Cryptogams as indicator organisms in ecology and conservation biology

DISSERTATION ZUR ERLANGUNG DES
DOKTORGRADES DER NATURWISSENSCHAFTEN (DR. RER. NAT.)
DER FAKULTÄT FÜR BIOLOGIE UND VORKLINISCHE MEDIZIN
DER UNIVERSITÄT REGENSBURG

vorgelegt von

Josef Simmel

aus

Mitterfels

im Jahr

2016

Das Promotionsgesuch wurde eingereicht am:

28.07.2016

Die Arbeit wurde angeleitet von:

Prof. Dr. Peter Poschlod

Declaration of manuscripts

The below-mentioned chapter of the present PhD thesis is largely identical with a manuscript already submitted for publication. All other chapters either have not yet been submitted or are not intended for separate publication.

*Chapter 2 was published in FUNGAL ECOLOGY with the thesis' author being the main author:

Simmel, J., Bässler, C., Poschlod, P.: Ellenberg indicator values for macromycetes – a methodological approach and first applications.

Fungal Ecology **26** (2017). DOI: 10.1016/j.funeco.2016.09.004

CONTENTS **PAGE**

Summary

The present thesis was designed to compare the influence of land-use effects on three groups of cryptogam species, namely the bryophytes, lichens, and macromycetes. Further topics were to newly develop an indicator value system for macromycetes and to compile a broad overview of functional traits applicable to macromycetes. These research topics are intended to (further) stimulate ecological research using macromycetes.

In **Chapter 2**, I present a methodology for Ellenberg indicator values (EIVs) for macromycetes, including a new indicator value scale, i.e., the substrate openness O. Furthermore, the hemeroby concept is incorporated for the first time in the system of indicator values. Based on the newly developed methodology, I compiled EIVs for 10 parameter scales for a set of nearly 640 macromycete species. To test the applicability of EIVs for this species group, I analysed the data set by dividing the species by Red List classes or by lifestyle groups. The EIVs light intensity, substrate nutrient availability, substrate openness, and hemeroby related to these two classifications significantly differed. Critically endangered species on average have distinctly higher demands regarding light and substrate openness than not or less strongly threatened ones, which in turn are more tolerant to human impact and have higher demands in nutrient availability. Mycorrhizal species on average have higher demands on substrate openness and are less tolerant to high nutrient levels than saprobiotic or parasitic species. This pattern clearly highlights the points of threat for many macromycete species.

Chapter 3 persued a similar approach like Chapter 2. Using the same macromycete species set, I compiled data for 31 functional traits that cover a broad range of features of, e.g., fruit body morphology, hymenial structure, spore morphology, and propagule dispersal. In a comparative way, Red List classification and lifestyle groups were used to analyse the species set and to get an insight which traits may be connected with the ecology or endangerment of species. Red List classification accounted for significant differences in three traits, and the lifestyle types in 28 traits. I describe the differentiations and discuss them against the background of ecological and morphological research.

Chapter 4 was designed to compare the influence of land-use history on vascular plants and cryptogams. I compared the results of previous studies on the vascular plant cover of ancient and recent sites of dry calcareous grasslands to the cryptogam vegetation of these sites. I also

applied Ellenberg indicator values and the indicator species concept. Species numbers and Ellenberg indicator values were quite similar in ancient and recent grasslands. Nevertheless, we could identify indicator species for both grassland types, with *Cladonia furcata* ssp. *subrangiformis* and *Hygrocybe persistens* var. *persistens* as strongest indicators of ancient grasslands, and *Rhytidiadelphus squarrosus* as strongest indicator of recent grasslands. The vascular plant vegetation of the recent grasslands also included arable weeds and crop species, being residuals of the former land-use type. This pattern is very useful in distinguishing recent from ancient sites. However, we found no counterpart for the cryptogam vegetation. Thus, land-use history seems to have less influence on the composition of the cryptogam vegetation in grasslands.

