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Exploiting hot-spots; effective determination of lichen diversity in a Carpathian virgin forest

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Abstract

Although lichenized fungi are among the most reliable indicators of forest quality and represent a considerable part of forest biodiversity, methods maximizing completeness of their species lists per area are lacking. Employing a novel methodological approach including a multi-expert competition and a search for local hot-spot plots, we have obtained outstanding data about epiphytic lichen biota in a part of the largest Central European virgin forest reserve 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 along an altitudinal gradient. Recorded alpha-diversities in plots ranged from 181–228 species, but estimated species richness is in the range 207–322 species. Detected gamma-diversity was 387 species; estimates are 409–484 species. 93% of the species found in the forest were recorded in plots, but only 65% outside the plots. This underlines the high-efficiency of the multi-expert competitive survey in diversity hot-spot plots. Species richness in each one-hectare plot was equal to the numbers of species obtained by floristic surveys of much larger old-growth forest areas in Central Europe. Gamma-diversity detected in the Uholka primeval forest far exceeded all numbers achieved in Central European old-growth forests. Our method appears to be both effective (it obtains a more nearly complete inventory of species) and practical (the resources required are not unreasonably large).

Introduction

Forests have the highest biodiversity among terrestrial biomes [1]. Regrettably, many natural forests have been destroyed during the last few centuries. In some regions, including Central

Europe, pristine forests have almost vanished, being altered by land use, and only fragments remain. These remnants support the greatest diversity of many forest organisms, among them epiphytic and epixylic lichens (e.g. [2–6]) which are considered the most reliable indicators of forest-continuity and forest quality [7,8]. Tiny crustose lichens, that are often neglected, are especially sensitive to environmental changes as they are intimately associated with microhabitats [9,10].

It has been shown many times that cryptogam diversity in old-growth forests is not uniformly distributed (e.g. [11–13]), and that large parts of these forests (much more than 50%) have rather low local diversity. Species richness of epiphytic lichens is much greater in hot-spots, such as humid valley bottoms, ridges with rock outcrops, gaps and screes or timber-line forest edges [14,15]. Furthermore, the diversity is not equally distributed within particular forest habitats. Each habitat has a specific variability in microhabitats and substrates suitable for numerous niche-specific lichens [16–18]. In old-growth forests, lichen diversity is positively correlated with the amount of variety in the forest structure [19–22], which is influenced by microclimatic and soil conditions and by natural disturbances. Diversity of lichens is not uniformly distributed in the vertical dimension either. Species composition and trait diversity of lichens in canopies differ strongly from that on tree trunks [23,24].

The simplest measure of the quality of a forest is its total biodiversity, i.e. the total number of species present. Although conceptually simple, actually obtaining it is far from simple: it is challenging, even for experts, to determine all (or nearly all) the species present. Remnants of several important European old-growth forests have been surveyed for lichen diversity using a variety of methods, including taxonomic surveys and ecological sampling [25], most of which were based on random records [15,26,27]. However, in a very heterogeneous environment random sampling can not obtain an inventory that is near to complete (unless the area under study is tiny, or the survey is impractically large). It will tend to omit specific microhabitats and locally rare species. Unrelated to that problem, there is the further difficulty that some lichen species are small, inconspicuous and very easily overlooked.

A related problem is that of plot size. If individual plots are large, the problems discussed above for the forest as a whole will occur (though to lesser degree) for each plot. That will result in incomplete and/or biased species lists for each plot, which makes comparisons between plots difficult or meaningless. The obvious solution is to use numerous small plots (much less than 1 hectare) that can be surveyed more easily [3,13,28–35]. This does facilitate some kinds of statistical data processing [25], but it creates new problems: (1) Rare species (which may have significant bioindicative value) are unlikely to be sampled [12]; (2) Uncommon substrates and microhabitats (which may have numerous species with specialised requirements) are unlikely to be sampled; (3) The majority of the plots will be in "boring" parts of the forest with low biodiversity and the rare localities with high biodiversity ("hot-spots") are unlikely to be sampled adequately, or at all. Although these problems can be reduced by increasing the number of plots, they can not usually be reduced enough unless the number of plots is increased to a level that would require impractical resources of time, manpower and money if each plot is to be surveyed thoroughly [36]. In practice, use of a large number of plots is likely to mean that plots are not surveyed thoroughly.

These kinds of problems led some researchers to try a different method: a detailed diversity survey in larger plots (one to several hectares), but with no or few repeats within a locality [37–39].These surveys were always performed by more than one researcher, which results in better recording of rare and inconspicuous species, as each researcher has different skills. Although this method can yield almost complete species lists per plots, it requires an enormous sampling effort. For example, Lõhmus et al. [38] reported an astonishing 500 person-hours for a single 2-hectare plot. This usually makes repeated surveys impractical. We are inclined to employ larger plots (we chose 1 hectare squares), but we realized that their placement in the forest must be carefully selected to avoid impractically large sampling effort.

Lichenologists do not seem to have available a sampling method that (1) allows meaningful comparison between different localities, (2) requires only a feasible amount of resources, and (3) yields species lists that are reasonably close to complete. As regards the first point, we extracted lichen diversity data from numerous surveys of Central European forests [39,40], and we concluded that the species lists are hardly comparable. They are strongly affected by the different survey methods used and the different skill sets of those who did the surveys. Here we propose a method that, in our view, goes a long way towards meeting all three goals.

Our method combines the multi-expert competitive approach [39] with a search for local diversity hot-spots. The former ensures that any plot that is studied will be studied very thoroughly, and the resulting species list for it will be close to complete. The latter ensures that all (or at least most) biologically important aspects of the forest will receive such attention. Together, these ensure that goal (3) above will be met. The resource requirements, though obviously greater than if only a single worker were to make the survey, are not excessive: goal (2). The method can be applied in a standardised way, which should ensure that goal (1) is met.

Our aim in the work reported here was simply to use the method to survey epiphytic lichens in a single large forest and to determine whether it worked, i.e. to determine whether we had overlooked any serious problems. Basically, that meant demonstrating that it meets goals (2) and (3). Our aim was not to confirm formally that it meets goal (1), though we expect that it does. Formal confirmation of that will require surveys of several forests and is beyond the scope of the present paper which is based on a research in the largest Central European primeval forest, Uholka–Shyrokyi Luh in the Ukrainian Carpathians.

Methods

Administration of the Carpathian Biosphere Reserve (Rakhiv, Ukraine) provided permission for our research.

Surveyed area and timing

We surveyed one of the Carpathian Biosphere Reserves, "Uholka–Shyrokyi Luh" (c. 30 km NE of Khust, western Ukraine), one of the largest old-growth forest complexes in Europe with 10400 ha [41]. It was systematically surveyed for lichen diversity by Dymytrova et al. [33], so we can compare our results with theirs. Rare lichen species known from the locality [33] indicate that the forest is rich in lichen species. We surveyed a 2300 ha part called Uholka, on the southern slopes of Mt Menchul (Fig 1). The terrain is rugged, often formed by steep slopes, separated by numerous valleys with watercourses at altitudes 400–1200 m. The area is dominated by *Fagus sylvatica*, but the forest is not homogeneous throughout (see [41] for details). Our field research in May 2015 lasted eight days; four days for seeking suitable plots and conducting an overall lichen diversity survey, four more for surveys in plots (see below).

Stratified non-random plot selection

The first four days were devoted to a search for hot-spots. We wished to find four 1 ha plots that could be expected to include most of the lichen biodiversity present in the forest. Our own field experience and discussions in the literature [12,13,24] indicated that we should look particularly for: (1) a multilayered canopy indicating a non-even-aged forest; (2) the presence of over-mature, dying and dead trees with weathered and mossy bark; (3) the presence of both standing and lying dead wood; (4) the highest diversity of tree species at the local scale; (5) the

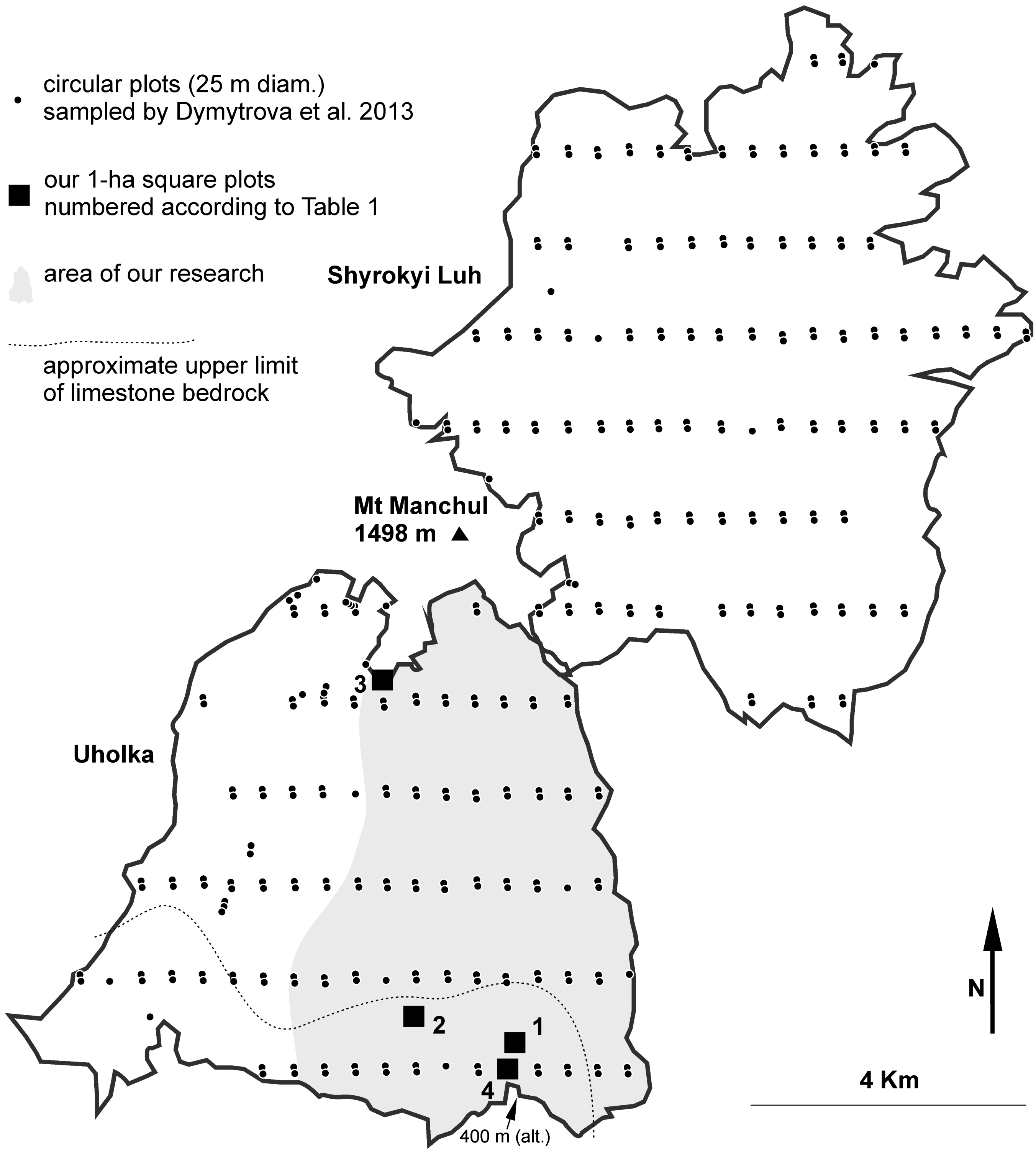

Fig 1. Sampling area. Protected area of old-growth beech forest "Uholka–Shyrokyi Luh" surveyed by Dymytrova et al. [33] by a systematic sampling on circular plots of 500 m^2 (black dots). The area is divided into a southern part, Uholka, and the northern one, Shyrokyi Luh. We surveyed only a part of 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 at lower altitude, in the area with limestone bedrock (below the dotted line).

