23'E, *Quercus*, 1989, *A. Nordin, R. Sundin & G. Thor* 353 (S); Atlingbo, 57°28'N, 18°22'E, *Fraxinus*, 1989, *A. Nordin, R. Sundin & G. Thor* 207 (S); Hemse, 57°13'N, 18°22'E, *Quercus*, 1990, *A. Nordin, R. Sundin & G. Thor* 999 (S).

Key to European corticolous sorediate *Lecanora* species containing atranorin

With well-developed apothecia .... Key A
Without apothecia .... Key B

Key A

1 Apothecia distinctly pruinose 2
  Apothecia slightly pruinose or pruina absent 5
2(1) Usnic acid present; soralia yellowish to bluish-green, prothallus arachnoid .... **L. thysanophora**
  Usnic acid absent; soralia white to white-grey; 3
3(2) Apothecia Pd+ yellow or Pd-; amphithecium with large crystals .... **L. variolascens**
  Apothecia Pd+ red; amphithecium with small crystals 4
4(3) Soralia coalescent; on bark of *Pinus* .... **L. mughosphagneti**
  Soralia delimited, rounded; on deciduous trees .... **L. albella**
5(1) Soralia C+ red, on bark of *Pinus* in coastal regions .... **L. grediomarginata**
  Soralia C- 6
6(5) Thallus and soralia yellowish; containing xanthones .... **L. alboflavida**
  Thallus white-grey, soralia whitish to yellowish; without xanthones 7
7(6) Amphithecium with small crystals (*allophana*-type) 8
  Ampthithecium with large crystals (*pulicaris*-type) 9
8(7) Ascospores 14–20 × 8–11 µm; terpenoids *allophana*-unknown present .... **L. allophana**
  Ascospores 10–14 × 5.5–8 µm; terpenoid *impudens*-unknown present or containing atranorin alone .... **L. impudens**
9(7) Soralia yellow or greenish-yellow, containing usnic acid 10
  Soralia white, grey-white to yellowish; usnic acid absent 11
10(9) Prothallus arachnoid, thallus leprose; *thysanophora*-unknown(s) present .... **L. thysanophora**
  Prothallus never arachnoid, soralia well delimited; 2-O-methylsulphurellin present .... **L. jamesii**
11(9) Ascospores broadly ellipsoid to subglobose, 14–17(–20) × 10–13 µm, epihymenium with fine granules (*pulicaris*-type) .... **L. farinaria**
  Ascospores ellipsoid to broadly ellipsoid, up to 15 × 10 µm, epihymenium with coarse granules (*chlarotera*-type) 12
12(11) Soralia confluent; zeorin present .... **L. barkmaniana**
  Soralia delimited at least when young; zeorin absent 13
13(12) Apothecial margin sorediate (at least when mature); roccellic acid present .... **L. substerilis**
  Apothecial margin without soredia, roccellic or nephrosteranic acid present 14

14 (13) Apothecia <1.0 mm in diam., thallus thin, soralia with a distinct thalline rim, concave to flat .... **L. exspersa**
Apothecia usually >1.0 mm in diam., thallus thick, coarse, soralia large (at least 0.5–1.0 mm), convex, delimited to locally confluent .... **L. cenisia**

Key B

1 Soralia Pd+ red (protocetraric acid); on *Pinus* bark .... **L. norvegica**
Soralia Pd+ yellow or negative 2
2(1) Soralia C+ red; on *Pinus* bark in coastal regions .... **L.orediomarginata**
Soralia C- 3
3(2) Thallus with fatty acid(s) 4
Thallus with other secondary metabolites 7
4(3) Caperatic acid present; soralia coalescent .... **L. mughosphagneti**
Caperatic acid absent; soralia delimited to confluent 5
5(4) Nephrosteranic acid present; soralia delimited by a dictinct thalline rim; usually on twigs of *Rhododendron* in subalpine belt, rarely on bark of *Fagus* and *Alnus* or on wood **L. exspersa**
Note: Rarely, roccellic acid is present instead of nephrosteranic acid; saxicolous ecotypes of L. cenisia rarely produce nephrosteranic acid as well.
Roccellic acid present; soralia rarely with a distinct thalline rime 6
6(5) Thallus at least locally pustulate, soralia mostly punctiform; on smooth bark of deciduous trees (mainly beech) in forests, continental species .... **L. substerilis**
Thallus immersed to very thin, soralia delimited to confluent; oceanic species .... **L. farinaria**
Thallus thin and smooth, soralia delimited, rounded, c. 0.5–2.0 mm in diam.; in beech forests .... **L. albella**
Thallus thick, coarse, areolate to postulate, soralia large (at least 0.5–1.0 mm), convex, delimited to locally confluent; mountain species .... **L. cenisia**
7(3) Usnic acid present 8
Usnic acid absent 9
8(7) Arachnoid prothallus absent, thallus white-grey, soralia delimited; 2-O-methylsulphurellin as a major compound .... **L. jamesii**
Arachnoid prothallus present, soralia coalescent, covering most of the thallus; with *thysanophora*-unknowns .... **L. thysanophora**
9(8) Thallus and soralia yellow; xanthones present; oceanic species .... **L. alboflavida**
Thallus grey, soralia whitish to yellow; xanthones absent 10
10(9) Zeorin present 11
Zeorin absent 12
11(10) Soralia with yellow tinge, covering almost whole thallus .... **L. barkmaniana**
Soralia white, delimited .... **L. variolascens**
12(10) Soralia coalescent, yellow-green; *viridissima*-unknown present .... **L. viridissima**
Soralia ±delimited, white or yellowish; terpenoids or atranorin alone present 13
13(12) *Impudens*-unknown and/or a fatty acid or atranorin alone produced .... **L. impudens**
Allophana-unknowns as major secondary metabolites .... **L. allophana**

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2.4. Methodology of diversity research

The efforts to capture the lichen diversity has changed a lot during the history of floristic research – from single records by old authors during 19th and 20th centuries, over first species lists from a delimited area published mainly during the second half of 20th century, up to several very precise and exhaustive diversity reports during the last 20 years. However, a majority of lichen diversity studies use data without any sophisticated methodological approach of collecting and published species lists are based on random records during field excursions. Big disadvantages of such data are the very difficult or impossible reproducibility as well as a possibility of reciprocal comparison among localities. Additionally, species lists are usually an underestimate due to insufficient survey effort. Therefore our aim was to create methods for capturing of complete diversity data as much as possible and use methods enabling a repetition of a survey and the comparison with other sites.

Fig. 11. The old-growth lowland forest in the Cahnov-Soutok National Nature Reserve (Czech Republic, Southern Moravia), a place of the first lichenological competition.

Firstly, we organized a field competition in the lichen diversity exploration. We applied it to epiphytic (including lignicolous) lichens in a large old-growth floodplain woodland in the Southern Moravia (Czech Republic, Fig. 11). A detailed diversity data, comparison among single researchers and diversity data at three different scales were the main goals of the competition. The most interesting results emerged from the comparison among eight lichenologists because individual researchers recorded only 53% to 69% of the total species list despite all of them were well motivated by the competition and the field research was quite exhaustive. We didn't only confirm our idea about the strongly underestimated lichen diversity, but also pointed out differences between individual lichenologists, respectively the amount and composition of species recorded by them, and that many taxa occur very rarely at localities (often on one or several objects only), so they are usually omitted during an ordinary survey.

Partially similar results were demonstrated by Cristofolini et al. (2014), who established that errors in identification of lichen species and a selection of different trees for a survey are main causes of results variation among single lichenologists or teams of lichenologists.

Fig. 12. The richest plot with 228 epiphytic and epixylic species in 1 ha plot of the old-growth beech forest Uholka, Ukraine.

Secondly, we attempted to apply the method with a team of competing researchers for an inventory enabling a comparison among localities and a comparison with other field methods. A team of seven skilled lichenologists explored a large virgin beech forest Uholka in the Ukrainian Carpathians. We subjectively chose four 1 ha plots at places with expected local lichen diversity hot spots. The total species richness at single plots was surprisingly high again (from 181 to 228 species) and moreover, the richest plot exceeded the total species list of the whole Uholka-Shyrokyi Luh Biosphere Reserve covering 10244 ha (Dymytrova et al. 2013) which contains only 203 lichenized fungi. The authors used a method of grid mapping consisting of 352 circular plots, each with 30 m radius. Therefore we recommend sampling of subjectively selected hot spots rather than a systematic sampling (used for example by Svoboda et al. 2009, Nascimbene et al. 2010, Dymytrova et al. 2014) because of its much higher efficacy.

Methods for obtaining more complete species lists in surveys of lichen biodiversity

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Abstract: We tested two methods to obtain more complete species inventories in surveys of lichen biodiversity. The first was to employ numerous lichenologists, all experienced and some of them specialists, in the same survey, with an element of competition. The second was to organise those lichenologists into competing teams. We show that overall biodiversity recorded is distinctly higher than the part of lichen biodiversity recorded by each single lichenologist or team. Use of these methods in a survey of epiphytic and epixylic lichens resulted in a list containing 112 species in 1 ha, 192 species in 13.5 ha and 212 species for 30 km^2 of lowland floodplain old-growth forest in the SE of the Czech Republic. Eleven recorded species are new to the country; four are rediscovered after more than 50 years. In comparison, few previous surveys of mixed montane forests in the same general region have yielded more than 200 species, even though it is certain that those forests have greater lichen diversity than our lowland forest.

Introduction

Biodiversity inventories are undoubtedly an indispensable part of basic research, but it is very difficult, perhaps impossible, to obtain a complete lists of species present in a large area. The problem applies to many groups of organisms (e.g. Chiarucci and Palmer 2009; Chiarucci et al. 2011) including lichens (Hunter and Webb 2002, Will-Wolf et al. 2004). The difficulty decreases as the area investigated becomes smaller, and for sufficiently small plots a complete list is achievable, e.g. as concluded by Klimeš, L. et al. (2001) for vascular plants and by McCune and Lesica (1992) for lichens and bryophytes. Modern work on lichen biodiversity usually uses surveys of small plots, from which the number of species in a larger region is extrapolated (McCune et al. 1997; Nascimbene et al. 2010; Dymytrova et al. 2013, 2014; Ravera and Brunialti 2013). Only a few studies primarily focused on cryptogams simultaneously used different methodological approaches for getting relevant data, i.e. the combination of random (probabilistic) approach (sampling plots/quadrats or transects) and a non-random 'floristic' research focusing on specific microhabitats (Edwards et al. 2004; Newmaster et al.,2005; Ravera and Brunialti 2013). Newmaster, S.G. et al. (2005) found that plot sampling of bryophytes is much less sensitive for detecting rare species. McCune and Lesica (1992) investigated which size of plot is best suited for making bryophyte and lichen inventories in various habitats. They concluded that use of numerous small plots gives reproducible results, but fails to capture many of the species present in the habitat. Use of fewer but larger plots captures more species, but many records have a "random" character: they represent rare species not found in most plots. In addition, any survey faces the practical problem that different recorders have different levels of skill, and many researchers have "blind spots" for some groups of taxa (Ketchledge and Leonard 1984; McCune and Menges 1986; McCune et al. 1997; Klimeš et al. 2001).

Here we present methods for obtaining α and γ biodiversity data. When applied to epiphytic and lignicolous lichens in a large old-growth floodplain woodland in the Czech Republic they appeared to give good results for both completeness and reproducibility. Their main drawback is that they require the participation of several skilled lichenologists.

The methods use simple floristic surveys at three levels and with different intensities of study, as follows: (1) detailed survey of a one hectare plot, (2) detailed survey in a 13.5 hectare area of a well-preserved woodland, and (3) surveys in the whole floodplain woodland of 30 km^2, in seven spots of overall area 25 ha. Levels (1) and (2) used several well-trained field lichenologists working in parallel or in teams, and with an element of competition among individual researchers or between teams. It was expected that a competitive element would increase motivation of involved researchers, both during the field work and in subsequent identification. Differences in results of individual recorders involved in inventories were studied before by botanists (e.g. Petřík and Boublík 2003) and it can be also traced in lichenological literature (e.g. McCune et al. 2009; Lõhmus et al. 2012), but the importance of competition was not evaluated.

Materials and Methods

Surveyed territory and field work

We selected a large flood-plain forest between the rivers Dyje and Morava in southern Moravia (Figs 1A, B, C, Table 1) covering approximately 30 km2. It was selected because it consists of fairly homogeneous lowland forest formations of native tree species (Table 1), it was presumed to have high lichen species richness (numerous tree species with various age, bark texture and acidity), is flat (which facilitates surveying), and is partly formed by preserved old growth forests: protected areas Cahnov (locations 1 &2 in Table 1), Ranšpurk (location 3) and Soutok (location 7). Eight researchers (the authors) were involved in the main experiments (see Table 1 for more details). All of them are experienced in collecting and identifying European epiphytic lichens. The experiment was conducted over the period 30 March – 4 April, 2014, the dates being chosen to provide good conditions for field work (good lighting, as leaves were absent, mild temperatures, and no mosquitoes). We examined the territory at three different spatial scales (see below). Diversity data from different spatial scales were inevitably produced by inconsistent methods and we are aware of limitations in comparisons among the three data sets.

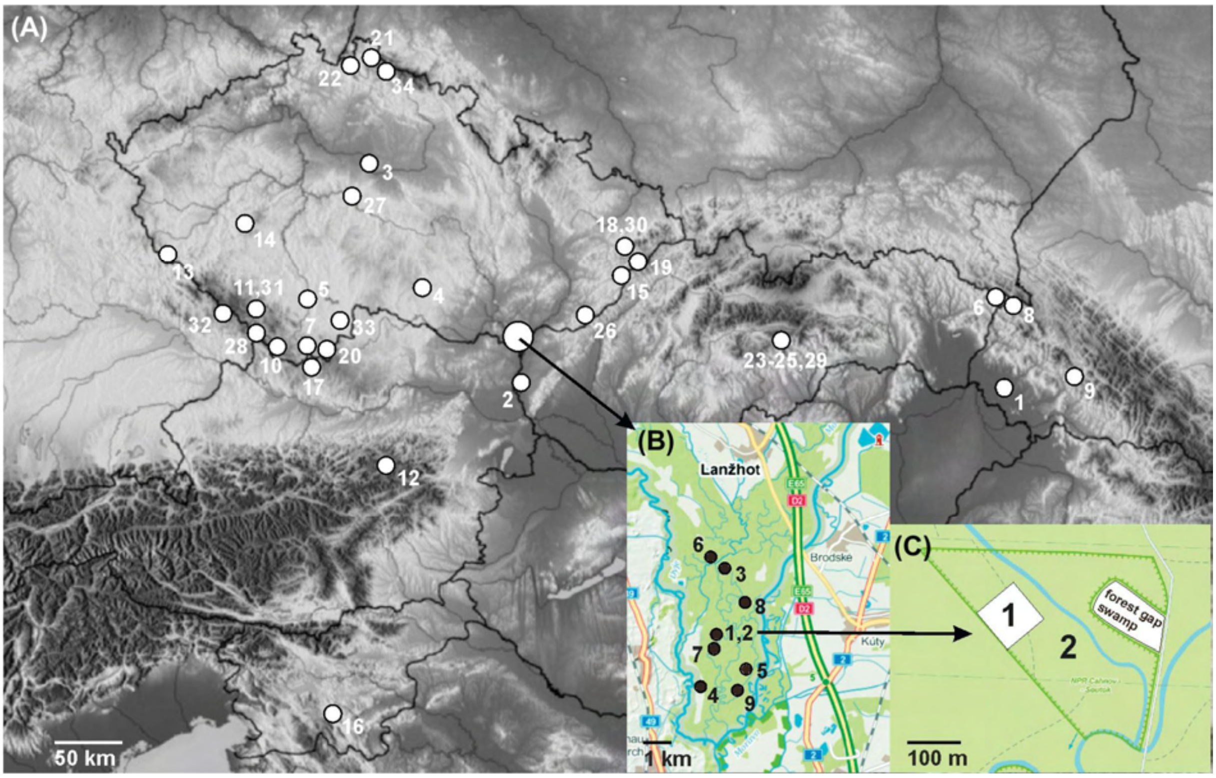


Fig. 1. A, Location of the investigated woodland (large circle) and localities of various old–growth forest types used for biodiversity comparison, nrs 1-34 correspond with Table 2; B, visited sites inside the investigated woodland, nrs 1-9 correspond with Table 1; C, localities of experiments (sites 1 and 2) within the protected area Cahnov (circumscribed by green line).

One-hectare plot experiment

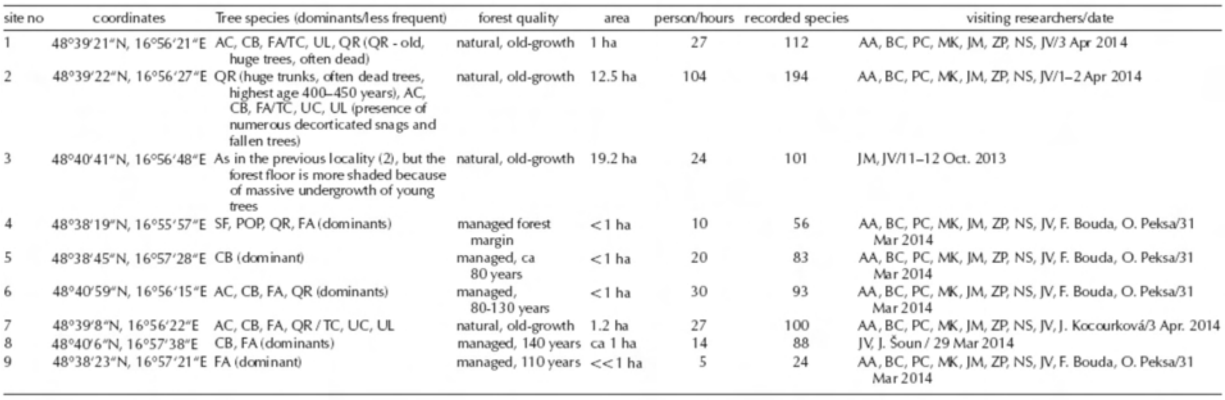
A single one hectare square plot was randomly marked out by people not involved in the experimental surveys (loc. 1 in Table 1, Fig. 1C). The plot was intensively surveyed for three hours by two independent teams, each team containing four co-operating specialists (details in Table 1). Teams operated mostly on separate half hectare areas, though there was some slight overlap. Records were listed for each half hour period, i.e. in six periods.

Floristic 12-hour experiment

This took place in the territory circumscribed by the fence within the protected area "Cahnov" (loc. 2 in Table 1, Figs 1B, C) but excluding the 1ha area used for the one-hectare plot experiment. Each of the eight investigators, working independently this time, recorded for 12 hours (two days; six hours per day). Records were listed for each 1-hour period.

Additional floristic

A further seven sites scattered over the whole floodplain woodland of c. 30 km^2 (locations 3–9 in Table 1, Fig. 1B) were also investigated for lichen biodiversity. They were selected to cover the habitat variability within the floodplain forest and their total area is about 25 hectares. Because this stage of the work involved both a larger area and greater habitat diversity, comparisons of the results with those from the earlier stages must be made with caution. This work used a total of 130 man-hours, with man-hours per site varying from a minimum of 5 to a maximum of 30. As in the 12-hour experiment, recorders worked independently. Table 1 and Table A1 have further details. Its aim was to show differences between α-diversity in the experimental site "Cahnov" (locations 1 and 2 in Table 1, Figs 1B, C) and γ-diversity of the whole 30 km^2 area.



site no	coordinates	Tree species (dominants/less frequent)	forest quality	area	person/hours	recorded species	visiting researchers/date
1	48°39′21″N, 16°56′21″E	AC, CB, FA/TC, UL, QR (QR - old, huge trees, often dead)	natural, old-growth	1 ha	27	112	AA, BC, PC, MK, JM, ZP, NS, JV/3 Apr 2014
2	48°39′22″N, 16°56′27″E	QR (huge trunks, often dead trees, highest age 400–450 years), AC, CB, FA/TC, UC, UL (presence of numerous decorticated snags and fallen trees)	natural, old-growth	12.5 ha	104	194	AA, BC, PC, MK, JM, ZP, NS, JV/1–2 Apr 2014
3	48°40′41″N, 16°56′48″E	As in the previous locality (2), but the forest floor is more shaded because of massive undergrowth of young trees	natural, old-growth	19.2 ha	24	101	JM, JV/11–12 Oct. 2013
4	48°38′19″N, 16°55′57″E	SF, POP, QR, FA (dominants)	managed forest margin	<1 ha	10	56	AA, BC, PC, MK, JM, ZP, NS, JV, F. Bouda, O. Peksa/31 Mar 2014
5	48°38′45″N, 16°57′28″E	CB (dominant)	managed, ca 80 years	<1 ha	20	83	AA, BC, PC, MK, JM, ZP, NS, JV, F. Bouda, O. Peksa/31 Mar 2014
6	48°40′59″N, 16°56′15″E	AC, CB, FA, QR (dominants)	managed, 80-130 years	<1 ha	30	93	AA, BC, PC, MK, JM, ZP, NS, JV, F. Bouda, O. Peksa/31 Mar 2014
7	48°39′8″N, 16°56′22″E	AC, CB, FA, QR / TC, UC, UL	natural, old-growth	1.2 ha	27	100	AA, BC, PC, MK, JM, ZP, NS, JV, J. Kocourková/3 Apr. 2014
8	48°40′6″N, 16°57′38″E	CB, FA (dominants)	managed, 140 years	ca 1 ha	14	88	JV, J. Šoun / 29 Mar 2014
9	48°38′23″N, 16°57′21″E	FA (dominant)	managed, 110 years	<<1 ha	5	24	AA, BC, PC, MK, JM, ZP, NS, JV, F. Bouda, O. Peksa/31 Mar 2014

Table 1. Sites observed in the investigated woodland (see also Figs 1B, C). Man-hours reflect intensity of research.

Material used and data analyses

Epiphytic and lignicolous lichens, lichenicolous fungi and non-lichenized microfungi were recorded (Table A1), but only lichens and facultatively lichenized fungi were included in analyses. By the latter we mean the genera *Chaenothecopsis*, *Leptorhaphis* and non-lichenized, non-lichenicolous species of the genera *Anisomeridium*, *Arthonia*, *Arthopyrenia*, *Lithothelium*, *Ramonia*, and the species *Melaspilea proximella*.

Data from recorders were collated by the first three authors, who also revised the suspicious records (possibly incorrectly identified or ambiguously identified specimens). Unidentified specimens (usually fragments of sterile thalli or some crusts with pycnidia only) were ignored entirely. Several records do not match any species known to us. These are included in the analyses, marked either by "cf.", or by the suffix "nom. ined." if the taxon will be formally described elsewhere (see Table A1). Data from all recorders were used to create individual species accumulation curves (Figs 2, 3), and the total accumulation curve. TLC was used to identify some lichens (see notes in Table A1).

Comparison with other inventories

We extracted presence/absence data for epiphytic lichens from 34 central European old-growth forest inventories to compare the number of species reached in our experiments with existing inventories of various forest types. We extracted data from Bilovitz et al. (2011), Dymytrova et al. (2013), Guttová and Palice (1999, 2002, 2004), Guttová et al. (2012), Hafellner and Komposch (2007), Kondratyuk et al. (1998), Kondratyuk and Coppins (2000), Malíček et al. (2013), Malíček and Palice (2013), Malíček and Vondrák (2014), Vondrák et al. (2015), and from eighteen unpublished inventories (see Table A3). Data extraction and work with our own dataset used the same taxonomic concepts.

Results

Overall, the one hectare plot yielded 112 lichen species (Table A1), but each group of researchers recorded only 89 and 93 species (79% and 83% of this total). The species accumulation curves have a broadly similar shape for each group, though one group appears to have been a little more productive in the first half of the recording period and less productive in the second half (Fig. 2). Neither the species accumulation curves of either group–nor the total accumulation curve had flattened at the end of the 3 hour recording period.

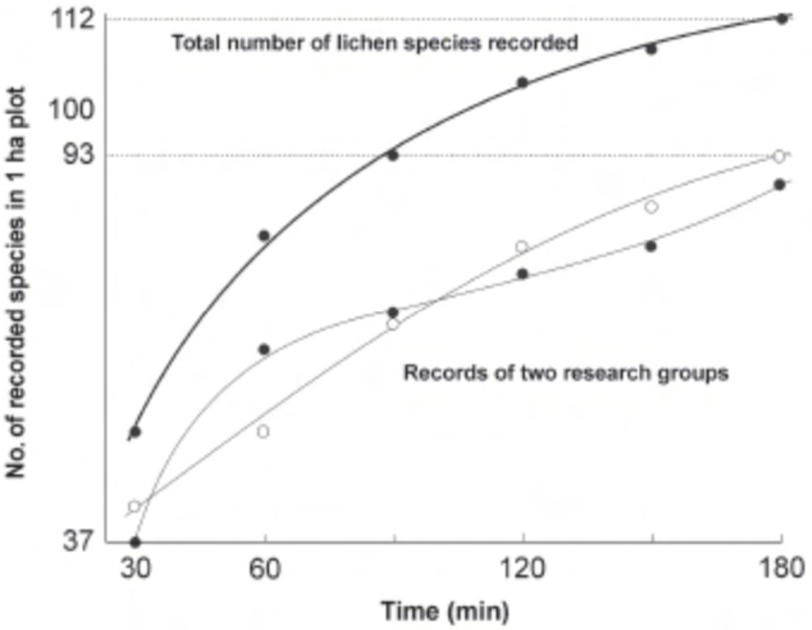


Fig. 2. Number of lichen species recorded during the one–hectare plot experiment. Cumulative numbers are shown for six 30–minute periods; results of two groups of researchers as well as total results are plotted. Results are approximated by "species accumulation curves"; total curve is thicker. Curves drawn by hand.

The 12-hour experiment yielded a total of 194 species (Fig. 3, Table A2) from the 13.5 ha area. The eight individual researchers recorded from 87 to 128 species (only 45% to 66% of this total). The individual species accumulation curves differ, but not dramatically. The three lowermost curves, which clearly cluster separately from the other six, belong to investigators without previous field experience in central Europe. The five upper curves have less scatter, with 114 to 128 species recorded at the end of the experiment (Fig. 3). None of the individual curves had completely flattened at the end of the recording period, though some appear to have been approaching saturation. The positive effect of an increasing number of researchers is evident; only 46 species (mostly common macrolichens) were recorded by all researchers but 40 species were recorded by only one researcher. The number of recorded species is positively correlated with the number of involved researchers (Fig. 4).

The survey of another seven sites (locs 3–9 in Table 1) within the whole floodplain woodland (involving a further 130 man-hours of recording) increased only slightly the total number of species recorded (γ-diversity of the whole 30 km^2 floodplain forest area), to 212 (112.5% of the13.5 ha α-diversity). The increase of the number of captured species from the 1 ha plot experiment to the whole 30 km^2 area is demonstrated by the species-area curve, shown in Fig. 5A. The total number of species recorded increases much more between 1 ha and 13.5 ha than between 13.5 ha and 30 km^2. Selected characters of the lichen biodiversity (γ-diversity) captured within the project are summarized in Table A2.

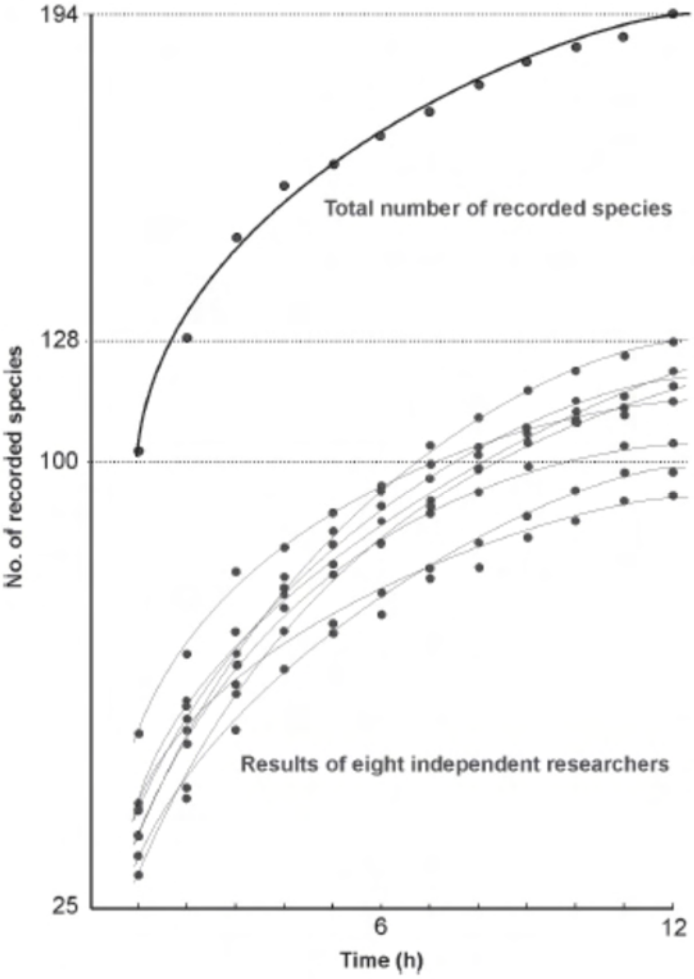


Fig. 3. Number of lichen species recorded during the 12–hour experiment (13.5 ha). Cumulative numbers are shown for twelve 1–hour periods; results are shown for individual researchers as well as the total. Results are approximated by "species accumulation curves"; total curve is thicker. Curves drawn by hand.

During our research, several unexpected species were recorded. *Agonimia borysthenica*, *Anisomeridium macrocarpum*, *Biatora pontica*, *Chaenothecopsis rubescens*, *Lecanora quercicola*, *L. subcarpinea*, *Lithothelium hyalosporum, L. phaeosporum*, *Phaeophyscia rubropulchra*, *Strigula affinis* and *Verrucaria* cf. *viridigrana* are new for the Czech Republic. *Bacidia auerswaldii*, *Cresporhaphis wienkampii*, *Melaspilea proximella*, *Diplotomma pharcidium* and *Phaeophyscia pusilloides* are rediscovered in the Czech Republic after more than 50 years (cf. Liška et al. 2008). Some noteworthy species recorded during our research, e.g. *Arthonia pruinata*, *Arthothelium spectabile* and *Bactrospora dryina*, have already been published in a separate paper (Malíček et al. 2014). Three probably undescribed species were recorded during the lichen inventory (Table A1: *Bacidia ‘albogranulosa’*, *Micarea ‘substipitata’* and *M. ‘inconspicua’*).

Discussion

Raising number of researchers and competitive effect

Fig. 3 shows that not one of the eight lichenologists managed to record more than 70% of the total species list obtained by collecting and correcting data from all researchers, even though the recorders are experienced and skilled workers. Clearly, raising the number of lichenologists involved improves completeness of lichen inventories (Fig. 4). Of course, there must come a point when further addition of researchers has negligible benefit, though we find it difficult to estimate just where that point would occur. Any estimate from our data might not work with different recorders or in other field conditions.

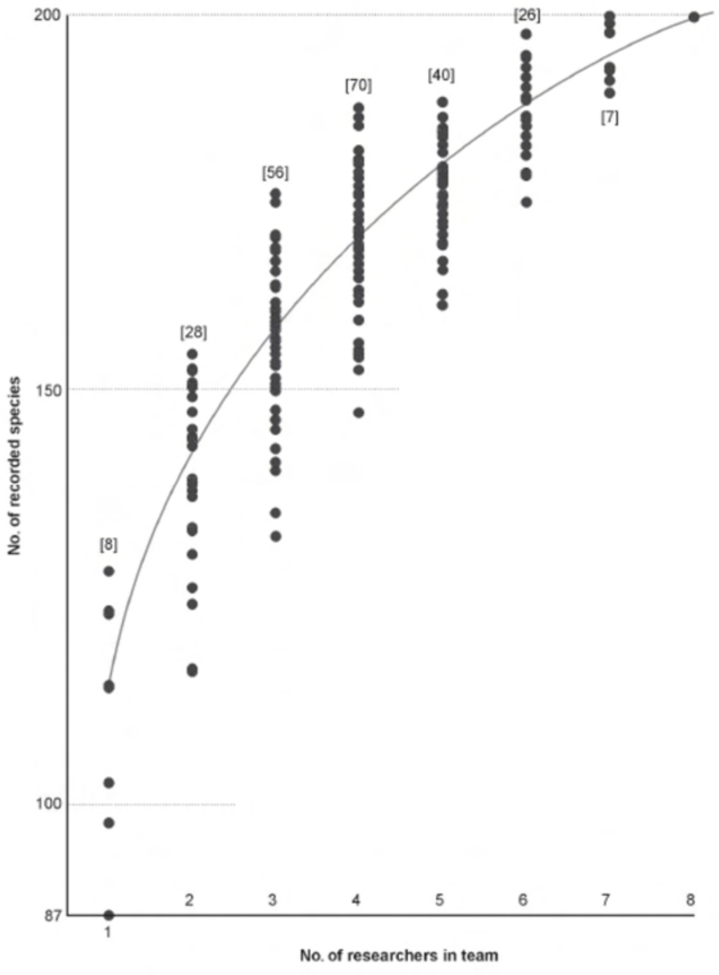


Fig. 4. Relation between the number of included researchers and the number of recorded species (based on our datasets from eight researchers for the 12–hour experiment). Possible combinations are in square brackets. Data approximated by hand-drawn curve.

Employing numerous lichenologists and taking advantage of competition does not guarantee a complete lichen inventory, but the species list should be close to complete if individual species accumulation curves (Fig. 3) reach plateaus. The methods probably work best only for small territories, up to tens of hectares, because individual accumulation species curves would not reach plateau in a reasonable time span in larger territories. However, even in larger territories, the new methods will probably work better than traditional methods.

The effect of competition among lichenologists cannot easily be quantified and tested, but that there is such an effect is an obvious consequence of human nature. It will obviously tend to improve the completeness of species lists. In lichen survey work the “stakes” are probably far too low for any undesirable effects of competition (such as identifying additional taxa on dubious grounds) to be a concern.

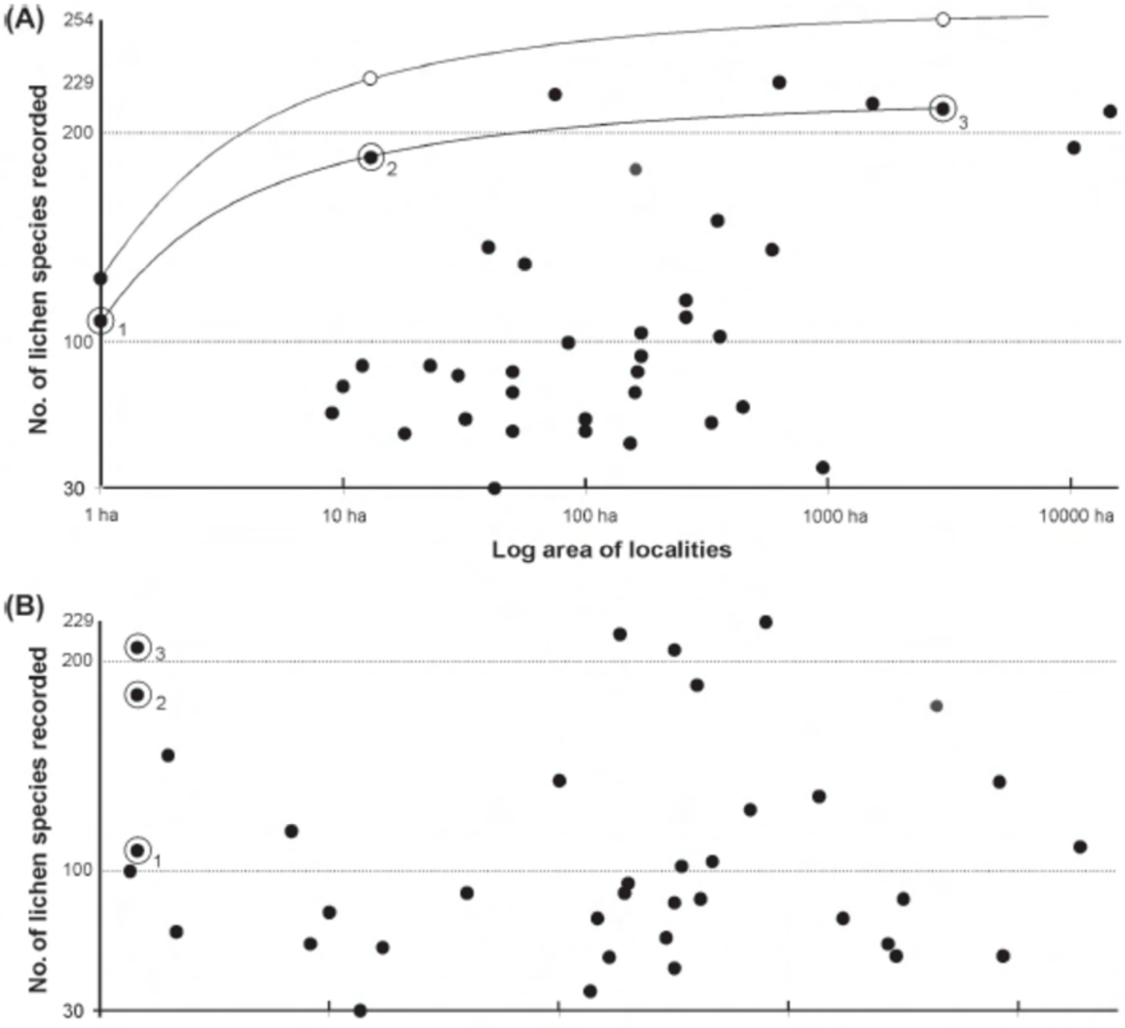


Fig. 5. Our data (shown as dots in rings; 1, 1 ha plot experiment; 2, 12–hour experiment; 3, γ–diversity in 30 km^2) and results from 34 inventories of central European old–growth forests (see Table A3). A, species/area relation (sampling effort per area has not been standardized due to missing data for the extracted inventories). Lower curve: species–area curve based on our three datasets; upper curve: hypothetical species–area "minimal" curve for mixed mountain forests (explained in text). B, species/altitude relation.

Our data in the context of central European surveys

The quality of inventory data obtained by our methods is demonstrated by comparison with 34 central European old-growth forest inventories (Table A3; Fig. 1A). Presumably these 34 inventories vary in quality according to who did the work, and how thoroughly.

The numbers of species recorded by these inventories are compared with ours in Figs 5A, B. We recorded fewer species in the 1-ha plot than Hafellner and Komposch (2007) who precisely studied a 1-ha plot in a beech-dominated virgin montane forest remnant. This is consistent with our experience that montane forests generally have higher lichen biodiversity than lowland ones. The reason is that montane forests have a mix of both deciduous and coniferous phorophytes that support both lowland and montane species. Lower air pollution and higher humidity also play a part. Higher species richness in montane mixed forests should be apparent in Fig. 5B, where maximum biodiversity would be expected at altitudes between 500 and 1200 m. Despite the large scatter, this is apparent in the chart (although the high number of species captured in our own, low altitude, datasets disturbs the pattern). We suggest that the relation between species numbers and altitude would show much less scatter and would have an obviously unimodal distribution if all sites had been surveyed by our method.