In **Chapter 5**, I present the first survey of the cryptogam vegetation of the grassland management project of Baden-Wuerttemberg. Using eight study sites the cryptogam vegetation found in the management and successional plots is compared. After a project term of 37 years, I assessed the effects of different mulching, mowing, and grazing methods as well as of undisturbed succession on the cryptogam vegetation, and give recommendations for the management and establishment of species-rich sites. The most species-rich bryophyte vegetation was found for the management types mulching every third year, mowing twice per year, and, for small acrocarpous species only, controlled burning. Macromycete species richness was highest in successional plots. These, despite the comparably short time for development, also yielded a surprisingly rich epiphytic vegetation. To enhance species diversity it is recommended to leave old trees and to newly create situations of high structural diversity by connecting wooded stands with grassland sites differing in the intensity of maintenance.

Chapter 6 is a holistic approach applying the three concepts of species identity, Ellenberg indicator values, and functional traits to analyse the influence of management and past draining on the macromycete funga of a calcareous fen, the Sippenauer Moor. I assessed changes by comparing the present mapping data with data from a study carried out in 1998 and 1999. While species numbers were similar for the *Sphagnum* patches, we found a considerable loss of species and of red listed species for the remaining fen area, and only very few species were found in both studies. Ellenberg indicator values and functional traits did not yield significant differences. However, we found a considerable increase in the number of ubiquitous species. These changes in species composition most probably are caused by an insufficiant management, tree encroachment, and after-effects of the past draining. We

recommend to apply a more adapted management to prevent further species losses and to maintain the high quality of the fen.

Acknowledgements

During my PhD time, many kind people helped me in many ways – by sharing their knowledge, their experience, their technical know-how, or ‘simply’ their time with me. I’d like to say “Thank you very much!” to all of you!

First of all, I want to thank my supervisor Prof. Dr. Peter Poschlod, for guiding me on a safe path through my PhD studies, for letting me work on ‘my’ fungi, and for maintaining such a friendly and homely atmosphere – both intra- and extra-professionally. It was a great time, and I’m especially thankful for your understanding during my times of Lyme borreliosis.

I’m also very grateful for the sustained support and scientific input I received from my mentors, Prof. Dr. Christoph Reisch and Dr. Claus Bässler, and I thank you very much for all kinds of help.

Several people guided me on the way to further expand my knowledge of the species and ecology of fungi and other cryptogams, and therefore I especially want to thank Dr. Helmut Besl (†), Prof. em. Dr. Andreas Bresinsky, Max Kronfeldner (†), Hans Halbwachs, Wolfgang von Brackel, and Helmut Zitzmann.

I always could rely on the help of Günter Kolb and Sabine Fischer, and I’m very much obliged for this.

Furthermore, I’d like to thank the past and present Viktor-von-Scheffel-members (Verena Busch, Annika Sezi, and Sara Saeedi), my past and present office colleagues (Christina Meindl, Juliane Drobnik, Daniela Listl, Franziska Kaulfuß, and Judith Lang), and my past and present colleagues, especially Maria Hanauer and Philipp Glaab.

Last but not least, I want to thank my family and friends, who always were there for me when I needed someone.

"Fungi are the grand recyclers of the planet
and the vanguard species in habitat restoration."
Paul Stamets

"Kryptogamen, meine Herren, meine Damen,
das sind Pflanzen ohne Samen;
Doch die samenlosen Dinger
wickeln Weise um den Finger."
Maria Klement

Chapter 1 – General introduction

Getting to know the cryptogams

Back in 1735, Carl Linnaeus divided the plants (using this term in the broadest sense to cover all groups of organisms traditionally treated by botanists) in 'phanerogams' and 'cryptogams'. He derived these terms from ancient Greek: *phaneros*, visible, apparent; *kryptos*, hidden, secret; *gamein*, to mate. Thus, phanerogams are those plants that produce clearly visible mating organs (i.e., flowers that result in seeds), and therefore nowadays are referred to as flowering or seed plants (Spermatophyta). In contrast, the term cryptogams subsumes a range of different taxonomic groups without flowering organs and seeds – ferns, bryophytes, fungi (including lichens), slime moulds, algae, blue-green algae, and sometimes also non-photosynthetic bacteria. While ferns, bryophytes, and the largest part of the algae, together with the flowering plants, belong to the Chloroplastida (LEWIS & MCCOURT 2004), the remaining groups of cryptogams belong to the animal, fungus, or bacteria kingdoms (SITTE et al. 2002). The cryptogams hence are a highly artificial group without coherant relationships, united only by the fact that spores are produced in the course of sexual reproduction. However, comparing the different groups of cryptogams the respective spores and sporangia also merely are analogous (SITTE et al. 2002).

