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Abstracts of the International Symposium „Fungi of Central European Old-Growth Forests“

Český Krumlov, Czech Republic, September 14–17, 2015

Held on the occasion of the 50th anniversary of the autonomous Mycological Department, National Museum, Prague (herbarium PRM, formerly a part of PR herbarium).

The symposium takes place in Český Krumlov (south Bohemia, Czech Republic), a UNESCO World Heritage Site, and former residence of the aristocrat Schwarzenberg family who declared the famous Boubínský virgin forest a protected site in 1858. Two days of presentations are followed by excursions to the nearby Boubínský and Žofínský virgin forests, the best-preserved old-growth forests in the Czech Republic.

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The abstracts are arranged in alphabetical order according to the surname of the first (presenting) author.

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How does connectivity of European beech forest reserves matter for fungal conservation?

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In this study, we aim to assess the influence of connectivity of European beech forest reserves on wood-inhabiting fungal communities, compared to the influence of local factors. For addressing this topic, we used a data matrix consisting of 344 fungal species in 1571 resource units sampled in 42 European beech forest reserves. Our results show that connectivity has significant effects on wood-inhabiting fungal communities in European beech forest reserves, and that the effectiveness of reserves for maintaining wood-inhabiting fungal diversity is compromised by habitat fragmentation. Connectivity at small scales had a strong influence on the occurrence of indicator species and was also critical for the number of species at resource level. Connectivity at larger scales seemed to be particularly critical for the community composition both at resource and reserve levels. Effects of habitat fragmentation were especially strong in western and northern European regions where the smallest and more isolated reserves were located. We propose that an effective conservation strategy of wood-inhabiting fungi should focus on increasing the areas of the present reserves as well as designating new reserves in the proximity of the existing ones.

Are ectomycorhizal *Russulaceae* important part of old-growth forests?

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During the succession process, several *Russulaceae* species are later incomers colonising root tips of trees in forests. A typical forest with high *Russulaceae* diversity is usually not connected to an old-growth European beech forest rich in decaying plant material. Moreover, only a small number of *Russulaceae* species are considered to prefer old-growth forests. This presentation summarises current knowledge of *Russulaceae* diversity in old-growth for-

ests based on studies of both ectomycorrhizal communities and data from collections of basidiomata.

Macrofungal biodiversity in silver fir and beech forests of south Europe (Liguria, Italy)

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Liguria is a coastal north-western Italian region characterised by a high variety of habitats of which forests constitute a remarkable percentage. Although Liguria does not comprise forests which have never been touched or have not been disturbed for several centuries, some sites with old-growth features can be found. Among these, two different stands, characterised by a dominance of *Abies alba* and *Fagus sylvatica*, respectively, were selected on the basis of old-growth criteria. Following a standardised sampling procedure, our aim was to assess the biodiversity value of these areas from the macrofungal point of view. Qualitative and quantitative sporomata analyses were performed in 40 plots surveyed over three consecutive years (2012–2014). We characterised macrofungal communities and identified potential indicator species by means of a set of biodiversity indices and statistics. The results showed that the two investigated sites had high biodiversity values especially in Species Richness and the Shannon Index. Ectomycorrhizal fungi were the most numerous. Some species were also significant indicators. Comparison of these results with those observed at other sites of Liguria, such as black pine plantations, chestnut and deciduous oak woods, indicated that both silver fir and beech sites had higher macrofungal biodiversity values than the other forest types.

Taxonomy of some old-growth forest fungi – what should we pay attention to

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Fungal species mostly differ in their morphological, molecular, ecological and distributional characters. Detailed studies showed that some species evidently “recognize” habitat naturalness, which correlates with their status of independ-

ent, often recently delimited taxa. Six model species preferring Central European old-growth forests (*Callistosporium pinicola*, *Clitocybula familia*, *Gymnopus herinkii*, *Ossicaulis lachnopus*, *Trichocybe puberula*, *Tricholomopsis flammula*) are discussed. We have observed several scenarios. 1. Two very similar species occurring in habitats of different degree of naturalness. All collections of *Ossicaulis lachnopus* from the Czech Republic and Slovakia originate from more or less natural habitats while most collections of its twin *O. lignatilis* are from man-made or man-influenced habitats. Further testing of their habitat preferences is necessary. 2. Two very similar species sharing the same habitat. The largest fruitbodies of the rare species *Tricholomopsis flammula* strongly resemble the much commoner *T. rutilans*. In some old-growth forests, the two species occur together. Each collection has to be studied carefully to reveal its identity. 3. Sudden appearance. *Callistosporium pinicola*, *Clitocybula familia* and *Trichocybe puberula* appeared in Central Europe in the last 15–20 years. They have not been collected before, not even at traditional localities. 4. Different regions – different preferences. *Callistosporium pinicola* and *Trichocybe puberula*, considered bioindicators of old-growth forests in Central Europe, grow in forest plantations or stands influenced by man in western or northern Europe.