Assuming similar species-area relations for lowland floodplain forests and for montane mixed forests, our datasets and the data by Hafellner and Komposch (2007) yield a hypothetical species-area "minimal" curve for mixed forests (upper curve in Fig. 5A). Although Hafellner and Komposch (2007) made their 1-ha inventory carefully they used only two recorders; our eight recorders should have captured noticeably more species. Our method, if employed for well-preserved montane mixed forests would probably get numbers of species above this species-area "minimal" curve.

Problems in lichen survey methods

A serious difficulty in surveying epiphytic lichens is their uneven vertical distribution. Some species do not usually occur on the lowermost 2 m of the trunk, the part of the tree that is most accessible (Eversman et al. 1987; Fritz 2009; Ellis 2012; Marmor et al. 2013). The overlooked richness of lichen biodiversity in tree canopies was noted by Jarman and Kantvilas (1995) and Boch et al. (2013). The latter authors found that information on more than 50 % of the lichen diversity may be lost if canopy lichens are not considered. Some recent forest lichen inventories that are otherwise done in detail unfortunately suffer from this problem (e.g. Dymytrova et al. 2013; Malíček and Palice 2013). Their species lists lack some canopy lichens and some common lichens restricted to twigs. To avoid this problem, we specifically searched for lichens on twigs and in the upper parts of trunks by observing fallen twigs (also in methods by McCune et al. 1997, Jovan 2008) and by climbing trees, and also made the experiments in a locality containing a natural forest gap (See Fig. 1C), where lichens on lower branches and sun-exposed young trees could easily be observed. The canopy makes a significant contribution to epiphytic lichen biodiversity (Table A2); twenty-four of our species were observed only on twigs - and even this probably under-estimates the diversity of canopy lichens, which were sampled mainly from fallen twigs.

The forests have other kinds of heterogeneity too (e.g. Fritz and Heilmann-Clausen, 2010; Lõhmus et al., 2012; Blasy and Ellis, 2014). Tables A1, A2 show many niche specialists (e.g. *Arthonia pruinata*, *Biatora veteranorum*, *Chaenotheca hispidula*, *Chaenothecopsis rubescens*, *Schismatomma pericleum* and *Verrucaria* cf. *viridigrana*) restricted to one substrate type. Many microlichens have been recorded from only one site (and usually recorded only once during the project) that is partly caused by overlooking some microhabitats. More than one half of recorded taxa have been found at one, two or three sites only, but some of them have been probably overlooked in other sites. Involving more lichenologists with field experience of lichens in specialized niches is beneficial for obtaining more complete species lists, but of course it will not always be feasible.

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Supplementary material

Appendix 1, Table A1. Species recorded in the surveys. Bold font denotes species used in the analysis (lichens or similar); other (lichenicolous fungi or epiphytic microfungi) are listed but were not analysed. Substrate abbreviations: AC Acer campestre, AG Alnus glutinosa, CB Carpinus betulus, FA Fraxinus angustifolia, POP Populus, QU Quercus robur, SAL Salix alba / fragilis, TIL Tilia, ULM Ulmus minor / laevis. Collector abbreviations:AA, BC, JM, JV, MK, NS, PC, ZP are acronyms of the authors; FB, František Bouda; JŠ, Jaroslav Šoun. Abundance (Ab.): 1, rare, recorded from only one visited site; 2, occasional, recorded from 2-3 sites; 3, common, recorded from 4 and more sites.

species	**substrate**	**sites (according to Table 1 & Fig. 1B)**									**vouchers**	**Ab.**	**note to identification**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**collector (collection nr)**		
Absconditella lignicola	wood	x	x								JV, MK, PC(2), ZP(2)	2	Sample ZP17555 approaching *Absconditella amabilis* T.Sprib.
Acrocordia gemmata	AC, CB, FA, QU, TIL, ULM, Crataegus	x	x	x		x	x	x	x		BC, JM(2), JŠ, JV(5), MK(2), PC(2), ZP(3)	3	Usually with perithecia, but anamorphic crusts seen (JV11974). BC specimen with smaller spores (14.5-16.5 µm long) somewhat resembling *A. cavata*.
Agonimia allobata	AC, FA, QU, TIL, ULM, wood	x	x				x		x		JM, JV(2), ZP	3	
Agonimia borysthenica	CB, TIL, ULM	x	x						x		JV, PC, ZP(2)	2	It matches the description by Dymytrova et al. (2011) except the thallus - distinct hyaline hairs up to 10 µm long observed in our material - are not mentioned in the protologue. Our examination of the isotype from W showed hairs only on several juvenile areoles; otherwise the isotype fits our specimens: overall habit, almost isodiametric globose areoles, black non-furrowed perithecia with 8 ascospores in asci.
Agonimia repleta	TIL		x								PC, ZP	1	
Agonimia tristicula	CB, QU, wood (bryophytes)		x								BC, PC	1	Only sterile specimens recorded; but their subsquamulous thalli are distinct from other lichens.
Ahlesia lichenicola	wood		x								ZP (cum Placynthiella icmalea)		

Amandinea punctata	AC, CB, FA, QU, SAL (also twigs), TIL, ULM, Crataegus, Euonymus, wood	x	x	x	x	x	x	x	x	x	FB, JM, MK(3), PC(3), ZP	3	
Amphisphaeria fallax	AC							x			JV		
Anaptychia ciliaris	FA (twigs)		x						x			2	
Anisomeridium biforme	CB, QU		x						x		AA, JV	2	Thallus whitish, lichenized, with *Trentepohlia*; only anamorph seen; pycnidia largely immersed, globose (wall K+ green); conidiogeneous cells thin with conidia arising apically; conidia subglobose, 3-5 x 2.5-4 µm (slightly larger than known for this species).
Anisomeridium macrocarpum	AC, FA, QU, TIL, ULM	x	x				x		x		JŠ, JV(5), MK, ZP(3)	3	
Anisomeridium polypori	AC, CB, FA, QU, TIL, ULM, Crataegus, Sambucus, wood	x	x	x		x	x	x	x	x	MK(2), PC, ZP(3)	3	Occassionally with perithecia; anamorphic stage common.
Arthonia atra	CB	x	x	x				x	x		JM(2), JV(4), MK(2), PC, ZP	3	
Arthonia byssacea	CB, FA, QU, TIL	x	x	x		x	x	x	x		JM(4), JŠ, JV(2), MK(2), PC, ZP	3	Apothecia rare; usually in anamorphic stage containing numerous black pycnidia with white thalline rim; conidia hyaline, non-septate, 5-7×1.5 µm
Arthonia didyma	AC, CB	x									ZP	1	
Arthonia dispersa	AC, FA (twigs)		x				x		x		JM(2), JŠ, JV(3), ZP	2	
Arthonia helvola	QU						x				JM	1	
Arthonia phaeophysciae	FA, on Phaeophyscia orbicularis					x					JV		
Arthonia pruinata	QU		x	x							JV(4)	2	
Arthonia radiata	CB		x			x			x		PC	2	
Arthonia ruana	CB, TIL		x	x							JM(2), JV	2	
Arthonia spadicea	AC, AG, CB, QU, TIL	x	x	x			x		x		JM, MK(2), PC	3	
Arthopyrenia cf. atractospora	AC		x								BC	1	Perithecial wall of short-celled pallisade prosenchyma, K-; paraphysoids slender, branched; asci c. 60-80 um long; ascospores 1-septate, 16-20 x 4 um; conidia 3-4 x 1 um.
Arthopyrenia punctiformis	ULM		x								ZP	1	
Arthothelium spectabile	CB		x	x							JM(1), JV(2)	2	
Arthrorhaphis aeruginosa			x										

Ascodichaena sp.	FA (twig)		x		x						JV		
Bacidia albogranulosa nom. ined.	AC	x	x					x			JM(3), JŠ, JV(4), MK, ZP	2	Grey-white sorediate crust; apothecia and pycnidia absent; TLC: atranorin; ITS nrDNA sequence data for two (JV) samples obtained
Bacidia auerswaldii	AC	x	x					x			JM, JŠ, JV(2), PC(2)	2	Hypothecium colourless, epihymenium brown, ascospores 25-32 x 4.5-6.5 µm; thallus of tiny granules (smaller than in B. subincompta), sometimes with blackish pigmentation
Bacidia circumspecta	AC, CB	x	x			x					JV, PC(3), ZP	2	
Bacidia fraxinea	AC, CB, FA, QU	x	x	x		x	x	x	x		FB, JM, JV, MK, PC(2), ZP	3	
Bacidia incompta	AC, FA, ULM	x	x	x		x			x		AA, JM(2), JV, NS, ZP(2)	3	
Bacidia pycnidiata	AC, QU, wood	x	x								JM, ZP(2), PC	2	
Bacidia rubella	AC, CB, FA, POP, TIL	x	x	x		x	x	x	x		JV(2), MK, PC	3	
Bacidia subincompta	AC, TIL	x		x							NS	2	
Bacidia trachona	AG, CB (trunk base)		x	x							BC, JV	2	Apothecia absent; pycnidia large black; wall K+ purple; conidia 3-4 x 1.5 um; thallus K+ yellow; TLC: no substances.
Bacidina brandii	QU	x									PC	1	Thallus not sorediate/blastidiate; apothecia with brownish discs and paler margins; hypothecium with Arnoldiana-brown pigment.
Bacidina chloroticula	AC, FA, ULM (twigs), CB		x			x					JV, ZP(2)	2	Minute white apothecia found together with immersed pycnidia with crescent/narrowly-sickle shaped macroconidia (ca 15 x 1.5 µm) that are not mentioned in Ekman (1996) for this taxon.
Bacidina cf. neosquamulosa	FA, wood, fallen branch	x	x	x							MK, PC	2	Thallus areolate, hypothecium very pale/colourless, epihymenium olive, K-, excipulum at the top orange brown, K+ darkening, ascospores acicular, c. 40 × 1.5 µm.
Bacidina sulphurella	AC, CB, FA, QU, TIL, wood	x	x	x			x	x	x		JM, JV, MK, PC, ZP(3)	3	Specimen ZP 17707 is richly fertile but its pycnidia contain non-hooked conidia. Hooked conidia found in some other specimens (e.g. JV11934).
Bactrospora dryina	FA, QU, TIL	x	x	x			x	x	x		JM(3), JŠ, JV(2), PC, MK	3	Ascospores filiform, breaking down within asci into cylindrical part-spores, up to 8 µm long c. 3 µm wide
Biatora albohyalina	CB		x								BC, JM, JV	1	All specimens in anamorphic stage.
Biatora globulosa	QU					x					JM	1	
Biatora pontica	CB	x	x								JM, MK(2), NS(2), ZP	2	TLC (ZP, MK samples): thiophanic acid, asemone, pontica uknown (in 366 UV++ white after reaction with sulphuric acid)

Biatora veteranorum	QU (bark, wood), (rarely TIL)	x	x	x							JM, JV(2), PC, MK, ZP(2)	2	Mostly in anamorphic stage.
Biatoridium monasteriense	AC, ULM		x	x		x	x				JM(2), MK(2), ZP(2)	3	
Bryoria cf. fuscescens	dry wood, fallen twig		x				x				JV	2	
Buellia griseovirens	CB, FA (also twigs), Crataegus, Euonymus, wood	x	x	x		x		x	x		JV(2), PC	3	
Calicium adspersum	CB, QU		x				x	x			BC, JM, JV, ZP	3	In anamorphic stage. Thallus with Norstictic acid (K reaction is distinct; confirmed by TLC)
Calicium glaucellum	wood	x	x					x			JM(2), MK, PC(4), ZP	2	
Calicium salicinum	QU		x			x					PC(2)	2	
Caloplaca obscurella	AC, CB, FA, POP, PYRUS, QU, SAL, TIL, ULM, wood	x	x	x	x	x	x	x	x	x	JM(4), JV, PC(2), ZP	3	
Caloplaca pyracea	AC, FA, SAL, POP (often twigs)		x		x			x	x		ZP	3	
Caloplaca substerilis	AC, (rarely CB)	x	x				x				JM(2), JV(2), MK, ZP(2)	2	Sterile, rarely with yellow pycnidia.
Candelaria concolor s.str.	FA, QU, ULM	x	x		x						JM	2	
Candelariella efflorescens s.lat.	AC, CB, FA, QU, SAL, TIL, ULM (often twigs), wood	x	x	x	x		x	x	x	x	MK, PC	3	Sterile thalli with marginal soralia on squamules (not *C. reflexa*)
Candelariella vitellina	FA, wood		x		x						MK, PC	2	
Candelariella xanthostigma	AC, CB, FA, POP, QU, SAL (often twigs), wood	x	x	x	x	x		x	x		PC, ZP	3	
Catillaria fungoides	AC, FA, QU (twigs), POP		x	x	x	x	x		x		JM, JV, PC, ZP	3	
Catillaria nigroclavata	AC, CB, FA, QU, POP, SAL, TIL, ULM (often twigs), Crataegus	x	x	x	x	x	x	x	x	x	FB, JM(2), JV, MK(3), PC(2), ZP	3	
Catinaria atropurpurea	FA, QU		x								JM, JV(2), PC(3), ZP	1	Pycnidia present (unknown in literature) and some crusts only with pycnida: pycnidia mostly immersed in thallus; pycnidial wall pale (yellow-orange), rarely blackened around ostiole, C-, K-, N-, conidia 4-5 x 1.5-3 µm
Chaenotheca brachypoda	AC, FA, QU		x	x				x			JM, JV	2	
Chaenotheca brunneola	wood of snag		x								MK	1	
Chaenotheca chrysocephala	FA, CB, QU, TIL, wood of snag	x	x	x			x	x	x		AA, ZP	3	AA sample; sterile yellow crust, partly with leprose appearance
Chaenotheca ferruginea	FA, POP, QU, TIL	x	x	x		x	x	x	x		ZP	3	
Chaenotheca hispidula	AC		x								PC	1	Two apothecia present only; thallus endophloedal, with

													Trentepohlia.
Chaenotheca phaeocephala	FA (rarely CB, TIL, QU, POP)	x	x	x		x	x	x	x		FB, JM(4), JŠ, JV(4), MK(2), NS(2), PC, ZP(2)	3	Some specimens with colourless stalks (albinomorphs)
Chaenotheca stemonea	CB, FA, QU, TIL		x	x			x	x			JM, MK, PC, ZP	3	Usually sterile; TLC (ZP17665): barbatic and cf. obtusatic acids. PC7696 is fertile.
Chaenotheca trichialis	AC, CB, FA, QU, TIL, ULM, wood	x	x	x			x	x	x		JV	3	
Chaenotheca xyloxena	wood		x					x			JM, JV, NS, PC	2	
Chaenothecopsis debilis	wood		x								AA, FB, JV, NS, PC, ZP	1	Stalk with prevailing reddish pigment, N+ purple; hypothecium ±black-green, N-; ascospores 1-septae, with dark septa, 5-7(9) x 2-3 µm; on hard wood; photobiont absent. (concept of Groner 2006)
Chaenothecopsis cf. nigra	CB (wood in hollow trunk), QU	x	x					x			AA, BC(2), JM, MK, ZP(2)	2	Hypothecium brown or olive green, stalk orange-brown, K-, N± intensively orange, ascospores 1 septate, pale, with darker septa, 5-7 x 2-2.5 µm; ± associated with *Stichococcus*. (orange-brown pigment in stalk does not fit *C. nigra* sensu Groner 2006); ZP17739 associated with *Stichococcus* algae on bark of *Quercus* matches *Ch. nigra* well
Chaenothecopsis pusilla	wood		x					x			AA, JM, JV, MK, NS, PC(2)	2	Green pigment in hypothecium and stalk, N- or N+ green intens., K+/- brown; ascospores 1-septate, 5-6 x 2 µm, with pale septum; some samples on *Stichococcus* crust. (concept of Groner 2006)
Chaenothecopsis rubescens	QU		x								JV	1	Distinct K+ red reaction of hypothecium; 0-septate ascospores; on dead white *Trentepohlia* crust in old QU bark fissures
Chrysothrix candelaris	QU		x	x							JM	2	
Cladonia cenotea	wood	x	x					x			JM, JV, ZP	2	
Cladonia chlorophaea	wood		x		x						MK, PC(2)	2	
Cladonia coniocraea (incl. *Cl. ochrochlora*)	CB, SAL, dry wood, mossy wood	x	x	x	x	x	x	x	x		JM	3	
Cladonia digitata	wood	x	x				x	x				3	
Cladonia fimbriata	AC, FA, QU, SAL, Crataegus, wood	x	x	x	x	x	x	x	x		JM, JV, ZP	3	TLC (ZP17684): fumarprotocetraric and cf. physodic acids
Cladonia glauca	wood		x								MK	1	
Cladonia incrassata	wood	x	x								JM, MK(2), PC, ZP	2	TLC (ZP, MK12509): didymic and squamatic acids, ±usnic acid; (MK12489): barbatic and thamnolic acids
Cladonia macilenta	dry wood	x	x	x	x		x	x			ZP	3	TLC (ZP17674): thamnolic, barbatic and didymic acids

Cladonia parasitica	dry wood		x					x			JM(2), JV(2), MK(3), PC	2	Squamules K+ yellow and Pd+ intensly yellow
Cladonia pyxidata	wood		x									1	
Cladonia squamosa	wood		x									1	
Clypeococcum hypocenomycis	Hypocenomyce scalaris		x					x					
Coenogonium pineti	CB, QU, TIL, wood	x	x	x			x	x	x		PC, ZP(2)	3	Sometimes only with pycnidia.
Cresporhaphis wienkampii	SAL				x						BC	1	
Dactylospora sp.	QU, on Verrucaria viridigrana		x				x				JV		
Diplotomma pharcidium	CB		x								BC	1	Apothecia little developed but with distinct true exciple; ascospores 3-septate, 18-20 x 6-7 um, dark; conidia streight, 6-8 x 1 um; norstictic acid absent.
Eopyrenula leucoplaca	AC, CB, FA, QU	x	x			x	x	x	x	x	JV(6), MK, NS, PC(3), ZP(5)	3	Perithecia rare, (eg. JV12009); anamorphic crusts common, recognizable by broadly ellipsoid, slightly melanized (blue-grey), 1-septate conidia, 7.0-8.5×3.5-4.0 µm.
Evernia prunastri	AC, CB, FA, QU, SAL, TIL (often twigs), Crataegus, Euonymus, wood	x	x	x	x	x	x	x	x		MK, PC	3	
Exarmidium inclusum	wood		x							x	ZP(2)		
Flavoparmelia caperata	AC, CB, FA, QU, SAL, TIL (also twigs), Crataegus, Euonymus, wood	x	x	x		x	x	x	x		FB, JM	3	
Graphis scripta s.lat.	CB, (rarely ULM)	x	x	x		x		x	x		JM, JV(3), MK(2), ZP	3	Samples of MK identified as *Graphis betulina*
Halecania viridescens	AC, CB, FA, QU, TIL (twigs)	x	x	x		x	x	x	x		JM, JV(2), MK, PC, ZP(2)	3	
Hyperphyscia adglutinata	AC, CB, FA, QU, POP (usually twigs)		x		x	x					JM, JV(2), PC, ZP(2)	2	Only young thalli observed
Hypocenomyce scalaris	QU, wood		x	x		x	x	x	x			3	
Hypogymnia physodes	AC, CB, FA, QU, SAL (mostly twigs), Crataegus, Euonymus, dry wood	x	x	x	x	x	x	x	x	x	FB	3	
Hypogymnia tubulosa	FA, QU, TIL, SAL (twigs), Euonymus	x	x	x	x	x	x	x	x	x		3	
Hysterium angustatum	POP, ULM		x								JV, ZP		
Hysterium pulicare	FA, QU		x								BC, MK		
Hysterobrevium sp.	wood		x								ZP		

Hysterographium fraxini	FA (twig), decorticated branch on dead tree		x								BC, AA		Brown muriform spores 32x15 um
Illosporiopsis christiansenii	Physcia adscendens, P. tenella		x				x				MK		
Imshaugia aleurites	dry wood		x									1	
Kirschsteiniothelia aethiops	AC, FA, TIL		x	x							BC, JV, ZP		Excipullum present also in lower side of perithecium; ascospores 22-24-28 x (7)8-11 µm, finely dotted. Sample JV11976 with ascospores 26-30 x 7-9 µm, brown, with smooth wall, hamathecium with dense paraphysoids.
Kirschsteiniothelia recessa	CB, ULM		x								JV(2)		
Lecania croatica	AC, CB, FA, QU, TIL, ULM	x	x	x		x	x	x	x		FB, JM(4), JV, MK, PC(2), ZP(3)	3	Only sterile specimens recorded.
Lecania cyrtella	AC, CB, FA, POP, QU, SAL, TIL, ULM (twigs), Sambucus	x	x	x	x			x	x	x	JM, JV, MK, PC, ZP	3	
Lecania cyrtellina	AC, CB		x					x			JM, JV(2), PC(2)	2	Ascospores usually simple, very thin (2-3 µm), conidia curved of two types (thin, non-septate and thicker, 1-septate); different ecology than in *L. cyrtella* - on shaded trunks of old-growth *Acer campestre.*
Lecania naegelii	AC, CB, FA, POP, QU, SAL, TIL (twigs), Crataegus, Sambucus	x	x	x	x	x	x	x	x	x	JM, JV(2), MK, PC(3), ZP(2)	3	
Lecanidion atratum	wood		x								ZP		Det. M.Šandová
Lecanora argentata	CB	x	x	x		x			x		JV, NS, ZP	3	
Lecanora chlarotera	CB, FA	x	x			x					JV(2), MK(3), PC	2	
Lecanora compallens	QU		x								MK	1	TLC: usnic acid, zeorin, +1 terpenoid (trace)
Lecanora conizaeoides	QU, dry wood	x	x		x			x	x		NS, PC	3	
Lecanora dispersa s.lat.	wood				x						MK(2)	1	
Lecanora expallens	AC, CB, FA, POP, PYRUS, QU, SAL, TIL, ULM, wood	x	x	x	x	x	x	x	x	x	JM(2), JV(3), MK(8), PC(2), ZP(3)	3	TLC (MK, all specimens): usnic acid, thiophanic acid, zeorin, cf. arthothelin, expallens unknown, ice blue terpenoid just above thiophanic acid
Lecanora glabrata	CB	x	x	x							JM(2), MK, NS, ZP	2	
Lecanora leptyrodes	CB	x	x	x		x			x	x	JM(3), MK(2), PC(2)	3	Some specimens may be identified as *L. carpinea*, but they fall into *L. leptyrodes* sensu Lumbsch et al. 1997
Lecanora persimilis	wood		x				x				JV	2	
Lecanora pulicaris	CB		x								ZP	1	
Lecanora quercicola	wood				x						MK	1	Distinguished from *L. saligna* on basis of conidial size (van den Boom & Brand 2008)

Lecanora saligna	AC twigs, wood	x	x	x	x		x	x	x		JV, PC(2), ZP	3	
Lecanora saxicola	wood				x						MK, PC	1	
Lecanora semipallida	wood				x						MK	1	
Lecanora subcarpinea	CB					x					PC	1	
Lecanora thysanophora	CB			x							JV	1	Thallus with distinct hyphal prothallus, hyphae 3-5 µm wide; soredia <30 µm diam. K+ yellow, C-, P-, UV+ yellow. TLC: "thysanophora unknowns", usnic acid, zeorin.
Lecidea nylanderi	wood		x					x			JM, JV(2), NS, PC(2), ZP(2)	2	PC7691 with apothecia, other samples sterile
Lecidella elaeochroma s.lat.	CB, FA, QU, SAL	x	x	x		x	x	x	x	x	FB, JM, JV(2), MK	3	Some specimens with strongly inspersed hymenium (*L. achristotera* type)
Lepraria elobata	CB		x								MK	1	
Lepraria finkii	AC, CB, FA, PYRUS, QU, SAL, TIL, ULM, wood	x	x	x		x	x	x	x			3	
Lepraria incana	AC, CB, QU, TIL, ULM, wood	x	x	x		x	x	x	x		JM, JV(2), ZP(3)	3	TLC (ZP17692): divaricatic acid, zeorin
Lepraria rigidula	QU						x					1	
Lepraria vouauxii	AC, CB, FA, POP, PYRUS, QU, SAL, TIL, ULM, Juglans	x	x			x	x	x			JM(2), MK(2), PC, ZP(3)	3	TLC (MK, both specimens): pannaric acid 6-methyl ester, related substances
Leptorhaphis atomaria	FA (twig)		x								ZP	1	
Lichenoconium erodens	Hypogymnia physodes, Parmelia sulcata		x								BC, MK		
Lithothelium hyalosporum	AC, CB		x								BC, JM	1	
Lithothelium phaeosporum	FA		x	x							BC, JV	2	
Lophiostoma sp.	POP		x				x				JV		
Macentina abscondita	AC, TIL, Sambucus, wood	x	x				x				JM, JV, PC, ZP(2)	2	
Macentina dictyospora	AC, ULM, wood	x	x					x			JM, JV(2), PC(3), ZP(4)	2	
Massarina cf. corticola	FA		x								BC		
Marchandiomyces corallinus	Hypogymnia, Parmelia, Physcia, Xanthoria		x				x				MK(2)		
Melanelixia glabratula	AC, CB, FA, QU, TIL, Crataegus	x	x	x	x	x	x	x	x	x	JM, ZP	3	
Melanelixia subargentifera	FA (twigs)		x						x		ZP	2	
Melanelixia subaurifera	FA, QU (twigs), Crataegus, Euonymus, Juglans		x	x		x	x	x	x		NS	3	
Melanohalea elegantula	AC, FA, QU (twigs), Euonymus	x	x		x	x		x			JM(3), JV(2), MK, ZP(2)	3	TLC (JV12018): no compound detected

Melanohalea exasperatula	AC, FA, POP, QU, SAL, ULM, Juglans (twigs), Crataegus	x	x	x	x	x	x	x	x		ZP(2)	3	
Melaspilea gibberulosa	AC, (rarely CB, FA, QU)	x	x	x				x			FB, JM(3), JŠ, JV(6), MK(2), PC(6), ZP	3	Apothecia and pycnidia with purplish, K+ dark green pigment like in Micarea nigella, Redinger (1937) reports tiny pycnidia with small bacilliform conidia while the present material contains large pycnidia (0.15-0.35mm, only apically pigmented) with large simple conidia 7.5-9.5 x (4-)4.5-5 µm
Melaspilea proximella	QU			x							JV	1	
Melaspilea sp.	wood		x				x				JV, NS		Non-lichenized taxon with ciliate ends of spores
Micarea botryoides	wood		x				x				PC(2), ZP	2	Anamorphic state.
Micarea byssacea	wood		x								JM, MK	1	TLC (both samples): methoxymicareic acid.
Micarea substipitata nom. ined.	wood		x								NS, ZP	1	Undescribed species close to *Micarea myriospora*. Habitually similar to *Biatora veteranorum*.
Micarea denigrata	wood		x			x	x				JM, JV, NS, PC(3), ZP	2	Anamorphic state.
Micarea inconspicua nom. ined.	wood	x	x								PC(2), MK, ZP	2	Undescribed species, member of Micarea prasina group. Apothecia very small, hyaline, spores ovoid, 1-septate, thallus inconspicuous.
Micarea melaena	wood		x								BC	1	
Micarea micrococca	wood		x	x		x			x		JM, JV(4), MK, PC, ZP	3	TLC (MK12387, ZP17695): methoxymicareic acid; apothecia white
Micarea misella	wood	x	x				x	x			JM, JV(3), MK, NS, PC(3), ZP	3	
Micarea prasina	QU, rotten wood	x	x				x	x	x		JM(3), JV, MK(2), PC(2), ZP(2)	3	TLC (JM, MK12441, ZP17697): micareic acid; dark form, epihymenium C+ violet, K+ violet, section not red in C
Muellerella hospitans	on Bacidia fraxinea (ap)					x					PC		
Mycocalicium subtile	dry wood		x								MK		Eurotiomycetes
Ochrolechia turneri	FA, QU		x					x	x		JŠ, MK, NS, PC	2	K-, C+ yellowish, KC+ yellow-orange. TLC (MK12399): variolaric acid, two uknowns (traces)
Opegrapha niveoatra	AC, CB, FA, QU, TIL	x	x	x	x	x	x	x	x		JŠ, JV(4), MK(3), PC(8), ZP(3)	3	Three types of conidia found within samples: (1) straight or slightly curved, 2.5-4 x 1.5 µm; (2) curved, 5-6 x 1-1.5 µm; (3) curved, 7-9 x 1-1.5 µm. Sometimes only with pycnidia.
Opegrapha rufescens	AC, CB, FA, PYRUS, QU (often young trees)	x	x	x		x	x	x	x	x	JM(3), JV(6), PC, ZP	3	
Opegrapha varia	AC, CB, FA, QU, ULM	x	x	x		x	x	x	x		JM(4), JV(5), MK(3), PC(2), ZP(5)	3	
Opegrapha vermicellifera	AC, CB, FA, QU, TIL, ULM, wood	x	x	x			x	x	x		FB, JM, MK(3), PC(2), ZP	3	

Opegrapha viridis	CB (rarely FA, TIL)	x	x	x							JM(4), JV(3), PC(2), ZP	2	
Pachyphiale fagicola	fallen branch		x								MK	1	
Parmelia sulcata	AC, CB, FA, QU, SAL, TIL, ULM (twigs), Crataegus, Euonymus, wood	x	x	x	x	x	x	x	x	x	MK(2), ZP	3	
Parmelina tiliacea	AC, CB, FA, POP, QU, SAL, TIL, ULM (twigs), wood	x	x	x	x	x	x	x	x		PC, ZP(2)	3	
Parmeliopsis ambigua	dry wood		x									1	
Peridiothelia fuliguncta	CB, ULM		x						x		JV, ZP(2)		
Pertusaria albescens	AC, CB, FA, QU, SAL	x	x	x				x	x		JM, MK, PC, ZP	3	TLC (MK12400): allopertusaric acid, dihydropertusaric acid, uknown fatty acid
Pertusaria amara	CB, FA, QU, wood		x	x		x		x				3	
Pertusaria coccodes	CB, TIL		x			x					FB, JM, JV	2	With high amount of norstictic acid (crystals).
Pertusaria coronata	CB		x								PC	1	K+ yellow, UV+ orange
Pertusaria leioplaca	CB (rarely TIL)	x	x	x		x		x	x		JM, JV, MK, ZP(2)	3	
Pertusaria pertusa	CB			x		x					JV	2	
Phaeophyscia endophoenicea	AC, CB, FA, QU, TIL, Crataegus, Sambucus	x	x	x		x	x	x	x		JM(3), MK, PC(3), ZP(2)	3	This species occurs in the area, but *P. rubropulchra* is common and may be misidentified as this species.
Phaeophyscia nigricans	AC, FA, SAL (twigs)		x		x			x				2	
Phaeophyscia orbicularis	AC, CB, FA, POP, QU, SAL, ULM (twigs), Juglans, Sambucus	x	x	x	x	x		x	x	x	MK	3	
Phaeophyscia pusilloides	AC (twig)		x								ZP	1	Rather young thallus, but distinguished from other similar taxa.
Phaeophyscia rubropulchra	AC, CB, QU						x				ZP(3)	1	More delicate lobes and smaller thallus than in *P. endophoenicea*; more rough (almost blastidiate) soredia than in *P. endophoenicea*; anthraquinones in higher concentration - continuous red layer well visible in section; soralia usually without anthraquinones.
Phlyctis argena	AC, CB, FA, QU, TIL, ULM, Crataegus, Euonymus	x	x	x	x	x	x	x	x			3	
Physcia adscendens	AC, CB, FA, QU, SAL, TIL, Juglans (usually twigs), Crataegus, Euonymus, Sambucus, wood	x	x	x	x	x	x	x	x	x		3	
Physcia aipolia	FA, ULM	x	x								JV, MK(2), ZP(2)	2	

	(twigs)											
Physcia aipolioides	QU, POP		x		x						PC	2	
Physcia dubia	fallen branch		x								MK	1	
Physcia stellaris	AC, FA, QU, SAL (twigs)	x	x	x	x	x	x	x	x	x	BC, MK	3	
Physcia tenella	AC, CB, FA, QU, SAL, TIL (usually twigs), Euonymus, Sambucus, ULM, wood	x	x		x	x	x	x	x	x		3	
Physciella chloantha	AC, CB, FA, Sambucus		x	x		x	x	x			JM(2), JV(3), PC, ZP	3	
Physconia distorta	FA (twigs)		x						x		PC	2	
Physconia enteroxantha	AC, FA, QU, SAL, TIL, ULM (usually twigs)	x	x	x	x	x	x	x			JM, JV(4), ZP	3	Some specimens keyed out as "*Ph. detersa*" - medulla K-, TLC: no substances. ITS fingerprint showed placement of one such specimen into *Ph. enteroxantha*. *Ph. detersa* is a boreal taxon, perhaps absent in C Europe.
Physconia grisea	AC, CB, FA, QU, POP, PYRUS, SAL, ULM (often twigs), Crataegus	x	x	x	x	x		x			JM(2), JV(2), ZP	3	
Physconia perisidiosa	AC, FA		x	x					x		JM(2), JV(2)	2	
Piccolia ochrophora	AC, CB, FA (twigs), Sambucus		x	x			x				JM, JV, ZP(2)	2	
Placynthiella dasaea	rotten wood	x	x		x	x	x	x			PC, NS	3	
Placynthiella icmalea	wood	x	x	x		x	x	x	x		MK, PC(3), ZP(3)	3	
Platismatia glauca	dry wood		x									1	
Polycoccum sp.	on *Xanthoria parietina*				x						PC		Perithecia simple in small gals 4/5 to 3/5 immersed in host thallus and apothecia; spores 12-14 x 6-8 µm, brown; asci cylindrical, 8-spored, paraphyses present.
Porina aenea	AC, CB, FA, TIL, ULM, Crataegus	x	x	x		x		x	x		BC(2), JV(2), PC, ZP	3	
Protoparmelia hypotremella	CB	x									JM, MK, PC, ZP	1	TLC (ZP17693): lobaric acid, aliphatic unknowns (?contamination); thallus Pd-, UV+ glaucous white.
Psammina cf. inflata	on bark (QU) and/or unidentified sterile thallus (?*Bactrospora dryina*)							x			ZP		
Pseudevernia furfuracea	TIL, QU (twigs), Euonymus	x	x	x		x		x				3	
Punctelia jeckeri	AC, CB, FA, QU, SAL, TIL, ULM, Juglans (usually twigs), Crataegus, Euonymus, wood	x	x	x	x	x	x	x	x		JV, MK, NS, PC	3	

Punctelia subrudecta	AC, CB, FA, QU, SAL, Juglans (usually twigs), Euonymus	x	x	x		x	x		x		ZP	3	
Pycnora sorophora	Wood (QU)		x										
Pyrenula nitida	CB	x	x	x				x	x		FB, JM, ZP	3	
Pyrenula nitidella	CB, (rarely FA)	x	x	x		x		x			JM, JV, MK, NS	3	Real *Pyrenula nitidella* (with narrower spores) is rare, but young specimens of *P. nitida* (resembling the former taxon) are common.
Ramalina farinacea	AC, FA, SAL (often twigs)		x	x			x		x			3	
Ramalina fastigiata	FA		x							x		2	
Ramalina pollinaria	FA, POP		x	x			x	x	x		MK, NS	3	
Ramonia chrysophaea	CB (wood in hollow trunk)	x									ZP	1	
Rebentischia massalongii	AC, CB, POP		x		x	x					ZP(3)		
Rhagadostoma sp.	AC	x	x				x		x		BC, JV(3), NS		Perithecia vertically compressed with wall cracked into polygons, carbonized, thick, developed also below hymenium; ascospores 35-50 x 10-15 µm, 1-septate, colourless; often grows together with *Lecania croatica* (lichenicolous?).
Rinodina degeliana	AC, FA, TIL		x	x							JM, JV, ZP	2	
Rinodina exigua	CB					x					JV	1	
Rinodina freyi	POP, QU twigs		x		x						MK, ZP	2	Ascospore sizes in MK specimen fit better *R. septentrionalis*, but distinguishing between these taxa is not clear to us.
Rinodina pyrina	FA (twigs), wood		x		x						BC, PC	2	
Schismatomma decolorans	CB, FA, QU, TIL	x	x	x		x	x	x	x		FB, JŠ, JM(3), JV11347, MK(2), PC(3), ZP(2)	3	
Schismatomma pericleum	FA		x	x							JV(2)	2	
Scoliciosporum chlorococcum	wood	x	x								PC(2), ZP	2	
Scoliciosporum sarothamni	AC, AG, CB, FA, POP, QU, TIL (twigs), wood	x	x	x	x		x	x	x		JM, MK(2), ZP(2)	3	Rarely fertile; usually as C+ red sorediate crust
Steinia geophana	wood	x	x		x						JV, ZP(4)	2	In two samples of ZP, apothecia are accomponied with tiny synnematous anamorphic stage (cf. *Graphium aphtosae*); perhaps not previously reported for the species.
Strangospora pinicola / moriformis	wood		x		x						NS, PC	2	We suggest *S. pinicola* and *S. moriformis* being synonyms; transitional forms are commonly collected.
Strigula affinis	AC									x	ZP(2)	1	

Strigula sp.	AC, ULM		x				x				BC(2), ZP	2	Thallus pale green-brown, inconspicuous, with Trentepohlia; perithecia partly immersed, < 0.2 mm diam; wall brown-olive, K-; asci c. 70-80 x 8-12 um; paraphysoids 2 um wide, non-branched; ascospores 3-septate, 16-26 x 5-7 um, slightly constricted at septa; pycnidia numerous, <0.1 mm diam; conidia (0-)1-septate, 13-20 x 1.5-3 um, streight to slightly curved, without distinct gelatinose appendages. Perhaps undescribed taxon. ZP specimen contains pycnidia only.
Taeniolella punctata	Graphis scripta		x			x					JV, MK		
Taeniolella sp.	Pertusaria leioplaca		x								MK, NS		
Thelenella vezdae	AC, FA, TIL	x		x			x				JM(2), JV, ZP	2	
Thelocarpon intermediellum	wood		x								JM, ZP	1	Usually with perithecia but occassionally in anamorphic stage.
Trapeliopsis flexuosa	wood	x	x	x		x	x	x	x		PC	3	
Trapeliopsis glaucolepidea	wood	x	x	x							JM, JŠ	2	Including "*Trapeliopsis percrenata*" morphotype
Trapeliopsis granulosa	wood	x	x		x	x	x	x			PC	3	
Tremella christiansenii	Physcia stellaris (thallus)		x								MK		Galls and probasidia as on Fig. 25 (galls) and Fig. 26 (probasidia) in Diederich (1996)
Trichonectria hirta	Placynthiella icmalea		x								MK		Perithecia pink-orange, with hairs, ascospores transversely septate, with obtuse ends, 105×6, 92×6, 85x7.5, 71×6.5 µm
Usnea hirta	FA (twigs), Euonymus, dry wood		x			x	x		x		JV	3	TLC: usnic acid, murolic acid
Usnea substerilis	QU		x								JM	1	
Verrucaria cf. viridigrana	AC, QU, ULM		x				x	x			JM, JV(4), PC(3), ZP(2)	2	The thallus quite variably developed. Internal structure of perithecia approaching both *V. viridigrana* and *V. bryoctona*.
Vezdaea cf. retigera	QU, SAL (wood and bryophytes)		x		x						ZP(3)	2	Only goniocysts present with blunt spines ca 2µm long.
Violella fucata	dry wood		x								MK	1	C-, K+ yellowish, Pd+ red.
Xanthoria parietina	AC, CB, FA, POP, QU, SAL, TIL, Juglans (twigs), Crataegus, Euonymus, Sambucus, ULM	x	x	x	x	x	x	x	x	x	ZP	3	
Xanthoria polycarpa	PYRUS, QU (twigs)		x									1	
Xanthoriicola physciae	Xanthoria parietina		x		x		x				MK		

Appendix 2, Table A2. Selected characteristics of epiphytic lichen diversity in whole studied territory (γ–diversity). Percents from all lichen species in the list are in brackets.