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Table 1. Surveyed one-hectare plots in the Uholka forest.

	Coordinates	mean alt. (m)	available substrates (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

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.

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presence of small natural forest gaps; (6) the availability of canopy lichens on fresh windthrows or at least on fallen big branches (as we had no other way to survey canopy lichens). These criteria are usually met in sites where several different forest habitats meet and where the length of ecotones is maximized. We established two plots at low altitude in a deep valley, one at medium-altitude on a limestone ridge and one at the upper forest limit (Fig 1); their midpoints were localized by GPS (Table 1). The four plots contained most of the forest habitat types present in the area (Fig 2). The predominant forest type, a dense beech forest without any other intermixed tree species, covering more than 99% of the studied area, was included in all plots.

The "recipe" for locating a hot spot is thus: seek a site that has several of the six factors listed above (the more the better). Each of those factors is easy to spot visually, because it corresponds to something that is different from "the bulk of the forest", so our method is not difficult to apply. A future worker would have no difficulty locating hot spots, though they would probably be different hot spots than ours.

Multi-expert competitive survey

In the second stage, each of the four selected plots was surveyed by a team of experienced lichenologists (the first seven authors) using the competitive method [39]. The surveys were conducted by 7 experienced lichenologists over a period of 4 days. That may sound like a lot of manpower, but Uholka–Shyrokyi Luh is a very large forest. Smaller forests could be surveyed with fewer resources.

It has been shown that this method leads to a more complete species list, as was the case here; Table 2 and Fig 3 show the difference between records of individual researchers and all records per plot. The survey time per plot was six hours. This was not set at the outset of the study but was based on experience in plot 1. Researchers noted individual cumulative species lists in half hour periods (Fig 3), and in the 12th period on plot 1 all researchers recorded fewer than five additional species; this was taken to mean that almost all species present had been recorded and the survey of plot 1 was terminated. For subsequent plots we could have repeated this procedure of examining cumulative lists to decide the termination point, but for simplicity we decided to apply the same 6 hour survey period to each plot. The question of which approach is preferable could be investigated in some subsequent survey. Records were collated by the first three authors, who also revised and eliminated all suspicious records (possibly incorrectly identified or ambiguously identified specimens).

Species identification and molecular barcoding

Some lichens can not be identified in the field, and field identification of some others is prone to error, so we collected specimens for almost all species; most species were collected repeatedly (S1 & S2 Tables). We identified the collected material by standard lichenological

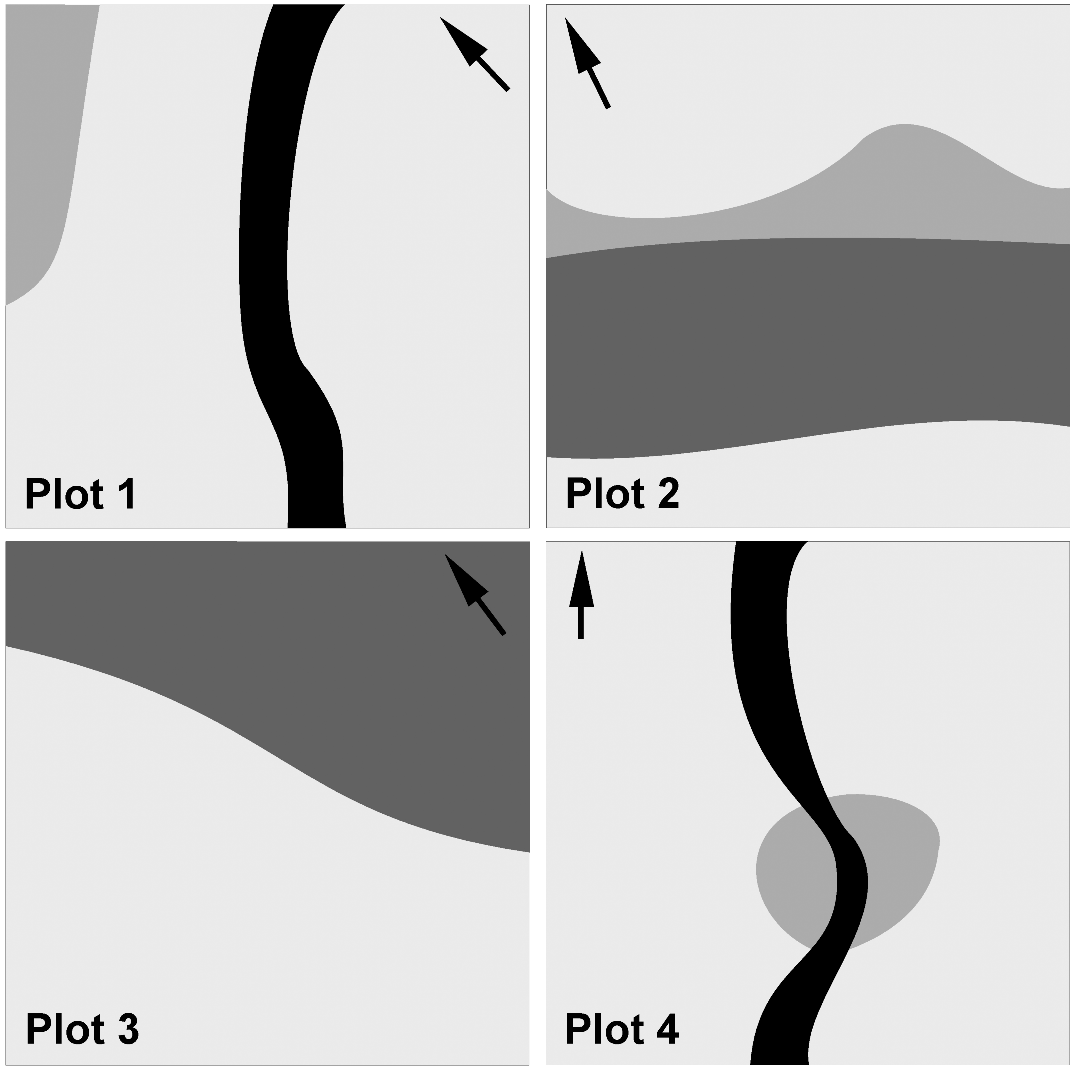

Fig 2. Variability of forest habitats in surveyed plots. The prevailing forest type, a dense beech forest without intermixed tree species, is present in all plots (pale grey). Wet ravine forest with common *Carpinus betulus* is present in the lowermost plots 1 and 4 (black). Sun-lit mixed forest on limestone 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.

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techniques (examination under the microscope, spot/UV reactions) and thin-layer chromatography (TLC) using solvent systems A, B', C, following [42]. Our appraisals of critical specimens/species and results of TLC analyses are described in S3 Table. Specimens with ambiguous characters (morphological or chemical) and specimens that appeared to belong to undescribed species were sequenced for nrITS and/or mtSSU DNA loci. We employed the NCBI's BLAST website [43] (http://blast.ncbi.nlm.nih.gov/Blast.cgi) to confirm their identity or at least to place them into a genus (S4 Table). Voucher specimens of all collections are deposited in the herbaria PRA (Palice and Vondrák), PRM (Bouda) and in personal herbaria of the other authors (S1 Table).

Table 2. Contrast between number of species from single researchers and the total number of recorded species.

researchers	plot 1	plot 2	plot 3	plot 4
Res. 1	110	124	134	111
Res. 2	99	106	139	90
Res. 3	85	97	136	90
Res. 4	76	61	83	65
Res. 5	78	67	96	68
Res. 6	75	82	97	75
Res. 7	62	—	94	81
Total	181	188	228	184

https://doi.org/10.1371/journal.pone.0203540.t002

Species and trait data for analyses

Because our concern in this study was with total biodiversity, not with how that diversity is distributed within the forest, we used only the presence or absence of lichen species in each plot (not data on abundance) to analyse the data: see S1 Table. Epiphytic and epixylic lichens, and facultatively lichenized fungi were included in the analyses. All species of the following genera are included, although some species are not lichenized: *Anisomeridium*, *Arthonia*, *Chaenothecopsis*, *Cresporhaphis*, *Cryptodiscus*, *Melaspileella*, *Mycocalicium*, *Naetrocymbe*, *Stenocybe* and *Ramonia*. We did record information on substrate, but it is not used in this analysis.

For simple analyses of functional traits (Fig 4), we employed a few basic traits commonly used in recent studies on lichen diversity [34,35,44,45]. They are: type of photobiont (cyanobacterial, trentepohlioid, others), complexity of thallus (microlichens, macrolichens) and presence/absence of vegetative diaspores.

Data analyses

Our four plots were compared with each other by the number of shared lichen species and by Sørensen's similarity index[46]. Each plot was also compared with those old-growth forest localities in Central Europe for which data is available ([15,39]; supplemented by some recent data). The whole dataset covered 43 localities and included 671 species (S5 Table). We applied the same taxonomic concepts throughout. Detrended Correspondence Analysis (DCA) in Canoco 5 [47], based on species presences/absences, was applied to display similarities (1) among our plots and (2) between our plots and other forest localities (Fig 5). Rare species were downweighted in DCA to reduce noise. In addition, species richness in our plots and in the whole studied area was compared with species richness per area obtained from 43 lichen inventories mentioned above (Fig 6).

Lists of species from each individual expert serve as incidence data usable for estimates of species richness. In other words, we may estimate how many species are present in total (i.e. including those species that were not recorded). We estimated species richness in each plot and also total species richness in the locality. We used the package Vegan for R (https://cran.r-project.org/web/packages/vegan/vegan.pdf) and employed four estimators implemented in the *specpool* function: Chao2 [48], jackknife1 & 2 [49] and bootstrap [50].