Diversity and dynamics of fungal communities on decomposing wood

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The recent advances of molecular biology have substantially changed our ability to explore the communities of fungi in the environment. This also applies to the exploration of the mycobiome of deadwood, which is of special importance in old-growth forests where it represents a considerable stock of organic matter. Recent results obtained by using the analysis of environmental nucleic acids from deadwood – both DNA and RNA – indicate that this substrate is inhabited by a rich community of fungi showing a dynamic successional development. Specifically, the initial stages of decomposition are characterised by rapid fungal colonisation and transformation of deadwood while the later stages of wood decomposition, often >40 years for large logs, are less dynamic and seem to be driven by the presence of highly abundant fungi colonising large stretches of wood and forming conspicuous fruitbodies. The exploration of RNA which helps to indicate the active members of the community confirms the successional development and existence of priority effects, and ultimately links the appearance of certain fungi with the biochemical events of wood decomposition. Obviously,

molecular methods in combination with fruitbody surveys are able to provide information important for the understanding of fungal ecology as well as for fungal conservation.

Beyond species – functional response of fungi to environmental changes in forests

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Fungi are major actors in the functioning of forest ecosystems and because of the tremendous number of rare species they are of special interest for conservation. A large number of studies have shown that climate and variables characterizing the forest stand are important drivers of species diversity of various fungal guilds. However, mechanistic understanding why and how species assemble in a given environment is still limited. Moreover, understanding the drivers of fungal functional diversity, a proxy for ecosystem processes, would improve recommendations for forest conservation. Our studies showed that lichen functional diversity was very susceptible to climate variables whereas wood-inhabiting fungal functional diversity is mainly driven by local forest structural variables. In that respect, dead wood diversity, known to reach a high level in old-growth forests, seemed to be more important than the pure amount of dead wood. The close relationship between functional and species diversity indicated a low level of functional redundancy. Loss of species is therefore expected to decrease ecosystem functioning. Our study showed that maintaining ecosystem processes is mainly in the hands of the forest manager. Finally, old-growth forests serve as an important reference to study the effects of forest management on fungal functional diversity and therefore on ecosystem functioning.

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What do rare saproxylic fungi indicate in previously managed beech forests?

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Macrofungi of four beech forest nature reserves (Bukové kopce, Habrůvecká bučina, Holý kopec, Slunná) in the southern part of the Czech Republic (at an altitude ranging from 300 to 550 m a.s.l.) were surveyed (with uneven intensity; 9–20 visits) during the last five years. Although all studied localities are protected by law and in most of them non-intervention management was established, the history of their spontaneous development is relatively short (max. 30 years). A surprisingly high fungal diversity (355–471 species) was documented from all sites, including many red-listed (41–67) and rare saproxylic species suggested as indicators of habitat quality (10–15), which classify some of these areas into the most valuable old-growth beech forests in Europe. The highest number of indicator species was found at localities where a rapid increase of dead wood mass was observed as a result of windblows in the past 5–30 years. In concordance with Vandekerkhove et al. (For. Snow Landsc. Res. 79, 1/2: 145–156, 2005) we presume that the "natural" structure of saproxylic fungi communities (comprising species considered as rare and/or with high indication value) may be relatively quickly re-established – a few years – after achieving a stage of disintegration (often induced or accelerated by wind disasters) of the overmature (>150–170 years old), previously managed homogeneous beech stands.

Climate change effects on fungal communities and activity

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Earth's climate is undoubtedly changing. Effects of climate change on geographic distribution of fungi, fungal communities within forests and decomposing wood, and fungal activity are hard to predict because they are mediated by many different biological processes, including: fungal physiology, reproduction, survival, interspecific competitive interactions, resource availability, spatial and temporal distribution of hosts, and in the case of pathogens host physiology.

Long-term changes have been revealed by fruit body records. In many European countries there is evidence of changes in fruiting phenology with the fruiting season extending on average, although for some species it is contracting. Changes vary depending on the ecology of the fungi and geographical location. Some wood decay fungi now fruit early in spring as well as in autumn, and the spring fruiting is getting earlier, reflecting changes in activity. Some fungi, e.g. *Auricularia auricula-judae*, appear to be changing hosts. Communities within decomposing wood are also likely to be changing, since community composition depends on arrival, growth and interspecific interactions, all of which are affected by environmental variables.