Substrate

substrate	nr of species	nr of specialists
Acer campestre	84 (39%)	6 (2.8%)
Carpinus betulus	91 (42%)	17 (7.9%)
Fraxinus angustifolia	93 (43%)	7 (3.2%)
Quercus robur	92 (43%)	10 (4.6%)
Salix alba / fragilis	35 (16%)	1 (0.5%)
Tilia	57 (26%)	1 (0.5%)
Ulmus minor / laevis	39 (18%)	1 (0.5%)
wet wood	24 (11%)	15 (6.9%)
dry wood	54 (25%)	24 (11.1%)
twigs (canopy)	52 (24%)	24 (11.1%)
tree bases	not calc.	6 (2.8%)

Growth forms

fruticose	foliose	microlichens (lichen crusts)
17 (8%)	35 (17%)	159 (75%)

Abundance in the studied territory

recorded on one site only	recorded on 2-3 sites	recorded on more than 3 sites
48 (22%)	70 (33%)	94 (45%)

Appendix 3, Table A3. Basic data, including number of recorded lichen species, from 34 central European old–growth woodland inventories.

forest type (country abbreviation)	locality (nr on fig. 1A)	species nr	median altitude (m)	area (ha)	source
floodplain (UKR)	Otok, Mukachevo (1)	161	190	350	our unpublised data
floodplain (SK)	Horný les (2)	101	140	85	our unpublised data
floodplain (CZ)	Libický luh (3)	70	200	446	our unpublised data
oak-horn beam (CZ)	Údolí Oslavy a Chvojnice (4)	130	350	261	J. Šoun (unpublished)
oak-horn beam (CZ)	Hluboká n Vltavou (5)	81	400	10	our unpublised data
beech-fir (SK)	Stužica (6)	230	970	630	Vondrák et al. 2015
beech-fir (CZ)	žofín (7)	223	780	98	Malíček & Palice 2013
beech-fir (UKR)	Stuzhitsia (8)	218	850	2492	Kondratyuk et al. 1998, Kondratyuk & Coppins 2000
beech-fir (UKR)	Ugolka (9)	197	880	10380	Dymytrova et al. 2013
beech-spruce-fir (CZ)	Hraničník (10)	188	1150	165	our unpublished data
beech-fir (CZ)	Boubín (11)	140	1040	56	E. Budějcká (unpublished)
beech-fir (A)	Neuwald (12)	133	950	1	Hafellner & Komposch 2007
beech (CZ)	Čerchov (13)	106	900	170	O. Peksa (unpublished)
beech (CZ)	Chejlava (14)	90	580	12	O. Peksa (unpublished)

beech-fir (CZ)	Razula (15)	90	785	23	our unpublised data
beech-fir (SLO)	Rajhenavski Rog (16)	87	885	50	Bilovitz et al. 2011
beech-fir (A)	Luxensteinwand (17)	85	850	30	Malíček et al. 2013
beech (CZ)	Čertův mlýn (18)	77	1070	50	our unpublised data
beech-fir (CZ)	Salajka (19)	57	765	18	our unpublised data
beech-fir (CZ)	Hojna voda (20)	67	840	9	Malíček et al. 2013
beech (CZ)	Jizerskohorske bučiny (21)	40	740	952	our unpublised data
beech (CZ)	Karlovské bučiny (22)	30	440	42	our unpublised data
mixed on scree (SK)	Cigánka (23)	148	700	40	Guttová & Palice 2004
mixed on scree (SK)	Hrdzava (24)	104	860	357	Guttová & Palice 1999
mixed on scree (SK)	Javornikova dolina (25)	95	790	170	Guttová & Palice 2002
mixed on scree (CZ)	Javořina (26)	77	750	160	our unpublised data
mixed on scree (CZ)	Ve studeném (27)	64	375	32	our unpublised data
spruce (CZ)	Trojmezná (28)	147	1275	588	our unpublised data
spruce (SK)	Fábova hola (29)	114	1380	260	Guttová et al. 2012
spruce (CZ)	Kněhyně (30)	64	1130	100	our unpublised data
spruce (CZ)	Boubín - top (31)	58	1280	100	our unpublised data
spruce (DE)	Reschbach Klause (32)	58	1140	50	our unpublised data
peat-bog pine (CZ)	Červené blato (33)	62	470	330	our unpublised data
peat-bog spruce, pine (CZ)	Rašeliniště Jizery (34)	52	850	153	Malíček & Vondrák 2014

Forest lichen diversity exceeds expectations; enormous species richness in hot-spots of an old-growth beech forest

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Abstract. Although lichenized fungi belong to the most reliable indicators of forest quality and represent a considerable part of forest biodiversity, methods for a complete diversity survey of forest lichens per area are lacking. Employing a novel methodological approach including a multi-expert competition and a search for movable hot-spot plots, we have obtained credible area-fixed data about local lichen biota in a part of the largest European virgin forest Uholka – Shyrokyi Luh situated in Ukrainian Carpathians. Our field research consisted of two four-day periods: (1) an overall floristic survey and a search for spots with raised lichen diversity, and (2) survey in four one-hectare plots established in lichen diversity hot-spots in an altitudinal gradient. Recorded alpha-diversities in plots ranged 181–228 species and the gamma-diversity was 381 species. 93% of the species found in the forest were recorded in plots, but only 65% outside the plots. This underlines high-efficiency of the multi-expert competitive survey in diversity hot-spot plots. Species richness in each one-hectare plot was equal to numbers of species obtained by "top-end surveys" of much larger old-growth forest areas in Central Europe. Gamma-diversity revealed by our survey more than twice exceeded the diversity recorded in the same area by the previous survey employing systematic cluster sampling. It also highly exceeded all numbers achieved in Central European old-growth forests. Unexpectedly high differences between our data and data from all previous inventories are better explained by our approach than by the exceptionality of the locality.

Keywords: altitudinal gradient, biodiversity, lichen inventory, lichenized fungi, method, movable hot-spot plots, multi-expert competition.

Introduction

Forests boast the highest biodiversity among terrestrial biomes (Loo 2009). Regrettably, natural forests have been destroyed in an unprecedented way during last centuries. In Central Europe pristine forests almost vanished, being altered by land use and only very small fragments of old-growth forests remain. These remnants support the greatest diversity of many forest organisms, among them also epiphytic and epixylic lichens (e.g. Hafellner & Komposch 2013, Malíček & Palice 2013, Dymytrova et al. 2013, Vondrák et al. 2015, 2016), which are considered the most reliable indicators of forest-continuity and forest quality (Johansson & Gustafsson 2001, Paillet et al. 2010). Tiny crustose lichens, that are often neglected, are considered most sensitive to environmental change as they are intimately associated with microhabitats (e.g. Tibell 1992, Selva 2003).

The most straightforward way how to evaluate quality of a forest locality is to measure its total biodiversity. Biodiversity data are then appreciated by a broad scientific community, environmentalists and even engaged politicians. Accurate and close-to-complete biodiversity assessment is a big challenge for many field biologists, including experts in lichens. Remnants of several important European old-growth forests were surveyed for lichen diversity by various designs and approaches (e.g. Hafellner & Komposch 2007, Dymytrova et al. 2013, Vondrák et al. 2016). Unfortunately, a majority of detailed surveys were extensive, based on random records (e.g. Guttová et al. 2012, Malíček & Palice 2014, Vondrák et al. 2015) being done without any sophisticated methodological approach and therefore are hardly comparable with other inventories. Although the area of the field research is usually fixed, i.e. it is often circumscribed by a border of nature reserve, the intensity and quality of surveys varies considerably. Surveyed areas are sometimes too large to allow exhaustive diversity exploration. Species lists are usually shortened due to underestimated survey efforts and it results into a random character of records showing biased similarities/dissimilarities among local species compositions.

Intention to compare lichen diversity among sites/habitats forced researchers to use numerous small plots (<< 1ha), where the diversity is easier assessed. Plots in most recent survey projects are based on random or systematic sampling (Giordani et al. 2009, Moning et al. 2009, Svoboda et al. 2009, Nascimbene et al. 2010, 2014, Dymytrova et al. 2013, 2014, Hofmeister et al. 2015, Bässler et al. 2015). Performing this approach however causes following drawbacks: (1) Plot sizes are usually too small to provide consistent species composition and the species lists vary due to random records of rare species as demonstrated by Dymytrova et al. (2014). (2) The local pool of various substrates and microhabitats is never covered within small-sized plots. (3) Plot locations do not reflect sites with increased local habitat/substrate diversity, i.e. hot-spots. (4) The high number of plots does not allow intensive, time-consuming research (Hunter & Webb 2002).

It was repeatedly demonstrated that cryptogam diversity in old-growth forests is not equally distributed (e.g. Peterson & McCune 2003, Newmaster et al. 2005, Dymytrova et al. 2014), and that large parts of these forests (>> 50%) have rather low local diversity which is strongly increased in hotspots, such as humid valley bottoms, ridges with rock outcrops, gaps and screes or timber-line forest edges (Neitlich & McCune 1997, Vondrák et al. 2015). Furthermore, the diversity is not equally distributed within particular habitats. Each habitat shows variability in the offer of substrates suitable for numerous niche-specific lichens (Kuusinen & Siitonen 1998, Fritz & Heilmann-Clausen 2010). An appropriate sampling methodology is crucial to understand diversity of particular area. We refrained from using "classical" randomly or geometrically designed plots / quadrats / transects. Although it is a time-effective and best statistically-fitted approach for receiving sound biodiversity data, it implies a serious disadvantage: frequent omitting of local diversity hot-spots with microhabitats harbouring rare specialized species having bioindicative value. Newmaster et al. (2005) clearly demonstrated that random plot sampling has a low sensitivity for detecting rare species.

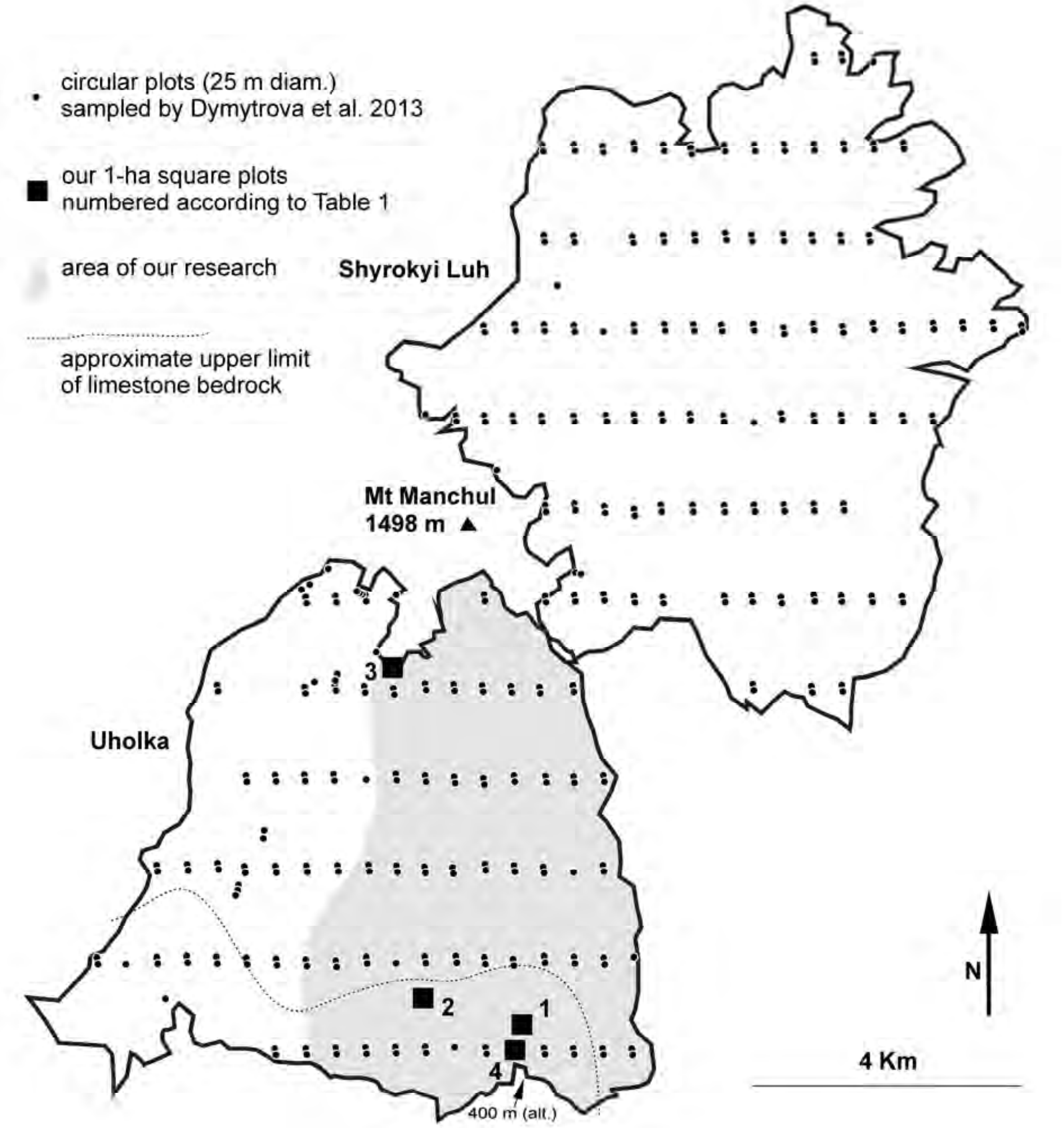

Fig. 1. Protected area of old-growth beech forest "Uholka – Shyrokyi Luh" surveyed by Dymytrova et al. (2013) by a systematic sampling on circular plots of 500 m^2 (black dots). The area is noticeable divided into southern part, Uholka, and the northern one, Shyrokyi Luh. We surveyed only a part of Uholka, the valley of the brook Velyka Uholka (area in grey) where we selected four plots (black squares) in hot-spots of lichen diversity. Forest habitat diversity is distinctly greater in lower altitude, in the area with limestone bedrock (below the dotted line).

Alternative approach is to asses diversity in larger plots (one to several hectares) representing particular forest types, but with no or few repeats (Hafellner & Komposch 2007, Lõhmus et al. 2012, Vondrák et al. 2016). These surveys are aimed to obtain almost complete species lists per plots. Their drawback is a time-consuming research that practically rejects the possibility for repeating design of the survey: Lõhmus et al. (2012) report unbelievable 500 person/hours per one 2-hectare plot.

In this study we introduce a non-random, one-hectare square plot design aimed to survey in local diversity hot spots. By a precise, multi-expert lichen diversity assessment, we obtained confident area-fixed data about the local lichen biota. A comparison among plots directed to local diversity hot-spots is a practical tool for assessing beta and gamma-diversities in forest stands. A peculiar, unexpected output from our research is a high number of species regularly recorded per plot. Species richness in our one-hectare plots is equal to numbers of species obtained by "top-end surveys" of much larger old-growth forest areas.

Methods

Surveyed area & timing

We selected an old-growth beech forest on southern slopes of Mt Menchul in Ukrainian Carpathians (c. 30 km NE of Khust) because it has been systematically surveyed for lichen diversity by Dymytrova et al. (2014) and we have thus a possibility to compare our results with recently published data. Rare lichen species listed by Dymytrova et al. (2014) indicated a high diversity potential of the forest. The area of our research was a 2300 ha part of the protected area "Uholka – Shyrokyi Luh" (Fig. 1) that represents one of the largest virgin forests in Europe with 10400 ha (Commarmot et al. 2013). The whole area is dominated by *Fagus sylvatica*, but the forest is not homogeneous throughout (see Commarmot et al. 2013 for details). Most area is on steep slopes with prevailing southern exposition in altitude 400–1200 m, divided by numerous brook valleys. Amount of dead wood is surprisingly low in comparison to famous Czech virgin forests (Boubínský and Žofínský prales) and the Austrian Rothwald. Our field research in May 2015 lasted eight days; four days were devoted to plot searching and an overall lichen diversity survey, another four days involved surveys in plots (see below).

	Coordinates	**mean alt. (m)**	**available substrata (rare, in brackets)**	**research intensity**
Plot 1	48.250831N, 23.696454E	510	FS, CB, logs, snags, (AP, Apl, CA, FE, SN, UG)	7 researchers / 6 hours
Plot 2	48.256089N, 23.661366E	800	FS, AP, Apl, CA, CB, FE, TB, TIL, UG, logs, snags, (QU, SA)	6 researchers / 6 hours
Plot 3	48.297948N, 23.666583E	1200	FS, logs, snags	7 researchers / 6 hours
Plot 4	48.244879N, 23.694648E	430	FS, CA, CB, logs, snags, (AP, Apl, FE, SN, TIL, UG)	7 researchers / 6 hours

Table 1. Surveyed one-hectare plots in the Uholka forest. Substrate abbreviations: Apl, *Acer platanoides*; AP, *Acer pseudoplatanus*; CA, *Corylus avellana*; CB, *Carpinus betulus*; FE, *Fraxinus excelsior*; FS, *Fagus sylvatica*; QU, *Quercus*; SA, *Sorbus aucuparia*; SN, *Sambucus nigra*; TIL, *Tilia*; UG, *Ulmus glabra*. Substrates in brackets are not common in plots.

Non-random plot selection

The crucial condition of our survey method was the search for "**movable hot-spot plots**". One-hectare plots were selected during four days of the overall survey of the whole area with the respect to cover the highest lichen diversity within the study area. The main search criteria were: (1) multilayered canopy indicating a non-even-aged forest; (2) presence of old trees with weathered bark; (3) presence of both standing and lying dead wood; (4) the highest variability of tree species at the local scale; (5) presence of small natural forest gaps; (6) availability of canopy lichens on fresh windthrows. In the altitudinal gradient (400–1200 m), we established two low-altitude plots in a deep valley, one medium-altitude plot on a limestone ridge and one plot at the upper forest limit (Fig. 1, Table 1). Within the four plots, we captured most of forest habitat types present in the area (Fig. 2). The prevailing forest type, a dense beech forest without any other intermixed tree species covering more than 99% of the studied area, was involved in all plots. Although the surveyed plots are localized by GPS co-ordinates, our approach allows repeated future surveys in spatially shifted plots (thus the term *movable* hot-spot plots). Movable nature of the plots is important because locations of diversity hot-spots within a forest locality are changing in time.

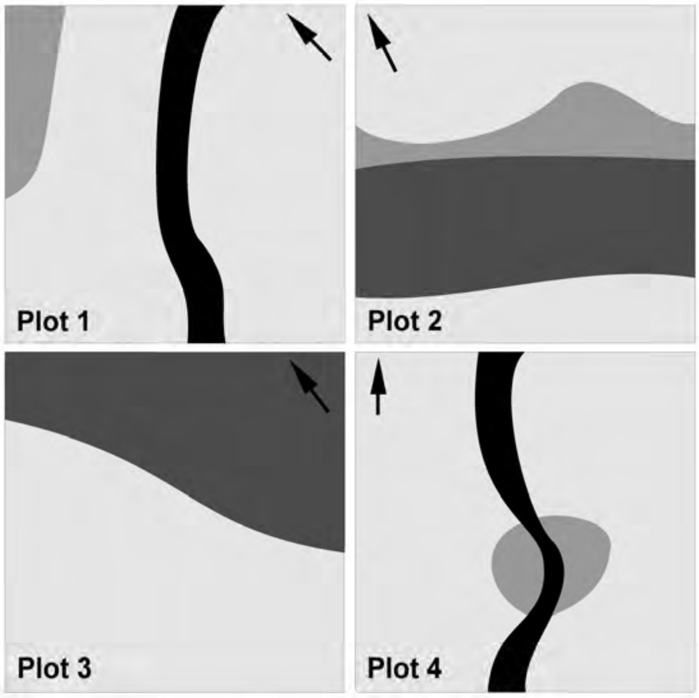

Fig. 2. Variability of forest habitats in selected plots. Prevailing forest type, a dense beech forest without intermixed tree species, is present in all plots (pale grey). Wet ravine forest with common *Carpinus betulus* is present in the lowermost plots 1 and 4 (black). Sun-lit mixed forest on limestone rocks and scree (medium grey) is present in plots 1, 2 and 4. Damp mixed forest on steep slope with limestone outcrops, dominated by *Acer platanoides*, *A. pseudoplatanus*, *Fraxinus* and *Tilia*, is present in plot 2 (dark grey). Sparse beech forest occurs in plot 3 (dark grey) at the artificially lowered timber line with the occurrence of large, old and deformed trees with weathered bark. Lower parts (up to 2 m height) of beech trunks in this forest type are sun-lit due to summer grazing and often harbour more than 40 lichen species.

Multi-expert competitive survey

Field work was performed by experienced lichenologists, i.e. the first seven authors, as a competitive survey (sensu Vondrák et al. 2016) supporting more complete species list, which is demonstrated on our data as the difference between records of individual researchers and all records per plot (Table 2, Fig. 3). The survey time per each plot was set to six hours; it was derived from the accumulation rate of recorded species in the plot 1, where researchers noticed individual cumulative species lists in 12 half-an-hour periods (Fig. 3). All researchers recorded less than five additional species in the last period. Records were collated by the first three authors, who also revised and eliminated all suspicious records (possibly incorrectly identified or ambiguously identified specimens).

Species data for analyses

Our primary data are based on presences/absences of lichen species in and outside plots. The table with primary data (Supplementary table 1) also includes substrata and collected vouchers for each taxon. Epiphytic and epixylic lichens and facultatively lichenized fungi were included into analyses. All species of the following genera are included, although some species are not lichenized: *Anisomeridium*, *Arthonia*, *Arthopyrenia*, *Chaenothecopsis*, *Cresporhaphis*, *Cryptodiscus*, *Lithothelium*, *Melaspilea*, *Mycocalicium*, *Stenocybe* and *Ramonia*. Records of additional non-lichenized fungi are listed at the bottom of the Supplementary table 1, but they were excluded from analyses.

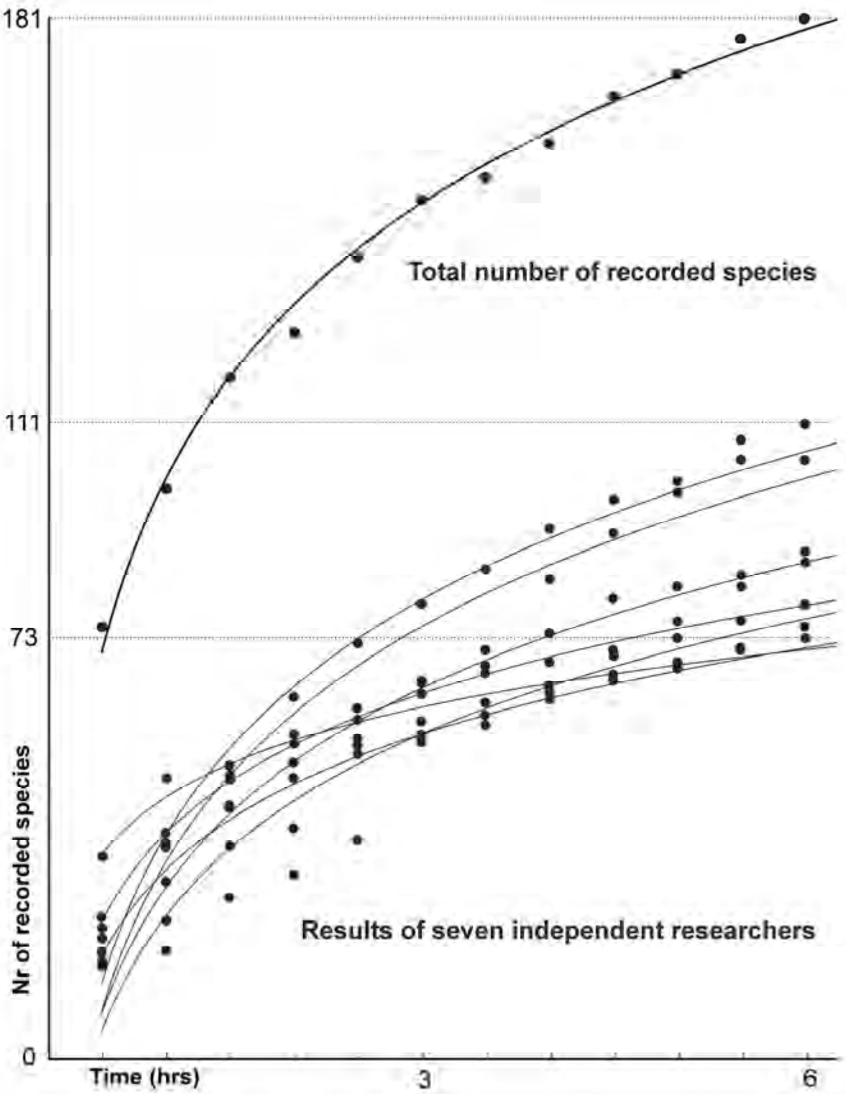

Fig. 3. Lichen species recorded in plot 1 in twelve half-an-hour periods. Records of individual researchers (thin curves) and total records (thick) are approximated by logarithmic functions.

	plot 1	plot 2	plot 3	plot 4
researcher 1	104	109	146	95
researcher 2	87	96	135	91
researcher 3	109	126	134	112
researcher 4	76	88	99	84
researcher 5	73	–	103	87
researcher 6	79	62	84	64
researcher 7	84	74	98	70
Total	181	187	228	182

Table 2. Contrast between species numbers from single researchers and the total number of recorded species.

Species identification & molecular barcoding

Many lichen species are hardly identifiable in the field, especially sorediate crustose lichens, where identical morphology is commonly shared by several, even unrelated taxa. To increase credibility of our diversity data, vouchers were collected for vast majority of species, most of them were repeatedly collected and are deposited in herbarium PRA (Palice & Vondrák), PRM (Bouda) and in personal herbaria of the other authors (Supplementary table 1). We identified the collected material mostly by standard techniques (microscoping procedures, spot/UV reactions) and TLC (Thin Layer Chromatography; solvent systems A, B', C following Orange et al. 2010). Our appraisals of critical specimens/species and results of TLC analyses are described in the Supplementary table 2. Specimens ambiguously identified by morphological and chemical characters or specimens that did not fit a description of any known species were sequenced for nrITS and/or mtSSU DNA loci. We employed the NCBI's BLAST website (Johnson et al. 2008; http://blast.ncbi.nlm.nih.gov/Blast.cgi) to confirm their identity or at least to place them into a genus (Supplementary table 3).

Data analyses

Four movable hot-spot plots within the studied area were compared among each other by the number of shared lichen species and by Sørensen's similarity index (Sørensen 1948). Species composition in each plot was given into a context of available diversity data from old-growth forest localities in Central Europe. Presence/absence data for epiphytic lichens from Central European old-growth forest inventories abstracted by Vondrák et al. (2015, 2016) were supplemented by some recent data and resulted in a dataset of 671 species from 43 localities (Supplementary table 4). We applied the same taxonomic concepts when extracting data as we used in our own dataset. Detrended Correspondence Analysis (DCA) in Canoco 5 (ter Braak & Šmilauer 2012), based solely on species presences/absences, was employed to display similarities (1) among our plots and (2) among our plots and other forest localities (Fig. 5). The downweighting of rare species was applied in DCA. Alpha-diversities in plots and Gamma-diversity in the whole studied area were compared with diversities per area reached by lichen inventories in various old-growth forests (Fig. 6).

Results

Alpha & beta diversity in plots

Numbers of lichen species recorded in plots 1, 2 and 4 in lower altitudes are very similar, between 181 and 187, but distinctly higher number of species (228) was recorded in the plot 3 situated at the upper tree limit (Fig. 4A). Sørensen's similarity indexes confirmed an expectation that the species composition in the uppermost plot 3 is different from all other plots and the plots 1 & 4, close to each other, comprising the same forest habitats, are the most similar in species composition (Table 3). Seventy-three species represent a "common group", i.e. they occur in all plots. This group consists of common lichens with great ecological amplitude, but also some rare species of old-growth forests (e.g. *Heterodermia speciosa*, *Menegazzia terebrata* and *Thelopsis rubella*). Plots 1 & 4 share many species absent from other plots, e.g. lowland species *Arthonia cinnabarina* and *A. helvola*. Among numerous species recorded only in the plot 3, the most remarkable records are i) subalpine species *Caloplaca sorocarpa*, *Lecanora exspersa* and *Rinodina malangica*,ii) lichens characteristic for high montane coniferous forests, e.g. *Catillaria erysiboides*, *Frutidella pullata*, *Lecanora subintricata*, *Micarea globulosella* and iii) primarily saxicolous lichens (e.g. *Acarospora fuscata*, *Circinaria caesiocinerea*, *Porpidia macrocarpa*) on bases of old beeches. The plot 2 is characterised by a rather heterogeneous lichen biota,(Supplementary table 1). Obvious differences between plots are in the diversity of some taxonomic groups; such as Arthoniomycetes diversity strongly decreases with rising altitude (Fig. 4B).

	plot 1	**plot 2**	**plot 3**	**plot 4**
plot 1	–	119	102	136
plot 2	0.65	–	132	113
plot 3	0.5	0.63	–	102
plot 4	0.75	0.62	0.5	–

Table 3. Number of shared species (above diagonal) and Sørensen's similarity indices (below diagonal) for all pairs of plots.

Beta-diversity described above is also shown in the context of lichen inventories in various Central European forests. DCA ordination (Fig. 5) is based on lichen species presence/absence in 43 localities (details in Supplementary table 4) including our four plots. While lichen species composition in plots 1, 2 & 4 is the most similar to deciduous mixed forests on limestones in the Muránska Planina Mts, Slovakia (locs 7 & 11 in Fig. 5; Guttová & Palice 2002, 2005), the species composition in the uppermost plot 3 is more similar to beech forests Stužica in Slovakia, Stuzhitsa in Ukraine (locs 33 & 34; Vondrák et al. 2015) and to an upland mixed forest in Hrdzavá dolina (loc. 10, Slovakia; Guttová & Palice 1999).

Differences in functional diversity among plots are shown in Figs 4C–F. Ratio of lichen species with trentepohlioid photobiont considerably decreases with rising altitude (Fig. 4C), but the ratio of cyanolichens (lichens with cyanobacterial photobiont) is always low, slightly raised in the plot 2 that is strongly influenced by its limestone bedrock and with presence of trees with subneutral bark pH, e.g. *Acer platanoides* (Fig. 4D). Macrolichens (i.e. foliose and fruticose lichens) are not frequent in all plots (c. 20–30%), but their ratio rises with the altitude (Fig. 4E). Ratio of species with and without vegetative diaspores is about 50% in all plots (Fig. 4F).

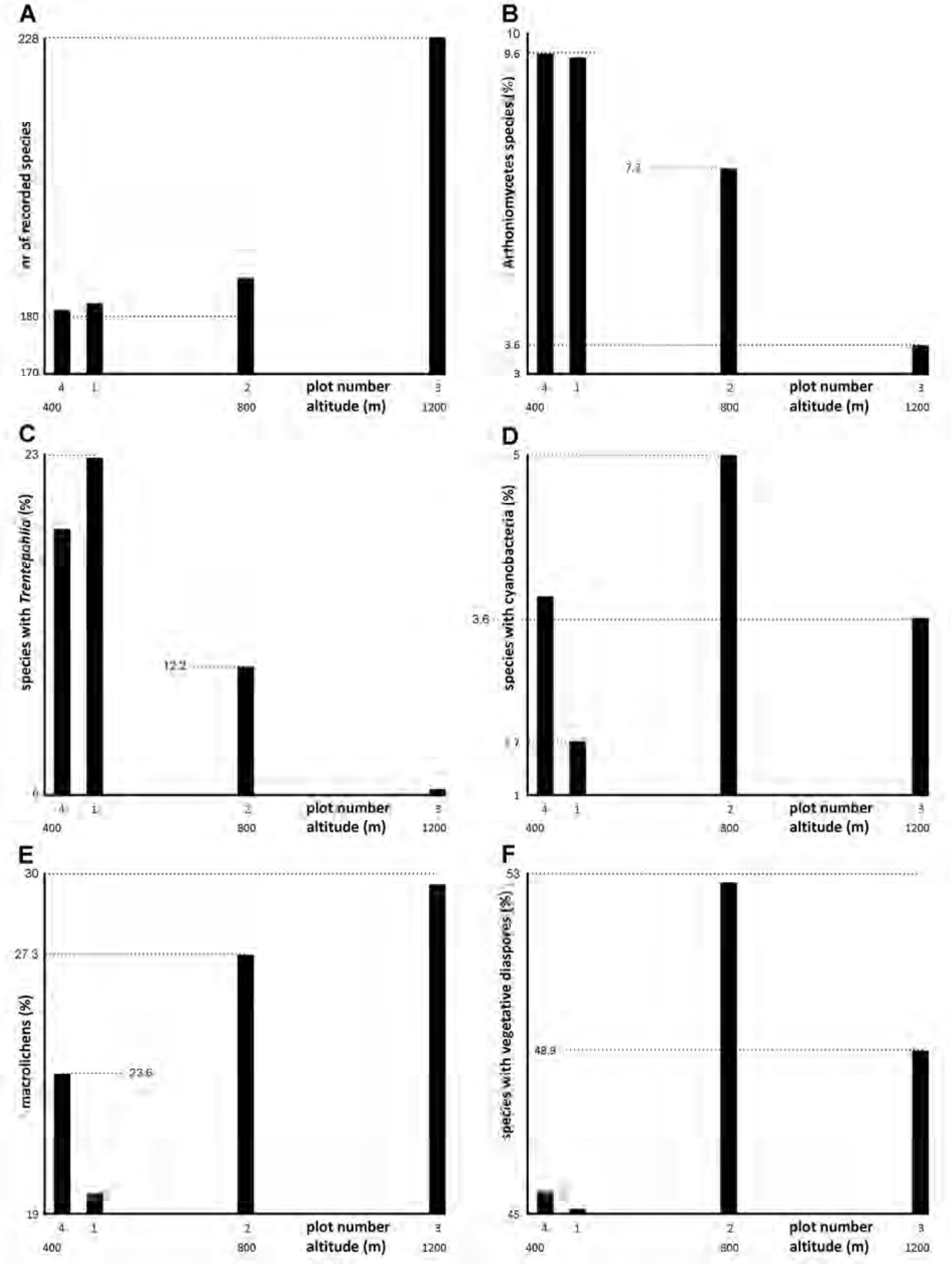

Fig. 4. Alpha-diversities of lichens (A, B) and the diversity within functional groups (C–F) on altitudinal gradient. Values in charts B–F are % of all species recorded in a respective plot.

Gamma diversity

Species diversity of the whole studied area (Fig. 1) has two partitions, (1) 353 species recorded in all plots during four days and (2) 248 species recorded outside plots during four days of overall "floristic" research. These datasets have a large overlap and the total species number is 381. Time spent in plots was approximately equal to the time spent outside the plots (c. 24 hours), but almost 93% of species were recorded in the plots and only 65% outside the plots. The "floristic research" contributed with less than thirty species that were not recorded in plots into the Gamma-diversity dataset.

Valuable lichen records

Lichen boita in the Uholka forest is includes many rare taxa and typical old-growth forest species – e.g. *Bacidia circumspecta*, *Cetrelia* sp. div., *Gyalecta* sp. div., *Leptogium teretiusculum*, *Lobaria pulmonaria*, *Normandina pulchella*, *Sclerophora farinacea* and *S. pallida*. Rare cyanolichens (e.g. *Leptogium saturninum*, *Lobaria amplissima*, *Nephroma parile*, *N. resupinatum*, *Peltigera collina*) prefer old beeches in sun-lit forests at higher elevation. *Arthonia glaucella*, *Opegrapha fumosa* and *Pyrenula chlorospila* represent oceanic species very rare out or Western Europe. *Biatora longispora*, *Calicium montanum*, *Menegazzia subsimilis*, *Micarea perparvula*, *Opegrapha ochrocheila*, *Pertusaria macounii*, *Pyxine sorediata* and *Thelotrema suecicum* are examples of phytogeographically remarkable or other very rare lichens. About thirty lichen species are new to Ukraine (marked in Supplementary table 1). *Biatora bacidioides* is new to Europe.

parameters	**Previous survey (Dymytrova et al. 2013; only data from the part "Uholka" in Fig. 1)**	**Our data**
nr of plots	163	4
size / shape of plots	500 m2 / round plots with diam. c. 25 m	10.000 m2 / 1 ha square plots
method of plot selection	non-stratified systematic cluster sampling (Fig. 1)	aimed to local habitat diversity hot-spots & to maximize beta-diversity
total area of plots / area of study	8.15 ha / c. 5000 ha	4 ha / c. 2300 ha
nr of recorded lichen species	156	353 (in four 1 ha plots) / 381 (with records outside plots)
nr of species per plot: min - mean - max	1 - <20 - 40	181 - 195 - 228

Table 4. Comparison between our survey of lichen species richness and the previous research in the same area (Uholka in Fig. 1).

Discussion

Our lichen diversity survey vs. previous research in the locality

Systematic survey of lichen diversity in the entire Uholka forest (Fig. 1) resulted in a list of 156 lichen species (Dymytrova et al. 2013). This is about 44% of species that we recorded in four hectares of our *movable hot-spot plots* and it is only 41% of our total number of species (Fig. 6). These ratios, compare only numbers of species, but the previous and our surveys considerably differ in species composition, which is demonstrated in Figure 5. We have not recorded 23 species listed by Dymytrova et al. (2013) and we explain it by the following reasons: (1) time and spatial limitations of our survey, (2) some species are undoubtedly rare, e.g. *Wadeana dendrographa* or *Rinodina conradii*, and their recording has a random character, and (3) the same species are differently named. The latter reason is probable in about a half of species recorded solely by Dymytrova et al. (2013). Methods and results of both surveys in the Uholka forest are compared in Table 4; it is obvious that our methods are more efficient in approaching knowledge of the total lichen diversity.