Within the artificial group of cryptogams, various life forms and lifestyles can be found. In the present PhD thesis only the bryophytes, lichens, and macromycetes are taken into account, with macromycetes being those fungi producing fruit bodies larger than 5 mm in size (again, another artificial group!). Also within this subgroup of cryptogams a plenty of ecological adaptations and lifestyles are present, including mycorrhizal lifestyles, desiccation or cold tolerance, epiphytic or endolithic growth, and many more (BROWN & WOOD 1953; DÖRFELT 1989; MASUCH 1993; FRAHM 2001; SITTE et al. 2002; CORNELISSEN et al. 2007; GIORDANI et al. 2014). Based on these diverse adaptations, lifestyles, and ecological demands, cryptogams can be used as significant indicator organisms.

What are indicator species – and what do they indicate?

Indicator organisms are such species that can be used as a proxy in examining or monitoring specific ecological conditions, changes, etc. In many cases, the use of indicator species allows

at least a rough assessment of the studied factors, at the same time saving time and costs of more profound measurements or research in the lab. Such factors may be, e.g., phytosociological aspects, air quality, abiotic substrate conditions, climate and climate change, nutrient availability, primary succession, and land-use history or changes (WINTERHOFF 1992; MILES & WALTON 1993; POTT 1995; SCHNEIDER & POSCHLOD 1999; ELLENBERG et al. 2001; DIEKMANN 2003; KARLÍK & POSCHLOD 2009; FRAHM et al. 2010; CHIKISHEV 2013; LICHT 2015; POSCHLOD 2015).

Besides the use of species identities, i.e., the pure comparison of species or species sets found at certain sites, another common way to use organismic indicators is to apply Ellenberg indicator values or functional traits. Ellenberg indicator values are commonly used to describe ecological parameters related to climate and substrate conditions (ELLENBERG 1974; ELLENBERG et al. 2001). Regarding these parameters, the realised niche of a species is assessed and classified using a scale. These scales exist for light intensity, mean annual air temperature, continentality, and the substrate's moisture, reaction (pH range), nutrient availability, and salt content. Furthermore, there is a classification scale for the frequency of species. For Central Europe, such indicator values are available for vascular plants (ELLENBERG 1974; LANDOLT 1977; ELLENBERG et al. 2001; WEBER 2001), bryophytes (DÜLL 2001), and lichens (WIRTH 2001). BRIEMLE et al. (2002) also compiled scales for the trampling resistance, mowing and grazing resistance, and fodder value of vascular plants. Based on the floristic composition or the plant cover or both, mean indicator values can be calculated which allows to compare different study sites or to analyse temporal shifts (cf. LANDOLT 1977; ELLENBERG et al. 2001). Therefore, this method is widely used in environmental (impact) assessments or to quickly identify important environmental filters in plant, habitat, or landscape ecological studies.

In a similar way, functional traits of species can be taken into account. These can be compiled for any part, organ or function of the respective species, such as sizes, colours, temporal scales, growth types, lifestyles, physiology, germination characteristics, dispersal, uptake and usage of water and nutrients, population biology, or population genetics (e.g.: POSCHLOD et al. 2003; HILL et al. 2007; KLEYER et al. 2008). Thus, in contrast to Ellenberg indicator values that give information on a species' ecological niche, functional traits give information about a species' makeup and function or how they react to any kind of disturbances, and therefore, both measures may also be combined to get a comprehensive insight in the factors controlling, e.g., composition of and shifts within species sets, or the threat or spread of species.

Cryptogams as indicator species

As noted above, Ellenberg indicator values are available for bryophytes and lichens; however, they are still missing for fungi. On the other hand, functional traits are available for bryophytes, lichens, and fungi (e.g.: HILL et al. 2007; BÄSSLER et al. 2012; BÄSSLER et al. 2015; HALBWACHS & BÄSSLER 2015; BÄSSLER et al. 2016; HALBWACHS et al. 2016), but as compared to vascular plants this measure is relatively rarely used for these species groups. Thus, there are two major tasks: to newly establish a system of Ellenberg indicator values for fungi; and to further enhance the use of functional traits for cryptogams.