Influence of forest type on fungal diversity in Mediterranean old-growth forests

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The macrofungal communities of Mediterranean old-growth forests in southern Italy were examined through the collection of sporocarps, over three consecutive years. The dominant trees of the observed vegetation encompasses various distribution areas ranging from *Fagus sylvatica* forests, extending from southern Sweden to northern Sicily, to *Quercus ilex* forests, limited to the Mediterranean basin. Sampling of 32 plots revealed 434 species of macrofungi, of which 177 were found in beech forests, 175 in chestnut forests, 246 in Turkey-oak forests and 131 in holm-oak forests. Comparison of means showed that Turkey-oak forests had a significantly higher macrofungal species richness than the other forest types. There were no significant differences in species richness between beech and chestnut forests, whereas holm-oak had the lowest species richness. Specific communities of macrofungi were found in each of the forest types as confirmed by non-metric multidimensional scaling and the multi-response permutation procedure. Indicator species analysis was used to identify macrofungi which are indicative of the four forest types. Results highlight the importance of maintaining tree species variety, enabling the development of diverse communities of macrofungi in forest stands.

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Importance of old-growth forests for macrofungal diversity

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Based on field mycologists' experience, small remains of old-growth forests in Central Europe are irreplaceable refuges for sensitive fungal species, which is intuitively explained by special microclimatic conditions, high substrate diversity, amount of large-diameter dead wood, and a long uninterrupted development. This, however, was only rarely confirmed by direct comparison with less preserved forest stands. Therefore, 72 permanent plots (2500 m^2 each) representing various forest management approaches, including 16 plots in unmanaged old-growth forests (OGF), were established in four areas in the Czech Republic (450–900 m a.s.l.) to study their species diversity. In total, we found 1305 macrofungal species during regular two-year fungal fruit body surveys, of which 809 and 1102 occurred in unmanaged and managed forests, respectively. The overall species richness was the highest in OGF plots (with a maximum of 284 species), and OGF also had the highest number of red-listed species and species exclusively occurring in a particular forest type. These were predominantly lignicolous saprotrophs occurring on logs of *Fagus* and *Abies* in later stage of decay. We documented a complex and indirect relation between species diversity and observed environmental factors such as amount of coarse wood debris (CWD) and age of forest stand.

Selecting and testing fungi as biodiversity indicators in old-growth forests

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Indicator species are widely used to guide conservation actions such as reserve site selection. Unfortunately, the indicator species concept is very poorly understood and often misused. To be useful, indicator species should be rela-

tively easy to survey and yield unbiased, reliable information about their environment or other biota. Fungi are a challenging group to be used as indicators because their surveys are often laborious and the knowledge about their ecology and taxonomy may be inadequate. On the other hand, fungi have some special qualities making them an particularly promising indicator group. For example, fungi have several important roles in forest ecosystems and an observation of a fungal fruit body always indicates the presence of a breeding population. In this talk I review the concept 'indicator species' and provide some examples of cases where fungi have been used successfully as an indicator species group. Finally, I give some general guidelines for selecting and using fungi as biodiversity indicators in forest conservation.

Fungal biodiversity of beech logs: comparison of a virgin and an old-growth forest

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The fungal biodiversity of a virgin forest and a forest with a management history were compared between the UNESCO world heritage sites "Uhol'ka-Shyrokyi Luh" (Ukraine) and "Kellerwald-Edersee" (Germany). Both forests harbour mainly *Fagus sylvatica*. For our comparison of the areas lignicolous fungi were studied. Therefore, beech logs of different decay stages were sampled. All visible carpophores on all logs were collected as well as three wood samples from each log, which were taken with an increment borer. Parameters possibly influencing the occurrence of species, like decay stage or moss cover, were recorded. The combination of the two sampling techniques provides a broader insight into the fungal diversity of decaying beech logs. Both methods revealed similar species diversities in both regions. The parameter region had the highest influence on differences between species composition of each log, based on the data of carpophores as well as data of wood samples. Furthermore, the parameters decay stage and moss and bark cover, which resemble the average moisture content, were detected to influence the species compositions of the sampling logs. Moreover, differences between species composition could to a certain extent be caused by forest history, with e.g. fewer late-stage species occurring in Kellerwald-Edersee.

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Wood-inhabiting fungi in European beech forests – local community drivers, continental biodiversity patterns and conservation

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Fungal communities in dead wood are highly diverse, and many species are poorly known, both in terms of ecological functions and with regard to conservation needs. This is the case globally as well as relating to the highly fragmented and degraded temperate forests of Europe. Based on two decades of research in European beech forest reserves it is evident that local habitat factors, especially relating to wood decay stage and log size, are crucial and consistent drivers of species richness and community composition at resource level. At the continental scale, climate is an important factor affecting species composition at site level, and as forest history and climate are strongly correlated at the European continental scale, it has been a challenge to disentangle effects of forest history and climate on fungal communities. However, ongoing research strongly suggests severe effects of forest fragmentation and lack of naturalness on fungal communities. These effects include changes in guild structure, loss of specialist species and decreasing beta diversity in conservation areas situated in degraded forest landscapes. These findings highlight the importance of protecting larger areas of remaining little disturbed forest in Central and Southeast Europe, and the need to enlarge conservation areas around remaining old-growth forest patches in northern and western Europe, rather than increasing conservation efforts in areas lacking natural forest heritage.