Results

Alpha diversities–species richness in plots

We recorded a total of 358 species in the plots. Each of our lower altitude plots (1, 2 and 4) had almost the same number of species (between 181 and 188), but plot 4, at the upper tree limit,

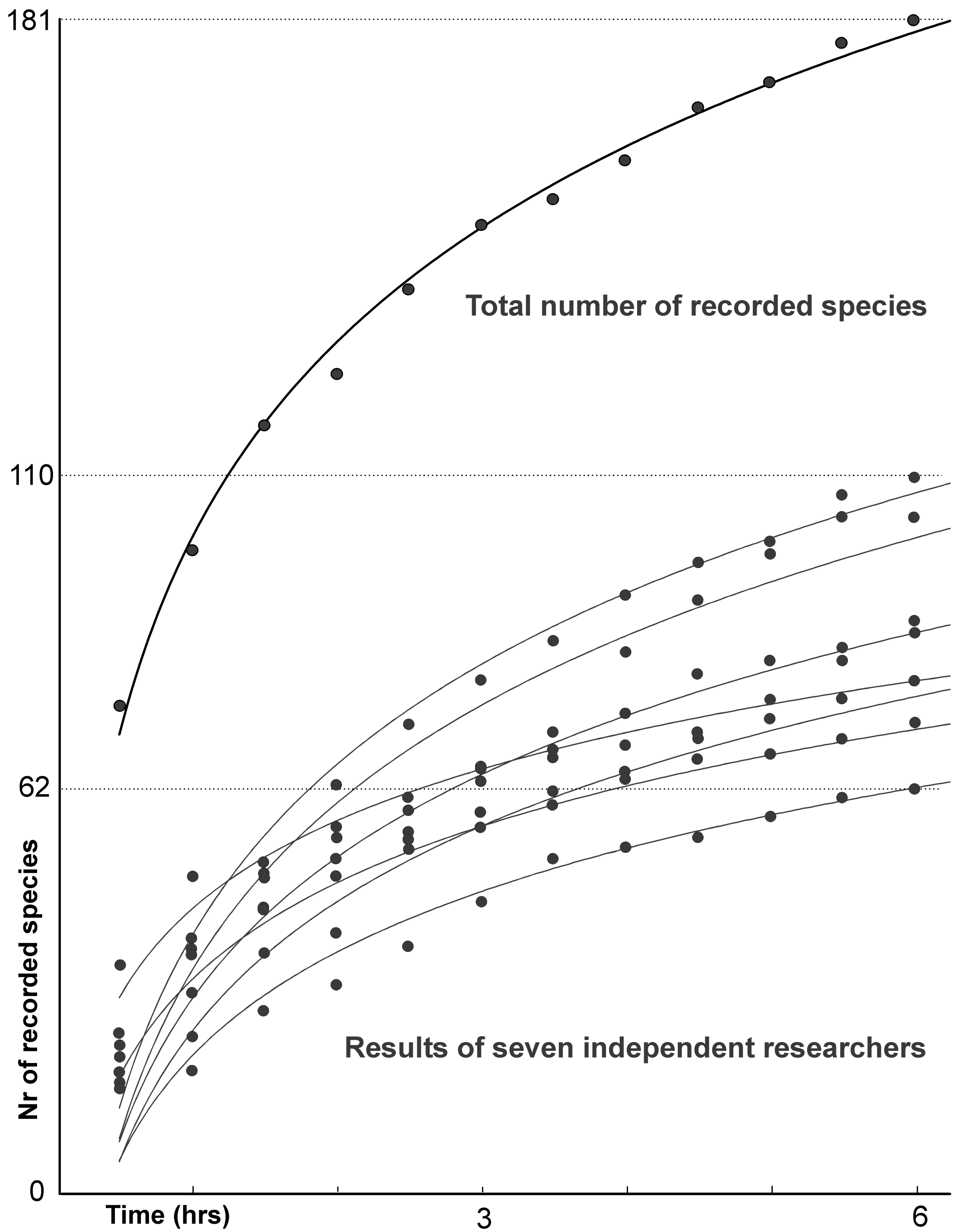

Fig 3. Lichen species recorded in plot 1 in twelve half-an-hour periods. Records of individual researchers (thin curves) and total records (thick) are approximated by logarithmic functions.

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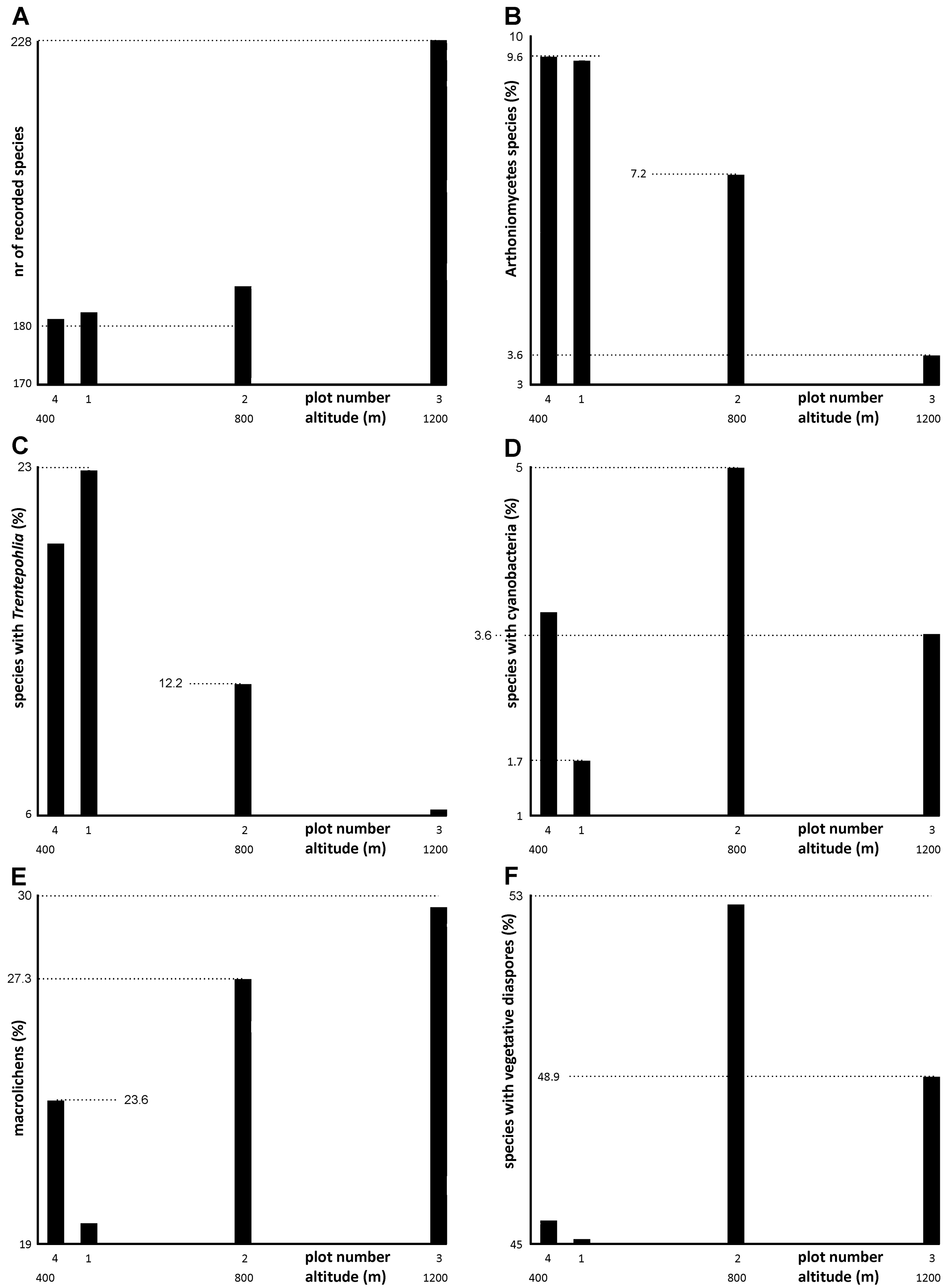
A
228
nr of recorded species
180
170
4
1
2
plot number
3
400
800
altitude (m)
1200
B
10
9.6
Arthoniomycetes species (%)
7.2
3.6
3
C
23
species with Trentepohlia (%)
12.2
6
D
5
species with cyanobacteria (%)
3.6
1.7
1
E
30
27.3
macrolichens (%)
23.6
19
F
53
species with vegetative diaspores (%)
48.9
45

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.

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had distinctly more species (228). Although these totals are satisfyingly high, the species richness analysis suggests that they are still far from a complete inventory (Table 3).

That analysis implies that we detected some 67–87% of the total number of species actually present (Table 3). The degree of completeness of our survey differs among plots. For example, plots 1 and 4 with similar numbers of detected species (181 and 184) differ in number of estimated species (249 and 275 species using Chao2 estimator). In other words, plot 1 was surveyed more effectively than plot 4 which had distinctly more rugged terrain and more varied forest structure.

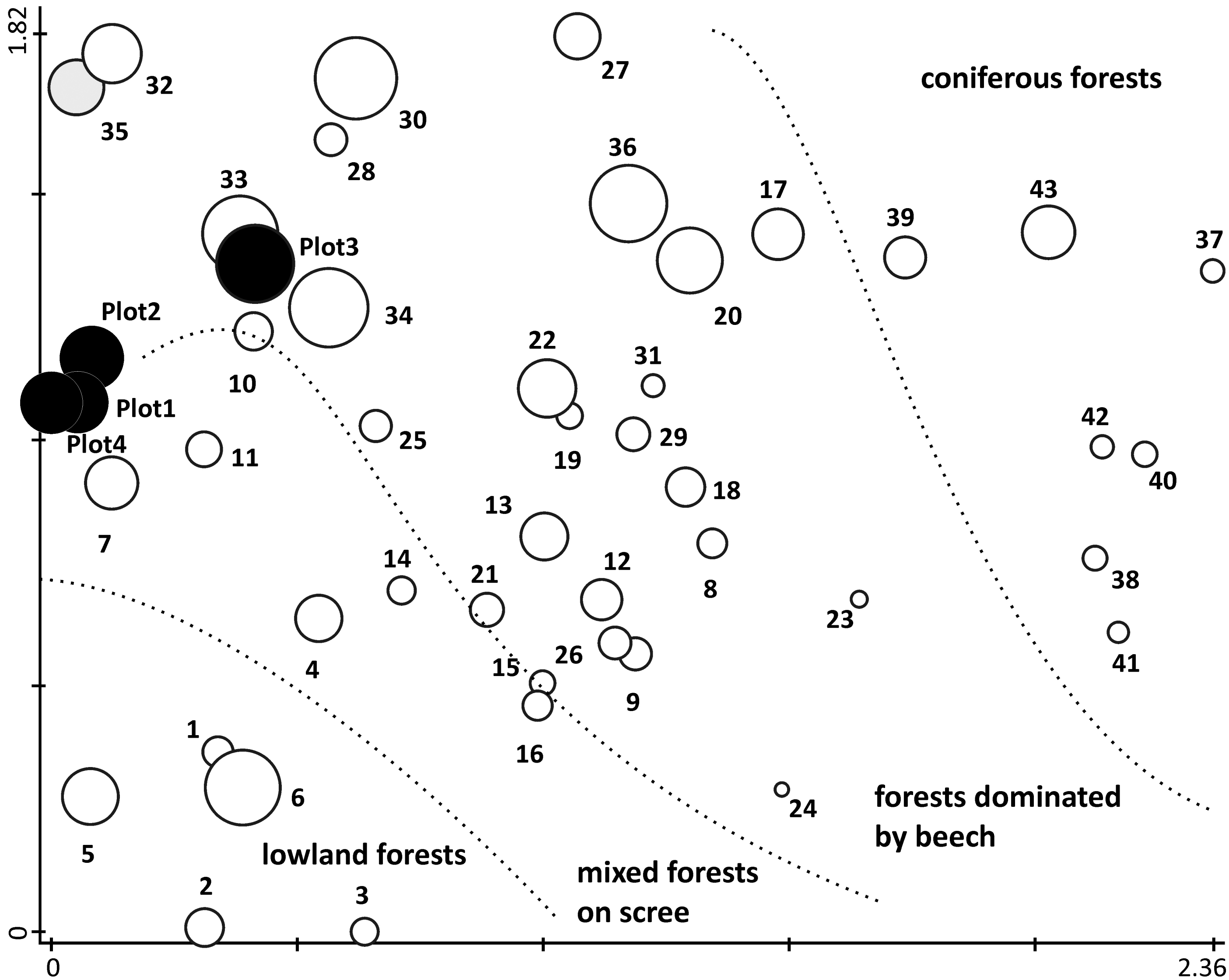

Fig 5. Revealed species composition compared with data available from Central European old-growth forests. DCA ordination diagram showing similarities in lichen species composition in our plots (black circles), in the previous inventory ([33]; grey circle) and in another 42 Central European old-growth forest localities (white circles). Numbers at localities correspond to S5 Table. 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. The plot is divided by the dotted lines into four areas corresponding to the main Central European forest types.