Although the use of cryptogams as indicator species hence still is limited in some respects, the different groups of cryptogams since a comparably long time are very valuable tools in ecology. With the exception of ferns, most cryptogamic organisms have a relatively simple body structure, e.g. lacking epithelial layers and specialised vascular tissue (SITTE et al. 2002; RAVEN & EICHHORN 2013). This simplicity makes them especially receptive regarding environmental impacts, such as shifts in temperature or hydrology or the deposition of fertilizing or toxic substances, which in turn qualifies them as indicator species exhibiting a reliable and relatively fast reaction on the short- or medium-term (BARKMAN 1958; ARNOLDS 1981; ARNOLDS 1983; HAWKSWORTH & HILL 1984; ARNOLDS 1991; WINTERHOFF 1992; DÜLL 2001; WIRTH 2001; FRAHM et al. 2010; LICHT 2015).

Among the topics in which cryptogams most commonly are used as indicator species are success assessment in restoration ecology (ZERBE & WIEGLEB 2009), phytosociological applications (BARKMAN 1958; POTT 1995; BERG & DENGLER 2005), and the evaluation of air quality using epiphytic species (HAWKSWORTH & ROSE 1970; CONTI & CECCHETTI 2001; HULTENGREN et al. 2004; FRAHM et al. 2010). Another field of research is the impact of hemeroby or the past and present land-use on cryptogam species and communities, which often is studied using coenological (DIGHTON et al. 1986; UTSCHICK & HELFER 2003) and floristic methods (EINHELLINGER 1976; EINHELLINGER 1977; PAKEMAN et al. 1998; GRAAE & SUNDE 2000; DÜRHAMMER 2003; VANDERPOORTEN et al. 2004; EIDENSCHINK 2011; WALZ & STEIN 2014), or using physiological patterns such as the mycorrhization rate of plant roots (WALLENDA & KOTTKE 1998; BERNHARDT-RÖMERMANN et al. 2009).

While cryptogams are used as indicator species in a broad range of different topics, only very few studies take into account several taxonomic groups or subgroups. Thus, only in a few cases it is possible to directly compare, e.g., bryophytes, lichens, and fungi regarding their reaction on ecological and man-made impacts. However, such comparative studies are

important in understanding the processes and demands controlling the establishment and occurrence of different cryptogam groups (LUCZAJ & SADOWSKA 1997; PHARO et al. 1999; PHARO et al. 2000; HUMPHREY et al. 2002; LÖBEL et al. 2006; ÓDOR et al. 2006; FRITZ et al. 2008).

Thesis outline

The present thesis was designed to compare the influence of land-use effects on three groups of cryptogam species, namely bryophytes, lichens, and macromycetes. Further topics were to newly develop an indicator value system for macromycetes and to compile a broad overview of functional traits applicable to macromycetes. These research topics are intended to (further) stimulate ecological research using macromycetes.

In **Chapter 2**, I present a methodology for Ellenberg indicator values for macromycetes, including a new indicator value scale, i.e., the substrate openness O. Furthermore, the hemeroby concept is incorporated for the first time in the system of indicator values. Based on the newly developed methodology, I compiled Ellenberg indicator values for 10 parameter scales for a set of nearly 640 macromycete species. To test the applicability of indicator values for this species group, I used the data set by correlating the species to the Red List classes or to lifestyle groups.

Chapter 3 persued a similar approach like Chapter 2. Using the same macromycete species set, I compiled data for 31 functional traits of these nearly 640 species. In a comparative way, Red List classification and lifestyle groups were used to analyse the species set and to get an insight which traits may be connected with the ecology or threat of species.

Chapter 4 was designed to compare the influence of land-use history on vascular plants and cryptogams. I compared the results of previous studies on the vascular plant cover of ancient and recent dry calcareous grasslands to the cryptogam vegetation of these sites. I also applied Ellenberg indicator values and, like it was done in the vascular plant studies, the indicator species concept.