Is this fungus an indicator of selected habitat variables, e.g. degree of naturalness? Methods, advantages and problems of the traditional approach

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The indicator value of any fungal species should be evaluated scientifically before starting its use in nature conservation praxis. The first step includes verification of its taxonomic status. Careful morphological and, whenever possible, molecular study is desirable in most cases. A preliminary question is important: which habitat variable is (is not) indicated by the selected fungus? Then we have

to select a wide range of habitats and test the fungus occurrence in all of them. The testing should be done on pan-European scale, as the habitat preferences of some fungi differ considerably in various regions. We can use occurrence data from literature, herbaria, public databases and the Internet, each of them with its specific limitations (reliability of identification, taxonomic concept used, completeness of data, etc.). One well-documented find published in a local journal is more valuable than dozens of poorly documented database records. The final dataset consisting of verified records and data on habitat conditions of each locality should be evaluated statistically, either with simple methods (e.g. percentage of occurrence in habitats) or with sophisticated ones (multivariate analyses). Several species will be discussed (*Amylocystis lapponica*, *Camarops tubulina*, *Chromosera cyanophylla*, *Pholiota henningsii*, *Pseudorhizina sphaerospora*, *Tricholomopsis flammula*) as model examples. Unfortunately, not even a detailed study based on occurrence of fruitbodies can show the real distribution of mycelia in substrates and habitats. This is a challenge to the molecular era, which however needs sound hypotheses based on classical methods.

Mycobiota of the virgin forest „Neuwald“, a remnant of montane old-growth forests in Austria

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The Neuwald or Lahnsattel virgin forest, 20 ha, is a small remnant of virgin forest in Austria, located on the Lahnsattel, St. Aegyd/Neuwald, Lilienfeld, Lower Austria, at 900–1000 m a.s.l. in a humid-cool oceanic climate. The owner, count Hoyos, prevented the forest from harvesting in 1830 and so it remained without any silviculture. Only high deer densities disturb population dynamics, especially regeneration. The vegetation is a montane climax forest of *Fagus*, *Abies* and *Picea*, on limestone. There are trees of enormous dimensions and high amounts of deadwood. Sixty-two mycological excursions have been performed from 1979 onwards and annually from 1991–2014 with only few exceptions. A total of 759 species were found mainly by members of the Austrian Mycological Society but also visiting mycologists: T. Bardorf, H. Forstinger, A. Hausknecht, W. Jaklitsch, W. Klofac, K. Kalamees, G. Koller, I. Krisai-Greilhuber, M. Meusers, M. Moser, M. Noordeloos, F. Reinwald, I. Rimóczi, R. Singer, A. Urban, H. Voglmayr, and G. Wölfel. Indicator species of unmanaged forest types and coarse woody debris occur here, e.g. *Clitocybula* spp., *Cortinarius renidens*, *C. saginus*, *C. sanguineus*, *Cystostereum murrayi*, *Entoloma nitidum*, *Galerina pruinatipes*, *Gymno-*

pilus bellulus, *Hericium* spp., *Hydnellum concrescens*, *Lentinellus ursinus*, *Mycena romagnesiana*, *M. viscosa*, *Phellopilus nigrolimitatus*, *Pholiota squarrosoides*, *P. subochracea*, and rare species, e.g. *Chromosera cyanophylla*, *Baeospora myriadophylla*, *Pholiota squarrosoides*. Neuwald has many species in common with the Czech Boubínský prales National Nature Reserve.

High-throughput sequencing insights into wood-inhabiting fungal communities in Sweden

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High-throughput sequencing (HTS) allows for describing whole fungal communities, including non-fruiting and rare species. We have applied 454 and Ion Torrent sequencing to fungal communities in decaying wood in different contexts since 2008. First, we described diversity patterns and ecological roles of fungi in Norway spruce logs from two climatically contrasting protected forests. Then, we developed new fungal-specific primers optimized for the HTS techniques. A next study linked the fungal communities to wood density loss and organic composition after 12 years of log decay. Another project aimed to compare communities in stumps and in naturally formed logs in nearby protected areas on a latitudinal gradient in order to detect possible consequences of stump harvest for bioenergy purposes to fungal diversity. The most recent study targeted the whole fungal diversity in a landscape. Stumps, snugs, logs, branches and twigs of Norway spruce, Scots pine and silver birch on young and old clear-cuts, in young and old managed forests and in nature reserves were analyzed in this case. Finally, we would like to discuss the idea of a new project to study fungal diversity in old-grown forest on the European level, to model climate change threats to it, and to define options for adaptive conservation.