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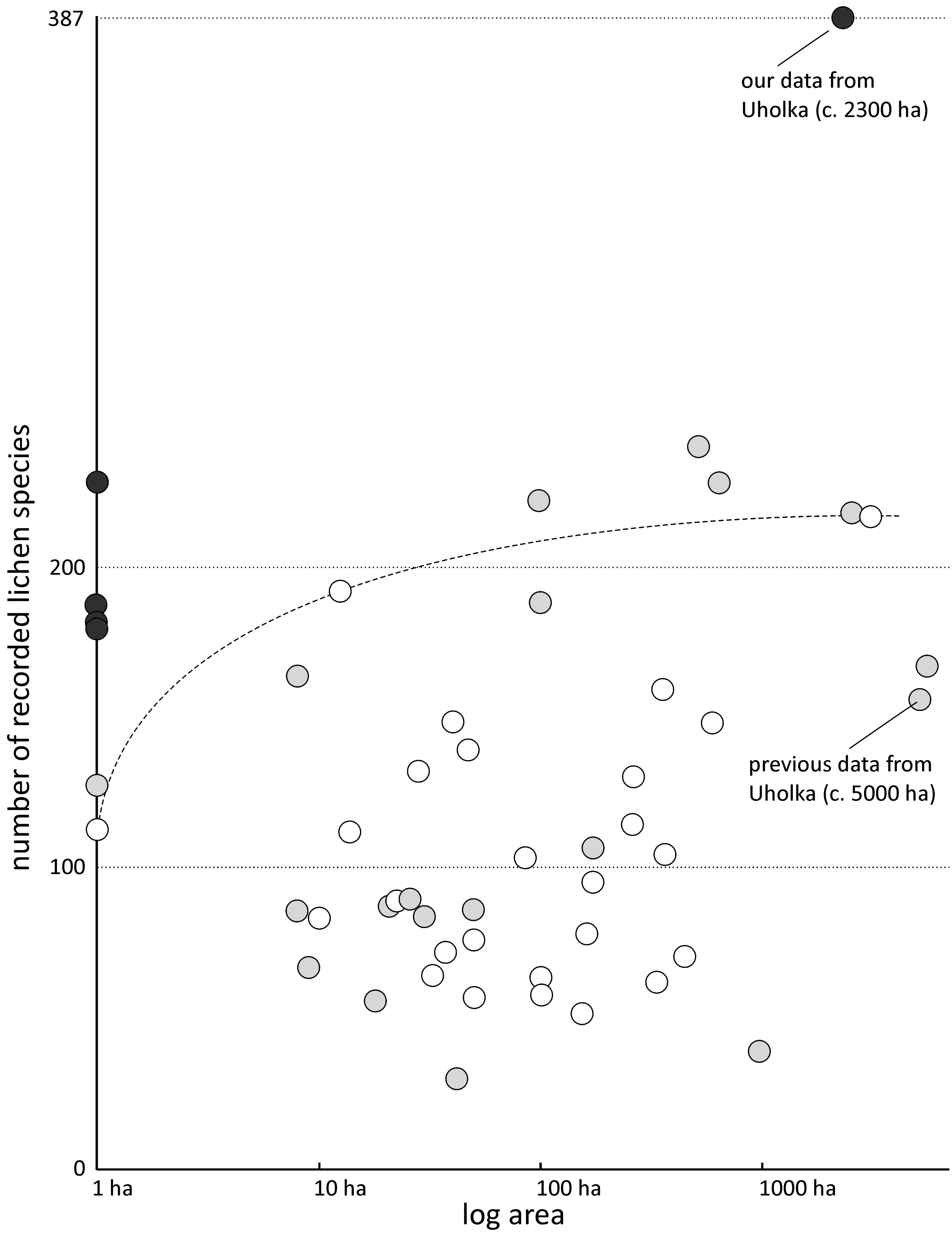
387
200
100
0
number of recorded lichen species
our data from
Uholka (c. 2300 ha)
previous data from
Uholka (c. 5000 ha)
1 ha
10 ha
100 ha
1000 ha
log area

Fig 6. Recorded species richness in the context of data from Central European old-growth forests. Our data (black dots) showing number of species in the 1-hectare 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* [39] is drawn by the dotted line.

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Gamma diversity–overall species richness

The total number of species recorded in all plots combined is 358. Recording outside plots yielded 251 species, but only 29 of them were not recorded within the plots (making an overall total for the forest of 387 species). The estimated number of species based on incidence data from seven researchers ranges from 409 to 484 (Table 3).

Beta diversity–differences among local diversities in plots

Sørensen's similarity indexes of species composition show that plot 3 (the high altitude plot) is different from all the others. Plots 1 and 4, which are close to each other and which have the same forest habitats, are the most similar (Table 4). Seventy-three species form a "common group" that occurs in all plots. This group has mostly common lichens with broad ecological amplitude, but also some rare species of old-growth forests (e.g. *Heterodermia speciosa*, *Menegazzia terebrata* and *Thelopsis rubella*). The lowland plots 1 and 4 share many species absent from other plots, e.g. the lowland species *Arthonia helvola* and *Coniocarpon cinnabarinum*. The upland plot 3 has numerous species not recorded elsewhere, some of them unexpected, including: i) the subalpine species *Caloplaca sorocarpa*, *Lecanora exspersa* and *Rinodina malangica*, ii) lichens characteristic of high montane coniferous forests, e.g. *Catillaria erysiboides*, *Frutidella pullata*, *Lecanora subintricata*, *Micarea globulosella* and iii) a few lichens that are normally saxicolous (e.g. *Acarospora fuscata*, *Circinaria caesiocinerea*, *Porpidia macrocarpa*) on bases of old beeches. Plot 2 situated on a limestone ridge has a rather heterogeneous lichen biota including sciophilous and hygrophilous as well as heliophilous xerothermic elements. The diversity of some taxonomic groups varies between plots; for example, in Arthoniomycetes diversity decreases strongly with increasing altitude (Fig 4B).

The proportion of lichens with trentepohlioid photobiont decreases considerably with increasing altitude (Fig 4C). The proportion of lichens with cyanobacterial photobiont is always low, though slightly raised in plot 2, which is influenced by its limestone bedrock and which has trees with slightly acidic to subneutral bark pH, e.g. *Acer platanoides* (Fig 4D). Macrolichens (i.e. foliose and fruticose lichens) are infrequent in all plots (c. 20–30%), but their proportion increases with altitude (Fig 4E), as they prefer higher humidity [34]. The proportion of species with vegetative diaspores is rougly constant, about 50%, in all plots (Fig 4F).

Uholka in the context of Central European forests

Lichen species composition in plots 1, 2 and 4 is most similar to deciduous mixed forests on limestone in the Muránska Planina Mts in the Western Carpathians in Slovakia (locs 7 and 11

Table 3. Detected and estimated species richness. Four estimators of species richness involved in the specpool function in the R package VEGAN are employed.

dataset / incidences (data from single researchers)	detected species richness	species richness estimations for incidence data; mean/standard error			
		chao2	jackknife1	jackknife2	bootstrap
all recorded species / 7	387	442/19	450/47	484	409/28
plot 1 / 7	181	249/23	235/22	265	207/11
plot 2 / 6	188	257/21	251/28	281	220/15
plot 3 / 7	228	297/21	291/29	322	259/16
plot 4 /7	184	275/28	249/30	286	215/15

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Table 4. Number of shared species (above diagonal) and Sørensen's similarity indexes (below diagonal) for all pairs of plots.

	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	–

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in Fig 5; [51,52]), but the higher altitude plot 3 is more similar to the Eastern Carpathian beech forest Stužica / Stuzhitsa (locs 33 and 34; [15]) and to an upland mixed forest in Hrdzavá dolina in Slovakia (loc. 10; [53]).

Discussion

Advantages and disadvantages of the new method

The trial at Uholka used a method which consists of exhaustive, multi-expert competitive sampling of 1-hectare moveable local hot-spots. It is an effective, practical method for obtaining representative datasets in biodiversity research. It can be applied in (almost) any type of forest in (almost) any region. The substantial increase in the number of species found by our method compared to the prior survey of the same area (357 versus 161) strongly suggests that our method works better than other survey methods that lichenologists have used. In contrast with conventional methods, our method has the following advantages:

1. **Movable character of the hot spot plots**. What we are calling a hot spot is basically any area that is very different from the bulk of the forest in ways that support species richness. Such areas are not fixed in position. They may—indeed, they almost certainly will—change over time, influenced by factors including natural disturbances, the presence of dying and overaged trees, accumulations of dead wood, etc. For that reason, a future survey of the same forest need not use the same plots that we used. If a substantial period of time has elapsed, then almost certainly it *should not* use the same plots. (This is why we use the expression *movable* hot-spot plots.)

2. Replicability. Theoretically, it is possible that selection of different hot spots in some future survey could result in a very different inventory of species than ours. In reality, we would not expect this to happen. First, we expect that similar hotspots, based on our 6 criteria, will give similar species. (We assume, of course, that future surveyors will make a sensible selection of hotspots, but this is not a particularly demanding task and does not require an unreasonably high level of skill.) Second, we believe our method has the potential to provide even greater replicability than conventional methods, as a simple consequence of the fact that our method samples the common species at least as well as conventional methods, but it samples the rare species much more thoroughly.

3. It yields more complete lists of species. 4) Data from a few hot-spots captures almost all of the diversity present within the entire forest. It will include most of those species that are widely distributed in the forest, either because their preferred substrate/habitat is widely distributed or because they are indifferent as to substrate/habitat. It will include most of the species that have specialised substrate/habitat requirements but which are fairly common when those requirements are met, because we have deliberately sought out these specialised substrates/habitats. However, it will include only some of the species that have specialised requirements but which are rare even when those requirements are met. (These are

typically species that have only a low population in the forest. They may occur at only very few sites, and whether or not they are recorded in any survey, even a focussed one like ours, is largely a matter of chance.) A conventional survey may do as well as ours for the first group of species, but it will do less well on the second and third groups. We expect that a repeated survey using our method at some future date will obtain an inventory that is similar to ours for the first two groups of species, but it may differ considerably for the third group, because the results for that group are more strongly influenced by chance factors. Species withIt will also include 5) Data from any hot-spot is directly comparable with data from other hot-spots. 6) Data from hot-spots can be compared in a useful way with data from larger plots/sites (even though the two datasets are not 100% compatible). 7) The data can be used to make statistical estimates of the total number of species present (i.e. including those that the survey failed to record). 8) The gaps in knowledge (or other kinds of "blind spot") of an individual lichenologist do not bias the results, because other recorders in the team compensate for them. 9) Each member of the team is likely to have specialised knowledge that the others lack, and may be able to record rare, or substrate-specific, or inconspicuous species, or species in difficult taxonomic groups that the other recorders would overlook. 10) Working in a team allows more expertise to be brought to bear on the identification of difficult specimens. 11) Field research is time-efficient. Only one (for a small forest) or a few (for a large forest) plots are required to survey a forest.