In **Chapter 5**, I present the first survey of the cryptogam vegetation of the grassland management project of Baden-Wuerttemberg. Using eight study sites the cryptogam vegetation found in the management and successional plots is compared. After a project term of 37 years, I assessed the effects of grazing, mowing and different mulching regimes as well

as of succession on the cryptogam vegetation, and give recommendations for the management and establishment of species-rich sites.

Chapter 6 is a holistic approach applying the three concepts of species identity, Ellenberg indicator values, and functional traits to analyse the influence of management and past draining on the macromycete funga of a calcareous fen, the Sippenauer Moor. I assessed changes by comparing the present mapping data with data from a study carried out in 1998 and 1999.

Finally, **Chapter 7** provides a general discussion and conclusion of the studies and data presented in the previous chapters. In form of an outlook, perspectives for further studies are given.

Chapter 2 – Ellenberg indicator values for macromycetes – a methodological approach and first applications

Abstract

In ecological research, Ellenberg indicator values (EIVs) are used to describe the realised niche of species and habitat parameters. This easy-to-use tool is commonly used for vascular plants, bryophytes, and lichens, but not yet for fungi. Here we provide a methodology for EIVs for fungi and compiled EIVs for nearly 650 species of macromycetes that have been thoroughly surveyed in recent studies. We propose two new EIV scales, namely substrate openness (O) and hemeroby (H). We also give the results of two applications and compare EIV values related to the Red List classification with those related to lifestyle classification. The EIVs light intensity, substrate nutrient availability, substrate openness, and hemeroby related to these two classifications significantly differed. Critically endangered species on average have distinctly higher demands regarding light and substrat openness than not or less strongly threatened ones, which in turn are more tolerant to human impact and have higher demands in nutrient availability. Mycorrhizal species on average have higher demands on substrate openness and are less tolerant to high nutrient levels than saprobiotic or parasitic species. This pattern clearly highlights the points of threat for many macromycete species.

Key words: continentality, light intensity, substrate moisture, substrate nutrient content, substrate salt content, substrate reaction, substrate exploitability, mean annual temperature.

Introduction

In Central Europe and adjacent countries, Ellenberg indicator values (EIV; e. g.: ELLENBERG 1974; ELLENBERG et al. 2001) are commonly used to describe ecological parameters. These parameters are related to climate and soil conditions. In addition, in Germany, a frequency measure of the percentage of occupied fields of the topographical map (1:25,000) is also given (ELLENBERG 2001). Climatic parameters include light intensity, mean annual air temperature, and continentality; substrate parameters include moisture, reaction (pH range), nutrient availability, and salt content. The realised niche of a species is assessed, and EIVs are

assigned to it using scales that classify the respective parameters. For Central Europe, such values have been compiled for vascular plants (ELLENBERG 1974; LANDOLT 1977; ELLENBERG 2001; WEBER 2001), bryophytes (DÜLL 2001), and lichens (WIRTH 2001). In turn, mean values can be calculated for study areas after recording the floristic composition or the plant cover or both, and the mean EIVS of, e.g., air temperature and soil moisture of different study areas can be compared. Thus, EIVs allow study plots, habitats, or whole landscapes to be easily characterized, and this method is therefore widely used in environmental (impact) assessments or to quickly identify environmental filters in plant, habitat, or landscape ecological studies.

However, it should be mentioned that EIVs were developed only in part from actual measurements of parameters, such as temperature and moisture (cf. THOMPSON et al. 1993). In most cases, these values are partially or predominately subjective ratings and thus represent empirical evaluations – the "expert opinion" – of the author (cf.: DIERSCHKE 1994; ELLENBERG et al. 2001), partly because parameter measurements for many species are lacking. From their inception, EIVs were designed to relate to ecological conditions integrated over the entire year (ELLENBERG 2001). In many cases, it would often be too complicated and time consuming to make measurements, especially because measurements always are punctual in time or space or both. Although this foundation of predominantly subjective opinions instead of measured data could be considered a weak point of the EIV concept, several studies have shown a distinct and universal correlation between EIVs and actual measurements of the respective ecological parameters (ERTSEN et al. 1998; SCHAFFERS & SÝKORA 2000; ELLENBERG 2001; DIEKMANN 2003; SMART & SCOTT 2004; HALBWACHS & BÄSSLER 2013; BARTELHEIMER & POSCHLOD 2015), or at least such a correlation within the same vegetation type (WAMELINK et al. 2002). EIVs, therefore, are a very useful tool in ecological research, but their empirical nature should be kept in mind.