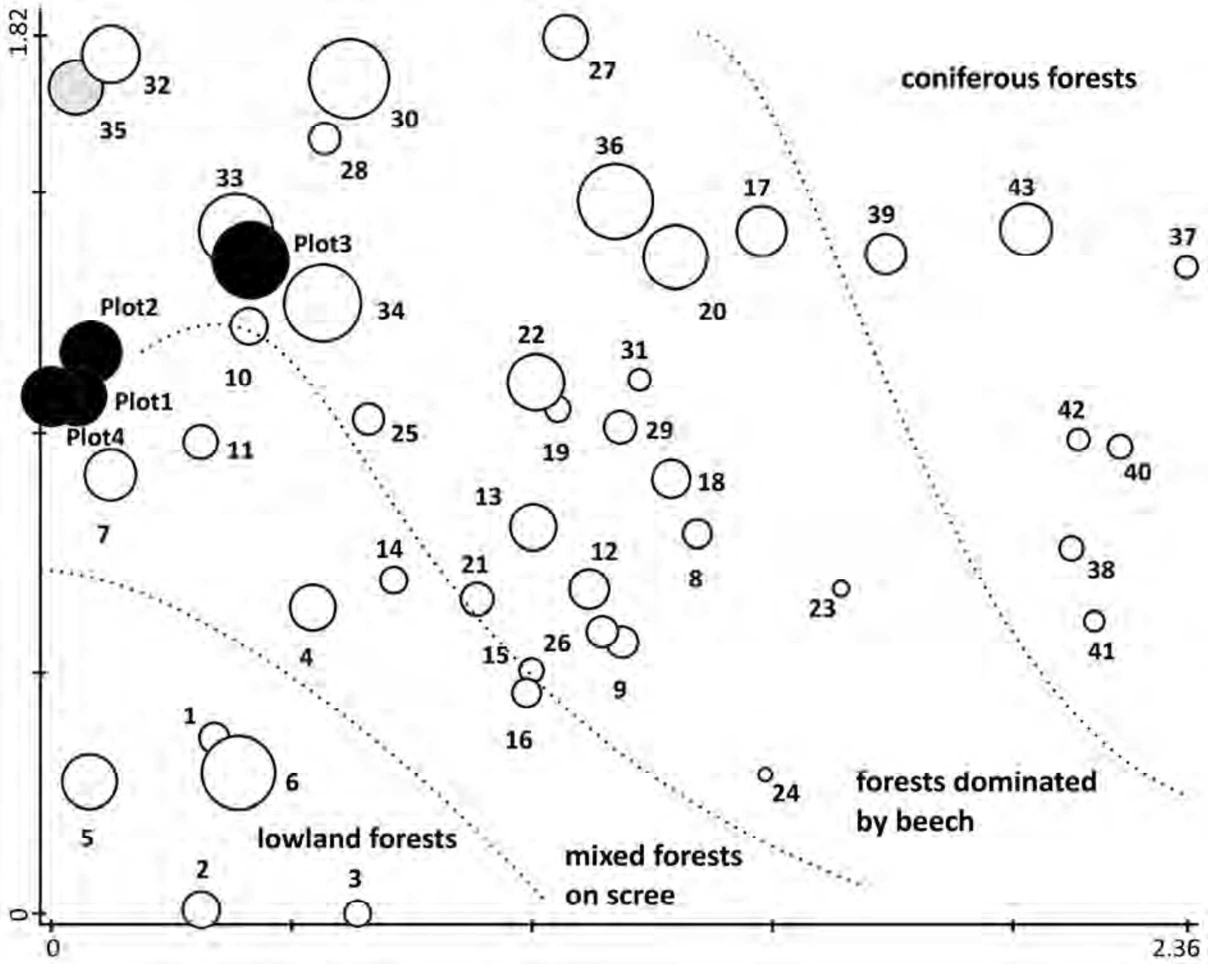

Fig. 5. DCA ordination diagram showing similarities in lichen species composition in our plots (black circles), in the previous inventory by Dymytrova et al. (2013; grey circle) and in another 42 Central European old-growth forest localities (white circles). Numbers at localities correspond to Supplementary table 4. First and second axes are plotted and explain 18.6% of the variability in species data. The size of circles corresponds to the number of species. Plot is divided by the dotted lines into four areas corresponding to main Central European forest types.

Underestimated species richness in Central European old-growth forests

Our data in the context of lichen inventories in Central European forests may suggest distinctly higher lichen diversity in the surveyed area (Uholka forest) than in any other Central European forest locality (Fig. 6). For example 228 species in the plot 3 in Uholka is comparable with the highest numbers from large beech forest areas: 228 species per 630 ha (Vondrák et al. 2015) and 222 species per 98 ha (Malíček & Palice 2013). However, real differences between species richness in Uholka and other primeval forests are supposed to be less distinct, or some localities could possibly have even more lichen species. The latter case is expected for the more humid Shyrokyi Luh forest (Fig. 1), where Dymytrova et al. (2013) recorded more species than in Uholka. Despite of huge area of Uholka and Shyrokyi Luh, slightly smaller old-growth forest remnants, such as the Slovakian Stužica (Vondrák et al. 2015), Ukrainian Stuzhitsa (Kondratyuk et al. 1998, Kondratyuk & Coppins 2000, Motiejūnaitė et al. 1999) and Austrian Rothwald (Türk & Breuss 1994, Bilovitz 2007, Türk 2015) should have comparable species richness per area if our methods, namely the *search for movable hot-spot plots* and *multi-expert competitive survey*, will be employed. Forests dominated by beech (grey dots in Fig. 6) are obviously more species rich than other forest types (white dots in Fig. 6). Nevertheless, numbers of species sampled in variously sized areas of a floodplain forest in the Czech Republic including old-growth remnants (Vondrák et al. 2016), approximated by a species/area curve (dotted line in Fig. 6), are exceptionally high, equal to highest numbers from beech forests obtained by previous surveys. In contrast with other inventories, data by Vondrák et al. (2016) were gained by the multi-expert competitive survey and it is the probable reason for the high species numbers. These numbers would be even higher when employing the search for movable hot-spot plots.

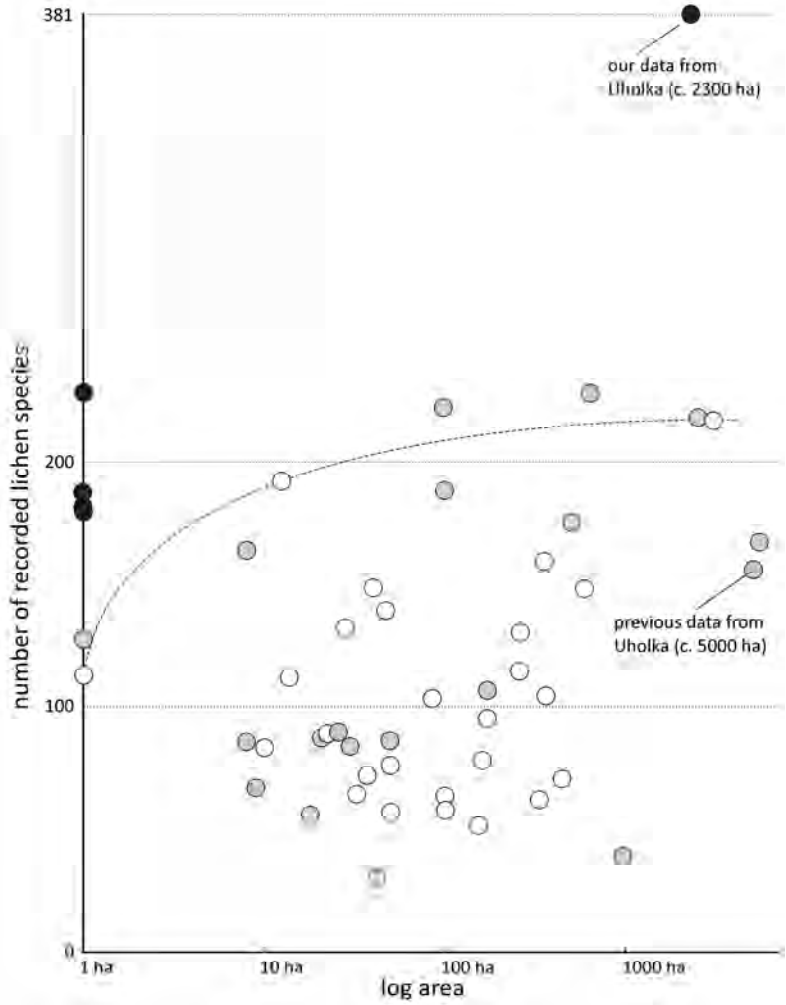

Fig. 6. Our data in the context of lichen diversity inventories of Central European old-growth forests. Our data (black dots) showing number of species in the 1-ha plots (alpha-diversities) and the number in the whole research area (gamma-diversity). Grey dots are data from other Central European forests dominated by beech; white dots show data from other forest types. Species/area relation for a floodplain forest surveyed by the method *multi-expert competition* (Vondrák et al. 2016) is drawn by the dotted line.

Biodiversity in beech forests: macrofungi >> lichens > vascular plants > bryophytes
The last paragraph brings lichens into context of beech forest biodiversity, but it suffers by scarcity of credible data. In comparison with lichens, non-lichenized macrofungi (fungi with macroscopic fruiting bodies) are more diverse in old-growth beech forests: 503 species in 47 ha of "Boubínský prales" in the Czech Republic (Holec et al. 2015), 759 species in a 20 ha area of "Neuwald" in Austria (Krisai-Greilhuber 2015), and about 800 species in 98 ha of "Žofínský prales" in the Czech Republic (Beran in Holec et al. 2015). The latter forest was precisely surveyed also for lichens (223 epiphytic and epixylic species; Malíček & Palice 2013), vascular plants (209 species; Lepší et al. 2007) and bryophytes (195 species; Kučera 2009). These data indicate that lichens contribute more than bryophytes and slightly more than vascular plants into the biodiversity (species pool) of montane beech and fir-beech forests, representing the most widespread Central European natural forest type.

Conclusions

We improved methods of field research on lichen species richness in forests: the results enable comparison among individual localities and capturing high proportion of the total species composition. The method of subjectively selected 1 ha plots in local diversity hot-spots surveyed by several competing lichenologists is distinctly more effective then random or systematic sampling designs. The method was tested in the the primeval forest Uholka-Shyrokyi Luh in Ukrainian Carpathians, which is extremely rich on lichens including many old-growth forests species and overall very rare and endangered taxa in Europe. The total number of recorded epiphytic and epixylic species reached 381 – the highest number of taxa known from European old-growth forests. A detailed survey of 1 ha plots revealed unexpected diversity data – the richest plot in a beech forest harboured 228 lichenized and facultatively lichenized species, again the highest recorded richness among all known temperate forest types. DCA analysis indicated similar species composition like in Stužica/Stuzhitsa forest at Slovak/Ukrainian border and also a similarity to mixed forests in Muránska planina (Slovakia, the Carpathians).

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Supplementary table 1. Diversity data from the research in plots and outside plots. Substrate abbreviations correspond with the Table 1. Vouchers are indicated by initials of the authors. ! = new to Ukraine.

	Plot 1	Plot 2	Plot 3	Plot 4	outside	substrate	vouchers
Absconditella lignicola	1	1	1	1	1	FS, log, snag	FrB2, JM, JV3, ZP3
Acarospora fuscata					1	FS (trunk bases)	JV
Acrocordia gemmata	1	1		1	1	Apl, AP, CB, FE, FS, QU, TIL	FB, JM, JV3, NS3, ZP8
Agonimia allobata	1	1		1	1	Apl, FE, log, snag	AA, JM, JV4, NS, ZP3
Agonimia borysthenica	1			1		FS	ZP2
!Agonimia flabelliformis	1					log	ZP
Agonimia repleta		1	1	1	1	Apl, FE, FS	AA, JV3, ZP2
Agonimia tristicula	1	1	1	1	1	(often on mosses)	FrB, JM2, JV3, ZP4
Agonimia sp.		1				QU	ZP
Amandinea punctata	1	1	1		1	Apl, AP, CB, FS, TIL, UG, snag	JV, NS2, ZP
Anaptychia ciliaris		1	1		1	Apl, FS, TIL (also twigs)	
Anisomeridium biforme	1			1	1	CB, FE, FS, UG	FB, NS, ZP
Anisomeridium macrocarpum		1		1		AP, FE, FS, TIL (trunk bases)	AA, FrB, JV3, ZP
Anisomeridium polypori	1	1		1	1	AP, Apl, CA, CB, FE, FS, TIL, UG, snag (FS)	FrB2, JV4, NS5, ZP8
Arthonia apatetica	1	1	1	1	1	AP, CA, CB, FS, SN	AA, FrB2, JM3, JV2, ZP3
Arthonia atra				1		CB, FS	ZP2
Arthonia biatoricola			1		1	FE, FS (on Lecania croatica, Biatora chrysantha)	ZP2
Arthonia byssacea				1	1	CB, FS	FB, JV2, ZP2
Arthonia cinnabarina	1			1	1	CB	FB, JV, NS
Arthonia didyma	1	1	1	1	1	Apl, AP, CB, FS, TIL	AA, FB, JM, JV5, NS2, ZP5
!Arthonia glaucella				1		CB	FrB, JV2*
!Arthonia helvola	1			1		CB, FS	FB, FrB, ZP
Arthonia mediella		1	1		1	CB, FS	JM, JV2, ZP4
Arthonia punctiformis	1					CA	AA
Arthonia radiata	1	1	1	1	1	Apl, CA, CB, FS, TIL, UG	JM, JV3, NS2, ZP
Arthonia ruana	1			1	1	AP, CA, CB, FE, FS, TIL, UG	FB, JM2, JV6, NS2, ZP2
Arthonia spadicea	1	1		1	1	CA, CB, FE, FS	JV, NS, ZP4
Arthopyrenia punctiformis		1	1		1	FS, TIL	JV4, ZP2
Arthothellium spectabile	1	1		1	1	CB, FS	FB, FrB, JM2, JV3, NS2, ZP5
Arthrorhaphis grisea				1		FS (root, associated with Baeomyces rufus)	ZP
Aspicilia caesiocinerea			1		1	FS (trunk bases)	JV, ZP
Bacidia albogranulosa ined.	1			1		FS	FrB*, JM*, JV, ZP2*
Bacidia aff. bagliettoana			1			FS	ZP!
Bacidia circumspecta	1	1	1	1	1	FS, TIL	AA, FB2, JM2, JV4, NS, ZP7
Bacidia fraxinea				1		FS, UG	JM
Bacidia incompta				1	1	FS	JV3
Bacidia laurocerasi					1	CB	ZP
Bacidia pycnidiata					1	log	FrB
Bacidia rosella	1	1			1	Apl, AP, CB, FS, TIL	JV
Bacidia rubella	1	1	1	1	1	Apl, AP, CB, FE, FS, QU, TIL, UG	ZP
Bacidia subincompta	1	1	1	1	1	Apl, AP, CB, FE, FS, TIL, UG	AA, FrB, JM, JV2, NS2, ZP2
Bacidia vermifera			1	1	1	FS	JM2, JV2, ZP
Bacidina delicata			1			FS	JV
!Bacidina etayana	1					wood of snag	FrB
!Bacidina neosquamulosa	1				1	FS	JM
Bacidina phacodes		1	1		1	FS (sometimes in hollows), polypore fung.	FB, FrB, JM2, JV3, ZP2
Bacidina sulphurella	1	1	1	1	1	CA, CB, FS, TIL, UG, log	AA, FrB, JV2, ZP2
Baeomyces rufus			1	1		CB (roots), FS (roots)	JM, ZP
Belonia herculina	1	1	1		1	Apl, AP, CB, FE, FS	AA, FB, FrB, JM, JV5, NS, ZP5
Biatora albohyalina			1			FS	ZP
Biatora amylacea ined.		1				CB, FS	ZP2*
!Biatora bacidioides	1			1	1	CB, FS (also bryophytes)	JM, ZP6*!
Biatora beckhausii			1		1	CB, FS	ZP2

Biatora chrysantha			1		1	FS (also bryophytes)	JM, JV5*, ZP6*
Biatora efflorescens		1	1		1	CB, FS	AA, FrB, JM2, JV2, ZP2*
Biatora globulosa		1	1		1	AP, Apl, FS, TIL, UG	AA, JM, JV2, ZP2
!Biatora longispora	1			1	1	FS	JM2, JV2, ZP3
!Biatora mendax	1			1	1	CB, FS, TIL	AA, FrB2, JM2, JV, NS2, ZP5
Biatora ocelliformis	1		1	1	1	AP, CA, CB, FS	AA, FB, FrB2, JM, JV4, ZP5
!Biatora pontica	1	1		1	1	AP, CA, CB, FS, TIL, UG	FB, FrB, JM2!, JV*, NS, ZP10*
Biatora radicicola ined.			1		1	FS (foot / roots)	FrB, JM, JV3, ZP2
Biatora vernalis	1			1	1	CB, FE, FS, snag (mosses)	AA, FB3, FrB4, JM, JV3, NS2, ZP7
Biatoridium monasteriense	1	1	1		1	Apl, AP, FE, FS, SN, TIL, UG	FrB, JM2, JV4, NS, ZP
Bilimbia sabuletorum		1	1		1	Apl, FE, FS, QU (often mosses)	AA, JM, JV, NS, ZP2
Bryoria fuscescens			1		1	FS	JV
Buellia disciformis	1	1	1	1	1	CB, FS, TIL	FB, JM3, JV5, ZP5
Buellia erubescens			1			FS	JV
Buellia griseovirens	1	1	1	1	1	Apl, AP, CB, FE, FS, TIL (also twigs), snag	FB, JV, NS2, ZP
Calicium glaucellum		1			1	QU, snag	FrB, JM
!Calicium montanum					1	snag (QU)	JV
Calicium salicinum		1	1		1	FS, TIL, snag	NS2
Calicium trabinellum					1	snag (QU)	FrB, JV
Caloplaca cerina			1		1	FS	
Caloplaca cf. cerinelloides	1	1				FE (twig)	AA
Caloplaca chrysodeta	1	1		1	1	CB, FE, FS, snag	JV, ZP
Caloplaca herbidella		1			1	TIL	FB, JV2
Caloplaca lucifuga					1	TIL	JV
Caloplaca monacensis			1		1	FS	JM3, JV, ZP
Caloplaca obscurella		1	1			AP, FS	AA, ZP2
Caloplaca aff. obscurella					1	FS	ZP!
Caloplaca sorocarpa			1		1	FS (trunk bases)	FrB2, JM, JV2!, ZP2
Caloplaca stillicidiorum		1	1		1	FS, TIL (mosses)	FrB
Caloplaca substerilis			1			FS	ZP!
Caloplaca turkuensis			1			FS (trunk bases)	JV!, ZP2
Candelariella efflorescens s.str.	1	1	1	1	1	Apl, AP, CB, FE, FS, snag	JM2, JV2
Candelariella reflexa s.str.		1			1	FE, QU	FB, JM, JV
Candelariella vitellina					1	FS (trunk bases)	JV
Candelariella xanthostigma	1	1	1	1	1	AP, FE, FS, TIL, FS, snag	FrB, JV, ZP5
Catillaria erysiboides			1			log	AA, FrB, JV, ZP
Catillaria nigroclavata	1	1		1	1	AP, CB, FE, FS, TIL (twig)	FrB, JM, JV2, ZP
Catinaria atropurpurea		1	1			FS, log, snag	AA, JV2, ZP2
Cetrelia cetrarioides					1	AP, FS	JV2*, ZP*
Cetrelia chicitae		1	1		1	FS, TIL	JV2*, ZP*
Cetrelia monachorum	1	1	1	1	1	CB, FE, FS, TIL, UG	FrB*, FB, JM4*, JV3*, ZP2*
Cetrelia olivetorum	1	1	1	1	1	AP, FE, FS (branch)	FrB*, JM, ZP2*
Chaenotheca brachypoda	1		1	1	1	FS, UG, snag	
Chaenotheca furfuracea	1		1	1	1	CB, FS (hollows at base)	
Chaenotheca gracilenta	1			1	1	CB, FS, snag (often hollows at base)	JM, JV
Chaenotheca trichialis	1		1		1	snag	
Chaenotheca xyloxena			1			FS, snag	JM
Chaenothecopsis debilis		1			1	FS, snag	JV, NS
Chaenothecopsis pusilla	1	1		1		snag	AA, JM2, NS2
Cheiromycina petri					1	CB	ZP
Cladonia coniocraea	1	1	1	1	1	Apl, CB, FS, log	JM
Cladonia fimbriata	1	1	1	1	1	CB, FS, TIL, log	
Cladonia chlorophaea s.lat.	1	1	1		1	CB, FS, TIL, log	
Cladonia macilenta			1			FS	
Cladonia pyxidata			1		1	CB, FS	JM, JV
Cladonia subulata			1		1	FS	JV*
Cliostomum griffithii			1			FS	FrB*
Coenogonium luteum	1			1		CB	NS
Coenogonium pineti	1	1	1	1	1	CB, FS, log, snag	NS, ZP3

Collema auriforme		1			1	Apl, FE, FS, QU	FB, JM, JV2, ZP2
Collema flaccidum		1	1	1	1	Apl, FE, FS, QU, TIL	AA, FB, JM2, JV2, ZP3
Collema nigrescens		1	1		1	TIL, FS	FB, JM
Cresporhaphis wienkampii	1					ULM	JV2
Cryptodiscus foveolaris		1	1	1		log, FS (wood in hollow trunk)	AA, FrB2, ZP2
Cryptodiscus gloeocapsa				1		BS (mosses)	
Cryptodiscus pallidus			1			log	AA
Cryptodiscus pini					1	wood of QU snag	FrB
Dictyocatenulata alba	1		1	1		CB, FS (usually trunk bases)	FB, FrB, JM, ZP4, JV2
Diploschistes muscorum			1		1	FS (partly on Cladonia squamules)	JV
Evernia divaricata					1	QU	
Evernia prunastri	1	1	1	1	1	CB, FS, TIL (often twigs)	
Fellhanera bouteillei			1	1		FS, log	
Fellhanera gyrophorica				1		FS	JV
Flavoparmelia caperata	1	1	1	1	1	CB, FE, FS, TIL (also twigs)	ZP
Frutidella pullata			1			FS	JM*, JV, ZP*
Fuscidea arboricola	1	1	1			FS, CB	JM*, JV*, NS, ZP
Fuscidea cyathoides	1	1				Apl, FS	JV2, ZP
Graphis scripta s.lat.	1	1	1	1	1	AP, CA, CB, FE, FS, TIL, UG	AA, ZP9
Gyalecta flotowii	1			1	1	AP, FS, UG	FB, FrB2, JM, JV2, NS, ZP4
Gyalecta truncigena	1	1			1	AP, Apl, FE, FS, TIL, UG	AA, FB2, JM3, JV4, NS, ZP7
Gyalecta ulmi					1	QU	JV
!Gyalideopsis helvetica			1			FS	ZP
Halecania viridescens	1	1				FS, TIL (twigs)	JM, ZP
Heterodermia speciosa	1	1	1	1	1	FS, FE, FS, TIL (often twigs)	FrB, JM, JV, ZP
Hypocenomyce scalaris			1			FS	
Hypogymnia farinacea		1	1		1	FS, TIL	
Hypogymnia physodes	1	1	1	1	1	FS, TIL (also twigs)	ZP
Hypogymnia tubulosa	1	1	1	1	1	FE, FS, TIL (often twigs)	
Hypotrachyna afrorevoluta	1	1		1	1	CB, FS (also twigs)	FB, FrB, JM, JV2, ZP2*
Hypotrachyna revoluta				1		CB (also twigs)	JV
Imshaugia aleurites					1	snag (QU)	FrB, ZP
Japewia dasaea ined.			1		1	FS	JM*!, ZP*, JV3*
Lecania croatica	1	1	1	1	1	AP, CA, CB, FE, FS, UG, Lonicera	AA, FB, FrB, JM3, ZP
Lecania cyrtella			1			FS (dry bark of lying trunk), snag	FrB, ZP
Lecania cyrtellina	1		1			FS	FB, JM2
Lecania naegelii					1	FS (twig)	FB
Lecanora albella				1	1	CB, FS	JV
Lecanora albellula			1			FS (foot), log, snag	AA, ZP
Lecanora cf. anopta			1			log	ZP2*!
Lecanora argentata	1	1	1	1	1	Apl, AP, CB, FE, FS	FrB, JV2, NS4, ZP4
Lecanora aff. campestris		1	1			Apl, FE, FS	ZP4*
Lecanora carpinea s.str.		1	1			FE, FS, TIL	JM, JV
Lecanora chlarotera		1	1			FS, TIL	JM, JV
!Lecanora cinereofusca	1			1	1	CB, FS	FB, FrB, JM2, NS, ZP2*
Lecanora compallens	1			1		AP, FS	JM2*, NS
Lecanora ecorticata	1					FS	JM*, ZP*
Lecanora expallens	1	1	1	1	1	CB, FS	JV
!Lecanora exspersa			1		1	FS	JM*, JV2*, ZP2*
Lecanora glabrata	1	1	1	1	1	Apl, CB, FS, TIL	JM3*, JV3, NS, ZP5
Lecanora intricata					1	FS (bark at base & exposed wood)	JV
Lecanora intumescens		1	1		1	CB, FS, TIL	AA, JM, JV3, NS, ZP3*
Lecanora leptyrodes		1	1	1		CB, FE, FS, snag	AA, JM3, JV2, ZP5
Lecanora muralis					1	FS (trunk bases)	JV
Lecanora phaeostigma			1			FS, snag	JV, ZP, FrB
Lecanora polytropa		1	1		1	FS, TIL (trunk bases)	JM*, JV2, NS, ZP3*
Lecanora pulicaris	1	1	1	1	1	CB, FE, FS, TIL (often twigs)	JV3, NS, ZP3
Lecanora saligna		1	1		1	FS, snag, log	JM, JV2, ZP3*
Lecanora sambuci			1		1	FS, snag	FrB, JM, JV, NS, ZP4
Lecanora subintricata			1			snag	JV*, NS

Lecanora substerilis ined.	1	1		1	1	AP, CB, FS	FrB2, JM4*, JV2*, ZP2*
Lecanora symmicta	1			1	1	CB, FS (often twigs)	AA, JM, JV, ZP
Lecanora thysanophora	1	1	1	1	1	AP, CB, FS, UG	JM2*, JV*, ZP3*
Lecanora varia		1	1		1	FS, TIL (also twigs)	JV
Lecidea erythrophaea	1		1	1	1	AP, CB, FS	FrB, JV, NS, ZP6
Lecidea turgidula			1			FS (wood in hollow trunk), snag	FrB, ZP2
Lecidella carpathica			1		1	FS (trunk bases)	JV, ZP
Lecidella elaeochroma (incl. L. achristotera)	1	1	1	1	1	Apl, CB, FE, FS, TIL	FrB2, JV4, NS, ZP4
Lecidella flavosorediata	1	1	1	1	1	AP, FE, FS, TIL (also twigs)	JM2*, JV, ZP*
!Lecidella subviridis s. l.	1	1		1	1	FS	JM3*, JV3*, ZP3*
Lepraria eburnea		1				TIL	ZP*
Lepraria elobata			1			FS	JM2*, JV*
Lepraria finkii	1	1	1	1	1	Apl, AP, CA, CB, FE, FS, QU, TIL, UG, snag	JV6*, NS2, ZP5*
Lepraria incana	1	1	1			FS, snag	
Lepraria membranacea					1	FS	
Lepraria rigidula	1	1	1	1	1	CB, FE, FS, UG, log	JM3*, JV4, ZP*
Lepraria vouauxii	1	1	1	1	1	Apl, CB, FE, FS, QU, TIL, UG	FrB2, JM, JV2*, ZP4*
Leptogium cyanescens		1		1		AP, FE, FS, TIL	AA, FrB, JM, ZP
Leptogium lichenoides				1		FS	ZP
Leptogium pulvinatum	1	1		1	1	Apl, AP, FE, FS, QU	JM2, JV, ZP2
Leptogium saturninum		1	1		1	FE, FS, TIL	FB, JM2, JV, ZP
Leptogium teretiusculum	1	1	1	1	1	Apl, FE, FS, QU, log	AA, FB, JV5, ZP
!Lithothelium hyalosporum	1					AP, FS	JV, ZP
Lobaria amplissima			1		1	FS	
Lobaria pulmonaria	1		1	1	1	AP, CB, FE, FS	
Lopadium disciforme	1	1	1		1	CB, FS	JV, ZP2
Loxospora aff. confusa	1	1				CB, FS	FrB*!, JM*
Macentina abscondita	1	1	1			log	JV
Macentina dictyospora		1		1		snag, log	JV, ZP2
Megalaria laureri	1			1	1	CB, FS	FrB, JM, JV4, NS, ZP2
Melanelixia glabra		1	1		1	FE, FS, TIL	AA
Melanelixia glabratula	1	1	1	1	1	AP, Apl, CB, FS, TIL (often twigs), snag	FrB2, NS, ZP3
Melanelixia subargentifera					1	TIL	
Melanelixia subaurifera	1	1	1	1		Apl, FE, FS, TIL (also twigs)	JM
Melanohalea elegantula	1	1	1	1	1	CB, FE, FS, TIL	FrB, JV4, NS, ZP2
Melanohalea exasperata	1				1	FS (twigs)	
Melanohalea exasperatula	1	1	1		1	CB, FS (twigs)	
Melaspilea gibberulosa	1	1	1		1	AP, FS, TIL	AA, JV3, NS, ZP
Melaspilea proximella		1				AP, QU, TIL	AA, JM, JV4!, ZP5
!Menegazzia subsimilis				1	1	CB, FS	JV2, ZP
Menegazzia terebrata	1	1	1	1	1	AP, CB, FS, TIL (often in canopy)	JM, ZP2
!Micarea anterior	1					log	ZP
Micarea botryoides	1			1		snag	ZP2
Micarea byssacea		1		1		log	AA2
Micarea cinerea	1					log	ZP
!Micarea deminuta				1		log	FrB, ZP
Micarea denigrata			1			log	JV
Micarea globulosella			1			FS	AA, JM*, ZP
Micarea inconspicua ined.	1		1	1		log, snag	FrB, JV2, ZP2
Micarea lilacina ined.				1		log	ZP
Micarea lithinella				1		FS (root)	ZP
Micarea melaena					1	snag (QU)	JV
Micarea micrococca	1	1	1	1	1	AP, CB, FS, UG, log	AA, JM2*, JV2, ZP4
Micarea misella	1		1	1	1	FS, log, snag	FrB, JV2, ZP5
Micarea nigella	1					wood	AA, ZP
Micarea peliocarpa			1				AA
!Micarea perparvula	1					wood	ZP
Micarea prasina	1	1	1	1		AP, FS, UG, log, snag	AA, ZP*

!Micarea soralifera				1	1	log	FrB*, ZP*
Micarea substipitata ined.			1			FS (dry wood and bark of lying trunk)	ZP2!
Microcalicium arenarium				1		FS (root)	ZP
Multiclavula mucida	1		1	1		log	NS2
Mycobilimbia epixanthoides		1				FE, TIL (often bryophytes)	AA, JM2!, ZP*
Mycobilimbia tetramera			1		1	FS (also bark mosses)	FrB, JV
Mycocalicium subtile	1	1	1	1		snag	FrB, JM2, JV2, NS3
Nephroma parile			1		1	FS	JM2
Nephroma resupinatum			1		1	FS	JV, FrB
Nephromopsis laureri			1		1	FS	JV2
!Normandina acroglypta		1		1		FS (mosses), TIL	JV, FrB, ZP*
Normandina pulchella	1	1	1	1	1	CB, FE, FS, QU, TIL (also twigs)	ZP
Ochrolechia alboflavescens			1			FS	AA, JM*
Ochrolechia androgyna s.lat.	1	1	1	1	1	AP, FE, FS, TIL, snag	JM, JV4, ZP2*
Ochrolechia arborea		1			1	CB, FS, TIL	FrB, JM, ZP
Ochrolechia microstictoides					1	snag	JV*
Ochrolechia pallescens		1	1		1	Apl, CB, FS, TIL	JM, JV4
Ochrolechia szatalaensis		1	1			Apl, CB, FS	JV*, ZP2*
Ochrolechia trochophora					1	TIL	JM*
Ochrolechia turneri		1	1	1		Apl, FE, FS, TIL	FB, JM*, JV3*, NS
!Opegrapha fumosa	1					FS	ZP*
Opegrapha niveoatra	1	1		1	1	Apl, FE, FS	FrB, JV
!Opegrapha ochrocheila			1		1	FS, CB (wood in hollow)	JM, ZP
Opegrapha rufescens	1	1	1	1	1	Apl, AP, CA, CB, FE, FS, QU, TIL	JV4, NS, ZP
Opegrapha trochodes	1	1		1	1	AP, CB, FE, FS, UG	AA, FrB2, JM, JV3, NS, ZP4
Opegrapha varia	1	1	1	1	1	AP, CB, FE, FS, UG, snag (FS)	FB, JV2, NS, ZP8
Opegrapha vermicellifera	1	1		1	1	AP, CB, FE, FS, UG	JM, ZP
Opegrapha viridis	1	1		1	1	Apl, AP, CB, FE, FS	AA, JM, JV4, NS2, ZP5
Pannaria conoplea		1				TIL	FB, JV
Parmelia saxatilis (incl. *P. ernstiae* , *P. serrana*)	1	1	1	1	1	FE, FS, TIL (often twigs)	FrB3, ZP*
Parmelia submontana	1		1	1	1	FS (also twigs)	FrB, NS
Parmelia sulcata	1	1	1	1	1	CB, FE, FS, TIL (often twigs), snag	ZP2
Parmeliella triptophylla		1	1	1	1	Apl, CB, FE, FS, QU, TIL	FB, JM2, JV, ZP5
Parmelina pastillifera	1	1	1	1	1	AP, CB, FE, FS, TIL (also twigs)	ZP
Parmelina tiliacea		1	1	1	1	Apl, CB, FS, TIL (also twigs)	ZP2
Parmeliopsis ambigua		1	1	1	1	AP, FS, TIL, snag	
Parmeliopsis hyperopta			1		1	FS	
Parmotrema arnoldii	1				1	FS	FrB, JM
Parmoterma crinitum				1	1	CB, FS (also twigs)	JV2
Parmotrema perlatum	1			1	1	CB, FS (also twigs)	FrB2, JV2, ZP*
Peltigera collina			1		1	FS	JM
Peltigera praetextata	1	1	1	1	1	Apl, AP, FE, FS, QU, TIL (usually bases)	JV
Pertusaria albescens	1	1	1	1	1	Apl, CB, FE, FS, TIL	JV5
Pertusaria amara	1	1	1	1	1	AP, Apl, CB, FE, FS, TIL (also twigs)	ZP*, JV2
Pertusaria coccodes		1	1		1	Apl, CB, FS, TIL	JM, JV, ZP
Pertusaria constricta				1	1	CB, FE, FS	FrB, JV, ZP2
Pertusaria coronata		1	1		1	CB, FE, FS, TIL	FB, JV4, ZP2
Pertusaria flavida		1			1	FS, TIL	JM, JV
Pertusaria leioplaca	1	1	1	1	1	Apl, CB, FS, TIL	JM, JV4, NS, ZP4
!Pertusaria macounii				1		CB	JV
Pertusaria pertusa	1	1	1	1	1	AP, CB, FS	FS, JM2, JV3, NS, ZP3
Pertusaria pupillaris	1	1		1	1	AP, CB, FS, UG	JM, ZP
Pertusaria trachythallina	1			1	1	CB, FS	FrB*, JV2*
Phaeophyscia endophoenicea	1	1	1	1	1	Apl, AP, CB, FS, TIL (also twigs)	JV, ZP2
Phaeophyscia nigricans			1			FS	
Phaeophyscia orbicularis	1	1	1	1	1	Apl, AP, CA, FE, FS (twigs)	ZP
!Phaeophyscia pusilloides					1	FS	FrB
Phlyctis agelaea		1		1	1	Apl, CB, FS	FrB, JV, ZP2
Phlyctis argena	1	1	1	1	1	AP, Apl, CA, CB, FE, FS, QU, TIL, UG	JV, NS, ZP3

Physcia adscendens	1	1	1	1	1	AP, CB, FS (often twigs)	JV
Physcia aipolia		1	1			FE, FS (twigs)	JV
Physcia dubia			1			FS	
Physcia stellaris		1		1	1	FS, TIL	JV
Physcia tenella	1	1	1	1	1	CB, FS, TIL (often twigs)	
Physciella chloantha		1	1		1	CB, FS	FB
Physconia detersa			1			FS	FrB, ZP!
Physconia distorta		1	1		1	FS, TIL	
Physconia enteroxantha			1		1	FS	
Physconia grisea		1				TIL	
Physconia perisidiosa		1	1		1	AP, FE, FS	JM, ZP
Piccolia ochrophora	1	1	1	1	1	Apl, FE, FS, SN, UG	FrB2, JM, JV
Placynthiella dasaea			1	1		log, snag	FrB*, ZP*
Placynthiella icmalea	1	1	1		1	FS, log, snag	JV*, ZP2*
Pleurosticta acetabulum					1	FS	
Platismatia glauca	1	1	1	1	1	AP, TIL, FS (often twigs)	
Porina aenea	1	1	1	1	1	AP, CB, FS, TIL	FrB, JV3, NS
Porina leptalea	1	1	1	1	1	AP, CA, CB, FS, TIL	FB, JM, JV4, NS, ZP11
Porina leptosperma ined.	1			1		CB, FS	FrB2
Porina pseudohibernica		1	1		1	FS, QU, TIL	JV2, ZP2
Porpidia macrocarpa (incl. P. nigrocruenta)			1		1	FS	AA2, JV4, ZP
Pseudevernia furfuracea	1	1	1	1	1	AP, FS, TIL (twigs)	
!Psoroglaena stigonemoides				1		FS	ZP
Punctelia jeckeri	1			1	1	FS	
Punctelia subrudecta	1	1		1	1	FS, TIL (also twigs)	JV, ZP3
Pycnora leucococca			1			FS	FrB, JV, NS
Pycnora sorophora					1	snag (QU)	
!Pyrenula chlorospila	1					AP	JM
Pyrenula coryli	1			1		CB	JV2, NS
Pyrenula dermatodes	1			1		CB	JV2
Pyrenula laevigata	1			1	1	CB, FE, FS	AA, FB2, JM2, JV3, ZP4
Pyrenula nitida	1	1	1	1	1	Apl, AP, CB, FS	ZP4
Pyrenula nitidella	1				1	CB, FE	JV, NS
Pyxine sorediata				1		CB (branch)	JV
Ramalina farinacea	1	1	1	1	1	Apl, AP, CB, FS, TIL (also twigs)	ZP2
Ramalina fastigiata		1	1		1	CB, FE, FS, TIL	JV, ZP
Ramalina fraxinea			1			FS	
Ramalina pollinaria	1	1	1	1	1	Apl, CB, FE, FS, QU, TIL	ZP*
Ramonia interjecta	1				1	SN	FrB, JV
Ramonia luteola		1	1			Apl, FS	AA, JM, JV, ZP
Rhizocarpon polycarpum					1	FS (trunk bases)	JV
Rinodina albana			1			FS	ZP3
Rinodina capensis			1			FS, log	JM, JV, NS
Rinodina degeliana	1	1	1		1	CB, FS (also twigs)	JV2, ZP3
Rinodina efflorescens	1	1	1	1	1	AP, CB, FS	AA, JM3, JV4*, ZP6*
Rinodina griseosoralifera			1	1	1	FS, snag	AA, JM2, JV*, ZP2
!Rinodina malangica			1			FS (foot)	JM, JV, ZP
Rinodina orculata			1			FS (trunk bases)	JM, JV
Rinodina sophodes	1	1			1	FS, TIL (twigs)	JV3
Rinodina trevisanii			1			FS	ZP
Ropalospora viridis	1	1		1	1	AP, CB, FE, FS	FrB, JM*, JV*, ZP3*
Sclerophora farinacea	1		1	1	1	FE, FS, UG (often dead trees)	AA, FB, FrB2, JM2, JV7, NS, ZP4
Sclerophora pallida	1	1		1	1	FS	JM2, NS
Scoliciosporum chlorococcum		1	1			FS, log, snag	JV
Scoliciosporum sarothamni	1	1	1	1	1	CB, FS, TIL (twigs)	JV, ZP
!Scoliciosporum schadeanum	1				1	AP, CB, FS (fallen branch)	ZP4
Scoliciosporum umbrinum	1	1	1	1	1	AP, CB, FE, FS, TIL	AA, FB, FrB, JM, JV3, NS2, ZP6
Steinia geophana	1	1	1	1	1	log, snag	JM, JV2, NS2, ZP5
Stenocybe pullatula	1					FS (twig)	AA