There are some limitations:

a. The method requires a team of experienced experts. b) All doubtful determinations made by the original team must be followed up by careful revision of the collections concerned, which can be time consuming. c) The small number of plots employed means that some kinds of statistical analyses can not be applied. d) Comparisons made among such plots must consider the possibility that selection of different hot-spots may yield slightly different results. (This could be tested, by replicating the study locally, though the effort involved might be excessive.)

Our lichen diversity survey vs. previous research in the locality

Grid ecological sampling (Fig 1) of lichen biota in the entire Uholka forest [33] resulted in a list of 161 lichen species. Their total sampling area was about eight hectares (163 plots × 500 m^2; see Table 5). Although they studied twice the area that we did, they recorded only about 45% as many species (Fig 6). Their survey differs considerably in species composition within some genera, e.g. *Arthonia*, *Biatora*, *Caloplaca* and *Micarea* (Table 5). They did record 24 species that we did not (though at least one third of that figure probably arises from different determinations of the same species). As noted above, we are well aware that the species list we obtained, though extensive, is not complete. Floristic differences are thoroughly discussed in Malíček et al. [40].

The percentage of macrolichens in beech-dominated forests is estimated to be about 27% [15]. It is 24% in our dataset from Uholka, but 41% in the previous survey. The high portion of macrolichens in the previous survey, together with the obvious imperfect detection within some microlichen genera (Table 5), suggest that a conventional survey tends to be a somewhat superficial survey.

Underestimated species richness in Central European old-growth forests

We do not claim that the Uholka forest has a distinctly higher lichen diversity than any other Central European forest, although a naive interpretation of our results might suggest that

Table 5. Comparison between our survey of lichen diversity and the previous research in the same area (Uholka in Fig 1).

parameters	Previous survey ([33]; only data from the part "Uholka"; see Fig 1)	Our data
Field research		
nr of plots	163	4
size / shape of plots	500 m2 / round plots with diam. c. 25 m	10.000 m2 / square plots
method of plot design	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
Detected lichen species richness		
nr of recorded lichen species	156	358 (in four 1 ha plots) / 387 (with records outside plots)
nr of species per plot: min—mean—max	1 - <20–40	181–195–228
portion of macrolichens in the species richness dataset	41% (64 of 156)	24% (91 of 381)
Nr of *Arthonia* species	3	13
Nr of *Biatora* species	5	13
Nr of *Caloplaca* (s.lat.) species	2	12
Nr of *Micarea* species	0	19

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conclusion (Fig 6). For example 228 species in plot 3 in Uholka is comparable with the highest numbers from large beech forest areas: 228 species per 630 ha [15] and 222 species per 102 ha [27]. We do claim that our survey method is superior to others and that this is a sufficient explanation for the differences. We suspect that the more humid Shyrokyi Luh forest (Fig 1), where Dymytrova et al. [33] recorded more species than in Uholka, is more species rich, while slightly smaller old-growth forest remnants, such as the Slovakian Stužica [15], Ukrainian Stuzhitsa [54–56] and Austrian Rothwald [57–59] may have comparable species richness per area. Forests dominated by beech (grey dots in Fig 6) are obviously more species rich than other forest types (white dots in Fig 6) which corresponds with results by Hofmeister et al. [4] considering old beech trees as a “lifeboat” for lichen diversity in Central European forests. However, some lowland forests are also known to be species rich (see the dotted line in Fig 6, which refers to a floodplain forest in the Czech Republic; [39]). These data were obtained by the multi-expert competitive survey, but without employing the search for diversity hot-spot plots.

Conclusions

We improved methods for recording epiphytic lichen diversity in forests so as to maximise the number of species detected per fixed area. Our method involves subjective selection of 1-hectare plots in local diversity hot-spots and a multi-expert competitive approach. It produces mutually comparable data and it appears to be substantially more efficient for assessment of species richness than methods used previously for ecological sampling or taxonomic surveys.

A detailed survey in the largest primeval forests in Central Europe, “Uholka-Shyrokyi Luh”, revealed unexpectedly high lichen diversity: 228 species recorded from a single 1-hectare plot is equal to the highest number of species recorded in Central European forests of far larger sizes. Gamma diversity revealed in the studied area (387 species) greatly exceeds all previous data from European forest localities. It also exceeds by more than a factor of two the Gamma diversity recorded from the same area by the previous detailed inventory employing a systematic grid sampling. We wish to stress the importance of local diversity hot-spots for lichen inventories and that such spots are usually sparse and unevenly distributed within a locality and must be deliberately searched for. In our opinion, any survey that does not pay particular attention to hot-spots will substantially under-estimate the number of species present. A future goal is a detailed evaluation of differences among species lists from different hot spots in the same locality.

Supporting information

S1 Table. Diversity data from the research in plots (1–4) and outside plots (out). Substrate abbreviations correspond with the Table 1. Vouchers are indicated by initials of the authors. Vouchers with asterisk are with TLC data; those with exclamation mark were sequenced (see S3 and S4 Tables). The nomenclature follows Hafellner & Türk (2016) [The lichenized fungi of Austria] and Wirth et al. (2013) [Die Flechten Deutschlands] in case of taxa missing in the former study. Species absent from both publications are provided by author initials.
(XLS)

S2 Table. Species lists made by individual researchers in plots 1–4.
(XLSX)

S3 Table. Notes to identifications and TLC results.
(XLSX)

S4 Table. Identifications of specimens according to NCBI's Blast results. NCBI's accession numbers are attached.
(XLSX)

S5 Table. The summary of lichen inventories in Central European old-growth forests, employed in Figs 5 and 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.
(XLSX)

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species	1	2	3	4	out	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 Dymytrova, Breuss & S.Y. Kondr.	1			1		FS	ZP2
Agonimia flabelliformis	1					log	ZP
Agonimia opuntiella				1		log	AA
Agonimia repleta		1	1	1	1	Apl, FE, FS	AA, JV3, ZP2
Agonimia sp.		1				QU	ZP
Agonimia tristicula	1	1	1	1	1	Apl, AP, FE, FS, QU, TIL, UG, snag (often on mosses)	FrB, JM2, JV3, ZP4
Alyxoria ochrocheila			1		1	FS, CB (wood in hollow)	JM, ZP
Alyxoria varia	1	1	1	1	1	AP, CB, FE, FS, UG, snag (FS)	FB, JV2, NS, ZP8
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 aff. *glaucella*				1		CB	FrB, JV2*
Arthonia atra				1		CB, FS	ZP2
Arthonia biatoricola			1		1	FE, FS (on Lecania croatica, Biatora chrysantha)	ZP2
Arthonia didyma	1	1	1	1	1	Apl, AP, CB, FS, TIL	AA, FB, JM, JV5, NS2, ZP5
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

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
Biatora albohyalina			1			FS	ZP
Biatora amylacea ined.		1				CB, FS	ZP2*
Biatora bacidioides Printzen & Tønsberg	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 (Degel.) Lendemer & Printzen	1			1	1	FS	AA, 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 Printzen, Palice & J.P. Halda			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
Bryostigma apateticum	1	1	1	1	1	AP, CA, CB, FS, SN	AA, FrB2, JM3, JV2, ZP3
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 aff. *obscurella*					1	FS	ZP!
Caloplaca cerina			1		1	FS	
Caloplaca cf. *cerinelloides*	1	1				FE (twig)	AA
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 sorocarpa			1		1	FS (trunk bases)	AA, 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
Chromatochlamys muscorum			1		1	FS	JV, NS, ZP2
Cladonia chlorophaea agg.	1	1	1		1	CB, FS, TIL, log	
Cladonia coniocraea	1	1	1	1	1	Apl, CB, FS, log	JM
Cladonia fimbriata	1	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 flaccidum		1	1	1	1	Apl, FE, FS, QU, TIL	AA, FB, JM2, JV2, ZP3
Collema nigrescens		1	1		1	TIL, FS	FB, JM
Coniocarpon cinnabarinum	1			1	1	CB	FB, JV, NS
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 furfuracea (Anzi) M. Westb. & M. Svenss.			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	1	1	1	1	1	AP, CA, CB, FE, FS, TIL, UG	AA, ZP9
Gyalecta croatica Zahlbr.					1	TIL, FS	NS
Gyalecta flotowii	1			1	1	AP, FS, UG	FB, FrB2, JM, JV2, NS, ZP4
Gyalecta herculina (Rehm) Baloch, Lumbsch & Wedin	1	1	1		1	Apl, AP, CB, FE, FS	AA, FB, FrB, JM, JV5, NS, ZP5
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
Hazslinszkya gibberulosa	1	1	1		1	AP, FS, TIL	AA, JV3, NS, 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
Inoderma byssaceum (Weigel) Gray				1	1	CB, FS	FB, JV2, ZP2
Japewia sp.			1		1	FS	JM*!, ZP*, JV3*
Lathagrium auriforme		1			1	Apl, FE, FS, QU	FB, JM, JV2, ZP2
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 J.R. Laundon s.l.	1			1		AP, 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 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 stanislai Guzow-Krzem., Łubek, Malíček & Kukwa	1					FS	JM*
Lecanora subintricata			1			snag	JV2, NS
Lecanora substerilis Malíček & Vondrák	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*
Lepra albescens	1	1	1	1	1	Apl, CB, FE, FS, TIL	JV5
Lepra amara	1	1	1	1	1	AP, Apl, CB, FE, FS, TIL (also twigs)	ZP*, JV2
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*
Leproplaca chrysodeta	1	1		1	1	CB, FE, FS, snag	JV, ZP
Leptogium cyanescens		1		1		AP, FE, FS, TIL	AA, FrB, JM, ZP
Leptogium saturninum		1	1		1	FE, FS, TIL	FB, JM2, JV, ZP
Lithothelium hyalosporum	1					AP, FS	JV, ZP
Lobaria pulmonaria	1		1	1	1	AP, CB, FE, FS	
Lopadium disciforme	1	1	1		1	CB, FS	JV, ZP2

Loxospora aff. *confusa* Lendemer	1	1				CB, FS	FrB*!, JM*
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)	
Melaspileella 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			FS	AA
Micarea perparvula (Nyl.) Coppins & Printzen	1					wood	ZP
Micarea prasina	1	1	1	1		AP, FS, UG, log, snag	AA, ZP*
Micarea soralifera Guzow-Krzem., Czarnota, Łubek & Kukwa				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
Myriolecis sambuci			1		1	FS, snag	FrB, JM, JV, NS, ZP4
Naetrocymbe punctiformis		1	1		1	FS, TIL	JV4, ZP2
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 agg.	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 Coppins & P. James	1					FS	ZP*
Opegrapha niveoatra	1	1		1	1	Apl, FE, FS	FrB, JV
Opegrapha trochodes	1	1		1	1	AP, CB, FE, FS, UG	AA, FrB2, JM, JV3, NS, ZP4
Opegrapha vermicellifera	1	1		1	1	AP, CB, FE, FS, UG	JM, ZP
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	
Parmoterma crinitum				1	1	CB, FS (also twigs)	JV2
Parmotrema arnoldii	1				1	FS	FrB, JM
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 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 (I.M. Lamb) Dibben				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 chloantha		1	1		1	CB, FS	FB
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)	
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*
Platismatia glauca	1	1	1	1	1	AP, TIL, FS (often twigs)	
Pleurosticta acetabulum					1	FS	
Polycauliona polycarpa			1		1	FS	
Porina leptalea	1	1	1	1	1	AP, CA, CB, FS, TIL	FB, JM, JV4, NS, ZP11
Porina cf. *leptosperma* Müll. Arg.	1			1		CB, FS	FrB2
Porina pseudohibernica Tretiach		1	1		1	FS, QU, TIL	JV2, ZP2