Fungi comprise a wealth of species important in ecology and conservation (HARLEY 1971; CARROLL & WICKLOW 1992; WINTERHOFF 1992; VAN DER HEIJDEN, M. G. A. et al. 1998; VAN DER HEIJDEN, M. G. A. 2002; BLACKWELL & SPATAFORA 2004), but they have not yet been evaluated using EIVs. This lack of EIVs for fungi could be explained by the incomplete understanding of the lifestyle of many fungal species, and by the high number of species. In Bavaria (Germany) alone, there are at least 5,000 species of macromycetes (KARASCH & HAHN 2009); worldwide, over 1.5 million fungal species might exist (HAWKSWORTH 1991; HAWKSWORTH 2001). The use of EIVs for fungi could promote further ecological research and help in understanding fungal species.

We aimed at taking the first step in developing EIVs for fungi. We compiled a "classic" set of EIVs (ELLENBERG 2001) using a dataset of 636 macromycete species recently ecologically characterised (SIMMEL 2011a; SIMMEL 2011b; SIMMEL 2013a; SIMMEL 2013b; SIMMEL & KRONFELDNER 2013). We also propose an additional scale for the evaluation of substrate openness (i.e., its accessibility and exploitability), and another scale that takes into account the hemeroby concept (ZECHMEISTER & MOSER 2001; KLOTZ & KÜHN 2002; WALZ & STEIN 2014) for fungi. In addition to these methodological aspects, we present applications using the Red List category and the lifestyle types of the species.

Materials & Methods

"Classic" EIVs

We considered the following seven indicator values of the EIV system as compiled by ELLENBERG (2001): L (light intensity), T (mean annual air temperature), K (continentality), F (substrate moisture), R (substrate reaction), N (substrate nutrient availability), and S (salt content of the substrate). We also used the non-EIV frequency measure (M), i.e., the percentage of occupied fields of a 1:25,000 topographical map. Scales of six of these values have 9 tiers; the F scale has twelve tiers (including also 3 tiers for living partially, seasonally, or completely submerged), and that of S has ten tiers (including also 1 step for intolerance of elevated salt contents: "glycophytes"); see Table 3. We used these scales for fungi in the same way as for lichens, bryophytes, and higher plants, with the considerations on L, K, F, and N given below. To enlarge the ecological spectrum covered by EIVs for fungi, we propose two additional scales (see "Additional scales").

When dealing with indicator values for fungi, especially two aspects should be taken into account: (i) while "atmospheric" environmental factors, such as temperature, have an influence on both soil-inhabiting species and those thriving on or in special substrates (cf. PARTON & LOGAN 1981), the influence of soil parameters, such as moisture and reaction, is more or less limited to the soil body itself or is transmitted to other substrates in a weakened or altered form; and (ii) fungi can grow on a broad range of substrates, from soil to dead and living plants or animals or parts of them.

An indicator value dealing with light requirements might be considered dispensable for fungi, as these organisms are saprobionts, mycorrhizal partners of green land plants or parasites without chlorophyll and, therefore, are not primary producers (CARROLL & WICKLOW 1992; LISIEWSKA 1992; BLACKWELL & SPATAFORA 2004). However, light is indeed important for