Strangospora pinicola			1		1	FS (also exposed wood)	JV
Strigula glabra	1	1				CB	FB, NS
Strigula stigmatella	1	1		1	1	CB, FE, FS, TIL (also exposed roots)	AA, FrB, JM, JV3, ZP5
Tephromela atra					1	TIL	JV
Tetramelas chloroleucus			1			FS	JV2, ZP
Thelenella muscorum			1		1	FS	JV, NS, ZP2
Thelocarpon epibolum	1		1	1		log	JV2, NS2, ZP
Thelocarpon lichenicola		1		1		log	AA, JV, FrB
Thelopsis flaveola	1	1				Apl, FS, TIL	JM2, ZP2
Thelopsis rubella	1	1	1	1	1	AP, CB, FS, TIL	FB2, FrB, JM2, JV4, ZP8
Thelotrema lepadinum	1			1	1	CB, FE, FS, TIL, UG	FrB, JV, ZP3
Thelotrema suecicum	1			1	1	AP, CA, CB	FrB, JV2, ZP4
Thelotrema sp.	1					FE	ZP*!
Trapelia corticola		1				log	JM
Trapeliopsis flexuosa		1	1	1	1	FS, TIL, snag	JV2, ZP
Trapeliopsis granulosa			1			log	
Trapeliopsis pseudogranulosa			1			FS	AA
Trapeliopsis viridescens		1				log	JV
Tuckermannopsis chlorophylla			1		1	FS	
Usnea hirta			1			FS (also twigs)	JV
Usnea scabrata		1	1			AP, FS, TIL (often twigs)	JM, ZP
Usnea subfloridana			1		1	FS	JM*
Usnea substerilis			1			FS	JM
Usnea sp. (when no identified species in plot)	1					twig on ground	AA
Varicellaria hemisphaerica	1	1	1			FS	FrB, ZP
Verrucaria breussii		1				QU	ZP
!Verrucaria hegetschweileri			1			FS (trunk bases)	ZP, JV4
Verrucaria viridigrana				1	1	log, FS (snag with bark)	FrB, ZP3
!Vezdaea retigera				1		wood of snag	ZP
Violella fucata	1	1	1	1	1	CB, FS (also twigs)	JV
Vulpicida pinastri			1		1	FS	
Xanthoria fulva			1		1	FS, snag	JV2, NS, ZP
Xanthoria parietina			1	1	1	FS (canopy)	
Xanthoria polycarpa			1		1	FS	
!Xylographa trunciseda			1			log	JM*
	180	188	228	182	249		
Abrothallus bertianus	1		1	1		*Melanelixia glabratula*	FrB2, JV
Bertia moriformis	1					log	ZP
Briancoppinsia cytospora	1		1			*Parmelia*	FrB2
Capronia moravica			1			log	AA
Cryptocoryneum condensatum	1					CA	ZP
Dactylospora lobariacearum			1			*Lobaria pulmonaria*	FrB
Dactylospora parasitica			1			*Pertusaria*	FrB
Durella melanocarpa			1			log	ZP
Durella connivens	1					log	ZP
Endophragmiella sp.				1		*Absconditella lignicola*	
Exarmidium inclusum	1		1			log	AA, JM, ZP2
Glonium lineare		1				log, snag	AA
Homosteggia piggeoti			1			*Parmelia saxatilis*	FrB
Hyalotrochophora lignitalis				1		log	FrB
Chalara lobariae			1			*Lobaria pulmonaria*	FrB
Intralichen christiansenii			1			*Lecanora leptyrodes*	FrB
Intralichen lichenum			1			*Lobaria pulmonaria*	FrB
Kirschsteiniothelia aethiops			1			FS	ZP
Kirschsteiniothelia recessa			1			FS	JV
Lophiostoma corticola					1	FS	ZP
Lichenochora weillii			1			*Physconia*	AA

Lichenostigma maureri			1			*Parmelia saxatilis*	
Merismatium heterophractum				1		*Biatora* sp.	FrB
Mniaecia jungermanniae				1		log	NS, ZP
Mycowinteria muriformis					1	log	AA
Opegrapha thelotrematis				1		*Thelotrema lepadinum*	
Perididiothelia fuliguncta	1	1			1	TIL	AA
Phaeopyxis punctum			1			*Cladonia* squamules	AA
Phoma lobariae			1			*Lobaria pulmonaria*	FrB
Propolis aff. versicolor		1				*log*	AA
Rhymbocarpus neglectus			1			*Lepraria*	FrB
Sphinctrina leucopoda				1		*Pertusaria pertusa*	JM
Spolvernia punctum			1			*Parmelia sulcatra*	
Stictis radiata	1			1	1	CA, FS, TIL, log	JM, JV2
Stigmidium microspilum					1	*Graphis scripta*	
Taeniolella punctata		1	1	1		*Graphis scripta*	NS
Taeniolella sp.	1					*Lecanora*	
Taeniolella verrucosa				1		*Thelotrema lepadinum*	
Tremella lichenicola	1			1		*Violella fucata*	FrB
Tremella lobariacearum			1			*Lobaria pulmonaria*	FrB
Trichonectria anisospora	1					*Hypogymnia physodes*	
Unguiculariopsis acrocordiae		1		1		*Acrocordia gemmata*	FrB, JM2, ZP
Vouauxiella lichenicola	1		1			*Lecanora pulicaris*	FrB, ZP

Supplementary table 2. Notes to identifications and TLC results.

taxon	voucher	note and/or TLC result
Agonimia sp.	ZP19965	The combination of subcoralloid thallus and sclerocia does not fit to any described Agonimia species. Unfortunately no perithecia were discovered.
Agonimia borysthenica	ZP19348, 19365	Collected specimens quite small and sterile, overgrowing bryophytes. Thallus composed of convex, finely hairy (sub)globose granules (distinct horny papillae are apparently breaking with age and hence not emphasized in original description).
Anisomeridium biforme	ZP19542	Only pycnidia present with subglobose conidia.
Arthonia apatetica	JM8276, 8289, JV13925	Swollen and brown-capped paraphyses are absent.
Arthonia glaucella	JV13947, 13949 (latter, sterile)	Thallus sordid white, +/- with white (soralia-like) dots, K-, C-, P-, UV+ white; apothecia <0.4 mm diam., flat, white pruinose; epihymenium brown, K+ green; hypothecium tall, colourless, I+ red; Hymenium I+ blue then red, KI+ blue; ascospores 3-4-septate, 16-19 x 5-7 µm, with (slightly) enlarged upper cell, not darkened. Two fatty acids and trace of norstictic acid in 1 sample by TLC.
Bacidia albogranulosa ined.	FrB29253, JM8166, ZP19366, 19392	atranorin by TLC
Bacidia aff. bagliettoana	ZP19352	Morphologically resembling terricolous Bacidia bagliettoana with whitish thick thallus, but differs internal apothecial pigmentation and distinctly granulose epihymenium.
Biatora amylacea ined.	ZP19170, 19363	Blue grey delimited soralia, no secondary metabolits by TLC, bluish-grey biatoroid apothecia with whitish rim, excipulum I+ dark blue (like in Biatora rufidula and B. aegrefaciens); spores ca 11 x 3 µm, low hymenium, purple and green pigments in epihymenium and outer exciple.
Biatora bacidioides	JM8178, ZP19221, 19295, 19304, 19324, 19619, 19685	TLC: argopsin, norargopsin, gyrophoric acid; sterile thalli resembling Biatora efflorescens, but chemistry and ITS/mtSSU data of one of the specimens suggest it is the species that was so far known only from the Pontic region of Turkey.
Biatora efflorescens	JM8226, ZP19318, 19334	argopsin, norargopsin
Biatora chrysantha	ZP19440, 19687, JV14057, 14129, 14130	gyrophoric acid
Biatora longispora	ZP19308	no compounds by TLC
Biatora ocelliformis	ZP19624	argopsin
Biatora pontica	JM8269, ZP19297, 19316, 19332, JV13912, 14141	thiophanic acid, asemone, cf. arthothelin and/or traces of additional xanthone(s) in some samples, pontica-unknown (minor) constantly present. The JM specimen(s) confirmed by ITS and mtSSU.
Biatora radicicola ined.	FrB s.n., JM8266, JV14327, 14142, ZP19170, 19363	No compounds by TLC. Description in Printzen et al. (2016, in prep.)
Caloplaca aff. obscurella	ZP19260	It contains Cinereorufa-green in epihymenium; soralia resemble *Caloplaca substerilis;* related to *C. obscurella* (Suppl. table 3), but distinct.
Cetrelia cetrarioides	ZP20359, JV14000, 14116	perlatolic acid, atranorin, anziaic acid
Cetrelia chicitae	ZP19330, JV14100, 14127	atranorin, α-collatolic acid, alectoronic acid
Cetrelia monachorum	all specimens	atranorin, imbricaric acid, perlatolic acid, anziaic acid, 4-0-demethylimbricaric acid
Cetrelia olivetorum	FBe29167, ZP19373	atranorin, olivetoric acid (major), anziaic acid, 4-0-demethylmicrophyllinic acid
Cladonia subulata	JM14114	fumarprotocetraric acid
Collema auriforme	JM8125	Specimens from mosses at bases of trees were originally identified as *C. subflaccidum* (published from the area by Dymytrova et al. 2013), however, they belong to *C. auriforme* widely distributed on limestone rocks in the area.
Collema flaccidum	ZP19451, etc.	Younger thalli with globose isidia and without flattened isidia may be identified as *C. subflaccidum*, but they usually grow with thalli with well-developed flattened isidia and we consider both being *C. flaccidum.*
Cresporhaphis wienkampii	JV13964, 13984	Probably non-lichenized thallus, but clusters of non-trentepohlioid algae observed within thallus; perithecia with low necks around ostiola; perithecial wall para-plectenchymatous; involucrellum absent; ascospores 25-33 x 3-4 µm, 0-1-3 septate; pycnidia not seen.
Frutidella pullata	JM8227, ZP19761	sphaerophorin
Fuscidea arboricola	JM8224, JV14110	fumarprotocetraric and/or protocetraric acids
Japewia dasaea ined.	JM8238, ZP19774	A brownish sorediate crust resembling *Placynthiella dasaea*. Aliphatic compounds (major one: A4, B4-5, C4) detected by TLC.
Lecanora aff. campestris	ZP19356, 19485, 19486, 19867	Possibly a new taxon very similar to *L. glabrata* and closely related to *L. campestris*. It is characterized by presence of the terpenoid *campestris*-unknown 1.
Lecanora albellula	ZP19952	Characteristic septate macroconidia with obtuse ends present

Lecanora carpinea / leptyrodes		According to Lumbsch et al. (1997), *L. carpinea* differs from *L. leptyrodes* in true cortex with crystals soluble in K, whereas the pseudocortex with insoluble crystals is present in *L. leptyrodes* . Following this concept, most of populations belong to *L. leptyrodes* . *Lecanora carpinea* with typical true cortex was recorded only very rarely in higher altitudes.
Lecanora cf. anopta	ZP20047	Ascospores quite narrow, 3.5-4.5 µm wide; characteristic gently curved conidia (6-8 x 1-1.3 µm) present.
Lecanora cinereofusca	ZP19230, 19258	atranorin, placodiolic and psoromic acids
Lecanora compallens	JM8168, 8300	usnic acid, zeorin, few minor compounds, but xanthones completely absent
Lecanora ecorticata	JM8173, ZP19362	Usnic acid, zeorin and cf. divaricatic acid (trace) by TLC. Collected specimens resemble *L. vouauxii* in having a quite thick, yellowish cottony sublobate thallus. The habit matches the broad concept of the taxon outlined by Kukwa (2006, as Lepraria ecorticata). The relationship between saxicolous (incl. type material) and epiphytic material attributed to this name, as well as relationship to chemically concordant Lecanora leuckertiana shall be studied further.
Lecanora exspersa	all specimens	Atranorin, nephrosteranic acid and traces of one or more fatty acids detected by TLC. Typical soralia with thalline rim present.
Lecanora intumescens	ZP19963	atranorin, psoromic and 2-O-demethylpsoromic acids
Lecanora polytropa	JM8223, ZP19266, 19494	usnic acid, rangiformic acid, zeorin (tr.)
Lecanora substerilis Malíček & Vondrák ined.	all specimens	A new sorediate taxon from the *L. subfusca* group, morphologically very similar to *L. farinaria* . All specimens tested by TLC contained atranorin and roccellic acid.
Lecanora thysanophora	JM8181, JV14040, ZP19357	atranorin (trace to major), usnic acid, zeorin, 1 to 3 thysanophora-unknowns (terpenoids) constantly present; atranorin was present in trace amount in juvenile specimens resembling morphologically Lecanora compallens/expallens, the diagnostic thysanophora unknowns were constantly present in material studied chemically
Lecidella flavosorediata	JM8140, 8191; ZP16164	arthothelin, granulosin or trace of unidentified xanthone
Lecidella subviridis	JM8110, 8214	atranorin, thiophanic acid, expallens-unknown
Lecidella subviridis s. l.	ZP19309, 19343, JM8163, JV13915, 13940	a related taxon of L. subviridis s.str.?; atranorin, thiophanic acid, in some samples also arthothelin and probably granulosin, expallens unknown is missing in all studied specimens
Lepraria eburnea	ZP19171	alectorialic acid, cf. protocetraric acid and derivatives
Lepraria cf. finkii	JV13916, 14075, 14045	atranorin, stictic acid complex
Lepraria elobata	JM8230, 8250, JV14106	atranorin, stictic acid complex, zeorin
Lepraria finkii	JV13906, 14115	atranorin, stictic acid complex, zeorin
Lepraria rigidula	JM8210, 8243, 8251, ZP19339	atranorin, nephrosteranic acid
Lepraria vouauxii	ZP19317, 19421, JV14108	pannaric acid 6-methylester and derivatives
Leptogium lichenoides	ZP20046	distinct from the common *L. pulvinatum* by coralloid isidia
Loxospora aff. confusa	FrB29222, 29239, JM8179	Sorediate crust resembling *Ochrolechia* or *Pertusaria amara* , containing planaic acid (very probably) with 2-5 related compounds (visible in B).
Melanohalea elegantula	all specimens	no compounds by TLC or negative spot reactions
Micarea cinerea	ZP19313	Only pycnidia present with characteristic long filiform septate conidia. C + faintly rose-red spot reaction (gyrophoric acid)
Micarea globulosella	JM8228, ZP19495	Morphologically our material fits M. globulosella well except the chemistry. In part of the material (JM8228) no gyrophoric acid has been found by TLC and by spot tests of thallus sections suggesting *Micarea synotheoides.* We follow the concept by A. Launis (pers. comm.), her preliminary results show that specimens from Central Europe previously published as *M. synotheoides* belong to *M. globulosella* .
Micarea inconspicua ined.	ZP19417, 19788	Specimens earlier included in "*Micarea prasina* " with membranaceous thallus, without granules/goniocysts, and with small colourless apothecia, <0.2mm diam. No secondary compounds revealed by TLC in non-Ukrainian specimens.
Micarea lilacina ined.	ZP19934	small dark convex apothecia, 0.2 mm diam.; sessile pycnidia, reddish brown, K+ crimson purple hypothecium, delimited black epihymenium and exciple, ellipsoid simple spores ca 7 x 3.5 µm
Micarea micrococca	JM8260	Methoxymicareic acid
Micarea prasina	ZP19436	Continuously finely granulose thallus; micareic acid by TLC
Micarea soralifera	FrB29249, ZP19300	Delimited soralia with fine soredia; micareic acid by TLC
Mycobilimbia epixanthoides	JM8199, ZP19665	Sterile sorediate thalli. No compounds by TLC. Identity confirmed by ITS and mtSSU (JM8199).
Normandina acroglypta	ZP19446, JV14062	Zeorin by TLC (in JV14062 only in trace amount: zeorin visible as a faint short line as late as after repeated TLC when one solvent systeme used only).
Ochrolechia alboflavescens	JM8239	variolaric acid, atranorin (tr.), lichesterinic & protolichesterinic acids, 1 microstictoides-unknown

Ochrolechia androgyna	ZP19303, 19319	ZP specimens should belong to Ochrolechia androgyna s.str.; TLC: gyrophoric & lecanoric acids, androgyna B unknowns in B'
Ochrolechia microstictoides	JV14133	variolaric acid, lichesterinic & protolichesterinic acids
Ochrolechia szatalaensis	ZP19167, 19327, JV14128	variolaric acid
Ochrolechia trochophora	JM8141	gyrophoric & lecanoric acids
Ochrolechia turneri	JM8196, JV14131	variolaric acid, norstictic acid (tr.) and unknown fatty acid (above variolaric acid in C) or microstictoides-unknowns
Parmelia ernstiae	ZP19820	atranorin, salazinic acid, lobaric acid, cf. protolichesterinic/lichesterinic acid
Parmotrema perlatum	ZP19400	atranorin, stictic acid complex
Pertusaria macounii	JV14091	like *Pertusaria pertusa* , but spores grey, containing Sedifolia-grey (K+ violet).
Pertusaria trachythallina	FrB29224, JV14074, 14213	thamnolic acid
Placynthiella dasaea	FrB29228, ZP18602	gyrophoric acid only
Porina leptosperma ined.	FrB29213, 29217	similar to *Porina leptalea* , but perithecia dark red and thallus rough with tiny goniocysts
Pyrenula coryli	JV13968, 14060	ascospores <15 µm long; thallus lichenized, with *Trentepohlia*
Pyrenula dermatodes	JV13904, JV14046	perithecia not forming projections above thallus, ascospores 18-25 x 7-9 µm, thallus pale grey-green, UV+ yellow-orange.
Pyrenula chlorospila	JM8155	Perithecia forming projections above thallus, ascospores 26-33 x 10-14 µm, thallus pale grey-green, UV+ white.
Rinodina degeliana	ZP19172	atranorin, zeorin
Rinodina efflorescens	JV13954, 14105, 14113, 14124, 14125, ZP19315, 19412	pannarin, secalonic acid A, zeorin
Rinodina griseosoralifera	JV14123	atranorin, zeorin
Ropalospora viridis	JM8213, ZP19386, 19632, JV13959	perlatolic acid
Sclerophora farinacea	all specimens	Some of the specimens have somewhat smaller ascospores approaching the spore size known in Scandinavian populations of Sclerophora amabilis (5.5-6.5um, Tibell 2002), only rarely reaching 7um. However the overall habit, dark pigmented stalks and grey-white pruinose apothecia match S. farinacea quite well.
Scoliciosporum sarothamni	ZP19398	gyrophoric acid (trace)
Thelotrema sp.	ZP19335	sterile white crust with trentepohlioid photobiont and occassional tiny round bluish soralia; TLC: stictic acid
Thelotrema suecicum	all specimens	Similar to *Thelotrema petractoides* , but the spore wall is thicker (Purvis et al. 1995).
Usnea subfloridana	JM8222	Usnic and alectorialic acid detected by TLC, however the medulla at the base had a distinct UV+ bluish reaction caused by squamatic acid. Alectorialic acid occured locally in soralia (KC+ reddish reaction).
Varicellaria hemisphaerica	ZP19328	lecanoric & gyrophoric acids by TLC
Xylographa trunciseda	JM8256	confriesiic acid

Supplementary table 3. Identifications of specimens by NCBI's Blast. New NCBI's accession numbers are attached.

voucher	identification based on Blast	nrITS	mtSSU
JV13925	*Arthonia apatetica*	pendant	pendant
ZP19352	*Bacidia* aff. *bagliettoana*	pendant	pendant
ZP19170	*Biatora amylacea* ined.	pendant	pendant
ZP19363	*Biatora amylacea* ined.	pendant	pendant
ZP19221	*Biatora bacidioides*	pendant	pendant
ZP19685	*Biatora bacidioides*	pendant	pendant
JM8178	*Biatora bacidioides*		pendant
ZP19334	*Biatora efflorescens*	pendant	pendant
ZP19307	*Biatora longispora*	pendant	pendant
JM8269	*Biatora pontica*	pendant	pendant
ZP19260	*Caloplaca* aff. *obscurella*	pendant	
JM8255	*Caloplaca monacensis*	pendant	pendant
JV14274	*Caloplaca sorocarpa*	pendant	
ZP19680	*Caloplaca substerilis*		pendant
JV14380	*Caloplaca turkuensis*	pendant	
JM8238	*Japewia dasaea* ined.	pendant	pendant
ZP19485	*Lecanora* aff. *campestris*		pendant
ZP20047	*Lecanora* cf. *anopta*		pendant
ZP19343	*Lecidella subviridis* s.l.		pendant
ZP19309	*Lecidella subviridis* s.l.		pendant
JV13940	*Lecidella subviridis* s.l.		pendant
FrB29222	*Loxospora* aff. *confusa*	pendant	pendant
JV14226	*Melaspilea proximella*	pendant	pendant
JV14359	*Melaspilea proximella*	pendant	pendant
ZP19683 (apothecia)	*Micarea substipitata* ined.		pendant
ZP19376 (pycnidia)	*Micarea substipitata* ined.	pendant	pendant
JM8199	*Mycobilimbia epixanthoides*	pendant	pendant
ZP19335	*Thelotrema* sp.		pendant

Supplementary table 4. Basic data for Central European old-growth forest lichen inventories employed in Figs 5, 6. Localities are sorted according to forest types. Five groups of forest types are separated by horizontal lines; from above: lowland forests, maple-lime scree forests, beech-dominated forests and coniferous forests. Tree species abbreviations correspond with the Table 1. See the list of references below the table.

Number on Fig. 5	Locality (country abbreviation)	forest type	Nr of lichen species	area (ha)	mean altitude	latitude	longitude	dominant tree species	references
1	Hluboká (CZ)	oak-hornbeam	83	10	400	49.0759569	14.4519764	CB, FS, QU, TIL	Vondrák et al. (unpublished)
2	Horný les (SK)	floodplain	103	85	140	48.3534039	16.8638483	AC, CB, FE, QU	Vondrák et al. (unpublished)
3	Libický luh (CZ)	floodplain	71	446	200	50.1106431	15.1670331	AC, CB, FE, QU	Malíček et al. (unpublished)
4	Oslava a Chvojnice (CZ)	oak-hornbeam	130	261	350	49.1391869	16.2446314	AC, CB,QU	Šoun et al. (unpublished)
5	Otok, Mukachevo (UA)	floodplain	159	350	190	48.219974	22.791930	AC, CB, FE, QU	Vondrák et al. (unpublished)
6	Soutok Moravy a Dyje (CZ)	floodplain	217	3000	150	48.660421	16.944199	AC, CB, FE, QU	Vondrák et al. 2016
7	Cigánka (SK)	mixed on scree	149	40	690	48.7561500	20.0570072	APS, FE, FS, QU, TIL	Guttová & Palice 2005
8	Čertův mlýn (CZ)	mixed on scree	76	50	750	49.4893369	18.3013794	APS, FS	Vondrák & Malíček (unpublished)
9	Dlouhý vrch (CZ)	mixed on scree	87	21	600	49.5734947	12.6466086	APS, FS, TIL	Peksa et al. (unpublished)
10	Hrdzavá dolina (SK)	mixed on scree	104	357	860	48.7489067	20.0097661	APS, FE, FS, QU, TIL	Guttová & Palice 1999
11	Javorníková dolina (SK)	mixed on scree	95	170	790	48.7360469	20.0062469	APL, APS, FS, TIL	Guttová & Palice 2002
12	Nad Hutí (CZ)	mixed on scree	112	14	680	49.5384839	12.6547111	APS, FS, TIL	Peksa et al. (unpublished)
13	Pleš (CZ)	mixed on scree	132	28	790	49.5501125	12.6387808	APL, APS, FS, TIL	Peksa et al. (unpublished)
14	Starý Herštejn (CZ)	mixed on scree	72	37	800	49.4699306	12.7144886	APL, APS, FE, FS, PA, TIL	Peksa et al. (unpublished)
15	Ve Studeném (CZ)	mixed on scree	64	32	375	49.4961458	18.3119836	FS, PA, TIL	Vondrák & Malíček (unpublished)
16	Velká Javořina (CZ)	mixed on scree	78	160	1070	48.8612431	17.6769053	APS, FE, FS, QU, TIL	Malíček & Vondrák (unpublished)
17	Boubínský prales (CZ)	beech-spruce-fir	139	47	1040	48.9751644	13.8138372	AA, FS, PA	Budějcká (unpublished)
18	Čerchov (CZ)	beech	106	170	900	49.3753494	12.8030950	APS, FS	Peksa (unpublished)
19	Hojná Voda (CZ)	beech-fir	67	9	840	48.7060061	14.7533444	AA, FS, PA	Malíček et al. 2012
20	Hraničník (CZ)	beech-spruce-fir	188	c.100	1150	48.763408	13.893805	AA, FS, PA	Palice et al. (unpublished)
21	Chejlava (CZ)	beech	90	26	580	49.5366553	13.5567981	FS	Peksa (unpublished)
22	Jilmová skála (CZ)	beech-spruce-fir	164	8	1000	48.9537397	13.7976125	AA, FS, PA	Malíček & Palice 2015
23	Jizerskohorské bučiny (CZ)	beech	39	952	740	50.8583389	15.1484250	FS	Malíček (unpublished)
24	Karlovské bučiny (CZ)	beech	30	42	440	50.7753486	14.9682492	FS	Malíček et al. (unpublished)
25	Luxensteinwand (A)	beech-fir	84	30	850	48.6418469	14.7288997	APS, FS, PA	Malíček et al. 2013
26	Malý Zvon (CZ)	beech	86	8	770	49.5351419	12.6444800	FS	Peksa et al. (unpublished)
27	Neuwald (A)	beech-fir	127	1	950	47.7713292	15.5222253	AA, FS, PA	Hafellner & Komposch 2013
28	Rajhenavski Rog (SLO)	beech-fir	86	50	885	45.6607664	15.0091175	AA, FS	Bilovitz et al. 2011
29	Razula (CZ)	beech-fir	89	23	785	49.3595764	18.3820217	AA, FS, PA	Malíček et al. (unpublished)
30	Rothwald (A)	beech-spruce-fir	237	500	1180	47.7829317	15.0923206	AA, FS, PA	Türk & Breuss 1994, Bilovitz 2007, Türk 2015, Malíček (unpublished)
31	Salajka (CZ)	beech-fir	56	18	765	49.4015075	18.4182764	AA, FS, PA	Malíček et al. 2013
32	Shyrokyi Luh (UA)	beech	167	5400	880	48.3365519	23.7268014	FS	Dymytrova et al. 2013
33	Stuzhitsa (UA)	beech-fir	218	2492	850	49.083840	22.574118	AA, APS, FS, PA	Kondratyuk et al. 1998, Kondratyuk & Coppins 2000, Motiejūnaitė et al. 1999
34	Stužica (SK)	beech-fir	228	630	970	49.088382	22.544935	AA, APS, FS	Vondrák et al. 2015
35	Uholka (UA)	beech	156	5000	880	48.2777842	23.6676608	FS	Dymytrova et al. 2013

36	Žofínský prales (CZ)	beech-spruce-fir	222	98	780	48.664866	14.706696	AA, FS, PA	Malíček & Palice 2013
37	Boubín - top (CZ)	spruce	58	100	1280	48.9917478	13.8210469	PA	Vondrák (unpublished)
38	Červené blato (CZ)	peat-bog pine	62	330	470	48.8648722	14.8071094	PA, PIN	Malíček & Vondrák (unpublished)
39	Fábova hola (SK)	spruce	114	260	1380	48.7715275	19.8862558	PA	Guttová et al. 2012
40	Kněhyně (CZ)	spruce	63	100	1130	49.4962056	18.3118853	PA	Malíček & Vondrák (unpublished)
41	Rašeliniště Jizery (CZ)	peat-bog spruce, pine	51	153	850	50.8566053	15.3244808	PA, PIN	Malíček & Vondrák 2014
42	Reschbach Klause (DE)	spruce	57	50	1140	48.9652239	13.5628747	PA	Vondrák & Pouska (unpublished)
43	Trojmezná (CZ)	spruce	148	588	1275	48.772881	13.833413	PA	Palice et al. (unpublished)

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2.5. Floristics

Floristic records belong to very important sources of basic data. They contribute to a general knowledge about species distribution, ecology, abundance and serve as a source of material for taxonomical studies. Floristic papers have been publishing for more than 200 years. In the current science, they are regarded as a secondary research and published usually in non-impact journals. In lichenology, floristic studies are still quite appreciated because our knowledge about species distribution in generally very low in comparison to vascular plants and bryophytes.

I included two more or less floristic papers into this thesis because they bring some valuable records from old-growth and natural forests in the Czech Republic and Slovakia. Publications based on more or less exhaustive field research are placed into the second chapter about diversity. The first paper contains one new species for Central Europe, thirteen new records for the Czech Republic, eight new species for Slovakia and several rare lichens rediscovered after a long time period. The second one is about a very poorly known species *Gyalidea minuta* which was found in Central Europe. Its ecology and variability among populations is discussed in detail.

Many other author's floristic records from old-growth forests were published in several papers that are not included here: e.g. Guttová et al. (2012), Malíček (2013, 2014b, 2016), Malíček et al. 2010, 2011, 2013, 2015), Malíček & Palice (2015) and Malíček & Vondrák (2014).

Some other papers included in this thesis present additional new country records. In total, another 27 lichenized, epiphytic and epixylic fungi were published as new for the Czech Republic, c. 30 for Ukraine, 16 for Slovakia and single records are new for Austria, Macedonia, Serbia and Russia. Some of these findings are of phytogeographic interest (e.g. *Biatora ligni-mollis*, *Cliostomum leprosum*, *Lecanora barkmaniana*, *L. cinereofusca*).

New lichen records and rediscoveries from the Czech Republic and Slovakia

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Abstract: MALÍČEK, J., PALICE, Z. & VONDRÁK, J. 2013. New lichen records and rediscoveries from the Czech Republic and Slovakia. – Herzogia **20**: 257–284.
Despite over two centuries of fairly intensive study, the lichen flora of Central European countries is still incompletely known. Based on revision of herbarium material and new field work, we report thirty-four species from the Czech Republic for the first time, and twenty-two from Slovakia. *Caloplaca brachyspora*, *Micarea confusa* and *Sclerophora amabilis* are new to Central Europe. *Caloplaca alaskensis* is reported outside the Arctic for the first time. Other noteworthy records worth of mention are e.g. *Arthonia incarnata*, *Bacidina etayana*, *Biatora pontica*, *Bryoria furcellata*, *Candelariella lutella*, *C. viae-lactae*, *Metamelanea caesiella*, *Peccania cernohorskyi*, *Rhizoplaca melanophthalma*, *Thelocarpon imperceptum*, *Verrucaria ulmi* and *Xanthoria papillifera*. Eight species (mainly from lowland forests) have not been found over 70 or more years from the territory of the Czech Republic or Slovakia. Four species were reported in the past but were omitted from the current national checklists. Other species new to the explored countries are *Bacidia pycnidiata*, *Bacidina brandii*, *B. saxenii*, *B. sulphurella*, *Buellia arborea*, *Caloplaca arcis*, *C. dichroa*, *C. tominii*, *C. xerica*, *Candelaria pacifica*, *Candelariella plumbea*, *Catillaria fungoides*, *Cladonia novochlorophaea*, *Collolechia caesia*, *Dendrographa decolorans*, *Fellhanera viridisorediata*, *Lecania sordida*, *Lecidea sphaerella*, *L. strasseri*, *Lecidella albida*, *Leptogium intermedium*, *Micarea globulosella*, *M. nowakii*, *Normandina acroglypta*, *Peltigera extenuata*, *Reichlingia leopoldii*, *Rhizocarpon timdalii*, *Rhizoplaca subdiscrepans*, *Rinodina capensis*, *Schismatomma umbrinum*, *Sclerococcum griseisporodochium*, *Thelocarpon citrum*, *Verrucaria beltraminiana*, *V. breussii*, *V. fuscovelutina*, *V. phloeophila*, and *Xylographa pallens*. ITS rDNA was used to confirm the identity of *Caloplaca alaskensis* and *C. arcis*. The lichen diversity of Central European countries and their phytogeographical connections are briefly discussed.

Key words: biodiversity, checklist, lichen-forming fungi, microlichens.

Introduction

Lichen records form an important source of knowledge about regional diversity, the distribution and ecology of lichens, and changes of lichen biota in time. The collections themselves are also a source of material for further studies. In the Czech Republic, field research has been quite intensive in the last two decades, a result of regular meetings and excursions (cf. KUBEŠOVÁ et al. 2012), as well as surveys of protected areas, which are currently supported by the Nature Conservation Agency and the Ministry of the

Environment (e.g. HALDA et al. 2011b, MALÍČEK & VONDRÁK 2012a, b). In Slovakia, exploration has been less intensive, but some areas have been thoroughly surveyed, especially the Muránska planina National Park (e.g. GUTTOVÁ & PALICE 1999, 2002, 2005, GUTTOVÁ et al. 2012). In recent years many new records from both countries have been published, e.g. in PALICE (1999), VAN DEN BOOM & PALICE (2006), VONDRÁK et al. (2007a, b), and MALÍČEK & PALICE (2013) for the Czech Republic; and in GUTTOVÁ & PALICE (1999, 2002, 2005) and PALICE et al. (2006) for Slovakia. In the present paper we provide additional records of the authors for the Czech and Slovak checklists. We also note some species that have been regarded as regionally extinct (cf. LIŠKA et al. 2008; PIŠÚT et al. 2001; GUTTOVÁ et al. 2013) but which have been rediscovered after a long period, usually about one hundred years.

A few of the lichens newly listed here are rather conspicuous, so their discovery is surprising (e.g. *Bryoria furcellata*, *Rhizoplaca melanophthalma*, *Xanthoria papillifera*). Unsurprisingly, however, most are easily overlooked small microlichens (e.g. inconspicuous pioneers of barren soil or mostly sterile lichen crusts). Ecologically, they are very varied: some are ephemeral crusts known mainly from human-disturbed habitats (e.g. *Thelocarpon imperceptum*), but others are indicators of natural habitats, such as old-growth forest epiphytes (*Bactrospora dryina* in floodplain and oak woodlands, *Arthonia incarnata* in montane spruce forests, *Sclerophora amabilis* in old-growth beech forests etc.). The list includes species with very different European distributions, including: Atlantic (e.g. *Dendrographa decolorans*, *Fellhanera viridisorediata*), Mediterranean (*Caloplaca xerica*, *Xanthoria papillifera*), continental (*Caloplaca tominii*), boreal (*Bryoria furcellata*, *Micarea globulosella*), and arctic-alpine (*Caloplaca alaskensis*). Some species are quite rare in Central Europe, as they require specific microhabitats (e.g. *Bactrospora dryina*, *Biatora pontica*, *Peccania cernohorskyi*). Our list also includes some recently recognized taxa: *Bacidina sulphurella*, *Candelaria pacifica*, *Peltigera extenuata*, *Rhizoplaca subdiscrepans*, *Thelocarpon citrum* and *Xylographa pallens*; some of these were recorded from the Czech Republic or Slovakia in the past but were subsumed under other taxa by later authors and/or were recognized by earlier authors only on a level of variety or form. Four species (*Caloplaca polycarpa*, *Lecanora glabrata*, *Melaspilea gibberulosa*, *Scutula dedicata*) were reported in the past but were omitted (presumably inadvertently) from the current national checklists.

Material and methods

Specimens were identified using routine methods, including TLC analyses (ORANGE et al. 2010) and UV light. Selected critical specimens were checked by the acknowledged specialists. Collected specimens are deposited in herbaria CBFS, PRA, and the private herbarium of J. Malíček (JM). We found some older herbarium specimens (of *Caloplaca brachyspora*, *Candelaria pacifica*, *Lecanora glabrata*, *Lemmopsis pelodes*, *Peltigera extenuata*, and *Rhizoplaca subdiscrepans*) in herbaria BRA, PRC and PRM. The list of taxa is in alphabetical order. In cases of some species currently ranked into artificial 'dustbin' genera, their generic names are indicated in quotation marks. Localities for each taxon are also in alphabetical order; Czech localities are first ordered by region (e.g. Central Bohemia, South Moravia, etc.). The locality descriptions refer to the herbarium labels, with minor formal corrections. The asterisk (*) marks new country records. GPS coordinates use the WGS84 datum.

New records

Arthonia byssacea (Weigel) Almq.

Czech Republic. S Bohemia, Hluboká nad Vltavou, Zámostí, on left bank of Vltava river, about 3 km NNE of village, alt. 400 m, 49°05'29"N, 14°28'1"E, on dry bark of old *Quercus robur*, 2010, J. Vondrák 7759, 7940 (CBFS); Písek, Vráž, in valley of river Lomnice, at junction of Lomnice with river Skalice, alt. c. 360 m, 49°24'50"N, 14°08'36"E, on dry bark of *Quercus robur*, 2010, J. Vondrák 8146 (CBFS); S Moravia, distr. Břeclav, Lanžhot, Ranšpurk National Nature Reserve, c. 48°40'41"N, 16°56'49"E, floodplain old-growth forest, alt. 150 m, on bark of *Fraxinus angustifolia* and *Quercus robur*, 2013, J. Malíček 6220, 6244 & J. Vondrák 11342 (CBFS, JM).

Previously recorded in the Czech Republic only in the first half of the 19th century; published several times by P. M. Opiz (cf. VĚZDA & LIŠKA 1999). Recent Czech collections are mostly sterile, with conspicuous blackish pycnidia with white tops, but specimen JV 7759 is fertile.

Arthonia incarnata Th.Fr. ex Almq.

***Czech Republic.** S Bohemia, Šumava Mts, Volary, Nová Pec, NE slope of Mt. Hraničník, alt. ca 1150 m, 48°45'8"N, 13°54'50"E, on bark of *Picea abies*, 2007, J. Vondrák 7615 (CBFS); Vimperk, Včelná pod Boubínem, spruce forest at top of hill Boubín, alt. ca 1200–1350 m, on bark of *Picea abies*, 2011, V. Pouska & J. Vondrák 8970 (CBFS).

Our specimens resemble *A. helvola* macroscopically and in their 2-septate ascospores, but can be distinguished by the K-negative reaction of the hymenium (REDINGER 1937). The ecology of this species is not well known, but it may prefer mountain spruce forests in Central Europe.

Arthonia pruinata (Pers.) A.L.Sm.

Czech Republic. S Moravia, Břeclav, Lanžhot, protected area Ranšpurk, c. 5 km S of Lanžhot, at confluence of rivers Morava and Dyje, alt. 150 m, 48°40'41"N, 16°56'47"E, on bark of *Quercus robur*, 2013, J. Malíček & J. Vondrák 11346 (CBFS).

In the Czech Republic, the species was recorded on bark of oaks in lowland areas of N and E Bohemia: Teplice and Proboštov (ANDERS 1922, as *A. impolita*) and Sendražice near Hradec Králové (MANN 1825, OPIZ 1825, as *A. pruinosa*). In Central Europe, *Arthonia pruinata* is currently an extremely rare lichen (cf. HAFELLNER & TÜRK 2001, WIRTH et al. 2013).

Arthothelium spectabile A.Massal.