Ecology, incidence and indication value of *Hericium erinaceus* in Slovakia and the Western Carpathians

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Hericium erinaceus (Bull.) Pers. is an easily recognisable fungus which is rare in Europe. The sporocarps occur on living, weakened trees or dead trunks of broadleaved tree species. In Slovakia it grows predominantly in old-growth, natural and protected forests and it is widespread almost over the whole country. Twelve-year monitoring of 20 fallen trunks of Sessile oak (*Quercus petraea*) confirmed sporocarp incidence on five trunks. The occurrence of sporocarps was predominantly linked to the 2nd stage of decay. Results based on GLMs showed a significant effect of trunk length and volume on the occurrence of sporocarps. The sporocarps occurred at the same position of a trunk for up to four continual years and were observed in different parts of trunks. We evaluated compiled data of collections of the fungus in the territory of the Western Carpathians (Poland, Czech Republic, Hungary and Austria). The fungus can be found here in comparable numbers on living or dead trees, less on stumps, especially of oaks (*Quercus* spp.) and European beech (*Fagus sylvatica*) from lowlands to mountains. Sporocarps can survive for several months. Although it is not very rare in Slovakia, it has an indicative potential due to the fact that it grows mostly on senescent trees in broadleaved forests with natural tree species composition.

Drivers of polypore species composition in beech and oak forests: the Mátra Mts., Hungary

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Polypore species compositions were compared in managed (n=107) and preserved (old-growth, n=8) forest plots of the Mátra Mts. Three major forest zones were studied with dominance of beech (B), oak–hornbeam (OH), and Turkey

oak–sessile oak (TS) tree species. Polypore species composition was revealed by means of non-metric multidimensional scaling; dead wood properties (type, diameter, volume, species identity, decay stage) were fitted as environmental interpretations. Eighty polypore taxa were discovered. Managed B forests had a different polypore community compared to the managed OH and TS forests. OH and TS forests harboured highly shared polypore taxa. Reserved and managed stands had a similar polypore species richness, but different polypore species composition. Studying all forest zones simultaneously, the relative importance of environmental drivers of polypore species composition decreased along total volume, type, decay stage and diameter of dead wood units. When OH and TS forests (jointly) and B forests were studied separately, the polypore community in B forests was formed primarily by volume, then diameter, type, and decay stage of dead wood, while the polypore community of OH and TS forests was driven primarily by decay stage, then diameter of dead wood units. This study was supported by the Swiss Contribution Programme (SH/4/8).

Fungal diversity of Kellerwald-Edersee National Park – a first check-list with indicator species of nature value and conservation

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Kellerwald-Edersee National Park, a UNESCO World Natural Heritage site in Germany, was investigated during 10 years for its macromycetes. A first checklist with 1108 species is presented, 62 of which are threatened species listed in the German red list of fungi and 147 are listed in the regional red list of the federal state of Hesse. Further, 44 species of interest according to the criteria of the International Union for the Conservation of Nature and Natural Resources (IUCN), 16 species with nature value on a German scale and 10 species of nature value within a European scope have been detected so far. Compared to other national parks included in the UNESCO World Natural Heritage site named "Ancient Beech Forests of Germany and the Primeval Beech Forests of the Carpathians", the Kellerwald-Edersee National Park has fewer tree species on poor soils, thus exhibiting lower species numbers. Based on observation of old tree stands and relict primeval forest fragments we expect the forest ecosystem of the Kellerwald-Edersee National Park to reach near naturalness within a few decades.

Modelling the assembly of dead wood inhabiting fungal communities in changing landscapes

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One of the key aims in community ecology is to study the assembly of communities at different spatial and temporal scales, and how environmental conditions and biotic associations affect it. Dead wood inhabiting fungi are a group of species joint together by their demand for a woody substrate, with communities inside individual decaying logs consisting of dozens to hundreds of species. Analytically, the processes governing community assembly can be seen more as stochastic than deterministic, so that knowledge about environmental conditions and species interactions influence the likelihoods of certain community compositions. Our research aims to provide insight into the processes influencing the community dynamics of these fungi by utilizing a new statistical framework, and several large data sets from around Europe. We will i) estimate the relative importance of environmental filtering, biotic interactions and neutral processes, ii) build links from species traits to their environmental niches and positions in biotic interaction networks, and iii) evaluate the responses of communities to habitat loss and fragmentation in the light of the aforesaid processes. The framework and how these questions can be answered will be illustrated with results for a data set collected from beech forests in the Basque country.

Trends in European diversity of aphyllophoroid fungi (Basidiomycota)

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Europe is the best studied continent in terms of regional diversity exploration of aphyllophoroid fungi (non-gilled Basidiomycota), a species group of mostly wood-decomposers or ectomycorrhizal agents. Despite this, diversity trends of these fungi across the continent have never been evaluated. We assembled infor-

mation on species composition of aphyllophoroid fungi in 31 regions located along the full range of geographic and climatic variation in Europe. Our dataset currently comprises 1542 species. We are principal contributors to the study of eight of these regions: 1 in Germany, 2 in Denmark, 2 in Russia, and 3 in Ukraine). The hierarchical structure of the aphyllophoroid fungal communities was studied with UPGMA clustering supplied by non-parametric bootstrapping. The obtained classification of regions differed from the one based on climatic and vegetation data. Alternatively, similarity of regional fungal communities in a multidimensional way was explored with NMDS. Fungal species with significant preference for a particular region or cluster of regions were found with the IndVal method. Fungi of different fruitbody morphotypes were unequally distributed across the Europe. The proportion of polypores was significantly higher in boreal regions than in other parts of the continent. Possible scenarios of geographical differentiation of the aphyllophoroid fungal communities in Europe after the last glacial period are discussed and compared with those of main tree species.