Porpidia macrocarpa (incl. *P. nigrocruenta*)			1		1	FS	AA2, JV4, ZP
Protoparmeliopsis muralis					1	FS (trunk bases)	JV
Pseudevernia furfuracea	1	1	1	1	1	AP, FS, TIL (twigs)	
Pseudosagedia aenea	1	1	1	1	1	AP, CB, FS, TIL	FrB, JV3, NS
Pseudosagedia byssophila					1	TIL	NS
Pseudoschismatomma rufescens	1	1	1	1	1	Apl, AP, CA, CB, FE, FS, QU, TIL	JV4, NS, ZP
Psoroglaena abscondita	1	1	1			log	JV
Psoroglaena dictyospora		1		1		snag, log	JV, ZP2
Psoroglaena stigonemoides				1		FS	ZP
Punctelia jeckeri	1			1	1	FS	
Punctelia subrudecta	1	1		1	1	FS, TIL (also twigs)	JV, ZP3
Pycnora sorophora					1	snag (QU)	
Pyrenula chlorospila Arnold	1					AP	JM
Pyrenula coryli	1			1		CB	JV2, NS
Pyrenula dermatodes (Borrer) Schaer.	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 agg.	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
Ricasolia amplissima			1		1	FS	
Rinodina albana			1			FS	ZP3
Rinodina capensis			1			FS, log	JM, JV, NS
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 subparieta (Nyl.) Zahlbr.	1	1	1		1	CB, FS (also twigs)	JV2, ZP3
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
Scytinium lichenoides				1		FS	ZP
Scytinium pulvinatum	1	1		1	1	Apl, AP, FE, FS, QU	JM2, JV, ZP2
Scytinium teretiusculum	1	1	1	1	1	Apl, FE, FS, QU, log	AA, FB, JV5, ZP
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
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 sp.	1					FE	ZP*!
Thelotrema suecicum	1			1	1	AP, CA, CB	FrB, JV2, ZP4
Toensbergia leucococca			1			FS	FrB, JV, NS
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 barbata		1	1			AP, FS, TIL (often twigs)	JM, ZP
Usnea hirta			1			FS (also twigs)	JV
Usnea perplexans			1			FS	JM
Usnea sp. (when no identified species in plot)	1					twig on ground	AA
Usnea subfloridana			1		1	FS	JM*

Varicellaria hemisphaerica	1	1	1			FS	FrB, ZP
Verrucaria breussii		1				QU	ZP
Verrucaria hegetschweileri Körb.			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	
Xanthomendoza fulva			1		1	FS, snag	JV2, NS, ZP
Xanthoria parietina			1	1	1	FS (canopy)	
Xylographa trunciseda			1			log	JM*
Zwackhia viridis	1	1		1	1	Apl, AP, CB, FE, FS	AA, JM, JV4, NS2, ZP5

S2 Table. Species lists made by individual researchers in plots 1–4.

	Berger				Bouda				Acton				Sanderson				Malíček				Palice				Vondrák			
species	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Absconditella lignicola	1		1	1			1				1	1						1	1		1		1	1	1		1	1
Acarospora fuscata																												
Acrocordia gemmata	1			1		1		1	1	1		1	1	1	1	1	1	1	1	1	1	1		1	1	1		1
Agonimia allobata										1		1	1									1		1		1		
Agonimia borysthenica																					1			1				
Agonimia flabelliformis																					1							
Agonimia opuntiella												1																
Agonimia repleta												1							1			1	1			1	1	
Agonimia sp.																						1						
Agonimia tristicula						1		1		1			1	1	1			1	1			1				1	1	
Alyxoria ochrocheila																			1									
Alyxoria varia	1			1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1		1	1	1	1	1	1
Amandinea punctata			1				1		1	1	1			1	1			1	1	1		1	1			1	1	
Anaptychia ciliaris			1								1							1	1			1	1				1	
Anisomeridium biforme					1								1											1				
Anisomeridium macrocarpum				1	1	1		1		1														1		1		1
Anisomeridium polypori	1			1					1	1		1	1			1	1	1		1	1			1	1	1		1
Arthonia aff. *glaucella*				1																								
Arthonia atra										1														1				
Arthonia biatoricola																							1					
Arthonia didyma					1								1	1				1	1	1		1	1		1	1		
Arthonia helvola				1	1																			1				
Arthonia mediella																			1			1	1				1	
Arthonia punctiformis			1						1												1							
Arthonia radiata					1				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Arthonia ruana	1			1	1	1	1		1			1	1			1	1			1	1			1	1			1
Arthonia spadicea	1			1	1		1		1			1	1	1		1	1			1	1			1	1			1
Arthothellium spectabile				1	1			1	1	1		1	1			1	1			1	1	1		1	1			1
Arthrorhaphis grisea																								1				
Aspicilia caesiocinerea																							1					
Bacidia aff. *bagliettoana*																							1					
Bacidia albogranulosa																	1				1			1	1			
Bacidia circumspecta						1		1				1	1				1				1	1	1		1	1	1	
Bacidia fraxinea																				1								
Bacidia incompta																												1
Bacidia laurocerasi																												
Bacidia pycnidiata																												
Bacidia rosella						1				1			1	1				1				1				1		
Bacidia rubella				1		1	1		1	1			1	1	1		1	1	1	1	1	1	1		1	1	1	1
Bacidia subincompta	1		1	1	1	1	1		1		1	1			1	1		1	1			1	1			1	1	
Bacidia vermifera																			1	1			1				1	
Bacidina delicata																											1	
Bacidina etayana																												

Bacidina neosquamulosa																	1											
Bacidina phacodes			1				1							1	1			1	1			1				1	1	
Bacidina sulphurella	1			1			1					1					1		1	1	1			1	1	1		1
Baeomyces rufus				1															1					1				
Biatora albohyalina																							1					
Biatora amylacea																						1						
Biatora bacidioides																								1				
Biatora beckhausii																												
Biatora efflorescens			1				1			1	1		1		1		1		1		1	1	1				1	
Biatora globulosa							1				1				1			1	1			1	1			1		
Biatora chrysantha											1		1		1				1				1				1	
Biatora longispora					1				1	1							1			1					1			1
Biatora mendax									1											1	1				1			
Biatora ocelliformis	1				1				1		1						1			1	1		1		1			1
Biatora pontica	1			1	1				1			1	1	1		1	1			1	1	1		1	1	1		1
Biatora radicicola																			1				1				1	
Biatora vernalis				1	1			1	1			1	1			1	1			1	1			1	1			1
Biatoridium monasteriense						1								1			1	1	1		1	1			1	1	1	
Bilimbia sabuletorum	1		1								1			1	1			1	1			1				1	1	
Bryoria fuscescens											1								1								1	
Bryostigma apateticum			1						1								1			1	1				1	1		1
Buellia disciformis	1			1	1	1				1		1						1	1	1		1	1		1	1		
Buellia erubescens																											1	
Buellia griseovirens	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Calicium glaucellum																		1										
Calicium montanum																												
Calicium salicinum			1			1	1							1	1				1				1			1	1	
Calicium trabinellum																												
Caloplaca aff. *obscurella*																												
Caloplaca cerina			1				1				1								1								1	
Caloplaca cf. *cerinelloides*									1	1																		
Caloplaca herbidella						1																				1		
Caloplaca chrysodeta					1				1			1	1			1	1			1	1				1	1		1
Caloplaca lucifuga																												
Caloplaca monacensis																			1				1				1	
Caloplaca obscurella							1				1											1	1					
Caloplaca sorocarpa			1																1				1				1	
Caloplaca stillicidiorum			1			1	1				1				1								1				1	
Caloplaca substerilis																							1					
Caloplaca turkuensis							1												1				1				1	
Candelariella efflorescens	1		1	1	1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Candelariella reflexa						1												1										
Candelariella vitellina																												
Candelariella xanthostigma	1		1	1		1	1				1							1	1	1		1	1			1	1	
Catillaria erysiboides											1												1				1	
Catillaria nigroclavata								1	1								1	1				1			1	1		

Catinaria atropurpurea										1													1				1	
Cetrelia cetrarioides				1																								
Cetrelia chicitae																							1			1		
Cetrelia monachorum	1		1		1	1		1	1		1		1	1	1	1	1		1	1		1			1	1	1	1
Cetrelia olivetorum			1															1	1	1	1			1				
Chaenotheca brachypoda	1		1	1	1			1				1	1			1				1				1	1			1
Chaenotheca furfuracea	1																			1			1		1			1
Chaenotheca gracilenta				1	1			1												1					1			
Chaenotheca trichialis	1		1						1				1												1			
Chaenotheca xyloxena																			1									
Chaenothecopsis debilis														1												1		
Chaenothecopsis pusilla									1	1			1	1		1		1		1								
Cheiromycina petri																												
Chromatochlamys muscorum			1								1				1								1					
Cladonia coniocraea			1	1	1	1	1	1			1		1		1	1		1	1		1	1	1	1	1	1	1	1
Cladonia fimbriata			1	1		1	1	1			1		1		1	1	1	1	1	1	1	1	1	1	1	1	1	
Cladonia chlorophaea	1		1						1		1								1			1	1		1	1	1	
Cladonia macilenta																			1									
Cladonia pyxidata			1		1		1				1			1	1				1								1	
Cladonia subulata																			1									
Cliostomum griffithii																												
Coenogonium luteum													1							1								
Coenogonium pineti	1			1					1		1	1	1			1		1	1	1	1	1		1		1	1	1
Collema flaccidum							1	1		1	1				1			1	1			1				1	1	
Collema nigrescens			1			1																						
Coniocarpon cinnabarinum								1					1															1
Cresporhaphis wienkampii																									1			
Cryptodiscus foveolaris			1	1						1	1												1	1			1	
Cryptodiscus gloeocapsa								1																				
Cryptodiscus pallidus											1																	
Cryptodiscus pini																												
Dictyocatenulata alba				1								1				1	1				1			1			1	1
Diploschistes muscorum			1																									
Evernia divaricata																												
Evernia prunastri	1		1		1	1	1			1				1	1		1		1		1		1	1		1	1	1
Fellhanera bouteillei				1																								
Fellhanera gyrophorica																												1
Flavoparmelia caperata	1				1	1	1	1	1			1		1		1	1	1		1	1	1		1	1	1		1
Frutidella furfuracea																			1				1				1	
Fuscidea arboricola															1				1		1	1				1		
Fuscidea cyathoides																					1				1	1		
Graphis scripta	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Gyalecta croatica																												
Gyalecta flotowii	1				1				1				1				1				1				1			1
Gyalecta herculina			1		1	1	1				1			1					1				1			1	1	
Gyalecta truncigena					1	1				1				1				1				1				1		