Czech Republic. S Moravia, distr. Břeclav, Lanžhot, Ranšpurk National Nature Reserve, c. 48°40'41"N, 16°56'49"E, floodplain old-growth forest, alt. 150 m, on bark of *Carpinus betulus*, 2013, J. Malíček 6219 & J. Vondrák 11343 (CBFS, JM).

Arthothelium spectabile was reported several times at the beginning of the 20th century mainly from Moravia (cf. VĚZDA & LIŠKA 1999). It occurs in old-growth lowland forest, especially on hornbeam (WIRTH et al. 2013) and it was probably a rare species even in the past.

Bacidia pycnidiata Czarnota & Coppins

***Slovakia.** Poloniny Mts, Ulič, Nová Sedlica, protected area Stužica, alt. 600–1200 m, 49°04'24''N, 22°32'35'', on mosses on bark of *Acer pseudoplatanus*, 2013, J. Malíček & J. Vondrák 11326 (CBFS).

B. pycnidiata sometimes forms anamorphic populations without apothecia, but our sample contains numerous pycnidia as well as apothecia. CZARNOTA & COPPINS (2006) reported it from mosses over soil and from mosses on trees in human managed habitats. Our record is from natural old-growth woodland.

Bacidina brandii (Coppins & van den Boom) M.Hauck & V.Wirth

***Czech Republic.** Silesia, Karviná, Stonava: dump with young birch forest W of village, 49°48'51"N, 18°31'01"E, alt. 260 m, on bryophytes growing on stump, 2010, J. Malíček 3174 et al. (JM).

The species seems to be sparsely distributed in Central Europe. It has been reported from Austria (BERGER & PRIEMETZHOFER 2010), Poland (KUBIAK & SPARRIUS 2004) and more localities are known from western Germany (WIRTH et al. 2013).

Bacidina etayana (van den Boom & Vězda) M.Hauck & V.Wirth

***Czech Republic.** S Bohemia, Šumava Mts, Volary: Mt. Trojmezná, 0.7 km NE of the top, dead old-growth spruce forest on N-facing slope, 48°46'34"N 13°50'03"E, on wood of dead standing trunk, alt. 1250 m, 2012, Z. Palice 15765, V. Pouska & J. Vondrák 10166 (PRA, CBFS).

The specimen was growing on hard wood in a pioneer nitrophytic lichen community (together with juvenile *Xanthoria* and *Lecania* spp.) on a sun-exposed trunk among otherwise acidophytic lichen assemblages on dead trees in an old-growth spruce forest. The specimen matches well the detailed description in EKMAN et al. (2012).

Bacidina saxenii (Erichsen) M.Hauck & V.Wirth

***Czech Republic.** S Bohemia, Šumava Mts, Volary, near the railway station along railway in direction Lenora and Černý Kříž, alt. 750 m, 1995, Z. Palice s.n. (PRA); Nové Údolí, valley of the Světlá creek, c. 2 km NNE of Mt. Kamenná, on *Sambucus racemosa*, alt. 850 m, 1995, Z. Palice s.n. (PRA); Volary: at railway (in direction Vimperk and Nové Údolí), c. 100–200 m from the railway station, on small stones, alt. 755 m, 1998, Š. Bayerová & Z. Palice 824 (PRA); Stožec: Studená Vltava valley, near the water purification plant, 48°51'45"N, 13°49'30"E, on small stones, alt. 775 m, 1998, Z. Palice 115 (PRA); Volary, Černý Kříž: along a forestry road "Hučická", on shaded, vertical part of a solitary granite boulder, alt. 740 m, 2002, Z. Palice 5904 (PRA); Středočeská pahorkatina upland, Týn nad Vltavou, Temelín, in village, alt. 480 m, 49°11'45"N, 14°20'37"E, on bryophytes in old shady railway, 2011, J. Vondrák 8894 (CBFS); E Bohemia, Orlické hory Mts, Dobruška, Sedloňov village, Polom settlement, on loose siliceous stone by military bunker, alt. 660–670 m, 1996, J. Halda & Z. Palice s.n. (PRA).
***Slovakia**. Bratislava – Lamač, near railway and gas stations, on plastic biscuit wrapper near the rails, 1997, Z. Palice s.n., det. P. Czarnota (PRA).

The genus *Bacidina* is in need of revision. Using current taxonomy, which is based mainly on thallus morphology (form and size of vegetative propagules) and internal pigmentation of apothecia, some specimens are not identifiable. It is unclear whether the difficulty arises from the existence of undescribed taxa, or from greater plasticity in the existing taxa than has been recognized. *B. saxenii* is said to be easily recognizable by the large vesicle-like cells (sometimes exceeding 20 μm in diameter) of the outer exciple, a brownish, K+ purplish pigment concentrated in a part of the exciple and epihymenium (sometimes accompanied by an olive pigment), and a colourless hypothecium (JACOBSEN

& COPPINS 1989, CZARNOTA & COPPINS 2007, COPPINS 2009, EKMAN et al. 2012). However, Bohemian material of non-pigmented *Bacidina chloroticula* is often very close to *B. saxenii* in the characters of the exciple, where at least a few cells exceeding 10 µm are regularly observed. According to COPPINS (2009) globose lumina reach 7 µm in *B. chloroticula*. The relationship between *B. chloroticula*-like specimens and *B. saxenii* should be studied further. We cite here only typically pigmented specimens. The pycnidia in the Slovak specimen are pigmented in their outer parts (K + purple) and the conidia are more or less straight and longer (40–55 µm) than reported by COPPINS (2009).

Bacidina sulphurella (Samp.) M.Hauck & V.Wirth

***Slovakia.** Muránska planina National Park, Pohronská Polhora, confluence of brooks in Čertova dolina ravine, 48°44'14''N, 19°51'27''E, alt. 680 m, on bark of *Fagus sylvatica*, 2012, J. Malíček 5285, A. Guttová, J. Halda & Z. Palice (JM); Hrdzavá valley W of town, along yellow marked tourist path in central part of protected area, 48°44'57''N, 20°00'19''E, alt. 590 m, on bark of young *Ulmus glabra*, 2012, J. Malíček 5244 (JM, deposited under *Bacidia laurocerasi*).

A widespread lichen, which has often not been distinguished from the similar and predominantly saxicolous *B. arnoldiana* (BRAND et al. 2009), and which was not included in the new Slovak checklist (GUTTOVÁ et al. 2013).

Bactrospora dryina (Ach.) A.Massal.

Czech Republic. S Bohemia, České Budějovice, Hluboká nad Vltavou, in valley of river Vltava, ca 4 km NE of village, at protected area Karbanice, alt. ca 380 m, 49°05'01"N, 14°27'46"E, in fissures in bark of *Quercus robur*, 2011, J. Vondrák 8470 (CBFS); ibid.: 2013, J. Vondrák 11340 (CBFS); S Moravia, distr. Břeclav, Lanžhot, Ranšpurk National Nature Reserve, c. 48°40'41"N, 16°56'49"E, floodplain old-growth forest, alt. 150 m, on bark of old *Quercus robur* and *Tilia cordata*, 2013, J. Malíček 6204, 6235 & J. Vondrák 11341, 11344 (CBFS, JM).

In the Czech Republic *B. dryina* was recorded only in the 19th century (cf. VĚZDA & LIŠKA 1999). It is a characteristic lichen of old-growth lowland forests which used to be more common in Central Europe. It is considered extinct in Slovakia (PIŠÚT et al. 2001) and critically endangered in Poland (CIEŚLIŃSKI et al. 2006), probably owing to loss of suitable habitats. The similar *B. corticola*, which differs in its K/I- exciple and shorter ascospore cells, has only one historical record in Central Europe, from northern Germany (EGEA & TORRENTE 1993). It has mainly a North European distribution and it is unlikely to occur in the study area.

Biatora pontica Printzen & Tønsberg

***Slovakia.** W Carpathians, Muránska planina plateau: the Hrdzavá valley – a deciduous forest on N-facing slope below the peat-bog "V machoch", c. 48°45'N, 19°59'50"E, on bark of *Acer pseudoplatanus*, alt. 600–650 m, 2003, A. Guttová, Z. Palice 6227 & C. Printzen (PRA); ibid.: hornbeam-beech forest in the valley of the brook, 48°44'50"N, 20°01'12"E, on bark of *Fagus*, alt. 497 m, 2012, Z. Palice 15400 (PRA); Muránska planina Mts, Brezno, Tisovec, protected area Čertova dolina, alt. 700–750 m, 48°44'15"N, 19°51'29"E, on bark of *Fagus sylvatica*, 2011, J. Vondrák 9244 (CBFS); ibid.: 48°44'05–15''N, 19°51'30–33''E, alt. 640–705 m, on bark of *Abies alba*, *Acer pseudoplatanus*, and *Fagus sylvatica*, 2012, A. Guttová, J. Halda, J. Malíček 5287 & Z. Palice 15390, 15397, 15447 (JM, PRA); W Slovakia, distr. Malacky, Záhorská ves, Horný les National Nature Reserve, old-growth flood-plain forest 3 km SSE of village, 48°21'10''N, 16°52'20''E, alt. 150 m, on bark of old *Populus alba*, 2014, J. Malíček 6900 et al. (JM).

This sorediate species resembles *B. efflorescens*, with which it often grows. It is distinguished by its blue-grey coloured apothecia, that are rarely produced, and the presence of xanthones (soralia C+ orange). The diagnostic UV+ whitish substance (before charring) called '*pontica*-unknown' (Rf 6 in solvents A, B, C; PRINTZEN & TØNSBERG 2003), detectable by TLC, distinguishes it from sterile samples of sorediate, xanthone-containing *Lecidella* species. In Europe, it is known from the Alps (PRINTZEN & TØNSBERG 2003) and southern Scandinavia (SANTESSON et al. 2004) and it was recently published from Poland (KUKWA et al. 2012).

Bryoria furcellata (Fr.) Brodo & D.Hawksw.

***Czech Republic.** S Bohemia, Šumava Mts, Nová Pec: Mt. Plechý, glacier cirque of the Plešné jezero lake, on vertical rock-face beneath the Stifter monument, alt. 1300 m, 1996, Z. Palice s.n. (PRC).

The specimen is quite small but has the distinctive, characteristic spinules arising from soralia and a Pd+ red spot reaction indicating the presence of fumarprotocetraric acid. In Central Europe (except the Alps) it seems to be a rare species restricted to humid mountain areas.

Buellia arborea Coppins & Tønsberg

***Czech Republic.** W Bohemia, Šumava Mts, Železná Ruda: glacial cirque of the Černé jezero lake, central part, on wood of *Picea*, alt. 1200–1250 m, 1995, Z. Palice 13361 (PRC).
***Slovakia.** W Carpathians, Muránska planina plateau: nature reserve Šarkanica, S-facing steep rocky slope with scattered trees, 48°43'04.5"N, 19°59'03.5"E, on hard, dry wood of *Larix*, alt. 960 m, 2009, Z. Palice 12720 (PRA); Mt. Cigánka, well lit deciduous forest on S-facing slope, 48°45'18.5"N, 20°03'20.5"E, alt. 815 m, 2010, J. Halda & Z. Palice 13469 (PRA).

All specimens are sterile, but have characteristic bluish crater-like soralia, and atranorin and placodiolic acid (TØNSBERG 1992) were detected by TLC.

Caloplaca alaskensis Wetmore
(= *Calogaya alaskensis* (Wetmore) Arup, Frödén & Søchting)

***Slovakia.** W Carpathians, N.P. Velká Fatra, Mt. Ostredok [1592], subalpine lichen-dominated-calcicolous community at sites with late-lying snow on N-facing slope, 48°54'10"N 19°04'45"E, terricolous, alt. 1560–1575 m, 1994, Z. Palice 16175 (PRA); Malá Fatra Mts, Žilina, Terchová, Mt Chleb, slopes SE of peak, alt. c. 1590 m, 49°11'14"N, 19°03'08"E, on limestone in alpine zone, 2011, J. Vondrák 10616 (CBFS); ibid.: S slope below Mt Pekelník, alt. c. 1560 m, 49°11'25"N, 19°01'02"E, on bryophytes in limestone crevices and directly on limestone in alpine zone, 2011, J. Vondrák 10625 (CBFS).

Although closely related to *Caloplaca biatorina* and other species with lobate thalli (ARUP et al. 2013), the thallus of C. *alaskensis* is reduced to scattered convex yellow areoles eroded into laminal or crateriform soralia. It is a rather inconspicuous lichen resembling *Caloplaca citrina* and similar sorediate taxa. *Caloplaca alaskensis* is known to be widely distributed in the Arctic (SØCHTING et al. 2008), but our records are the only ones from outside the Arctic or Subarctic. Sample JV10616 was sequenced for ITS (Genbank accession number: KF890254); it is >99% identical to the GenBank sequence of *Caloplaca* [as *Calogaya*] *alaskensis* from Sweden (KC179341); the only difference between the two sequences (length 518 bp) is in two 1-bp indel positions and one C/T substitution.

Caloplaca arcis (Poelt & Vězda) Arup

(= *Flavoplaca arcis* (Poelt & Vězda) Arup, Frödén & Søchting)

***Czech Republic.** Central Bohemia, Praha, Vyšehrad, on fort walls, alt. ca 240 m, 50°03'43"N, 14°25'25"E, on concrete and bricks, mostly on exposed horizontal faces, 2011, L. Syrovátková, F. Bouda & J. Vondrák 8688 (CBFS, record confirmed by ITS molecular data; Genbank accession nr: KM598764); S Moravia, Břeclav, Lednice, in town, on concrete crown of brick wall at chateau, alt. 160 m, 48°48'3"N, 16°48'15"E, 2014, B. Coppins, A. Acton, N. Sanderson & J. Vondrák (not collected).

In southern Europe, this species grows on base-rich siliceous rocks or limestone (VONDRÁK et al. 2009), but it is largely synanthropic in higher latitudes growing on stone walls or concrete (our data; COPPINS, pers. comm.). Similar behaviour is known in other Teloschistaceae: e.g. *Caloplaca albolutescens*, *C. austrocitrina* and *C. limonia*.

Caloplaca brachyspora Mereschk.

***Slovakia.** Belianske Tatry Mts, Monkova dolina, alt. 1280 m, on limestone [in subalpine zone], 1993, E. Lisická 6787 (BRA CR7689; sub *Caloplaca* sp.); Malá Fatra Mts, Žilina, Terchová, Mt Chlieb, slopes SE of peak, alt. 1590 m, 49°11'14"N, 19°03'08"E, on limestone in alpine zone, 2011, J. Vondrák 10654 (CBFS); ibid.: on S slope below Mt Pekelník, alt. 1560 m, 49°11'25"N, 19°01'02"E, 2011, J. Vondrák 10647 (CBFS); ibid.: Mt. Vel'ký Kriváň, 0.4 km NW of peak, alt. 1570 m, 49°11'25"N, 19°01'40"E, 2011, J. Vondrák 10648, 10649, 10653 (CBFS); Velká Fatra Mts, Drobkovo – Štrochy, [on limestone], 1996, E. Lisická 408 (BRA CR11108; sub *Caloplaca* sp.).

For over a hundred years, *C. brachyspora* was known only from its type locality in the Crimean Yayla Mountains, from the monastery of Kosma and Demian (Mereschkowsky: Lichenes Rossiae Exsiccati 276). Its characters, especially the short and broadly ellipsoid ascospores with thin septa, are described briefly in VONDRÁK et al. (2010). Surprisingly, the species appears to be common in the Western Carpathians; it is one of the most frequent *Caloplaca* in limestone outcrops in the alpine zone of the Malá Fatra Mts. and it was also collected by E. Lisická from two other Slovak mountains. It may have a rather eastern distribution in Europe, as we did not find any similar material from the Alps in GZU.

Caloplaca dichroa Arup

(= *Flavoplaca dichroa* (Arup) Arup, Frödén & Søchting)

***Slovakia.** Malá Fatra Mts, Žilina, Terchová, Mt. Vel'ký Kriváň, c. 0.4 km NW of peak, alt. c. 1570 m, 49°11'25"N, 19°01'40"E, on N-exposed limestone outcrops, 2011, J. Vondrák 10631 (CBFS, sterile specimen).

Sterile crusts of *C. dichroa* are usually distinguishable from a common *Caloplaca flavocitrina* and other sorediate species by their entirely blastidiate character, real soralia are absent. Blastidiate *C. limonia* has distinctly larger vegetative diaspores. See VONDRÁK et al. (2009) for further characters.

Caloplaca polycarpa (A.Massal.) Zahlbr.

(= *Flavoplaca polycarpa* (A.Massal.) Arup, Frödén & Søchting)

Slovakia. Slovenský kras National Park, Turňa nad Bodvou, Zádiel: Zádielská tiesňava, deep canyon in limestone, south part of protected area, 48°37'06''N, 20°50'04''E, alt. 330–350 m, on limestone rock, 2012, J. Malíček 5300, A. Guttová, J. Halda & Z. Palice (JM); Slovenský kras karst, Rožňava, Turňa nad Bodvou, rocky valley Hájska dolina, alt. 300–500 m, on limestone rock, 2006, J. Vondrák 4880 (CBFS); Malé Karpaty

Mts, Bratislava, Devín, SW slopes of Mt Devínská Kobyla, alt. 250 m, 48°11'N, 17°00'E, limestone rock, 2004, J. Vondrák 1877 (CBFS).

This calcicolous lichen has a distribution centered in the Mediterranean basin, with scattered localities in Central Europe (e.g. VONDRÁK & WIRTH 2013). In the Czech Republic, it is not rare in limestone areas (VONDRÁK et al. 2007a). It has commonly been confused with similar species from the *C. holocarpa* and *C. velana* groups. Although the species was not included in the Slovak checklist (GUTTOVÁ et al. 2013), it is not new to the country, as it was previously recorded from the Muránska planina plateau (GUTTOVÁ & PALICE 2005).

Caloplaca tominii Savicz
(= *Xanthocarpia tominii* (Savicz) Frödén, Arup & Søchting)

***Slovakia.** Cerová vrchovina upland, Fiľakovo, Hajnáčka, Šurice, S-slope of hill Soví hrad, 48°13'32–34"N, 19°54'44–45"E, alt. 240–250 m, on lime-rich outcrop of pyroclastics in steppe, 2012, Z. Fačkovcová, A. Guttová, J. Liška, Z. Palice 15923 & J. Vondrák 10211, 10199 (CBFS, PRA).

Caloplaca tominii is an epigaeic or epilithic sorediate lichen mainly distributed in arid continental regions in Eurasia (VONDRÁK et al. 2011). In the Slovak locality, *C. tominii* is a common lichen together with *Caloplaca molariformis* sharing a similar distribution pattern (VONDRÁK et al. 2013a).

Caloplaca xerica Poelt & Vězda

***Slovakia.** Cerová vrchovina upland, Fiľakovo, Hajnáčka, volcanic hill in village, alt. 250–300 m, 48°13'04–06"N, 19°57'18–19"E, on sun-exposed, base-rich volcanic outcrop, 2012, Z. Fačkovcová, A. Guttová, J. Liška, Z. Palice 15860, 15954, 15973 & J. Vondrák 10185 (CBFS, PRA); ibid., Šurice, S-slope of hill Soví hrad, alt. c. 250 m, 48°13'34"N, 19°54'45"E, on lime-rich outcrop of pyroclastics in steppe, 2012, J. Vondrák 10214 (CBFS); Kováčovské kopce hills, Štúrovo, Kamenica nad Hronom, rocks in S-slope of hill Burdov, alt. 150–200 m, on sun-exposed basal part of andesite rock, 2006, J. Vondrák 4814 (CBFS); Krupinská pahorkatina foothills of Javorie Mts, Krupina, Cerovo, ruin of castle Čabraď in Litava river walley, andesitic conglomerates, 2003, J. Vondrák 1263 (CBFS); Malé Karpaty Mts, Bratislava, Devín, SW slopes of Mt. "Devínská kobyla", alt. 250 m, 48°11'N, 17°00'E, limestone rock, 2004, J. Vondrák 1792 (CBFS).

The mainly Mediterranean *C. xerica* probably reaches its northern distribution limits in Germany (WIRTH et al. 2013), the Czech Republic (VONDRÁK et al. 2007a) and Slovakia (our data).

Candelaria pacifica M.Westb. & Arup

***Czech Republic.** Central Bohemia: Na kaštanech u nádraží v Černošicích, 1937, R. Traxler (PRC); Sedlčany region, Nalžovice, Nalžovické Podhájí: trees along road below settlement, alt. 350 m, on bark of *Fraxinus excelsior*, 2003, J. Malíček 156 (JM); Sedlčany region, Skrýšov valley of "Jedelský potok" brook, 900 m ENE of village, 49°38'54"N, 14°18'44"E, alt. 330 m, on twigs of *Larix decidua*, 2010, J. Malíček 2454 (JM).
W Bohemia: Český les Protected Landscape Area, Pivoň, two protected old lime trees near the church, 49°29'13.0''N, 12°44'18.8''E, alt. 590 m, 2013, on bark of old *Tilia cordata*, J. Malíček 5923, Z. Palice 16676, et al. (JM, PRA); Český les Mts, Hostouň, Mutěnín: protected old lime tree along road at W border of village, 49°32'39''N, 12°44'25''E, alt. 500 m, on bark of old *Tilia cordata*, 2013, J. Malíček 5936, A. Hrdinová & L. Syrovátková (JM).
N Bohemia: An alten Roβkastanien in Neugarten b. B.-Leipa, ca. 270 m s. m., 1931, J. Anders (PRC, Lich. exsic. Bohem. boreal. n. 211); Nordböhmen: Niederliebich [Dolní Libchava], Pflaumenbaum, 1910, E. Proschaiter? (PRC).

E Bohemia: Na švestkách u Hor. Jelení, 1911, A. Volc (PRC).
S Bohemia: distr. Tábor, in cortice Populi sp. Prope p. Řepeč /cota 497/, 1978, J. Liška (PRC); distr. Tábor: *Acer platanoides* secundum viam publicam in pago Turovec, 420 m s.m., 1975, J. Liška (PRC); distr. Tábor, in cortice Fraxini excelsioris in pago Drhovice prope p. Dražice, 480 m s.m., 1978, J. Liška (PRC); Dobronice, akát u kostelíku, alt. 400 m, 1997, Z. Palice s.n. (PRA); Soběslav, Krátošice, intravillane, 49°19'31.7"N, 14°47'12.6"E, on bark of *Fraxinus* in front of chapel, alt. 522 m, 2013, Z. Palice 16705 (PRA); Šumava Mts, Horní Planá, Pernek village, on bark of solitary *Tilia* beside a road leading to railway-stop, alt. 760 m, 2001, Z. Palice 5250 (PRA).
W Moravia: distr. Žďár n. Sázavou, Měřín, NW of village, on road to Černá, on bark of *Acer platanoides*, 2005, J. Malíček 249 & A. Müller (JM); distr. Žďár n. Sázavou, Černá, avenue with *Acer platanoides* and *A. pseudoplatanus*, in W part of village, alt. 530 m, on bark of *Acer platanoides*, 2005, J. Malíček 269 & A. Müller (JM); V Cikhaji, 1905, M. Servít (PRC).
S Moravia: Bílé Karpaty Protected Landscape Area, Velká nad Veličkou, Zahrady pod Hájem National Nature Reserve, 48°53'N, 17°32'E, alt. 350–480 m, on bark of *Prunus domestica*, 2011, J. Malíček 3804 (JM); Znaim, Zuckerhandelstraβe, auf Linde, 1919, A. Oborny (PRC); Mazků les u Zvole na Moravě, 1906, M. Servít (PRC).
***Slovakia.** Tribečské vrchy: ad corticem Robiniae pseudoacaciae in decl. merid. montis Žibrica, alt. c. 300 m.s.m., 1963, L. Opold (PRC, Lichenes Slovakiae exsiccati n. 15).

Candelaria pacifica was distinguished from *C. concolor* quite recently (WESTBERG & ARUP 2011). The thallus of *C. pacifica* is formed of egg yolk-yellow squamules to lobes, which are usually wider than they are long. The lower surface of the lobes is grey (the photobiont cells shine through), with an arachnoid appearance owing to the absence of a lower cortex, never white as in *C. concolor*. Rhizines are present, but are much shorter than in *C. concolor*. Apothecia were not observed in Czech material. *Candelaria pacifica* prefers bark of various deciduous trees (often fruit trees and lime trees) in open urbanized landscapes. *Candelaria concolor* seems to be rarer in the Czech Republic and we expect the same in Slovakia.

***Candelariella lutella* (Vain.) Räsänen**

***Slovakia.** Muránska planina National Park, Muráň, walnut avenue at N border of village, 48°44'37''N, 20°02'54''E, alt. 420 m, on twigs of *Juglans regia*, 2012, J. Malíček 5261, A. Guttová, J. Halda & Z. Palice, conf. M. Westberg (JM).

Candelariella lutella is a boreal lichen occurring mostly on small twigs of conifers and *Quercus*. In Europe, it is known from Macedonia (MAYRHOFER et al. 2012), Montenegro (BILOVITZ et al. 2008), Scandinavia and the Alps (WESTBERG 2007). The low altitude and substrate (slender twigs of a walnut tree) at the Muráň site are slightly atypical. We suspect that our material does not belong to *C. lutella* s. str., but to a similar, undescribed Mediterranean taxon which lacks the yellow granular thallus characteristic of the boreal *C. lutella*. We have also collected this Mediterranean taxon in Bulgaria (VONDRÁK 2006, as *C. lutella*) and in Greece (unpublished, deposited in CBFS, JV 8898).

***Candelariella plumbea* Poelt & Vězda (Fig. 1)**

***Czech Republic.** Central Bohemia, Český kras karst, Třebotov, rock at SW slope of Kulivá hora hill, c. 1 km SW of village, alt. c. 330 m, 49°57'51"N, 14°17'10"E, on sun-exposed limestone outcrop, 2012, I. Frolov & J. Vondrák 9639 (CBFS); S Bohemia, Českobudějovická pánev basin, České Budějovice, Mydlovary, settling pit "MAPE", alt. 400 m, 49°05'58"N, 14°20'07"E, on horizontal surface of concrete, 2009, J. Vondrák 7356 (CBFS); S Moravia, Moravský Krumlov, rocky steppe on a slope above Rokytná river, 49°03'00''N, 16°19'10''E, on calcareous conglomerate, 2004, J. Vondrák 1791 (CBFS);

A grey thallus (sometimes blastidiate, see WIRTH et al. 2013) distinguishes *C. plumbea* from the very similar *C. rosulans*, described from North America (= European *C. oleifera*;

Westberg & Sohrabi 2012). In addition to records of *C. plumbea* with a grey thallus (cited above), we observed lichens shifting from grey to yellow thallus and lichens with distinctly yellow thallus. The yellow thallus morphotypes of *C. rosulans* from Central Europe are possibly conspecific with *C. plumbea* with grey thallus.

Candelariella viae-lactae G.Thor & V.Wirth

***Czech Republic.** S Moravia, Mikulov, Klentnice, protected area Soutěska, alt. 400 m, 48°51'48"N, 16°38'40"E, on bark of *Quercus*, 2007, J. Vondrák 4964 (CBFS); ibid.: 2013, J. Vondrák 10677 (CBFS).

Our samples of epiphytic *C. viae-lactae* with a grey blastidiate thallus and zeorine apothecia have conspicuous hairs on the thalline exciple. Although this character appears not to have been desribed to date in the literature, we have also observed it in samples from the Russian Black Sea coast (three specimens in CBFS).

Catillaria fungoides Etayo & van den Boom (Fig. 2)

***Czech Republic.** S Bohemia, distr. Jindřichův Hradec, Novobystřická vrchovina: W slope of crest Homolka, Fabián, "Lesovna v Dubovici", c. 12 km S of Jindřichův Hradec, 49°02'N, 14°58'50"E, on bark of *Malus*, alt. 540 m, 1999, Z. Palice 1865 (PRA); S Moravia, distr. Břeclav, Lanžhot, Ranšpurk National Nature Reserve, c. 48°40'41"N, 16°56'49"E, floodplain old-growth forest, alt. 150 m, on bark of young *Fraxinus angustifolia*, 2013, J. Malíček 6241 & J. Vondrák (JM); Pálava Protected Landscape Area, Klentnice, Tabulová, Růžový vrch a Kočičí kámen National Nature Reserve, upper part of Stolová hora hill (459 m), c. 48°50'22"N, 16°38'10"E, alt. 450 m, on bark of *Fraxinus excelsior*, 2013, J. Malíček 6399 (JM); Mikulov, Klentnice, protected area "Děvín - Kotel - Soutěska" (forest E of Mt Děvín), alt. 500 m, 48°52'9"N, 16°39'9"E, 2013, J. Vondrák 11631 (CBFS); ibid.: along green-marked tourist path 0.4 km SSE of Horní Věstonice, 48°52'03''N, 16°37'56''E, alt. 315 m, *Fraxinus excelsior*, 2014, J. Malíček 6934 (JM).
***Slovakia.** Cerová vrchovina upland, Fiľakovo, Hajnáčka, Gortva, hill Stéblová skala, alt. 420-460 m, 48°14'42"N, 19°58'43"E, on oak bark in forest-steppe on E-slope, 2012, Z. Palice, J. Liška & J. Vondrák 10177 (CBFS); W Carpathians, distr. Revúca: W-slope of Žabica hill (1 km SW of Muráň), an orchard of middle-aged *Juglans* trees in a pasture, 48°44.00'N, 20°02.43'E, on bark of *Juglans*, alt. 456 m, 2007, A. Guttová, Z. Palice 11860 & J. Steinová (PRA); W Carpathians, distr. Revúca, Muráň, valley of Hrdzavý potok brook near margin of village, 48°44'37"N, 20°02'11"E, on bark of dying *Salix*, alt. 409 m, 2013, Z. Palice 16920 (PRA); W Slovakia, distr. Malacky, Záhorská Ves, Horný les National Nature Reserve, flood-plain forest 3 km SSE of village, 48°21'08–10''N, 16°51'41–47''E, alt. 150 m, on bark and branch of young *Fraxinus angustifolia*, 2014, J. Malíček 6894, Z. Palice 17759 et al. (JM).

The species is characteristic of *Xanthorion* communities of eutrophied bark of young solitary trees (van den Boom et al. 2007). Evidently it is an overlooked species so far collected in only a few countries of the Old World (Etayo & van den Boom 2002, van den Boom et al. 2007). *Catillaria fungoides* is often associated with *C. nigroclavata* (e.g. in the last two cited records), which has very similar apothecia. Apothecia of *C. fungoides* are said to differ in their inspersed hymenium and slightly larger spores (Etayo & van den Boom 2002). The first character is clearly visible in our fertile specimens (JM 6241, ZP 16920); the second is not reliable according to van den Boom et al. (2007). Our material was compared to Dutch material collected and sent by P. van den Boom, who co-described this taxon.

Fig. 1. *Candelariella plumbea* is a variable lichen occurring in limestone areas, usually on vertical and overhanging rocks (JM 5636, scale = 1 mm); all picture by J. Malíček.

Fig. 2. *Catillaria fungoides* is on overlooked nitrophytic species preferring bark of young trees. It is very characteristic due to the black soralia (scale = 1 mm).

Cladonia novochlorophaea (Sipman) Brodo & Ahti

***Czech Republic.** W Bohemia, Krušné hory Mts, Boží Dar, meadows 700 m NNW of village, 50°25'06''N, 12°54'57''E, alt. 1000 m, on acidic soil, 2011, J. Malíček 3912 et al. (JM).

Probably rare in the Czech Republic, as it prefers more oceanic parts of Europe (cf. LEUCKERT et al. 1971, KOWALEWSKA et al. 2008).

Collolechia caesia (Fr.) A.Massal.

***Slovakia.** Slovenský kras National Park, Turňa nad Bodvou, Zádiel: Zádielská tiesňava, deep canyon in limestone, south part of protected area, 48°37'09''N, 20°50'11''E, alt. 400 m, on vertical limestone rock, associated with *Placynthium subradiatum*, 2012, J. Malíček 5309, A. Guttová, J. Halda & Z. Palice, det. M. Schultz (JM).

Collolechia caesia has traditionally been misidentified as *Placynthium garovaglioi* and reported under this name. It differs from *Placynthium* in its crustose-leprose thallus, absence of an upper cortex, incrustations of calcium oxalate crystals, asci with a distinct internal amyloid ring-structure and multiseptate acicular-fusiform spores (JØRGENSEN 2005). In the Czech Republic and Slovakia, it is probably a rare lichen restricted to karst areas.

Dendrographa decolorans (Turner & Borrer ex Sm.) Ertz & Tehler

***Czech Republic.** S Bohemia, České Budějovice, Hluboká n. Vltavou, protected woodland area Karvanice in Vltava River valley, c. 4.5 km N of town, alt. c. 370 m, 49°05'49"N, 14°27'52"E, on bark of *Quercus robur*, 2010, J. Vondrák 7930 (CBFS); České Budějovice, Hluboká nad Vltavou, in valley of river Vltava in protected area "Baba", alt. c. 370 m, 49°04'40"N, 14°27'12"E, on bark of *Quercus robur*, 2011, J. Vondrák 8446, 8447 (CBFS); S Moravia, distr. Břeclav, Lanžhot, Ranšpurk National Nature Reserve, c. 48°40'41"N, 16°56'49"E, floodplain old-growth forest, alt. 150 m, on bark of *Carpinus betulus*, *Fraxinus angustifolia* and *Quercus robur*, 2013, J. Malíček 6243, 6250 & J. Vondrák 11347, 11348 (JM, CBFS).

This sorediate lichen has been recorded only as a sterile crust in the Czech Republic. In four collections analyzed by us, we confirmed unknown fatty acids by TLC, as reported by WOLSELEY & HAWKSWORTH (2009). It is a distinctive lichen (see NIMIS & MARTELLOS 2008 for images) growing in dry places on bark of old trees in lowland woodlands.

Eopyrenula leucoplaca (Wallr.) R.C.Harris

Czech Republic. S Moravia, Pálava Protected Landscape Area, Horní Věstonice, Děvín-Kotel-Soutěska National Nature Reserve, in forest along red tourist path in S part of reserve, 1.0–1.5 km N of Klentnice, c. 48°51'30"N, 16°38'41"E, alt. 370 m, on bark of old *Fraxinus excelsior*, 2013, J. Malíček 6371 & J. Vondrák (JM).
Slovakia. Muránska planina Mts, Revúca, Muráň, hill c. 2500 m W of village, alt. c. 800 m, 48°44'14"N, 20°00'30"E, on bark of *Fraxinus excelsior*, 2011, J. Vondrák 9247 (CBFS).

Last recorded in Slovakia at the end of the 19th century (cf. SZATALA 1927) and from the Czech Republic by SUZA (1944).

Fellhanera viridisorediata Aptroot, M.Brand & Spier

***Czech Republic.** S Bohemia, Šumava Mts, Volary: boggy, taiga-like forest with *Pinus* dominating near the Hučina brook, c. 0.6 km ESE from the railway-stop Černý Kříž, 48°51'30"N, 13°52'11"E, on dry twigs of young *Picea*, alt. 740 m, 2010, J. Halda & Z. Palice 13352 (PRA); ibid., young managed spruce forest by a brooklet below the forestry road 'Krejčová', 48°51'24.5"N, 13°51'10.5"E, on twigs of young *Picea*, alt. 750

m, 2014, Z. Palice 17821 (PRA); Novohradské hory Mts, Pohorská ves, Pohoří na Šumavě: Stodůlecký vrch Nature Monument, boggy pine forest, 48°35'09''N, 14°42'20''E, alt. 955 m, on twig of *Picea abies*, 2012, J. Malíček 5709, J. Kocourková, Z. Palice & J. Vondrák (JM); N Bohemia, Vysoká Lípa: National Park "České Švýcarsko", on N-facing rock-face above a narrow E-declining streamless ravine, nature reserve Babylon, ca 2.5 km NW of Jetřichovice, 50°52'11.8"N, 14°22'46.2"E, alt. 330 m, on twig of young *Picea abies*, 2014, Z. Palice 17688 (PRA).

According to WIRTH et al. (2013) this species is not rare in Germany and we expect the same to be true in the Czech Republic. It probably occurs in most suitable places where other (facultatively) foliicolous species also occur (*Fellhanera bouteillei*, *F. subtilis*, *Fellhaneropsis myrtillicola*, *Scoliciosporum curvatum*). The collected material is fertile except the specimen from northern Bohemia where roccellic acid was detected by TLC. Characteristic crater-like soralia are present in younger thalli in all samples, as well as a few dark apothecia in southern Bohemian material.

Lecania sordida Reese Næsborg (Fig. 3)

***Czech Republic.** W Bohemia, Český les Protected Landscape Area, Pivoň, cemetery at N border of village, 49°29'18"N, 12°44'23"E, alt. 595 m, on vertical concrete wall, 2013, J. Malíček et al. 5924, det. P. van den Boom (JM, dupl. in PRC).

This recently described saxicolous lichen has been reported from Central Europe only from Germany and Switzerland (REESE NÆSBORG 2008). It prefers calcareous substrates in urban habitats.

Lecanora glabrata (Ach.) Malme

Slovakia. Montes Slovenské stredohorie, regio protecta Poľana, reservatio naturalis Hrončecký grúň, alt. 900–1000 m s. m., ad corticem arborum (*Fraxinus excelsior*), 1996, Š. Bayerová 1676 (PRA); Muránska planina plateau: collected at many sites, J. Malíček 2364, 2383, 2411, 3074, 4090, 5268 & Z. Palice 1745, 1798, 4202, 5559, 5615, 9035, 11883, 11909 (JM, PRA); Slovenský kras National Park, Turňa nad Bodvou, Zádiel: Zádielská tiesňava Nature Reserve, bottom of deep canyon in limestone, central part of protected area, 48°38'11''N, 20°49'20''E, alt. 470 m, on bark of *Fagus sylvatica*, 2012, J. Malíček 5333 (JM); Bukovské vrchy Mts, Nová Sedlica, along forest road c. 1.5 km ENE of village, 49°03'29''N, 22°32'18''E, alt. 680 m, on bark of *Fagus sylvatica*, 2013, J. Malíček 6487 & J. Vondrák (JM).

An overlooked lichen that is very similar to other members of the *Lecanora subfusca* group (e.g. *L. argentata*). It is widely distributed in Carpathian beech and hornbeam forests, especially in the Muránska planina mountains. *Lecanora glabrata* prefers smooth bark of *Fagus* and *Carpinus*, but also grows on *Fraxinus* and some other genera. It has been reported several times from Slovakia (e.g. HAZSLINSZKY 1884, SERVÍT & ČERNOHORSKÝ 1935, SUZA 1948) but is absent from the new Slovak checklist (GUTTOVÁ et al. 2013). The identity of historical collections was not checked, but based on experience from the revision of Czech material (MALÍČEK 2014), most specimens may be misidentified and should be verified.

'*Lecidea*' *erythrophaea* Flörke ex Sommerf.