fungi. It plays an essential role in mycelial growth and fruit body formation for many species (MANACHÈRE 1980; MOORE 1998; CORROCHANO & GALLAND 2006; PURSCHWITZ et al. 2006), and although it is presumably not essential for the formation of primordia (MOORE 1998; CORROCHANO & GALLAND 2006), the further development of fruitbodies strongly depends on light as a stimulus for correct growth, e.g., in *Coprinus cinereus* (Schaeff. : Fr.) Gray, which forms only dark stipes in the dark, and the fruitbodies of many species exhibit phototropism (MANACHÈRE 1980; MOORE 1998; CORROCHANO & GALLAND 2006). Moreover, many macromycete species show a preference for open, i.e., well sunlit or dense, i.e., shaded, habitats. This of course can be explained in part by their nutrition source, e.g. dead wood is more abundant inside forests and grassy substrates are usually commoner outside forests, but by far not completely. For example, in the case of the genus *Agaricus* L., which almost exclusively comprises soil saprobionts, the whole range can be seen from species growing in open grasslands (e.g., *A. campestris* L. : Fr.) to species growing in dense forests (e.g., *A. silvaticus* Schaeff.) (CAPELLI 1984; KRIEGLSTEINER & GMINDER 2010). For ectomycorrhizal fungi KUMMEL & LOSTROH (2011) found light to be strongly influencing the community structure. Therefore, we considered light as an indicator value for fungi. If one wants to emphasize the non-photosynthetic lifestyle of fungi, the light value could be re-interpreted as a "habitat openness" value, for which the focus then lies not on increasing strong solar radiation itself but rather on structures causing shading (see Table 1).

Table 1. Re-interpretation of the EIV light scale (L) of ELLENBERG (2001) as a habitat openness scale.

	EIV light	Habitat openness
L1	In deep shade, may be less than 1% relative insolation	In confined sites between high rocks, in cave entrances etc.
L2	Between L1 and L3	Inside dense forests with closed canopy and dense young growth or shrub vegetation
L3	Shade plant, mostly less than 5% relative insolation	Between L2 and L4
L4	Between L3 and L5	Inside light woodlands with open canopy
L5	Semi-shade plant, rarely in full light	Semi-open at the forest edge, in light hedges etc.
L6	Between L5 and L7	Between L5 and L7
L7	Plant generally in well lit place, but also in partial shade	In the open landscape, but adjacent to scattered trees, in dense high-grass vegetation, etc.
L8	Light-loving plant, rarely found with < 40% relative insolation	Between L7 and L9
L9	Plant in full light, found mostly in full sun	In completely open sites, i.e., distant to trees, shrubs, rocks, etc.

The continentality (K) is expected to play an important role in studies on a continental scale (HEILMANN-CLAUSEN et al. 2014), but is difficult to deal with for fungi in Central Europe because only few species exhibit a more pronounced preference for either an oceanic or a continental climate. Many macromycete species have a very wide distribution area, pro parte even throughout the Holarctic or in both the northern and southern hemispheres (e.g.:

SERZANINA 1984; WASSER 1990; VELLINGA 2004 (for Lepiotaceous fungi)). Therefore, K values of 5, which indicate species seemingly without preference for an oceanic or continental climate) and in quite few cases, K values of 4 or 6, which indicate suboceanic or subcontinental species, constitute almost the entire K scale given in the present study.

Many species of fungi, especially lower fungi, have an aquatic lifestyle and grow in or under water (MUELLER et al. 2004: 513-586). By contrast, higher fungi, including subgroup macromycetes, are primarily found outside of the water body itself, but there are also exceptions, and the EIV scale for substrate moisture (F) should therefore also range from F1 to F12 for macromycetes. Species such as *Lactarius lacunarum* (Romagn.) J. E. Lange ex Hora, which grows in fens or on the edge of pools or creeks, have to be classified as F10, and other macromycetes, e.g. *Vibrissea truncorum* (Alb. & Schw.) Fr. (ELLIS & ELLIS 1997) and *Psathyrella aquatica* J. L. Frank, Coffan & Southworth (FRANK et al. 2010) have nearly or completely submerged fruit bodies and are therefore classified as F11 or F12.

The substrate nutrient availability value (N) has repeatedly been discussed in the past. Even ELLENBERG (1974) was unsure about this indicator scale. He could characterize the minimum (N1, N2) and maximum values (N 8, N 9) well and easily classify the respective indicator species, but the gradient in between these values was difficult to determine. However, most species revealed tendencies, and at least approximate classifications were possible (ELLENBERG 1974; ELLENBERG 2001).