Gyalecta ulmi																												
Gyalideopsis helvetica																						1						
Halecania viridescens									1								1					1						
Hazslinszkia gibberulosa									1	1	1		1	1							1				1			
Heterodermia speciosa			1			1	1				1				1		1		1			1	1				1	1
Hypocenomyce scalaris			1																									
Hypogymnia farinacea						1													1									
Hypogymnia physodes	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Hypogymnia tubulosa	1		1	1	1	1	1	1		1					1		1		1	1	1		1		1	1	1	1
Hypotrachyna afrorevoluta	1				1			1		1			1			1		1		1	1			1	1			
Hypotrachyna revoluta																												1
Imshaugia aleurites																												
Inoderma byssaceum								1																1				1
Japewia sp.															1				1				1				1	
Lecania croatica	1			1	1			1	1				1	1		1	1	1		1	1	1	1	1	1	1		1
Lecania cyrtella			1																				1					
Lecania cyrtellina					1														1									
Lecania naegelii																												
Lecanora aff. *campestris*																												
Lecanora albella																												1
Lecanora albellula											1												1					
Lecanora argentata			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1
Lecanora carpinea			1	1		1	1			1	1											1	1			1	1	
Lecanora cf. *anopta*																							1					
Lecanora cinereofusca				1	1			1					1				1			1	1							
Lecanora compallens																	1			1								
Lecanora ecorticata																					1							
Lecanora expallens												1	1	1		1		1				1		1	1	1	1	1
Lecanora exspersa							1				1								1				1				1	
Lecanora glabrata				1		1	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1	1		1
Lecanora chlarotera			1	1			1											1	1									
Lecanora intricata																												
Lecanora intumescens														1				1	1			1				1		
Lecanora leptyrodes			1	1			1				1			1	1			1	1	1		1				1	1	
Lecanora phaeostigma																							1				1	
Lecanora polytropa											1				1				1				1			1	1	
Lecanora pulicaris			1		1	1	1	1	1		1				1	1	1	1	1	1	1	1	1	1	1	1	1	1
Lecanora saligna			1				1				1							1	1				1			1	1	
Lecanora stanislai																	1											
Lecanora subintricata			1												1												1	
Lecanora substerilis	1																1	1		1	1				1			1
Lecanora symmicta									1			1								1				1	1			
Lecanora thysanophora				1	1			1	1			1	1			1	1		1	1	1	1		1	1	1		1
Lecanora varia			1			1	1												1							1		
Lecidea erythrophaea													1								1				1		1	
Lecidea turgidula																							1					
Lecidella carpathica																							1					

Lecidella elaeochroma	1			1	1	1	1	1		1	1	1		1	1	1		1	1	1		1	1		1	1	1	1
Lecidella flavosorediata				1		1								1	1			1	1			1	1		1	1		
Lecidella subviridis																	1	1										
Lepra albescens	1		1	1	1	1	1			1	1			1	1			1	1		1	1	1	1	1	1	1	1
Lepra amara			1	1	1	1	1	1	1		1	1	1	1		1	1	1	1	1	1	1		1		1	1	
Lepraria eburnea																						1						
Lepraria elobata																			1								1	
Lepraria finkii				1	1	1	1	1	1			1	1	1		1	1	1	1	1	1	1	1	1	1	1		1
Lepraria incana			1															1	1		1		1					
Lepraria membranacea																												
Lepraria rigidula	1					1		1										1	1		1				1	1	1	
Lepraria vouauxii									1	1		1	1	1		1	1	1		1	1	1	1	1	1	1		1
Leptogium cyanescens				1				1		1		1								1				1				1
Leptogium saturninum			1			1	1				1				1				1				1				1	
Lithothelium hyalosporum																					1				1			
Lobaria pulmonaria			1				1	1			1				1				1	1			1		1		1	1
Lopadium disciforme													1	1							1	1	1		1			
Lothagrium auriforme						1				1				1				1				1				1		
Loxospora cristinae																												
Megalaria laureri				1									1				1								1			
Melanelixia glabra			1			1	1				1							1	1							1	1	
Melanelixia glabratula	1		1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Melanelixia subargentifera																												
Melanelixia subaurifera	1				1	1	1	1	1			1	1			1	1		1	1		1				1		1
Melanohalea elegantula	1					1	1	1					1					1	1			1	1			1	1	
Melanohalea exasperata									1	1	1										1				1			
Melanohalea exasperatula					1										1								1		1	1	1	
Melaspilea proximella										1								1				1				1		
Menegazzia subsimilis								1								1				1								1
Menegazzia terebrata	1			1	1	1		1				1	1			1	1			1	1	1	1	1	1			1
Micarea anterior																					1							
Micarea botryoides																					1			1	1			
Micarea byssacea										1		1																
Micarea cinerea																					1							
Micarea deminuta																								1				
Micarea denigrata																										1	1	
Micarea globulosella											1								1				1					
Micarea inconspicua																					1			1				1
Micarea lilacina																								1				
Micarea lithinella																								1				
Micarea melaena																												
Micarea micrococca										1								1	1	1	1			1				1
Micarea misella	1		1	1	1						1							1	1	1	1		1	1			1	1
Micarea nigella									1												1							
Micarea peliocarpa											1																	
Micarea perparvula																					1							

Micarea prasina									1		1	1									1			1				
Micarea soralifera																				1								
Micarea substipitata																							1					
Microcalicium arenarium																								1				
Multiclavula mucida			1	1					1				1			1					1				1			1
Mycobilimbia epixanthoides											1	1						1				1						
Mycobilimbia tetramera			1				1																					
Mycocalicium subtile			1				1	1						1	1	1	1		1							1	1	
Myriolecis sambuci			1								1				1				1				1				1	
Naetrocymbe punctiformis																							1			1	1	
Nephroma parile			1				1				1				1				1				1				1	
Nephroma resupinatum			1				1				1				1				1				1				1	
Nephromopsis laureri							1												1								1	
Normandina acroglypta				1																		1						1
Normandina pulchella	1			1	1	1	1	1	1			1	1	1		1	1	1		1	1	1		1	1	1	1	1
Ochrolechia alboflavescens			1								1								1									
Ochrolechia androgyna							1											1	1		1	1			1	1	1	1
Ochrolechia arborea																						1						
Ochrolechia microstictoides																												
Ochrolechia pallescens						1					1							1								1		
Ochrolechia szatalaensis														1								1						
Ochrolechia trochophora																												
Ochrolechia turneri						1	1				1			1	1			1					1			1	1	1
Opegrapha fumosa																					1							
Opegrapha niveoatra	1			1	1	1		1				1					1			1					1			1
Opegrapha trochodes	1			1					1	1		1	1				1				1			1	1			1
Opegrapha vermicellifera	1			1	1			1	1			1	1			1	1	1		1	1			1	1	1		1
Pannaria conoplea						1																				1		
Parmelia saxatilis	1		1	1	1	1	1		1		1	1	1		1	1	1		1	1	1		1		1	1	1	1
Parmelia submontana			1				1				1				1		1		1				1				1	1
Parmelia sulcata			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Parmeliella triptophylla				1		1		1			1			1	1	1		1				1	1	1		1	1	1
Parmelina pastillifera			1			1	1			1	1				1			1	1	1		1	1		1	1	1	1
Parmelina tiliacea			1			1	1							1	1			1	1			1	1			1	1	1
Parmeliopsis ambigua			1				1				1				1				1				1			1	1	1
Parmeliopsis hyperopta			1				1				1				1				1				1				1	
Parmoterma crinitum																												1
Parmotrema arnoldii	1																1											
Parmotrema perlatum	1		1	1																				1				1
Peltigera collina			1				1																1					
Peltigera praetextata			1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1		1		1	1	1	1	1
Pertusaria coccodes			1												1			1	1			1	1					

Pertusaria constricta																												1
Pertusaria coronata						1	1				1				1							1	1			1	1	
Pertusaria flavida							1																					
Pertusaria leioplaca	1			1	1	1	1	1	1	1				1			1	1	1	1	1	1		1	1	1		1
Pertusaria macounii																												1
Pertusaria pertusa			1	1	1	1		1	1	1		1	1	1	1	1	1	1	1	1				1	1		1	
Pertusaria pupillaris					1	1		1									1					1			1			
Pertusaria trachythallina	1								1																			1
Phaeophyscia endophoenicea					1	1	1	1						1			1	1	1		1	1	1		1	1	1	1
Phaeophyscia chloantha			1	1											1							1	1					
Phaeophyscia nigricans																											1	
Phaeophyscia orbicularis									1	1	1				1					1			1			1	1	1
Phaeophyscia pusilloides									1	1	1	1																
Phlyctis agelaea																						1						
Phlyctis argena	1		1	1	1	1	1	1					1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Physcia adscendens					1	1	1	1		1	1	1	1		1				1				1		1	1	1	
Physcia aipolia							1			1	1								1								1	
Physcia dubia							1				1				1				1				1					
Physcia stellaris						1		1																				
Physcia tenella				1	1		1	1	1	1							1	1		1	1	1		1	1	1		1
Physconia detersa			1																								1	
Physconia distorta																							1			1		
Physconia enteroxantha			1				1				1				1				1				1					
Physconia grisea						1																						
Physconia perisidiosa			1				1				1				1			1					1				1	
Piccolia ochrophora	1							1		1						1			1				1			1		
Placynthiella dasaea			1								1	1																
Placynthiella icmalea			1				1				1				1			1	1		1		1			1	1	
Platismatia glauca			1				1				1				1		1		1				1		1	1	1	1
Pleurosticta acetabulum																												
Polycauliona polycarpa																											1	
Porina cf. *leptosperma*	1																											
Porina leptalea	1			1	1	1		1	1	1		1	1	1			1			1	1	1	1	1	1			1
Porina pseudohibernica									1		1	1		1	1							1	1			1	1	
Porpidia macrocarpa											1												1				1	
Protoparmeliopsis muralis																												
Pseudevernia furfuracea	1		1	1	1	1	1	1	1	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pseudosagedia aenea	1			1	1	1	1	1	1	1		1	1				1	1		1	1	1	1	1	1	1	1	
Pseudosagedia byssophila																												
Pseudoschismatomma rufescens				1	1	1		1		1		1		1				1		1		1			1	1	1	1

Psoroglaena abscondita																									1	1	1	
Psoroglaena dictyospora																						1		1		1		
Psoroglaena stigonemoides																								1				
Punctelia jeckeri																1									1			
Punctelia subrudecta					1											1		1		1	1	1				1		1
Pycnora sorophora																												
Pyrenula coryli													1												1			1
Pyrenula dermatodes																									1			1
Pyrenula chlorospila																	1											
Pyrenula laevigata					1			1	1								1			1				1	1			1
Pyrenula nitida			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Pyrenula nitidella													1															
Pyxine sorediata																												1
Ramalina farinacea	1		1	1		1	1		1	1					1		1	1	1		1	1	1	1	1	1	1	1
Ramalina fastigiata			1			1	1			1					1				1			1	1			1	1	
Ramalina fraxinea							1																1					
Ramalina pollinaria			1			1	1		1	1		1	1		1	1	1	1	1	1		1	1		1	1	1	1
Ramonia interjecta																									1			
Ramonia luteola											1								1				1			1		
Rhizocarpon polycarpum																												
Ricasolia amplissima			1				1								1				1								1	
Rinodina albana																							1					
Rinodina capensis							1								1				1								1	
Rinodina efflorescens	1										1				1		1	1	1	1	1	1			1	1	1	
Rinodina griseosoralifera								1			1								1				1					
Rinodina malangica																			1				1				1	
Rinodina orculata																												
Rinodina sophodes									1																	1		
Rinodina subparieta																					1	1						1
Rinodina trevisanii							1			1	1								1				1				1	
Ropalospora viridis				1	1	1		1				1					1	1	1		1	1	1	1	1	1	1	1
Sclerophora farinacea	1				1			1	1				1			1				1	1		1		1		1	1
Sclerophora pallida				1	1			1	1	1		1	1			1	1			1								
Scoliciosporum chlorococcum											1					1		1	1				1				1	
Scoliciosporum sarothamni								1								1	1			1			1	1	1	1		1
Scoliciosporum schadeanum																					1							
Scoliciosporum umbrinum			1		1	1	1	1	1		1	1		1	1	1		1	1	1		1	1		1	1	1	1
Scytinium lichenoides																								1				
Scytinium pulvinatum								1		1		1	1	1			1	1		1		1			1	1		1
Scytinium teretiusculum						1			1	1	1							1				1				1		1
Steinia geophana							1						1			1				1	1		1	1	1	1	1	1
Stenocybe pullatula									1																			
Strangospora pinicola			1																									