Czech Republic. S Bohemia, Šumava Mts, Volary, Černý Kříž: Mt. Jelení vrch (c. 3 km SSW of Černý Kříž), 48°50'00–05"N, 13°51'15–20"E, remnants of beech forest on E slope, on bark of *Acer platanoides* and *Ulmus glabra*, alt. 860–900 m, 2000 & 2011, Z. Palice 3910 & 15288 (PRA); Volary: Mt. Stožec – Medvědice, a mountain scree forest, 48°53'N, 13°50'10"E, on bark of *Acer platanoides*, alt. 900–950 m, 2000, A. Guttová, J. Halda, Z. Palice 4163 & P. Uhlík (PRA); Volary, Nová Pec, NE slope of Mt. Hraničník, alt. c. 1150 m, 48°45'08"N, 13°54'50"E, on bark of *Acer pseudoplatanus*, 2007, J. Vondrák 7596 (CBFS); N Moravia,

Jeseníky Mts., old-growth mixed forest with beech dominating, below Františkova myslivna (nature reserve "Bučina"), bark of *Acer pseudoplatanus*, alt. 1050–1100 m, 2002, J. Halda & Z. Palice 6518 (PRA).
Slovakia. Poloniny Mts, Ulič, Nová Sedlica, protected area Stužica, alt. 600–1200 m, 49°04'24''N, 22°32'35'', on bark of *Acer pseudoplatanus*, 2013, J. Vondrák 11133 & J. Malíček (CBFS).

In the Czech Republic and Slovakia, *L. erythrophaea* was recorded only a few times in the late 19th and early 20th centuries (see VĚZDA & LIŠKA 1999, SZATALA 1942). The species is characterized by reddish-brown *Lecidella*-like apothecia, *Biatora*-type asci, capped paraphyses, narrowly elipsoid ascospores, and insoluble pigment granules in the exciple. For the main characteristics see WIRTH et al. (2013). In Central Europe, it is quite a rare woodland species of subneutral bark. In the Czech Republic and Slovakia, it appears to be an old-growth forest species confined to humid woodlands.

'*Lecidea*' *sphaerella* Hedl.

***Czech Republic.** W Bohemia, Krušné hory Mts, Stříbrná: Rájecké údolí, near a former game-keeper's-house, 50°22.67'N, 12°33.06'E, on bark of *Acer platanoides*, alt. 660–670 m, 2004, J. Liška, Z. Palice 9297 & P. Uhlík (PRA); Šumava Mts, Modrava: deciduous forest at the Czech-German border near Weitfällerská slať peat bog, on bark of *Acer pseudoplatanus*, alt. 1060 m, 1995, Z. Palice 4280 (PRA); Javoří Pila: Mt. Medvěd, NNW slope, spruce plantation with dispersed old maples, 49°00.47'N, 13°25.07'E, on bark and wood of *Acer pseudoplatanus* snag, alt. 1125–1130 m, 2005, F. Bouda, Z. Palice 9676, 9679, 9695, O. Peksa & J. Steinová (PRA); ibid.: NE slope, 49°00.52'N, 13°25.24'E, bark of old *Acer pseudoplatanus*, alt. 1125 m, 2005, F. Bouda, Z. Palice 9741, O. Peksa & J. Steinová (PRA); S Bohemia, Šumava Mts, Volary, Mt. Jelení vrch, E slope, fragment of old-growth beech forest, on weathered bark of *Fagus*, alt. 850–900 m, 1995, Z. Palice 3893 (PRA); Volary: Mt. Stožec, nature reserve "Stožecká skála", scree forest around Stožecká kaple chapel, 48°52'45"N, 13°49'30"E, on *Acer platanoides*, alt. 940 m, 1996, Z. Palice 4099 (PRA); ibid.: on bark of *Fraxinus*, alt. 900 m, 1998, Z. Palice 1571 (PRA); Volary, Stožec: E slope of hill "Na vrchu" [873.8], managed young mixed forest below "Tovární cesta" (forest trail), 1.3 km SW of Černý Kříž (railway station), bark of *Acer platanoides*, alt. 830 m, 2001, Z. Palice 4621, det. C. Printzen (PRA); Želnava: Mt. Bulov, rocky crest with a scree forest ESE of the top, c. 2 km NE of village, 48°49'17"N, 13°59'30"E, on bark at base of *Fraxinus excelsior*, alt. 975 m, 2010, J. Malíček & Z. Palice 13679 (PRA); Nová Pec: Mt. Hraničník, N slope, remnants of mountain mixed forest, 48°45'15–25"N, 13°54'30"E, on bark of *Acer pseudoplatanus* together with *Lecania cyrtella*, alt. 1200–1250 m, 1995, Z. Palice 1346 (PRA); ibid.: NNW slope, 48°45'11"N, 13°54'15"E, on bark and bryophytes over trunk of *Acer pseudoplatanus* and *Fagus* snag, alt. 1170 m, 2000 & 2007, Z. Palice 4083 & 11270 (PRA); Nová Pec, shady forest in valley of Rasovka brook 1.4 km SW of Klápa settlement, on bank of brook, 48°45'25''N, 13°55'11''E, alt. 990 m, on bark of *Acer pseudoplatanus*, 2012, J. Malíček 4718, F. Bouda, O. Peksa, D. Svoboda & L. Syrovátková (JM).

This is a woodland species of slightly nutrient-rich bark but it is not a member of *Xanthorion* communities. It prefers shaded and humid microhabitats but apparently may tolerate small-scale forestry. It seems to be easily overlooked. The colour of the apothecia varies from completely pale to dark brown depending on local habitat conditions and age. The species may be mistaken for *Biatora helvola* or *Lecania cyrtellina*, with which shares a similar ecology and the type of ascospores. *L. sphaerella* is distinguished by distinctly thick-walled (gelatinized) ends of the excipular hyphae and a darkened subhymenium when the apothecia are pigmented. In addition, *B. helvola* is easily distinguishable from *L. sphaerella* by the presence of gyrophoric acid in the apothecia and *Lecania cyrtellina* almost always produces pycnidia with crescent-shaped conidia (WIRTH et al 2013). The species was called *Lecidea (Biatora) sylvana* (sensu Th.Fr., non Körb.) by older authors (HEDLUND 1892, SANTESSON et al. 2004). Körber's taxon was described from the Czech Republic and is a synonym of *Biatora globulosa* (PRINTZEN 1995). Most references to *Biatora sylvana* from the Czech Republic (cf. VĚZDA & LIŠKA 1999, under *Catillaria globulosa*) refer to the original specimen by Körber except the record by SPITZNER (1897), which needs revision.

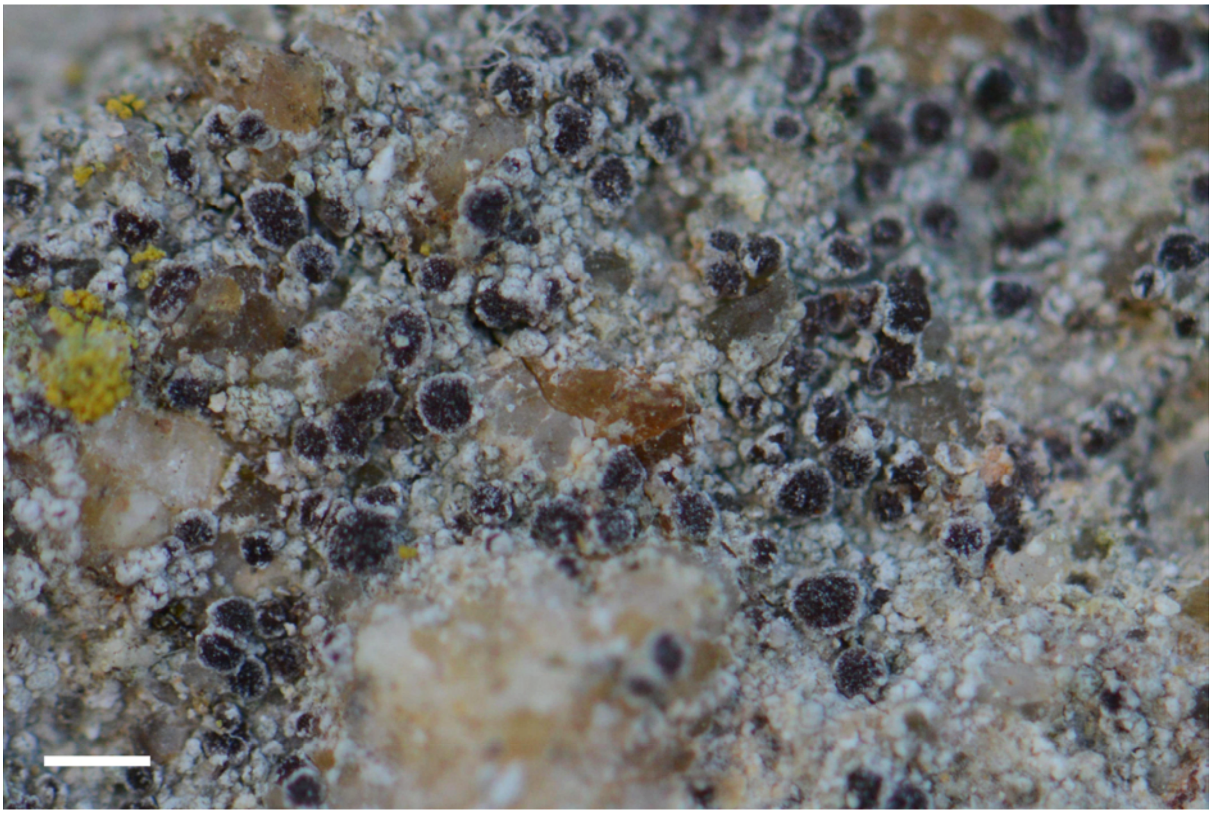

Fig. 3. *Lecania sordida* is a widespread but rare lichen. It prefers calcareous substrates, e.g. concrete (JM 5924, scale = 1 mm).

Fig. 4. *Peccania cernohorskyi* has been known only from the Czech Republic for a long time. Material from the type locality in Central Bohemia (PRC, scale = 1 mm).

'*Lecidea*' *strasseri* Zahlbr.

***Slovakia.** Muránska planina National Park, Muráň, limestone quarry at N border of village, 48°44'41''N, 20°02'50''E, alt. 450 m, on moss on limestone rock, 2012, J. Malíček 5256, A. Guttová, J. Halda & Z. Palice (JM).

This species is closely related to the arctic-alpine *Lecidea berengeriana* but seems to prefer lower elevations (e.g., oak woodlands). *Lecidea strasseri* has even been suggested to be a synonym of *L. berengeriana* (PRINTZEN 1995), but with more material available it has been been possible to distinguish it based on minor morphological characteristics and ecology as a separate taxon (SPRIBILLE et al. 2010, PRINTZEN in litt.). It was previously published from Slovakia as *Lecidea* aff. *berengeriana* (det. C. Printzen) from more or less the same locality as that reported here (GUTTOVÁ & PALICE 2005: 25).

Lecidella albida Hafellner

***Czech Republic.** Central Bohemia, Vltava River valley, Prostřední Lhota, Vymyšlenská pěšina Nature Reserve, oaks on rocky slopes, 49°44'33''N, 14°22'50''E & 49°44'45.5''N, 14°21'45.2''E, alt. 290–340 m, on bark of *Quercus petraea*, 2012, J. Malíček 4432 & 4440, K. Knudsen, J. Kocourková & J. Vondrák (JM); S Bohemia, Český Krumlov, Nové Dobrkovice, protected area "Vyšenské kopce", in the valley of brook "Hučnice", alt. 490 m, on bark of *Salix fragilis*, 2006, J. Vondrák 4233 (CBFS, PRA; with apothecia).

An overlooked lichen, which occurs mostly as a sterile sorediate crust resembling a pale form of *Lecanora expallens*. Secondary metabolites detected by TLC (atranorin, thiophanic acid, capistratone, arthothelin) correspond to results of DIETRICH (2007).

Leptogium intermedium (Arnold) Arnold

***Czech Republic.** N Moravia, Jeseníky Protected Landscape Area, Bělá pod Pradědem, Šumárník Nature Reserve 5 km W of town, rock on top of Šumný Mt. (1073 m), 50°11'19''N, 17°07'45''E, alt. 1060–1070 m, on calcareous soil associated with mosses, *Lempholemma polyanthes*, and *Agonimia tristicula*, 2012, J. Malíček 5231 (JM).

Three localities from the Czech Republic (Český kras, Třebíč, Mokrá hora near Brno) are cited by GUTTOVÁ (2006) in her Ph.D. thesis, but these records have not been formally published. The species strongly resembles a diminutive form of *L. gelatinosum*. Nowadays both species are rare in the Czech Republic, *L. gelatinosum* being recently reported from the Bohemian Karst (SVOBODA 2007), Železné hory Mts (HALDA et al. 2011a) and also known from the Krkonoše Mts (Palice, unpublished data).

Melaspilea gibberulosa (Ach.) Zwackh

Slovakia. Muránska planina National Park, Muránska Huta, Šiance National Nature Reserve: central part of reserve, c. 48°46'17''N, 20°05'06''E, alt. 750–950 m , on bark of *Quercus petraea*, 2011, J. Malíček et al. 4110 (JM); Poloniny Mts, Ulič, Nová Sedlica, protected area Stužica, alt. 600–1200 m, 49°04'24''N, 22°32'35'', on mosses on bark of *Fagus sylvatica*, 2013, J. Malíček 6492, 6525 & J. Vondrák 11325, 11329, 11334 (JM, CBFS).

More records of this taxon are included in the first list of Czech and Slovak lichens (VĚZDA 1980), but it is absent from the recent checklists because it was regarded as a non-lichenized fungus (VĚZDA & LIŠKA 1999, MALÍČEK et al. 2013). However we have observed a distinct thallus with more or less dispersed cells of a trentepohlioid photobiont. *Melaspilea gibberulosa* seems to be an indicator of old-growth forests in Central Europe.

Metamelanea caesiella (Th.Fr.) Henssen

***Czech Republic.** Central Bohemia, Beroun, Srbsko, S-exposed rocks in protected area Koda ca 1.5 km SW of the village, alt. 300–350 m, 49°56'N, 14°08'E, on overhanging hard limestone rock, 2004, J. Vondrák 2610, det. M. Schultz (CBFS); Beroun, Králův Dvůr, Trubín, S-oriented rocks in protected area "Trubínský vrch", alt. 330–350 m, 49°56'40''N, 13°59'40''E, on lime-enriched basaltic rock under an overhang, 2004, J. Vondrák 2427, det. M. Schultz (CBFS); S Bohemia, Český Krumlov, Nové Dobrkovice, protected area "Vyšenské kopce", alt. 520 m, under dry and lit, SW exposed limestone overhang, 2005, J. Vondrák 2704, det. M. Schultz (CBFS).

A poorly known lichen scarsely reported from Europe (JØRGENSEN 2007, SCHULTZ et al 2007). The Czech specimens form sterile leprose crusts on overhanging limestone rocks. Although the species frequently lacks apothecia, it is recognizable due to the rather thick, poorly lichenized, subpulverulent nodulose-areolate thallus containing packets of chroococcoid cyanobacteria (JØRGENSEN 2007). Usually a pale felt of mycobiont hyphae is formed among areoles and the thallus shows a paraplectenchymatic structure in section (SCHULTZ et al 2007; for more details see therein).

Micarea confusa Coppins & van den Boom

***Czech Republic.** N Bohemia, W Sudetes, Krkonoše Mts, Velký Kotel corrie – E slope, uppermost part, 50°45'08"N, 15°31'56"E, on humus in crevice of gneissic rock, alt. 1400 m, 2002, J. Halda & Z. Palice 6882 (PRA); E Bohemia, W Sudetes, Krkonoše Mts, Mt. Sněžka – W facing boulder scree above the SE margin of Krakonošova rukavice corrie, 50°43'30" N, 15°44'10" E, on bare soil and over bryophytes below stone overhang, alt. 1550 m, 2000, Š. Bayerová, J. Liška & Z. Palice 4095 (PRA).

New to Central Europe. The lichen closely resembles *Micarea denigrata* and is distinguished from the latter by consistently shorter mesoconidia and its ecology (substrates rich in heavy metals). In the Czech Republic it has been collected in more or less natural habitats at high altitudes in the Krkonoše Mountains, while in Belgium and the Netherlands, where the species was described, it occurs in industrial sites (COPPINS & VAN DEN BOOM 1995). It has also been recorded on wood in Spain (SARRIÓN TORRES 2001).

Micarea globulosella (Nyl.) Coppins

***Czech Republic.** Central Bohemia, distr. Benešov, Bernartice, Sedlice: Hadce u Želivky National Nature Monument, pine forest with serpentinite outcrops at right bank of Želivka dam, 49°41'12''N, 15°06'05''E, alt. 380–390 m, on stump of *Pinus*, 2013, J. Malíček 6164 et al. (JM); W Bohemia, Šumava Mts, Modrava: unnamed point [<1120] with managed beech forest, c. 0.5 km W–WSW of former bridge over Roklanský potok brook, 49°01.12'N, 13°26.17'E, on bark of *Fagus*, alt. 1100 m, 2006, E. Loskotová, Z. Palice 10934 & O. Peksa (PRA); S Bohemia, Šumava Mts, Volary: a depression in spruce forest near southern margin of Plešné jezero lake, 48°46'30"N, 13°51'55"E, on bark at base of *Picea*, alt. 1095 m, 1998, Z. Palice 1510 (PRA); Mt. Plechý [1378], dead natural spruce forest c. 0.7 km NW of the top, just N of the point 'Rakouská louka', 48°46'33.3"N, 13°50'56.2"N, on bark of dead *Picea* near brooklet, alt. 1310 m, 2011, Z. Palice 14537 & V. Pouska (PRA); Mt. Trojmezná, 130–150 m NNW of the top, dead old-growth spruce forest on N-facing slope, 48°46'22"N 13°49'33.5"E, on bark at base of dead standing *Picea*, alt. 1330 m, 2012, I. Frolov, Z. Palice 15772, 15776, 16089, 16090, V. Pouska & J. Vondrák (PRA); ibid.: 0.7 km NE of the top, dead natural spruce forest on N-facing slope, 48°46'34"N 13°50'03"E, on bark at base of dead standing *Picea* (E exp.), alt. 1250 m, 2013, Z. Palice 17195 & V. Pouska (PRA); Nová Pec: Mt. Hraničník, NE-slope, remnants of mountain mixed forest, 48°45'02.8"N, 13°54'34.4"E, on bark of *Acer pseudoplatanus*, alt. 1197 m, 2013, Z. Palice 17169 & V. Pouska (PRA).

All listed specimens were tested by the C reagent giving at least a faint reddish spot reaction, and the presence of gyrophoric acid was confirmed by TLC in two of the samples. In the Šumava Mountains, another rare species, *Micarea synotheoides*, also occurs (CZARNOTA 2007). It differs from *M. globulosella* in the absence of gyrophoric acid and its overall slightly paler habit and more gelatinose thallus. The Bohemian material of *M. globulosella* is heterogeneous. Comparing to the collection from a low elevation in Central Bohemia, the specimens from montane forests in the Šumava Mts produce distinct emergent pycnidia, the thallus is poorly developed and the concentration of gyrophoric acid is low. This heterogeneity is in accordance with observations by CZARNOTA (2007), who suggests that the Central European montane material may represent an undescribed taxon.

Micarea nowakii Czarnota & Coppins

***Czech Republic.** S Bohemia, Šumava Mts, Volary: Mt. Plechý, well lit boggy spruce forest NW of "Rakouská louka" and NE of "Trojmezí", 48°46'30–40"N, 13°50'30–45"E, on wood (twig) half-immersed in a pool, alt. c. 1300 m, 1998, Z. Palice 1542 (PRA); Volary: Mt. Trojmezná, 0.7 km NE of the top, dead natural spruce forest at N-facing slope, 48°46'34"N 13°50'03"E, on wood of lying trunk, alt. 1250 m, 2012, Z. Palice 15780, V. Pouska & J. Vondrák (as cf.; PRA); N Moravia, Králický Sněžník Mts, Staré město, Králický Sněžník Mt., in valley of Morava brook, 50°12'12''N, 16°50'45''E, alt. 1200 m, on stump of *Picea abies*, 2011, J. Malíček 3383 & L. Syrovátková (JM).

This recently described species resembles *M. misella* or *M. denigrata*, but differs in having a sharply delimited pigment in the epihymenium and especially in the presence of micareic acid and absence of gyrophoric acid (CZARNOTA 2007). It was described from Poland (CZARNOTA 2007) and has also been reported from Sweden (SVENSSON & WESTBERG 2010) and Germany (CZARNOTA et al 2014). Micareic acid was detected by TLC in all samples, although in the collection ZP 15780 only in trace amounts (cf. micareic acid). This sample is only tentatively assigned to *M. nowakii* since only pycnidia and no apothecia are present.

Normandina acroglypta (Norman) Aptroot

***Slovakia.** Muránska planina plateau: nature reserve Šarkanica, a forested SW-facing rock outcrop above Martinova dolina valley, 48°42'43"N, 19°59'31"E, on *Frullania* sp. on a thick branch of *Tilia*, alt. 550 m, 2009, Z. Palice 12893 (PRA); Muránska planina plateau: the Hrdzavá valley, hornbeam-oak-ash-lime forest on rocky SSE-facing slope, N48°44'52.1" E20°01'15.5", on mossy bark of *Tilia*, alt. 512 m, 2012, Z. Palice 15423 (PRA); Muránska planina National Park, Pohronská Polhora, junction of brooks in Čertova dolina ravine, 48°44'14''N, 19°51'27''E, alt. 680 m, on bark of young *Acer pseudoplatanus*, 2012, J. Malíček 5286, A. Guttová, J. Halda & Z. Palice (JM).

All Slovak material is sterile but it was compared to a fertile specimen from Scotland (ZP 10387). The specimen JM 5286 was analyzed by TLC and zeorin was detected as a major secondary metabolite. This compound has not been previously mentioned in the literature for this species, but according to the Norwegian lichen database (http://nhm2.uio.no/botanisk/nxd/lav/nld_e.htm) one specimen of *N. acroglypta* from Sør Trøndelag (Haugan 4839a) contains zeorin (det. T. Tønsberg). Secondary metabolites are rarely reported from *Verrucariaceae* and only a few terpenoids are known from *Flakea* and *Botryolepraria* (THOR & KASHIWADANI 1996, KUKWA & PÉREZ-ORTEGA 2010). *Normandina acroglypta* resembles several other mostly sterile lichens without a spot reaction of soralia, e.g. *Lecania croatica* and *Mycobilimbia epixanthoides*. Unlike those two species, the thallus of *Normandina* is somewhat areolate-subsquamulose, at least in part, and usually not continuous. The species has a similar ecology to *Normandina pulchella* and it too may grow on shaded rocks covered by bryophytes, especially by liverworts of the genus *Frullania*, which is likely the case of both published Czech records (SERVÍT 1936, 1954, as *Thelidium acroglyptum*).

Peccania cernohorskyi (Servít) Czeika & Guttová (Fig. 4)

***Slovakia.** Slovenský kras National Park, Turňa nad Bodvou, Zádiel: Zádielská tiesňava, deep canyon in limestone, south part of protected area, 48°37'09''N, 20°50'11''E, alt. 400 m, on vertical limestone rock, 2012, J. Malíček 5307, A. Guttová, J. Halda & Z. Palice, conf. M. Schultz (JM).

Most published localities are from the Czech Republic (from where it was originally described), especially the area known as the Bohemian Karst (SERVÍT & ČERNOHORSKÝ 1935, CZEIKA et al. 2007, ŠPRYŇAR et al. 2008, JØRGENSEN et al. 2013). *Peccania cernohorskyi* is however more widespread (M. Schultz in litt.), but is easily mistaken for other cyanolichens, namely *Anema* spp. and *Peccania coralloides*. Recently reported also from France (ROUX 2012) and Siberia (URBANAVICHUS 2010). It was even listed, with some uncertainty, from California (SCHULTZ 2009).

Peltigera extenuata (Nyl. ex Vain.) Lojka

***Czech Republic.** Central Bohemia, Sedlčany region, Chramosty: Mečkov gamekeeper's house, 49°39'16"N, 14°19'05"E, alt. 350 m, on soil, 2007, J. Malíček 949 (JM); Sedlčany region, Milešov, xerothermic grasslands on SW facing slope at SE border of village, 49°35'04"N, 14°13'27"E, alt. 425 m, on ±sandy soil on granitoid bedrock, 2013, J. Malíček 6192 & J. Steinová (JM); N Bohemia, distr. Česká Lípa, Doksy, railway at N border of Staré Splavy, 50°35'42''N, 14°37'39''E, alt. 275 m, on sandy soil along railway, 2013, J. Malíček 6057 (JM); [S Moravia], Thajatal, rechter Hang oberhalb Znaim, ...Konitzer... [illegible], 1919 and 1923, A. Oborny (PRC); Znaim, Granitztal, 1915, A. Oborny (PRC); Znaim, Stadtwäldchen, Schottergrube, 1918, A. Oborny (PRC).

Peltigera extenuata differs from the similar *P. didactyla* in the C+ red reaction of the soralia (due to methyl gyrophorate and gyrophoric acid), the character of the rhizines and the presence and position of apothecia (GOFFINET et al. 2003, VITIKAINEN 2007, SÉRUSIAUX et al. 2009). However according to our observations, the rhizines are variable, as noted by VITIKAINEN (2007). Furthermore, the differences in rhizines between the two taxa given by authors are not uniform (cf. VITIKAINEN 2007 and SÉRUSIAUX et al. 2009 or WIRTH et al. 2013). We publish here only specimens of *P. extenuata* with distinct C+ red soralia, following GOFFINET et al. (2003). Revision of our specimens and collection in PRC shows that *P. extenuata* is distinctly rarer than *P. didactyla*. However, we did not test secondary metabolites using TLC. Apothecia were found in only one specimen (JM 949).

Pertusaria pseudocorallina (Lilj.) Arnold (Fig. 5)

Czech Republic. Central Bohemia, Křivoklátsko Protected Landscape Area, Roztoky u Křivoklátu, open acidophilous oak forest on S-exposed slopes of Sokolí hill, 50°01'43''N, 13°52'51''E, alt. 390 m, on siliceous outcrop, 2011, J. Malíček 3731 (JM).

In the Czech Republic, this taxon is known only from several old records in the north part of Bohemia: Adršpašké skály [Adersbach] (MANN 1825), the castle Hněvín in Most [Schloβberg, Brüx] (ŠTIKA 1858), and Chomutov [Komotau] (ERICHSEN 1936). The species has an oceanic bias and has not been reliably recorded from either Moravia or Slovakia. VĚZDA & LIŠKA (1999) mentioned also an excerpted Moravian record by SUZA (1925, as

Pertusaria isidioidea), which refers to an epiphytic collection by F. Kovář and evidently does not belong to *P. pseudocorallina*, which is saxicolous.

Reichlingia leopoldii Diederich & Scheid.

***Slovakia.** N.P. Slovenský raj, Hrabušice: Veľký Sokol brook valley, 48°55'30"N, 20°20'50"–21'00"E, on bark of *Ulmus* and *Acer pseudoplatanus*, alt. 650 m, 1998, Š. Bayerová, J. Halda & Z. Palice 850 & 900 (PRA); N.P. Slovenský raj, Hrabušice: Suchá Belá gorge, 48°57'15–20"N, 20°23'05–10"E, on bark of *Acer pseudoplatanus*, alt. 600–620 m, 1998, Š. Bayerová, J. Halda & Z. Palice 921 (PRA); Muránska planina plateau: Javorníková dolina valley – the ravine part (48°44'10"N, 20°00'30"–20°01'E), on bark of *Fagus*, alt. 480–500 m, 2001, A. Guttová, J. Halda & Z. Palice 5379 (PRA); Muránska planina plateau, Zlatno: nature reserve Zlatnica, steep S-facing slope above Sviniarka valley, dark fir-beech forest, 48°49.28'N, 20°06.18'E, on bark of *Acer pseudoplatanus*, alt. 825 m, 2007, A. Guttová, J. Halda & Z. Palice 11458 (PRA); Muránska planina National Park, Pohronská Polhora, in deep ravine at W border of Čertova dolina Nature Reserve, 48°44'15"N, 19°51'29"E, alt. 700–750 m, 2011, on bark of *Acer pseudoplatanus*, *Abies alba* and *Fagus sylvatica*, J. Vondrák 9203, 9189 & 9206 (CBFS); ibid.: 48°44'05''N, 19°51'31''E & 48°44'06"N, 19°51'42"E, alt. 640 & 758 m, on bark of *Acer pseudoplatanus*, 2012, A. Guttová, J. Halda, J. Malíček 5283 & Z. Palice 15476 (JM, dupl. in PRC, PRA); Muránska planina National Park, Muráň, Hrdzavá valley W of town, along yellow marked tourist path in E part of protected area, 48°44'53''N, 20°01'05''E, alt. 470 m, on bark of *Acer pseudoplatanus*, 2012, J. Malíček 5240 et al. (JM).

This sterile lichen strongly resembles some *Lepraria* species in its sorediate felty thallus, but is distinctive by the production of brown conidia arising on the thallus surface, trentepohlioid photobiont and the presence of 2'-*O*-methylperlatolic acid. It prefers humid shady sites, usually in valleys of brooks and rivers, where it occurs on bark of deciduous trees and more rarely on rocks.

Rhizocarpon timdalii Ihlen & Fryday

***Czech Republic.** S Bohemia, Novohradské hory Mts, Hojná Voda: Mt. Kraví hora [953], 200 m SE of the top, half-shaded boulder field at ESE-facing slope, 48°43'48"N, 14°43'20"E, on granite boulder, alt. 867 m, 2012, Z. Palice 15620, conf. A. Fryday (PRA).

The species belongs to the difficult complex around *R. obscuratum*, which was recently revised by IHLEN (2004). *R. timdalii* is distinguishable from similar taxa mainly by its distinctly convex areoles, dominant *cinereorufa*-green pigment in apothecia and eumuriform ascospores (IHLEN 2004). Its distribution is still poorly known. The species was described from southern Fennoscandia, the British Isles (Wales) and the northeastern U.S.A. (IHLEN & FRYDAY 2002). It was recently reported from the western Carpathians, Belarus and the Crimean Peninsula (MATWIEJUK 2011). The Bohemian specimen contained no substances by TLC as well as those reported by MATWIEJUK (2011). According to IHLEN & FRYDAY (2002), about half of specimens contained an unknown fatty acid, with the occurrence of the fatty acid exhibiting no obvious geographic correlation.

Rhizoplaca melanophthalma (DC.) Leuckert & Poelt

***Czech Republic.** N Bohemia, Lovosice, Třebenice, rocks on S. slope of ruin Košťálov, alt. 460 m, 50°29'23"N, 13°59'04"E. 2003, J. Vondrák 1173, 1127; ibid.: 2012, J. Vondrák 9590 (CBFS).

This specimen was used in the phylogeographical study of the *R. melanophthalma* complex by LEAVITT et al. (2013a), which revealed six species. In the ITS phylogeny, the Czech specimen was placed in the geographically most widespread clade, *R. melanophthalma* s. str. (LEAVITT et al. 2013b).

Fig. 5. *Pertusaria pseudocorallina* was regarded as an extinct species in the Czech Republic. It prefers oceanic climate (JM 3731, scale = 1 mm).

Fig. 6. *Xanthoria papillifera* is a lichen with the continental distribution. It is characteristic by cylindrical isidia and the thallus covering usually large areas (scale = 1 cm).

Rhizoplaca subdiscrepans (Nyl.) R.Sant.

***Czech Republic.** Central Bohemia, Kladno, Zákolany, rocks in valley of Zákolanský potok brook, c. 200 m SE of railway stop Zákolany, alt. 250 m, 50°11'48"N, 14°15'11"E, on SW-exposed chert rock, 2012, J. Vondrák 9843, O. Vondráková, I. Frolov (CBFS, previously reported by HILITZER 1929, as *Lecanora rubina*); N Bohemia, Lovosice, Třebenice, rocks on S slope of ruin Košťálov, alt. 460 m, 50°29'23"N, 13°59'4"E, 2012, J. Vondrák 9589, 9622 (CBFS).

The species was known from various localities in Central Bohemia, though cited as *Lecanora rubina* (Vill.) Ach. (= *Rhizoplaca chrysoleuca* (Sm.) Zopf). All revised samples from that region north of Prague (PRM; leg. A. Hilitzer and J. Suza as *Lecanora rubina*) belong to *Rhizoplaca subdiscrepans*. It is not known whether the *R. chrysoleuca* s.str. occurs in the Czech Republic; see also the note under *R. chrysoleuca* in VĚZDA & LIŠKA (1999). For the present it should be excluded from the checklist of the Czech Republic.

Rinodina capensis Hampe

***Czech Republic.** W Bohemia, Šumava Mts, Modrava: Medvědí hřbet crest, remnants of old-growth deciduous forest between Mt. Beerenkopf (1158 m) and Mt. Medvěd (1136 m), c. 49°00'N, 13°25'E, on old *Acer pseudoplatanus*, alt. 1120 m, 1995, Z. Palice 1541 (PRA); S Bohemia, Šumava Mts, Nová Pec: glacier cirque of Plešné jezero lake, *Acer pseudoplatanus*, alt. 1200–1250 m, 1996, Z. Palice s.n., det. H. Mayrhofer (PRC; together with *Rinodina orculata*); Volary: not far from yellow tourist footpath above the right bank of Plešné jezero lake, on older solitary *Fagus* surrounded by young *Picea* stand, alt. c. 1130 m, 1998, Z. Palice 539 (PRA); Frymburk: Vítkův Kámen, wooded area of the castle-ruin (48°38'40"N, 14°06'15"E), on bark of *Acer platanoides*, alt. 1030 m, 1997, Z. Palice 3874 (PRA); Horní Vltavice, Zátoň: Jilmová skála Nature Monument, scree old-growth forest, 48°57'13''N, 13°47'48''E, alt. 1000–1030 m, on trunk of dead *Fagus sylvatica*, 2014, J. Malíček 7324 (JM).

This is a characteristic woodland species that might have been partly overlooked in the past. Presently, it seems to be quite rare, preferrably occurring in well lit montane old-growth forests. It is easily to identify among atranorin containing corticolous species of *Rinodina* with the *Physcia*-type of ascospores due to the slightly amyloid exciple (GIRALT & MAYRHOFER 1994).

Schismatomma umbrinum (Coppins & P.James) P.M.Jørg. & Tønsberg

***Czech Republic.** S Bohemia, Kaplice, Děkanské Skaliny, at ruin of castle Sokolčí, alt. c. 590 m, 48°44'45"N, 14°33'8"E, 2011, J. Vondrák 8455, 8456, conf. D. Ertz (CBFS).

This usually sterile crust containing schizopeltic acid (UV+) as a major constituent (TØNSBERG 1992) is likely overlooked in acidophytic skiophilous saxicolous lichen communities.

'*Sclerococcum*' *griseisporodochium* Etayo

***Slovakia.** W Carpathians, Muránska planina plateau: Javorníková dolina valley, the narrower, ravine part (48°44'10"N, 20°00'30"–20°01'E), on moist vertical calcareous rock, alt. 480–520 m, 2001, A. Guttová, J. Halda & Z. Palice 5367 (PRA); Slovenský kras karst, Rožňava, Bôrka, in protected area 'Havrania skala' NE of village, alt. c. 750 m, 2006, J. Vondrák 4597 (CBFS).

Today considered to be a lichenized hyphomycete (SMITH 2009), apparently belonging in a separate genus within *Arthoniales* which also contains several other sporodochiate taxa (ERTZ et al. 2011, 2013). Its correct generic placement is uncertain, pending molecular studies. It was reported from the Czech Republic by VONDRÁK et al. (2007b) from lowland and submontane limestone areas.

Sclerophora amabilis **(Tibell) Tibell**

***Czech Republic.** W Bohemia, Český les Protected Landscape Area, Bělá nad Radbuzou, Nad Hutí Nature Reserve, N part of protected area, old-growth forest on E-facing slope of Nad Hutí Mt. (716 m), c. 49°32'29''N, 12°39'25''E, alt. 670–690 m, on dead trunk of *Fagus sylvatica*, 2013, F. Bouda & J. Malíček 5933 (JM); Šumava Mts, Modrava, Javoří Pila: Mt. Medvěd, NE slope, spruce plantation with scattered old maples, 49°00.52'N, 13°25.24'E, on bark of old *Acer pseudoplatanus*, alt. 1125 m, 2005, F. Bouda, Z. Palice 9327, O. Peksa & J. Steinová (PRA).

New for Central Europe. Species of *Sclerophora* are indicators of well preserved old-growth forests and they are all very rare in the Czech Republic. *S. amabilis* is similar to *S. pallida* and *S. peronella*, but differs in its intermediate ascospore size (5–6 µm in diam.) and taller ascomata (see TIBELL 1999 for other differences). TIBELL (1999) points out that European material differs slightly from specimens from New Zealand, where the species was originally described, and the European material may represent a distinct species.

Scutula dedicata **Triebel, Wedin & Rambold**

Czech Republic. Central Bohemia, Brdy Mts, Jince, on railway 0.8 km S of Čenkov, W of pond, 49°45'56.7''N, 14°00'15.5''E, alt. 410 m, railway embankment, on *Peltigera didactyla*, 2012, J. Malíček 4952 (JM, dupl. in M); Vltava River valley, Kamýk nad Vltavou, sand pit at W margin of village, 49°38'16"N, 14°14'58"E, alt. 300 m, on *Peltigera didactyla* on sandy soil, 2014, J. Malíček 7245 & A. Kulíková (JM); W Bohemia, Kdyně, Dobříkov: railway station, 49°22'18"N, 13°05'18"E, alt. 520 m, railway embankment, on *Peltigera didactyla*, 2010, J. Malíček 2947 (JM); S Bohemia, Šumava Mts, Volary: at road-side Nová Pec – Černý Kříž, a transient wood-storage place c. 100 m W of the railway stop Pěkná, on decaying thallus of *Peltigera didactyla*, alt. 735 m, 2001, Z. Palice 5280 (PRA); Prachatice, Husinec, Výrov, stony heap near village, alt. ca 500 m, 49°03'00''N, 13°59'50''E, lichenicolous on *Peltigera didactyla*, 2010, O. Merkulova & J. Vondrák 7853 (CBFS).

From the Czech Republic, this taxon has already been published from the Šumava Mts (KOCOURKOVÁ 2000) as a lichenicolous fungus and the last specimen listed above was recently issued in an exsiccate (HAFELLNER 2013). Although it is distinctly lichenized, it was not included in the checklist (LIŠKA et al. 2008). The first two specimens were fertile and the ascospore dimensions, (8–) 9–11.5 × 3.0–3.5 (–4.0) µm, indicated *S. dedicata* following TRIEBEL et al. (1997). The collection JM 4952 is accompanied by an anamorphic state identified as *Libertiella* aff. *fennica* Alstrup by D. Triebel. This anamorph, present also in JV 7853, JM 2947 and the specimen published by KOCOURKOVÁ (2000), is characterized by conspicuous, pale to black, globose to subglobose pycnidia, 0.1–0.3 mm in diam., containing tear-shaped or subglobose conidia which are 4–7 (–8.5) × (2.5–) 3–4 µm (measurements of 35 conidia from various pycnidial phenotypes). Such conidia correspond roughly with mesoconidia of *S. dedicata* in TRIEBEL et al. (1997), but they are slightly wider. Conidia known in *Scutula heeri*, a similar taxon, are very different in their size and shape from those in our sample.

Thelocarpon citrum **(Wallr.) Rossman**

***Czech Republic.** S Bohemia, Šumava Mts, Volary, Černý Kříž: Studená Vltava valley, in front of game-keeper house, 48°51.66'N, 13°51.46'E, on sandy soil in alluvium of the river, alt. 740 m, 2005, Z. Palice 8985 (PRA).