Forest reserves as refuges for polypores in Hungary

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The Forest Reserve Programme was started in Hungary in the early 1990s. As a result of this, 63 forest stands became strictly protected reserves in the country with a total core area of 3,600 ha (0.19% of Hungary's woodland). Altogether, 168 lignicolous polypore species have already been reported from Hungary, out of which 115 species are also found in these forest reserves. It is known that polypore diversity is driven mainly by the amount and quality of dead wood, which is available in much larger quantities in reserved forests compared to managed stands. Hence, several polypore species are selective for forest reserves. We aimed to sum up the records of polypores collected from Hungarian forest reserves. We have already surveyed 14 reserves. Our results indicate that around 70 % of the lignicolous polypore species known from Hungary can be found in the studied 14 reserves (e.g. *Buglossoporus quercinus*, *Frantisekia mentschulensis*, *Ganoderma cupreolaccatum*). This study was supported by the Swiss Contribution Programme (SH/4/8).

Ecological niche analysis of ectomycorrhizal fungal species in an old-growth beech forest

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About 5000 to 6000 ectomycorrhizal fungal species (EMFs) are currently described worldwide. They play a major role in nutrient uptake and have a key function in temperate and boreal forests. EMFs respond very sensitively to anthropogenic impacts and environmental disturbances. Concepts to classify endangered EMF species are mainly based on monitoring methods such as presence/absence or amount of carpophore collections. This can be problematic, because carpophores are ephemeral and absence of a fruitbody does not prove the absence of the species. Furthermore, abundance of carpophores cannot be equated with the rareness of a species. For an appropriate classification of endangered species, it is important to know the factors limiting their occurrence. Based on population genetic studies from the last twenty years, which have showed that the mean mycelium size in ectomycorrhizal fungi is in most cases less than 5 m, a fruitbody-based sampling strategy was evaluated. We focused on the question whether the distribution of ectomycorrhizal carpophores is random or correlated with abiotic soil characteristics. Based on our dataset, we will give a short introduction to using a multivariate niche separation analysis tool. The advantages and disadvantages of our sampling method will be discussed.

Wood-inhabiting fungi of a Central-European mountain spruce forest

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The spruce forest on Plechý (Plöckenstein) and Trojmezná (Bayerischer Plöckenstein) Mts. in the Bohemian Forest is one of the largest natural forests in the Czech Republic. Both dominant and suppressed trees have been the source of various types of dead wood in all decay stages providing habitat for a diverse community of fungi. In total, 189 species of fungi were recorded on wood of *Picea abies* during sporocarp surveys from 2003 to 2015. Several species rare in Central Europe were found; e.g., ascomycetes: *Camaropella pugillus*, *Camarops*

tubulina, *Helminthosphaeria stuppea*, *Pseudographis pinicola*; basidiomycetes: *Antrodiella citrinella*, *Chrysomphalina chrysophylla*, *Cystostereum murrayi*, *Entoloma tjallingiorum*, *Hymenochaete fuliginosa*, *Kuehneromyces lignicola*, *Laetiporus montanus*, *Lentinellus castoreus*, *Oligoporus undosus*, *Panellus ringens*, *Panellus violaceofulvus*, *Phellinus nigrolimitatus* (locally abundant), *Phlebia centrifuga* and *Skeletocutis stellae*. *Globulicium hiemale* is classified as critically endangered in the Czech Red List but it is rather overlooked. Remarkably, *Tubulicrinis globisporus*, which is classified as possibly extinct, was found on one lying trunk on the mountain ridge. *Tubulicrinis globisporus* was found in the Bohemian Forest also on Großer Arber (Velký Javor) and on Pancíř (Panzerberg).

Wood-inhabiting fungi in mature mixed broadleaved forests of different management intensity

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Temperate lowland mixed broadleaved forests of Central and East Europe are rich in species, but little is known about their importance for wood inhabiting fungi. We studied forest characteristics and the diversity of rare poroid wood-inhabiting fungi species in differently managed mixed broadleaved non-beech forests in Lithuania, Poland, Belarus and Russia. The aim of the study is to determine the most favourable stand structure for the development of rare wood-inhabiting fungi. A total of 27 red-listed and old-growth forest indicator species were recorded. Downed dead wood, stand's stocking level and stand's tree age were the most important forest structure variables determining fungi species richness. Coarse woody debris was the most important substratum type and fungi species abundance on coarse logs was several times higher than on any other type of substrata. We recorded the highest number of fungi on *Quercus robur*, *Picea abies* and *Populus tremula*, while other tree species were at most half as important. The survey revealed lower species richness and abundance in intensively managed forests than in forests untouched by man for a long time. The number of studied fungi species was not significantly correlated neither to species richness for rare and indicator lichens nor for bryophytes.