Strigula glabra					1									1														
Strigula stigmatella								1				1				1	1							1		1		1
Tephromela atra																												
Tetramelas chloroleucus																							1				1	
Thelocarpon epibolum				1				1	1				1			1							1		1			1
Thelocarpon lichenicola										1																1		
Thelopsis flaveola																	1	1				1						
Thelopsis rubella	1			1	1	1		1	1			1	1			1	1	1		1	1	1	1	1	1	1		1
Thelotrema lepadinum	1			1	1			1	1			1	1			1	1	1		1	1			1	1			1
Thelotrema sp.																					1							
Thelotrema suecicum	1																				1			1	1			
Toensbergia leucococca			1				1								1												1	
Trapelia corticola																												
Trapeliopsis flexuosa			1				1				1				1				1				1			1	1	1
Trapeliopsis granulosa																		1	1									
Trapeliopsis pseudogranulosa											1																	
Trapeliopsis viridescens																										1		
Tuckermannopsis chlorophylla																			1								1	
Usnea barbata			1				1				1								1				1				1	
Usnea hirta															1												1	
Usnea perplexans											1								1									
Usnea subfloridana							1												1								1	
Usnea sp.									1																			
Varicellaria hemisphaerica	1		1																			1	1					
Verrucaria breussii																						1						
Verrucaria hegetschweileri			1																				1				1	
Verrucaria viridigrana				1																				1				
Vezdaea retigera																								1				
Violella fucata	1			1	1	1		1	1			1						1	1	1	1	1	1	1	1			
Vulpicida pinastri			1				1				1				1				1				1				1	
Xanthomendoza fulva			1				1				1				1				1				1				1	
Xanthoria parietina							1												1									1
Xylographa trunciseda																			1									
Zwackhia viridis	1			1		1		1	1			1	1			1	1				1			1	1			1
	62	0	94	80	75	82	97	75	79	67	96	69	76	61	83	65	86	97	135	91	99	106	139	90	110	124	134	111

S3 Table. 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 found.
Agonimia borysthenica	ZP19348, 19365	Collected specimens are quite small and sterile, overgrowing bryophytes. Thallus composed of convex, finely hairy (sub)globose granules. Distinct hairy papillae are apparently diminishing with age and hence not emphasized in the original description.
Anisomeridium biforme	ZP19542, NS s.n.	Only pycnidia present with subglobose conidia in ZP19542. Specimen collected by NS has well-developed perithecia.
Arthonia aff. *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	sterile, small granulate species of dry subneutral bark, seemingly resembling a *Lepraria* ; atranorin by TLC
Bacidia aff. *bagliettoana*	ZP19352	Morphologically resembling terricolous *Bacidia bagliettoana* with whitish thick thallus, but differs in 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	Sterile specimens; TLC: argopsin, norargopsin, gyrophoric acid; thalli resemble Biatora efflorescens, but chemistry and ITS/mtSSU data confirmed the identification.
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	FrB s.n., JM8266, JV14327, 14142, ZP19170, 19363	No compounds by TLC. Collected specimens represent paratype material of this taxon.
Bryostigma apateticum	JM8276, 8289, JV13925	Swollen and brown-capped paraphyses are absent.
Caloplaca aff. *obscurella*	ZP19260	Dark apothecia contain 'Cinereorufa-green' pigment 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	JV13382, 13394, 14101, 13982, ZP19399, 19583	atranorin, imbricaric acid, perlatolic acid, anziaic acid, 4-0-demethylimbricaric acid
Cetrelia olivetorum	FrB29167, ZP19373	atranorin, olivetoric acid (major), anziaic acid, 4-0-demethylmicrophyllinic acid
Cladonia subulata	JM14114	fumarprotocetraric acid
Collema flaccidum	ZP19451, etc.	Younger thalli with solely globose isidia may be misidentified for *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 furfuracea	JM8227, ZP19761	sphaerophorin
Fuscidea arboricola	JM8224, JV14110	fumarprotocetraric and/or protocetraric acids
Gyalecta croatica	NS s.n.	normally 8 celled non-halonate ascospores with occassional longitudinal septa; we follow Vězda (1958) in distinguishing this species from W-European *G. derivata* which has slightly longer, thinner and usually more septate spores
Japewia sp.	JM8238, ZP19774	A brownish sorediate crust resembling *Placynthiella dasaea* . Aliphatic compounds (major one: A4, B4-5, C4) detected by TLC.
Lathagrium auriforme	JM8125	Specimens from mossy bases of trees were originally identified as *Collema subflaccidum* (published from the area by Dymytrova et al. 2013), however our epiphytic specimens belong to *Lathagrium auriforme* , which is widely distributed on mossy limestone rocks in the area.
Lecanora aff. *campestris*	ZP19356, 19485, 19486, 19867	Except for the common chemotype I of *L. glabrata* , the chemotype II detected in previous samples. This strain is characterized by presence of the terpenoid *campestris* -unknown 1 according to Malíček (2014). It may represent a separate species and we call it as *L.* aff. *campestris* here.
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* sensu Lumbsch et al. with typical true cortex was recorded only very rarely in higher altitudes.
Lecanora cf. *anopta*	ZP20047	Isousnic acid by TLC. 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 ecorticata	JM8173, ZP19362	Usnic acid, zeorin and one unknown substance (trace, ?contamination) by TLC. Both collected specimens resemble *Lepraria vouauxii* in having a quite thick, yellowish cottony sublobate thallus, matching best description of Lecanora leuckertiana Zedda, a southern taxon not expected to occur in Central Europe (Kukwa 2006). We distinguish our specimens from recently described, thinly leprose *Lecanora stanislai,* awaiting additional studies on this group.
Lecanora exspersa	JV14117, 14118, ZP19165, 19235	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, traces of zeorin
Lecanora stanislai	JM8168	Usnic acid, zeorin, 2 unknown minor compounds.
Lecanora substerilis	JM8111, 8162, 8294, JV13946, 14050, ZP19223, 19611	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	Possibly a related taxon to *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 elobata	JM8230, 8250, JV14106	atranorin, stictic acid complex, zeorin
Lepraria finkii	JV13906, 13916, 14045, 14075, 14115	atranorin, stictic acid complex, zeorin (last substance not always detected)
Lepraria rigidula	JM8210, 8243, 8251, ZP19339	atranorin, nephrosteranic acid
Lepraria vouauxii	ZP19317, 19421, JV14108	pannaric acid 6-methylester and derivatives
Loxospora aff. *confusa*	FrB29222, 29239, JM8179	Sorediate crust resembling *Ochrolechia* or *Pertusaria amara* , containing 2'-O-methylperlatolic acid with 2-5 related compounds (visible in B' systeme).
Melanohalea elegantula	JV14098, 14099, 14102, 14122, ZP19283, 19387	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. The specimen JM8228 contains no gyrophoric acid by TLC as well as by spot tests of thallus sections, which suggests *Micarea synotheoides.* We follow the concept by A. Launis (pers. comm.), her preliminary results show that specimens from Central Europe without gyrophoric acid also belong to *M. globulosella* .
Micarea inconspicua ined.	ZP19417, 19788	Specimens earlier included in "*Micarea prasina* " with 'membranaceous thallus' (non associated algae), 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.
Micarea substipitata ined.	ZP19376, 19683	Pale sessile to shortly stipitate pycnidia resemble somewhat *Biatora veteranorum* , but they are non-crystalline; and thallus with micareoid photobiont. Tiny, non-pigmented apothecia contain dacryoid spores.
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)
Ochrolechia alboflavescens	JM8239	variolaric acid, atranorin (tr.), lichesterinic & protolichesterinic acids, 1 microstictoides-unknown
Ochrolechia androgyna	ZP19303, 19319	ZP specimens 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 cf. *leptosperma*	FrB29213, 29217	Anatomically most similar to *Porina leptalea* , but perithecia dark garnet red and thallus rough with tiny goniocysts. It was found twice in hollows of very old leafy trees in very shaded situations along the river. Material from both localitites is too scanty for critical examination whether it fits the Macaronesian material.
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 efflorescens	JV13954, 14105, 14113, 14124, 14125, ZP19315, 19412	pannarin, secalonic acid A, zeorin
Rinodina griseosoralifera	JV14123	atranorin, zeorin
Rinodina subparieta	ZP19172	atranorin, zeorin
Ropalospora viridis	JM8213, ZP19386, 19632, JV13959	perlatolic acid
Sclerophora farinacea	JV (7 specimens), ZP19405, 19601	Some of the specimens have somewhat smaller ascospores with the 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)
Scytinium lichenoides	ZP20046	Distinct from the common *S. pulvinatum* by coralloid isidia.
Thelotrema sp.	ZP19335	Sterile white crust with trentepohlioid photobiont and occassional tiny round bluish soralia; TLC: stictic acid.
Thelotrema suecicum	JV13922, 13970, ZP19635, 19652, 19702	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

S4 Table. Identifications of specimens according to NCBI's Blast results. NCBI's accession numbers are attached.

voucher	identification based on Blast	nrITS	mtSSU
JV13925	*Arthonia apatetica*	MG773662	MG773672
ZP19352	*Bacidia* aff. *bagliettoana*	MG773660	MG773690
ZP19221	*Biatora bacidioides*	MG773663	MG773673
ZP19685	*Biatora bacidioides*	MG773664	MG773674
JM8178	*Biatora bacidioides*	–	MG773674
ZP19334	*Biatora efflorescens*	MG773665	MG773676
ZP19307	*Biatora longispora*	MG773667	MG773678
JM8269	*Biatora pontica*	MG773666	MG773677
ZP19260	*Caloplaca* aff. *obscurella*	MG773661	
JM8255	*Caloplaca monacensis*	MG773668	MG773679
JV14274	*Caloplaca sorocarpa*	MG773658	–
ZP19680	*Caloplaca substerilis*	–	MG773691
JV14380	*Caloplaca turkuensis*	MG773657	–
JM8238	*Japewia dasaea* ined.	MG773669	MG773680
ZP20047	*Lecanora* cf. *anopta*	–	MG773687
ZP19343	*Lecidella subviridis* s.l.	–	MG773682
ZP19309	*Lecidella subviridis* s.l.	–	MG773683
JV13940	*Lecidella subviridis* s.l.	–	MG773684
JV14226	*Melaspilea proximella*	MG773655	MG773692
JV14359	*Melaspilea proximella*	MG773656	–
ZP19683 (apothecia)	*Micarea substipitata* ined.	–	MG773686
ZP19376 (pycnidia)	*Micarea substipitata* ined.	MG773659	MG773688
JM8199	*Mycobilimbia epixanthoides*	MG773670	MG773685
ZP19335	*Thelotrema* sp.	–	MG773689

S5 Table. The summary of lichen inventories in Central European old-growth forests, employed in Figs 5 and 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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