Thelocarpon citrum (syn. *T. vicinellum* Nyl.) usually occurring on soil was not distinguished from epixylic *T. superellum* by recent monographers (e.g. KOCOURKOVÁ-HORÁKOVÁ 1998). APTROOT & SPARRIUS (2010) argue for distinguishing these two taxa because the terricolous specimens are consistently smaller and no intermediates were found between specimens occurring on soil and wood. We follow their concept. Terricolous records published as *T. superellum* by KOCOURKOVÁ-HORÁKOVÁ (1998) and VONDRÁK et al. (2006) probably also belong to *T. citrum*.

Thelocarpon imperceptum (Nyl.) Migula

***Czech Republic.** Central Bohemia, Bohemian Karst, distr. Praha – západ, Roblín, Kuchařík, W-WSW-facing, east upper side of the quarry 'Na skalkách', 49°58'16"N, 14°15'22.5"E, immersed in loamy/sandy soil, alt. 365 m, 2012, Z. Palice 15124 (PRA).

This is a sporadically recorded species known so far only from a few countries in Europe, mainly from historical collections, and recently collected only in the Netherlands (VAN DEN BOOM 2000), Poland (BIELCZYK et al. 2009) and Ukraine (KHODOSOVTSEV et al. 2011, as *Athelium imperceptum*). The fruits are immersed in soil and hence easily overlooked, although it is probably not a common species.

Toninia philippea (Mont.) Timdal

Czech Republic. Central Bohemia, Praha – Radotín, Kosoř, protected area Černá rokle, E of village, S-SW facing xerothermic slopes, 49°59'21–23"N, 14°20'08–18"E, alt. 250–300 m, on limestone in shrubby steppe, 2011, Z. Palice 14995 & J. Vondrák 10493 (PRA, CBFS, cum *Caloplaca variabilis* s. l.).

The only previous record from the Czech Republic was published by SERVÍT (1930 & 1954: 90, as *Catillaria subgrisea*) from a xerothermic region around Prague, where we confirmed its occurrence after some 80 years.

Verrucaria beltraminiana (A.Massal.) Trevis.

***Slovakia.** Belianské Tatry Mts, Lendak, S-exposed slopes of Skalné vráta Mt., 500 m NE of Plesnivec cottage, 49°13'36.7''N, 20°16'53.1''E, alt. 1500 m, on limestone rock, 2010, J. Malíček 3230, conf. O. Breuss (JM).

This taxon strongly resembles *Verrucaria* (*Verruculopsis*) *lecideoides*. Both species are characterized by perithecia arising between angular grey areoles. *V. beltraminiana* differs from the former in larger ascospores and the absence of a black basal layer (WIRTH et al. 2013).

Verrucaria breussii Diederich & van den Boom

***Czech Republic.** Central Bohemia, Bohemian Karst, Svatý Jan pod Skalou, S-SW-facing xerothermic slope with oak, below the view-point, 49°58'11", 14°08'17"E, on bark of *Quercus*, alt. 370–380 m, 2005, J. Halda & Z. Palice 8839, det. O. Breuss (as *Verrucaria sorbinea*) (PRA); ibid.: S-facing slope with oaks, ESE of the view-point, 49°58.21'N, 14°08.27'E, on bark of *Quercus*, alt. 370–390 m, 2007, Z. Palice 11044, 11101, 11105, 11127, 11137 (PRA); Kolín, Velký Osek, protected floodplain forest Libický luh, alt. 200 m, 50°6'35"N, 15°10'3"E, on bark of *Populus*, 2014, J. Vondrák 11859 & F. Bouda (CBFS); S Moravia, Pálava Protected Landscape Area, Horní Věstonice, Děvín-Kotel-Soutěska National Nature Reserve, in forest along red tourist path near S border of reserve, 0.5 km N of Klentnice, 48°51'21''N, 16°38'41''E, alt. 340 m, at base of *Tilia cordata*, 2013, J. Malíček 6340 & J. Vondrák 11630 (CBFS, JM).

Our recent experiences show that this may be a common species of lowland forests, where it usually occurs at the base of trunks of various broad-leaved tree species. *Agonimia allobata* has a similar ecology and external morphology, but in *V. breussii* the perithecia are more pigmented and largely immersed in the thallus. *Verrucaria viridigrana* has also a similar ecology, but differs in ascospore dimensions, less pigmented perithecia with a thin hyaline layer on the surface and has a more distinct, at least partly blastidiate/coralloid thallus (BREUSS 1998b).

Verrucaria fuscovelutina Servít

***Czech Republic.** Central Bohemia, Prague, Motol, natural monument "Kalvárie", W part, S-SE facing slope, 50°03.95'N, 14°19.38–39'E, on crumbling shaded diabase rock, alt. 315 m, 2007, Z. Palice 11103, 11159, det. O. Breuss (PRA); ibid.: alt. 320 m, 2009, Z. Palice 13136 & A. Redchenko (PRA).

A poorly known taxon previously recorded only from three localities: in Montenegro (SERVÍT 1949, type locality), Austria (BREUSS & BERGER 2010) and Finland (PYKÄLÄ 2013). It belongs to the difficult *Verrucaria nigrescens* group and is close to *V. fuscoatroides* (BREUSS & BERGER 2010) and *V. nigroumbrina* (PYKÄLÄ 2013), both taxa described by Servít. In Prague it was collected on crumbling rock pieces. It was reported to grow on pebbles in Finland too (PYKÄLÄ 2013), so is probably a locally occurring pioneer species.

Verrucaria phloeophila Breuss

***Slovakia.** W Carpathians, Muránska planina plateau: nature reserve Šarkanica, S-SSE-facing slope, a well-lit oak-lime forest, 48°42'53"N, 19°59'22.5"E, on bark at foot of *Quercus polycarpa*, alt. 670 m, 2009, Z. Palice 12989 (PRA); Muránska planina plateau: Mt. Šiance – S-SSE slope, light scree forest, 48°46'10"N, 20°04'30"E, on bark at base of old *Quercus*, alt. 800–860 m, 1999, A. Guttová, J. Halda & Z. Palice 2102, det. O. Breuss (PRA); ibid.: SE exposed slopes with limestone rocks and hardwood forest, c. 3 km NE of Muráň, alt. 600–800 m, 48°46'13"N, 20°04'47"E, on bark of *Quercus*, 2011, J. Vondrák 9187, 9288, conf. O. Breuss 2012 (CBFS); ibid.: S-facing crest with well lit forest, 0.9 km W-WNW of Muránska Huta, 48°46'25.7"N, 20°05'27.5"E, alt. 892 m, 2011, F. Bouda, I. Černajová, J. Malíček, Z. Palice 14493, L. Syrovátková & J. Vondrák (PRA).

Interestingly, the type material of this taxon (holotype and paratypes) originates from two ecologically different collections that may eventually represent two different taxa: one growing on bark (mainly *Quercus*) and the second on wood subjected to water (BREUSS 1998a). The terricolous *Verrucaria geophila* Zahlbr., which also occurs in the Muránska planina plateau (PALICE et al. 2006), appears to be morphologically close to specimens from bark and might be conspecific.

Verrucaria ulmi Breuss

***Slovakia.** Muránska planina Mts, Revúca, Muráň, loc. "Šiance", SE exposed slopes with limestone rocks and hardwood forest, c. 3 km NE of village, alt. 600–800 m, 48°46'13"N, 20°04'47"E, on bark of *Quercus*, 2011, J. Vondrák 9289, conf. O. Breuss 2012 (CBFS).

The Muránska planina National Park is a diversity hotspot for corticolous *Verrucaria*. In addition to the two previously mentioned, *Verrucaria hegetschweileri*, *V. breussii* (as *V. sorbinea*), *V. tuerkii*, and *V. viridigrana* have been reported (BREUSS 1998b, GUTTOVÁ & PALICE 1999, 2005, PALICE et al. 2006). *Verrucaria ulmi* is distinguished from the above mentioned taxa by the blackish pigmented thallus, ±closed, non-spreading involucrellum (firmly enclasping the exciple, basally non-continuous, formed usually only in spots) and relatively large ascospores reaching 30 µm (BREUSS 1998a). So far it has been collected only twice, in Lower Austria: on bark of *Ulmus* (BREUSS 1994) and *Acer pseudoplatanus* (BREUSS 2010).

Xanthoria papillifera (Vain.) Poelt (Fig. 6)

***Czech Republic.** S Moravia, Mikulov, rocks on eastern slope of the Kozí hrádek ruin, alt. 270 m, 48°48'34"N, 16°38'18"E, 2001, J. Vondrák 203 (CBFS); Mikulov, chateau on hill in the town, alt. ca 250 m, 48°48'30''N, 16°38'20''E, 2002, J. Vondrák 249 (CBFS); Mikulov, protected area Kočičí kámen rock c. 2 km N of town, alt. 345 m, 48°49'49.9''N, 16°38'12.7''E, 2005, J. Vondrák 2847 (CBFS); Mikulov, protected area Kočičí skála rock ca 1.5 km N of town, alt. 361 m, 48°49'33.9''N, 16°38'30.3''E, 2005, J. Vondrák 2811 (CBFS); ibid.: 2009, J. Malíček 2158 (JM); Horní Věstonice, Děvín-Kotel-Soutěska National Nature Reserve, limestone outcrops along blue-marked tourist path 0.9 km SSE of village, W-facing slope of Obora Mt. (483 m), 48°51'47''N, 16°38'00''E, alt. 390 m, on limestone rock, 2014, J. Malíček 6941 et al. (JM).

It is a rare continental *Xanthoria* distributed mainly in central and southeastern Europe ranging eastwards to Caucasus and Karakorum (POELT 1954, GIRALT et al. 1993). The species occurs on calcareous rocks, usually on exposed sites on tops affected by bird excrement, where it covers large areas. In the Czech Republic, *X. papillifera* was collected only from limestones in the Pálava region.

Xylographa pallens (Nyl.) Harm.

***Czech Republic.** E Bohemia, Krkonoše Mts, Špindlerův Mlýn, Vysoké kolo (1509 m) Mt., E-facing slope, alt. 1340 m, on wood, 2004, J. Malíček 65, det. T. Spribille (JM); S Bohemia, Šumava Mts, Stožec, Černý Kříž: valley of Lesní potok brook 1.1 km SSE of settlement, 48°51'06.8''N, 13°51'55.2''E, alt. 750 m, on tree stump, 2010, J. Malíček 2723 & Z. Palice, det. T. Spribille (JM, together with *Xylographa vitiligo*).

A poorly known taxon similar to the common *X. parallela*, from which differs in usually star-like aggregated apothecia. It is a widespread species in Europe occurring mainly in montane to subalpine conifer forests (SPRIBILLE et al. 2014). The taxon was previously reported from the Czech Republic as *X. parallela* var. *pallens* by SERVÍT (1910) from Moravia, but the relevant Servít specimen in PRC is apparently poorly developed *X. parallela* following the description in SPRIBILLE et al. (2014).

Discussion

Our results show that, despite over 200 years of fairly intensive study, the lichen flora of central European countries is still incompletely known. In the Czech Republic, there are several reasons for this. First, the lichen biota can be expected to be rich, as the Czech Republic forms an area of overlap for oceanic and continental as well as Mediterranean and boreal species; all these elements are represented (though not well represented) in the lichen biota. Second, the geology is extremely variable and several substrate specialists are known from the country, e.g. *Aspicilia dominiana* on diabases (ČERNOHORSKÝ 1940, MALÍČEK & PALICE 2009) or *Aspicilia serpentinicola* and *Porpidia nadvornikiana* on serpentinites (PALICE et al. 2005, NORDIN 2013). Finally, several species of old-growth forest remnants in various woodland types are present, though they were not recorded until intensive investigations were carried out. For instance *Arthonia incarnata*, *Buellia arborea*, *Lecidea sphaerella*, *Micarea globulosella, M. nowakii*, *Rinodina capensis*, and *Sclerophora amabilis* are new Czech country records from montane spruce and beech old-growth forests.

The new Slovak checklist (GUTTOVÁ et al. 2013) contains about 100 lichen species more than the checklist of the Czech Republic (LIŠKA et al. 2008). Slovakia has the high Carpathian mountains (above 2000 m a.s.l.) and many large regions with a rugged topography and covered by rather natural vegetation; the presence of montane and alpine areas with calcareous substrates is especially important for total lichen diversity. The Czech Republic, however, lacks these features. However, Slovakia also has about 100 species more than Poland (FAŁTYNOWICZ 2003), even though many these favorable features are present in Poland. However, they are restricted in Poland to small areas and the most of the landscape is formed by intensively managed lowlands.

Much higher lichen diversity, exceeding 2000 taxa, is known from countries with the Alps, specifically Austria (HAFELLNER & TÜRK 2001) and Germany (WIRTH et al. 2013). Alpine areas are especially enriched by high-mountain lichens (e.g. *Caloplaca cacuminum*, *C. paulii*, *Dactylina ramulosa*, *Lecanora flavopunctata*) as well as epiphytic lichens preferring high humidity (e.g. *Byssoloma subdiscordans*, *Degelia plumbea*, *Gyalideopsis piceicola*, *Pannaria rubiginosa*, *Sticta limbata*), which are mostly absent from other Central European countries.

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Gyalidea minuta found in Central Europe – new data on the distribution, ecology and morphological variation of the species

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ABSTRACT — New localities of *Gyalidea minuta* in Central Europe are reported. The distribution, ecology and morphological variation of the species are discussed and differentiating characters presented.

KEY WORDS — lichenized fungi, lichens, Gomphillaceae, Poland, Czech Republic

Introduction

The genus *Gyalidea* was resurrected by Vězda (1966) and by Vězda & Poelt (1991). It is currently included in the Solorinellaceae family (Baloch et al. 2010); earlier it was included in the Asterothyriaceae and Gomphillaceae (see Henssen & Lücking 2002, Lumbsch & Huhndorf 2010). The genus is characterized by a crustose thallus, zeorine apothecia with a mostly well-developed thalline margin, an ascus of the Ostropales-type, a non-amyloid hymenium with simple to sparsely branched and septate paraphyses, and hyaline, muriform (or transversally septate) ascospores (Vězda 1966; Vězda & Poelt 1991; Henssen & Lücking 2002; Aptroot & Lücking 2003). The thallus is usually inconspicuous and the apothecia small. Gyalidea is a cosmopolitan genus with over 40 species (Vězda & Poelt 1991; Kirk & Cooper 2009), of these many have been described in the last two decades (see Lumbsch et al. 2009). They are rather rare lichens, some known only from the type material or very few collections. Most species grow on soil, rocks, mosses and plant debris and only a few occur on tree bark. In Europe there are only two epiphytic species, *G. minuta* (van den Boom & Vězda 1995) and the recently described *G. fruticola* (Svensson & Thor 2007). Until recently, *G. minuta* had only been found in three localities in south-western and western Europe. This paper presents the first record of this species in Central Europe together with general information on distribution, ecology and morphological variation of the species.

Materials & methods

The morphology of the specimens was examined by standard microscopic techniques. Hand-cut sections and squash preparations were examined in water, a 10% aqueous solution of potassium hydroxide (KOH), and Lugol's solution. Only well-developed, free ascospores lying outside the asci were measured. Measurements were made in water at x1000 magnification. The description below is based on the isotype and newly collected specimens.

The taxon

Gyalidea minuta Van den Boom & Vězda, Mycotaxon 54: 423. 1995.
TYPE: Portugal, Algarve; HOLOTYPE: herb. van den Boom 14875 [not seen]; ISOTYPE: herb. A. Vězda (PRA-V-05556!).

DESCRIPTION – THALLUS epiphloedal or partly endophloedal, corticolous, scattered among substrate wrinkles, grayish green, without visible prothallus. APOTHECIA sessile, hyaline with a brownish tinge, translucent when wet, 0.15–0.2 mm diam., 0.1 mm tall (0.2–0.4 x 0.1–0.15 mm in water preparation). HYMENIUM colorless, 45–75 µm tall. Paraphyses simple, not broadening towards the tips, 1.5–2.0 µm in diam., indistinctly septate. Asci cylindrical-clavate, wall slightly thickened at apex, 8-spored, 28–40 x 7–9 µm. Ascospores ellipsoid, with rounded to attenuate ends, muriform, with 3–5 transverse septa, and 1–3(–4) longitudinal septa, (9.5–)10–17(–20) x 4.5–7.5(–9) µm. PYCNIDIA not observed. CHEMISTRY not tested by TLC (Fig. 1).

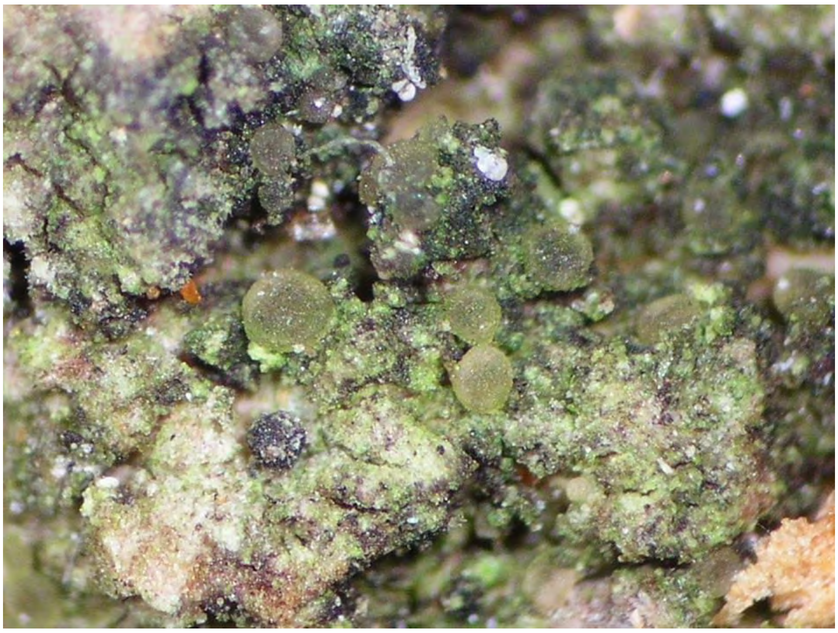

Fig. 1. Habit of *Gyalidea minuta*

ECOLOGY – In western Europe the species has been reported from the bark of *Alnus glutinosa* and *Fraxinus* sp. trees in shady, humid forests and among shrubs (van den Boom & Vězda 1995, Sparrius et al. 2002). In Poland, it has been found only in forest conditions. One locality is a narrow strip of land (ca. 50 m wide and about 2 km long) adjacent to a lake with an anthropogenic forest community of an unusual structure. The tree layer consists of middle-aged pine, the shrub layer of *Berberis* sp., *Crataegus* sp., *Euonymus europaea*, *Rhamnus cathartica*, *Sambucus nigra*, of which the common buckthorn (*Rhamnus cathartica*) is dominant. The dense shrub-layer and the proximity to the lake cause sheltered conditions with high humidity. *Gyalidea minuta* grows here on the bark of the buckthorns only and is intermixed with common lichen species in this area, e.g., *Anisomeridium polypori* (Ellis & Everh.) M.E. Barr, *Bacidina sulphurella* (Samp.) M. Hauck & V. Wirth, *Coenogonium pineti* (Schrad. ex Ach.) Lücking & Lumbsch, *Lepraria incana* (L.) Ach., *L. lobificans* Nyl., *Melanelixia fuliginosa* (Fr. ex Duby) O. Blanco et al., *Micarea micrococca* (Körb.) Gams ex Coppins, *Psoroglaena abscondita* (Coppins & Vězda) Hafellner & Türk and *Parmelia sulcata* Taylor. The second locality is in a pine forest planted in soil conditions which naturally favor oak-lime-hornbeam forest. In this habitat, *G. minuta* grows at the bottom of Acer pseudoplatanus trunks, mixed with abundant *Bacidina sulphurella*. Additional species include *Lepraria incana*, *L. elobata* Tønsberg, and *Parmelia sulcata*.

In the Czech Republic *Gyalidea minuta* has been collected in shady, damp forest that consists of mostly *Alnus glutinosa* and *Fraxinus excelsior*. The locality is a part of an old spruce-beech forest reserve. Here the species grows abundantly around bark rifts of *Fraxinus* trunks, accompanied by *Lepraria* sp., *Lecanora pulicaris* (Pers.) Ach. and *Phlyctis argena* (Ach.) Flot.

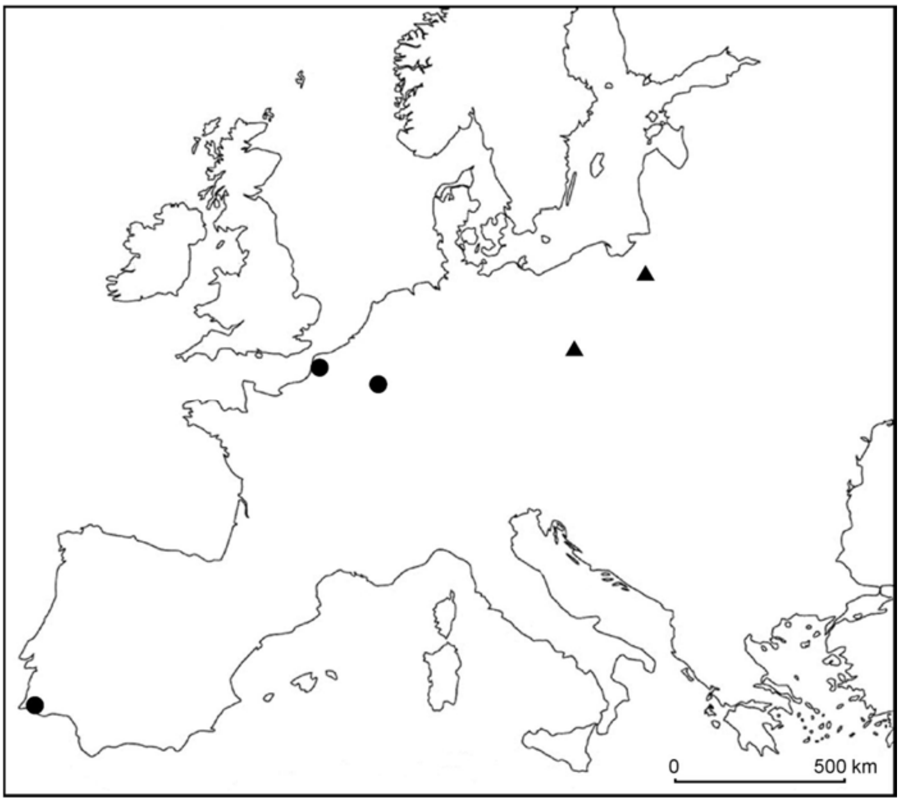

Fig. 2. Distribution of *Gyalidea minuta*. ● – previously published localities, ▲ – new localities.

GEOGRAPHICAL DISTRIBUTION – *Gyalidea minuta* is known only from Europe (Fig. 2); previously it had been reported in three localities, in Portugal (van den Boom & Vězda 1995), in northern France and in Belgium (Sparrius et al. 2002).

SPECIMENS EXAMINED —POLAND. Olsztyn Lake District, Olsztyn, Łupsztych settlement, near lake Ukiel (20°24'20''E 53°46'50''N): 10.VII. & 10.XI.2001, leg. D. Kubiak (OLTC L–1425, PRA-V-03137, PRA-V-03138); ibid. 15.IX.2002, leg D. Kubiak (OLTC L–1976); ibid. 26.IV.2005, leg D. Kubiak (OLTC L–2879); ibid. 7.II.2009, leg. D. Kubiak (OLTC L–3113); Olsztyn, Dajtki settlement, near lake Ukiel (20°25'20''E 53°46'53''N): 6.VI.2009, leg. D. Kubiak (OLTC L–3190). —CZECH REPUBLIC. Eastern Bohemia, Železné hory Mts, Nasavrky – Horní Bradlo, Polom Nature Reserve (ca. 15°45'16''E 49°47'34''N): 24.IX.2009, leg. J. Malíček, J. Halda & A. Müller (herb. J. Malíček 2018).

ADDITIONAL SPECIMENS EXAMINED —PORTUGAL: Algarve. Serra de Monchique, road 267 to S. Marcos da Serra (Alferce), 1.8 km E of crossing to Monchique (8°32.3'W 37°19.0'N): 28.VII.1993, leg. P. v.d. Boom (PRA-V-05556) [isotype]

COMMENTS – This paper presents the first report of *Gyalidea minuta* in Central Europe. The first specimens from Poland were found in 2001. They differ from the type of the species by the shape of apothecia as well as by the number and arrangement of septae. A. Vězda suggested (pers. comm.) that these differences were so great that the specimen was a new species. The final determination was postponed in view of the small size of the collected specimen. For several years, no new material was found, until in 2009 the first author found a larger population of the species within 2 km from the first locality. In the same year the species was also found in the Czech Republic. Analysis of the rather rich material from both countries showed that all specimens belong to a single species, *Gyalidea minuta*. Detailed measurements have shown that the Central European specimens are slightly deviating: the ascospores are slightly smaller with 3–4 transverse septa and the apothecia are generally larger and more flattened (Table 1). Furthermore, the exciples of dead apothecia are not persistent as in the isotype specimen. These differences are probably due to the fact that the previously collected specimens are small and poorly developed and do not reflect the full variability of the species.

It is worth noting that despite the relatively detailed and long-term observations in Poland, the records of *G. minuta* are very few. This may indicate that the species has an ephemeral nature. However, it is also easily overlooked in the field.

Despite its variability, *Gyalidea minuta* is a quite distinctive species due to its occurrence on the bark of trees and shrubs, its very small, pale and almost translucent apothecia, and the hardly visible thallus. The only other epiphytic *Gyalidea* species, the recently described *G. fruticola* (Svensson & Thor 2007), which also occurs on the bark of shrubs, differs in that it has larger, whitish grey to light yellowish brown apothecia, as well as considerably longer, more septate ascospores. Additionally, it has a well-developed true exciple that almost encloses the disc. In wet conditions in the field, *G. minuta* resembles *Coenogonium pineti*, but the microscopic features differ markedly. Rich photo documentation of the isotypus and Central European collections is available on http://www.jjh.cz/foto/.

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2.6. List of papers included in this thesis

P1: **Malíček J.** & Palice Z. (2013): Lichens of the virgin forest reserve Žofínský prales (Czech Republic) and surrounding woodlands. – Herzogia, 26: 253–292.

P2: Vondrák J., **Malíček J.**, Šoun J. & Pouska V. (2015): Epiphytic lichens of Stužica (E Slovakia) in the context of Central European old-growth forests. – Herzogia, 28: 104–126.

P3: Hofmeister J., Hošek J., Brabec M., Dvořák D., Beran M., Deckerová H., Burel J., Kříž M., Borovička J., Běťák J., Vašutová M., **Malíček J.**, Palice Z., Syrovátková L., Steinová J., Černajová I., Holá E., Novozámská E., Čížek L., Iarema V., Baltaziuk K. & Svoboda T. (2015): Value of old forest attributes related to cryptogam species richness intemperate forests: A quantitative assessment. – Ecological Indicators, 57: 497–504.

P4: Hofmeister J., Hošek J., **Malíček J.**, Palice Z., Syrovátková L., Steinová J. & Černajová I. (2016): Large beech (*Fagus sylvatica*) trees as 'lifeboats' for lichen diversity in central European forests. – Biodiversity and Conservation, 25: 1073–1090.

P5: Malíček J. (2014): A revision of the epiphytic species of the *Lecanora subfusca* group (Lecanoraceae, Ascomycota) in the Czech Republic. – Lichenologist, 46: 489–513.

P6: **Malíček J.**, Berger F., Palice Z. & Vondrák J.: Corticolous sorediate *Lecanora* species (Lecanoraceae, Ascomycota) containing atranorin in Europe (manuscript, submitted to Lichenologist).

P7: Vondrák J**., Malíček J.**, Palice Z., Coppins B.J., Kukwa M., Czarnota P., Sanderson N. & Acton A. (2016): Methods for obtaining more complete species lists in surveys of lichen biodiversity. – Nordic Journal of Botany 34: 001–008.

P8: Vondrák J., **Malíček J.**, Palice Z., Bouda F., Berger F., Sanderson N., Acton A., Pouska V. & Kish R.: Forest lichen diversity exceeds expectations; enormous species richness in hot-spots of an old-growth beech forest (manuscript submitted to Ecology and Evolution).

P9: Malíček J., Palice Z. & Vondrák J. (2014): New lichen records and rediscoveries from the Czech Republic and Slovakia. – Herzogia, 27: 257–284.

P10: Kubiak D. & **Malíček J.** (2012): *Gyalidea minuta* in Central Europe – new data on its distribution, ecology, and morphological variation. – Mycotaxon, 119: 11–16.

3. Conclusions

Forest lichens are one of major ecological groups among lichenized fungi in Central Europe. They are important indicators of forest continuity, age, fragmentation, tree composition, amount of dead wood, type of management and stand heterogeneity. These factors and their influence on species richness and composition have been demonstrated in numerous studies, especially from Scandinavia, Italy and Central Europe. In cooperation with foresters and other researchers specialized in cryptogams, the importance of old trees, especially old beeches, and coarse dead wood objects for maintenance of species richness in Czech forests was proved (papers 3 and 4).

Simultaneously, floristic data from various old-growth forest remnants in the Czech Republic and Slovakia were collected mainly due to a better knowledge of species composition, distribution and variability (papers 9–10). Similarly like the two previous ecological studies (papers 3 and 4), numerous floristic records also helped towards a better understanding of forest parameters influencing the lichen biota in Central European forests.

Surprisingly, almost no previous publications were focused on a detailed diversity inventory, for example with emphasis on complete species lists from the most preserved Central European primeval forests. Of course, a great number of floristic papers with single records or more or less short species lists exist, but the simple question "How many lichens occur in an old-growth forest reserve?" was very difficult to answer. We studied lichen diversity of two of the most valuable Central European primeval forests, Žofínský prales and Stužica (papers 1 and 2), and some other old-growth woodlands (e.g. Guttová et al. 2012, Malíček & Palice 2015). The papers give us quite a good vision about species richness in Central European primeval forests, present long species lists, new country records and data on distribution of species regarded as regionally rare or extinct.

However, it remained still unclear, if the captured diversity was close to the real species richness or not. Additionally, it was very difficult to compare our results to each other as well as to repeat the survey with similar results. Therefore, we focused on sophisticated field methods for obtaining more complete and comparable species lists. It was clearly indicated that lichen inventories done by one or two lichenologists strongly underestimate the total diversity (papers 7 and 8). An exhaustive survey of subjectively selected hot spots by several competing lichenologists was evaluated as the most effective field method for more complete species lists (paper 8). Such data collected from a defined area (a 1 ha plot recommended) are comparable to each other in contrast to randomly collected records from areas of various sizes. This new method was also used for a comparison of old-growth vs. managed Czech beech and spruce forests. Preliminary results indicate surprisingly high diversity in all forest types and great differences in the species richness and composition among managed and unmanaged forests.

Unfortunately, the new methods didn't solve all problems with the primary data, even when collected using sophisticated methods. Other problems were hidden in the identification of samples – it was impossible to recognize several species despite the using of chemical methods and DNA barcoding. It was necessary to start with taxonomical work, focused mostly at a very large and problematic genus *Lecanora*. Some identification problems were connected with a large variability of single species, an incorrect concept of some species or a wrong character interpretation (papers 5 and 6). Nevertheless, several crustose lichens from old-growth forests remained undetermined and they were evaluated as new species even though the Central European lichen flora is one of the best explored in the world. It was more evidence of how poor our knowledge is about forest lichens. Most of undescribed species are sterile sorediate crusts, e.g. *Lecanora substerilis* Malíček & Vondrák ined., hardly distinguishable without an analysis of secondary metabolites (e.g. Paper 6). A short overview of several other undescribed taxa (genera *Bacidia*, *Japewia*, *Loxospora*, *Micarea*, *Verrucaria*) from Central European forests is included as well. However, their descriptions still remain in preparation.

Old-growth forests are a unique example of native habitats, which predominated in the Central European landscape up to the Middle Ages. Localities without a visible human impact are extremely rare, small and isolated. Therefore, they should have the highest priority in nature protection. Cryptogams are very probably the most suitable group for an evaluation of a forest quality because their species richness distinctly exceed e.g. vascular plants and vertebrates; old-growth forests are usually local hot spots of fungi, lichens and bryophytes, they are occupied by many red-listed species, substrate specialists and species absent in managed stands. Lichens as sensitive bioindicators reach their peak of diversity on trees and dead wood in old woodlands. Therefore, they are an optimal model group for forest studies. However, lichens still belong to poorly known and studied organisms. This study tries to contribute to our better knowledge of their diversity, ecology and taxonomy; it tests and suggests new methods for surveys of forest lichens and summarizes basic data on old-growth forest lichens that could be used, for example, for a more effective nature conservation in the future.

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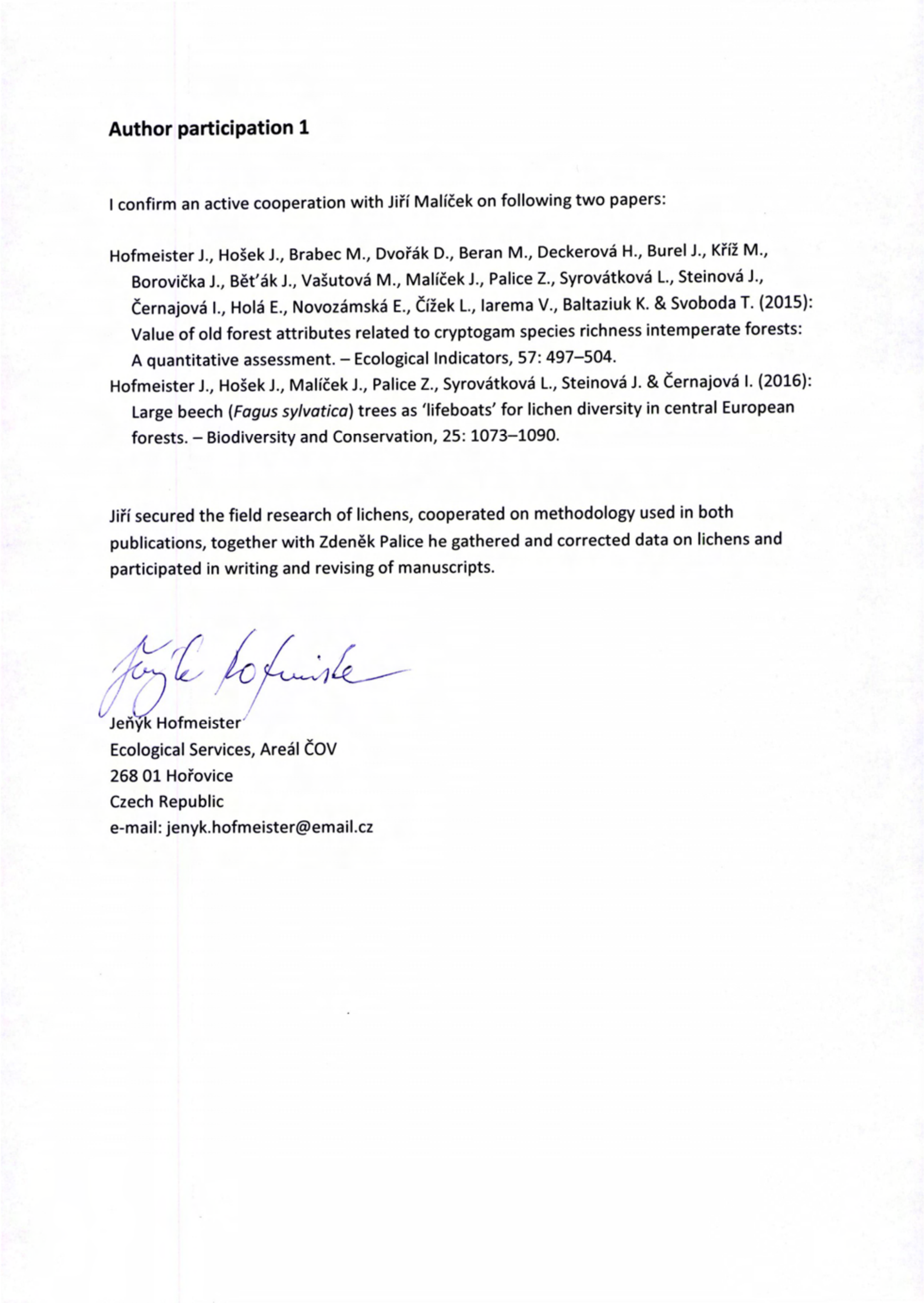
5. Supplement – author participation



Author participation 1

I confirm an active cooperation with Jiří Malíček on following two papers:

Hofmeister J., Hošek J., Brabec M., Dvořák D., Beran M., Deckerová H., Burel J., Kříž M., Borovička J., Běťák J., Vašutová M., Malíček J., Palice Z., Syrovátková L., Steinová J., Černajová I., Holá E., Novozámská E., Čížek L., Iarema V., Baltaziuk K. & Svoboda T. (2015): Value of old forest attributes related to cryptogam species richness intemperate forests: A quantitative assessment. – Ecological Indicators, 57: 497–504.

Hofmeister J., Hošek J., Malíček J., Palice Z., Syrovátková L., Steinová J. & Černajová I. (2016): Large beech (*Fagus sylvatica*) trees as 'lifeboats' for lichen diversity in central European forests. – Biodiversity and Conservation, 25: 1073–1090.

Jiří secured the field research of lichens, cooperated on methodology used in both publications, together with Zdeněk Palice he gathered and corrected data on lichens and participated in writing and revising of manuscripts.

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Contribution by Jiří Malíček to the following publication:

Dariusz Kubiak, Jiří Malíček. 2012. *Gyalidea minuta* in Central Europe – new data on its distribution, ecology, and morphological variation. Mycotaxon 119: 11-16.

Both authors collected the material and contributed to manuscript preparation. I estimate the overall percentage contribution of Jiří Malíček in the creation of the article at 50%.

D. Kubiak
Dariusz Kubiak

Contributions by Jiří Malíček to the following publications

VONDRÁK, J., **MALÍČEK, J.**, ŠOUN, J. & POUSKA, V. 2015 Epiphytic lichens of Stužica (E Slovakia) in the context of Central European old-growth forests. – Herzogia 28: 104-126.

Jiří Malíček participated in the field work, identification of lichen specimens and revision of the manuscript.

VONDRÁK, J. , **MALÍČEK, J.**, PALICE, Z., COPPINS, B., KUKWA, M., CZARNOTA, P., SANDERSON, N. & ACTON, A. 2016. Methods for obtaining more complete species lists in surveys of lichen biodiversity. – Nord. J. Bot. Doi: 10.1111/njb.01053 (in press).

The methods were figured out by Jiří Malíček and me.
He also participated in organizing the field work, gathered field data, identified lichen material, and wrote parts of the manuscript.

VONDRÁK, J., **MALÍČEK, J.**, PALICE, Z., BOUDA, F., BERGER, F., SANDERSON, N., ACTON, A., POUSKA, V. & KISH, R. Forest lichen diversity exceeds expectations; enormous species richness in hot-spots of an old-growth beech forest (submitted to New Phytologist).

Jiří Malíček contributed to the methods and the plot design.
He also participated in organizing the field work, gathered field data, identified lichen material (employing TLC and molecular barcoding), revised part of difficult specimens from other co-authors, excerpted part of literature data, and revised the manuscript.

V Českých Budějovicích
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Jan Vondrák