What can we learn from species-specific fruiting phenologies?

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Conservation and management decisions considering fungi rely mostly on datasets in which the occurrences of species are based on observations of their fruit bodies. Detailed surveys considering species-specific fruiting phenology, a trait which has a great effect on the detectability of fungal species, are however surprisingly scarce. We conducted a highly intensive fruit body survey, in which the same 26 logs and their wood-inhabiting fungal communities were repeatedly investigated during one fruiting season. We monitored the timing and longevity of the fruiting for each observed fruit body group and used this information to study differences between different morphological groups. We also studied whether species-specific fruiting longevity is related to fruit body size. The within-group variation in fruiting longevity was high and the correlation between species-specific fruit body size and fruiting longevity was non-significant. The usefulness of these results in performing fruit body surveys and assessing the threat statuses of wood-inhabiting fungi, giving special emphasis on poorly known fungal groups, is discussed.

‘Old-forest polypores’ can be more useful for forest management than for recognizing old-growth

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Sustainable forest management and effective biodiversity conservation depend on adequate information feedback from current practices. Old-forest species constitute an obvious focal group for evaluating the state of forest biodiversity. Many species of polyporous fungi have been reported to be confined to old forests and this information has been used in practical conservation, particularly for identifying forests of high conservation value. The extent and causes of

old-forest affinity of these 'indicator' species are however insufficiently studied. We assessed the North-European lists of old-forest indicator polypores by using fruit-body survey data from 92 forest plots (representing old-growth forests, mature managed forests, and clearcuts of varying age) in Estonia. We asked the following questions: (1) how strong is the old-forest affinity for putative old-forest indicator fungi; and (2) can this affinity be explained simply by distinct substrate pools in old forests? We found that only a very few indicator polypores (all spruce-inhabiting) are entirely restricted to old-growth stands in Estonia, while most of them depend on specific substrates. 'Old-forest species' could thus serve well as targets for habitat management and restoration actions in silviculture, reserve management and landscape planning. However, the current approach of using such species as 'old-forest indicators' appears too simplistic and in need of revision.

Wood-inhabiting fungi in Białowieża National Park, Poland

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A series of polypore inventories was carried out by the Helsinki team of mycologists in the strictly protected area of the Białowieża National Park in 2008–2012, followed by a polypore identification course and a tutorial published in 2013. The activity resulted in a substantial collection of herbarium specimens, images and georeferenced observation records of more than 140 polypore species, including a few species new to Poland. A number of specimens are now under taxonomic scrutiny as candidate species new to science. This traditional approach of revisiting the mycota of Białowieża was followed by a plot survey of polypores and of corticioids of all dead wood elements in 24 plots of 20 × 20 m, 12 plots inside and 12 outside the strictly protected area in different habitats. The fruit body data collected outside the reserve borders are being complemented by e-DNA evidences of the presence and abundance of wood-inhabiting species.

In the search of indicator species among fungi, lichens and mosses for old growth forests in Switzerland

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Conservation strategies for fungi should be based on sound knowledge of the ecology of target species. As forest history shows, larger stands of old-growth forests are no more present in most parts of Western Europe. Therefore the search of appropriate indicator species of natural forest stands is complicated and the probable loss of species difficult to prove. For Switzerland we tried to define indicator and target species among fungi, lichens and mosses specific of forest types and forest management classes in five altitudinal belts. Indicator species for each forest type were defined using cluster analyses with data from the national databases. A total of 161 species show a significant correlation with a specific forest type, the subalpine larch-stone pine forest being best characterised with a high number of indicator species. Inclusion of ecological information from vegetation surveys and forest management history from the national forest inventory allowed for the definition of indicator species for forests without any management intervention for the past 50 years. A spatial analysis showed that present forest reserves in Switzerland are probably not richer in indicator species than non-protected sites. We recommend including evidence of indicator species for the segregation of future forest reserves.

Ellenberg indicator values and functional traits of macromycetes as indicators of ecosystem quality and land-use history

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Ellenberg indicator values (EIVs) and functional traits (FTs) are commonly used in ecology to describe site properties or to evaluate the impact of maintenance measures and land-use. FTs are still more commonly used for vascular plants and bryophytes than for fungi. However, there are databases like PILZOEK that can serve as reference and stepping stones in further research. On the contrary, EIVs are available for vascular plants, bryophytes, and lichens, but completely missing for fungi. To make a first step in filling this gap, EIVs were worked out for a dataset of 640 species of macromycetes. With this dataset it is now pos-

sible to use macromycetes along with other groups for ecological topics. As there are > 6000 species of macromycetes in Central Europe, the EIV list is to be continued in the future. In the presentation it will be demonstrated how EIVs and FTs of macromycetes can be utilised to evaluate different habitat types (e.g., ancient vs. recent forests, hemeroby of grasslands), and how the EIV list itself was compiled.

Biodiversity of different forest conservation concepts in Hesse, Germany

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For more than 10 years, we have been inventorying and monitoring the fungal diversity in Kellerwald-Edersee Nationalpark. Most of the samplings revealed many indicator and unique red-list species for this area. The Department of Forestry in Hesse utilises different concepts of nature conservation to sustain the biodiversity of organisms in managed and unmanaged forests. This long-term field study in and around Kellerwald-Edersee Nationalpark is the initial phase of further studies which aim to figure out how these different concepts support the abundance and appearance of wood-inhabiting fungi in beech dominated forests. In this study, 53 logs within 6 plots were sampled regularly for over one year. These plots differ in total area size, age of protection and anthropogenic influence. Our point of interest is to compare and underline how community composition is dependent on the abovementioned factors and in which of them the forestry concepts differ from each other.

Taxonomy and indicator value of selected wood-decaying fungi (*Polyporales*, *Hymenochaetales*)

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During 2004–2014 several taxonomical studies on *Polyporales* and *Hymenochaetales* were conducted. Some investigated species are characterised by a remarkable ecology and have habitats rare in Central Europe. Such habitats are usually legally protected. Therefore, these species may be selected as indicators

of ecological continuity of their habitats. *Laetiporus montanus* is distinguishable from its kin *L. sulphureus* by larger spores, exclusive growth on conifers, and DNA sequences. In Central Europe, the species is distributed in montane spruce and larch forests at elevations higher than 1000 m a.s.l. and does not occur in artificial coniferous stands. *Phellinus nigricans* belongs to the *Phellinus igniarius* group and can be confused with *P. alni* or *P. igniarius*. It is a North European species growing almost exclusively on living and dead *Betula*. In Central Europe it occurs in montane mire forests and margins of raised bogs. *Spongipellis litschaueri* used to be confused with the related *S. delectans*. It grows on old living or dead oaks, mainly on *Quercus cerris* and *Q. petraea* in thermophilous and acidophilous oak forests. The species is distributed mainly in the Pannonian basin and surrounding areas. The distribution of these species in Central Europe is known insufficiently and worth studying in detail.

Substrate specificity does matter – macrofungal succession on coarse woody debris in an old-growth oak forest

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The “Johannser Kogel” nature reserve is characterised by huge veteran trees of *Quercus petraea* and *Q. cerris*, many of which are now in the phase of dieback and breakdown, resulting in large quantities of dead wood. Macrofungi on recently fallen, marked and georeferenced trees were monitored between June 2009 and December 2014. Frequency of fungal species on logs of the two oak species, *Q. petraea* and *Q. cerris*, was compared. Both common and rare species appear to differ in substrate preference. Some common species like *Auricularia auricula-judae* and *Fomes fomentarius* prefer *Q. cerris*, just as *Hericium coralloides* and *Ossicaulis lachnopus* do. Some of the rarer species likely prefer *Q. cerris*: *Inonotus nidus-pici*, *Protomerulius caryae* and *Simocybe quebecensis*. Some common species like *Fistulina hepatica*, *Daedalea quercina* and *Phellinus robustus* appear to prefer *Q. petraea*. Rarely recorded species with a possible preference for *Q. petraea* are *Clitocybe* cf. *subbulbipes*, *Hemimycena cephalotricha*, *Piptoporus quercinus* and *Xylobolus frustulatus*. These results indicate that there are major differences in fungal communities on coarse woody debris of different *Quercus* species. Infrageneric substrate specificity may have important implications for the conservation of lignicolous fungi and possibly other saproxylic organisms.

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What should you know when you go to pick mushrooms in a Central European virgin forest?

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There are two different reasons why the most important and oldest Czech forest reserves were established: the romantic admiration of virgin nature (Žofín, 1838) and the scientific goals of foresters (Boubín, 1858). Both reserves have provided data on natural forest dynamics since 1851, when the first stem position map in the world was published (from Boubín). The exact classification of developmental stages, spatio-temporal patch dynamics of natural forests, soil mixing and genesis as affected by tree uprooting, deadwood decomposition processes and many other new results from the two reserves were recently published. The naturalness assessment methodology used for all Czech forest reserves was developed on the basis of knowledge of Boubín and Žofín. New data processing methods based on 3D terrestrial LiDAR scanning are presently being developed (Žofín). Stem position maps and 3D data could be the meeting point for forest ecologists and fungi biologists who wish to discover the complexity of ecosystem functioning and, of course, love virgin nature.