Whereas initially the N value was thought to be a classification refering solely to the nitrogen content of the soil or rather that available for plants (ELLENBERG 1974), other authors came to different results (e. g.: BOLLER-ELMER 1977; FRANK et al. 1990). In their works the correlation between the N value and the soil content of all nutrients (i.e., including phosphorous, potassium, etc.) was much more distinct than that with only nitrogen. These authors advocated the use of the N value as “nutrient value” instead of “nitrogen value”, as done for lichens (WIRTH 2001). Such a broader classification also solves the dilemma of ELLENBERG (2001) of how to achieve indicator scales for the soil content of phosphorous, potassium, sulfur, and calcium, and it reduces the problems of classifying nitrogen availability as described above because there is no longer a need to separate the influence of nitrogen alone from that of other nutrients. In addition, it should be noted that the amount of accessible nutrients differs among the various substrates. WIRTH (2001) therefore considered terricolous lichen species separately from corticolous and saxicolous species.

Nitrogen is increasingly important due to high, man-made atmospheric depositions (e. g.: SKEFFINGTON & WILSON 1988; MATSON et al. 2002; PHOENIX et al. 2006). By disarranging nutrient networks, these depositions lead to shifts in the abundance of species and thus to an increasing number of threatened or extinct species in nutrient- or nitrogen-poor habitats (SKEFFINGTON & WILSON 1988; ARNOLDS 1991; SALA et al. 2000; MATSON et al. 2002; PHOENIX et al. 2006; POSCHLOD 2015).

The correlation of N values and nutrient (or nitrogen) content might still be only a part of the whole story. For example, HILL & CAREY (1997) have shown that biomass yield fits better than soil nutrient content with N values, and proposed the name "productivity values" for N. BARTELHEIMER & POSCHLOD (2015) even found 16 eco-physiological determinants of the N value.

In the present study, these issues were taken into account as follows. First, the N scale refers to the available nutrients as a whole. However, to a certain degree, we focused on nitrogen because excess nitrogen greatly influences mycorrhizal fungi and saprotrophic fungi growing on nutrient-poor substrates (cf.: ARNOLDS 1991; EGERTON-WARBURTON & ALLEN 2000; LILLESKOV et al. 2002; JANSSENS et al. 2010). Second, we considered the two substrate types soil and dead or living plants or animals separately. Third, biomass yield and other determinants were not considered, because very little data on this topic suitable for interpretations has been published.

Additional and excluded scales

We propose two additional indicator values for fungi, i.e., substrate openness and hemeroby. The accessibility and exploitability of a substrate is of high relevance for newly arriving fungi. Therefore, we considered substrate openness (O value) as an indicator value, where "substrate" refers to all nutritional sources that can be used by macromycetes, specifically soil and dead or living plants or animals or parts of them. Soil has a quasi infinite spatial expansion, whereas plants and animals are distinctly delimited in space and time and in most cases develop and decay rapidly (LISIEWSKA 1992). We therefore distinguished these two substrate types and compiled separate scales for them (Table 2); this distinction is in congruence with the separation of substrate types for the N value (see above). Because of these separations in the O and N scales, species growing on soil are not to be directly compared with those growing on plant or animal substrates. Difficulties in classification were encountered for fungi growing on special substrates buried in the soil, e.g. *Strobilurus*

esculentus (Wulfen : Fr.) Singer growing on spruce cones and deadwood-inhabiting species thriving on roots. In such cases, the scale for plant and animal substrates is to be used despite of apparent terricolous occurrence.

For soil-inhabiting species, the substrate openness scale considered two factors: humus richness, i.e. soil thickness, and soil cover by litter and ground vegetation. Humus richness is important in determining the availability and amount of organic matter as well as characteristics such as soil structure and waterholding capacity (AK STANDORTSKARTIERUNG 1996; AD-HOC-AG BODEN 2005; BLUME et al. 2010). We adressed it according to the "Humuszahl" (humus value) of LANDOLT (1977), whereas his "Dispersitätszahl" (dispersability value) or "Durchlüftungsmangelzahl" (aeration deficiency value) was omitted as it does not yield a good differentiation (MEIER 2002). Soil aeration is explained well by water saturation and temperature (GRUNDMANN et al. 1994; BLUME et al. 2010) and thus by the EIVs substrate moisture (F) and air temperature (T). Soil cover by litter or vegetation (e.g., a dense bryophyte layer) greatly affects the accessibility by dispersal units (spores, conidia) and also some chemical, physical, and biological characteristics (SYDES & GRIME 1981; FACELLI & PICKETT 1991; BLUME et al. 2010).

The scale for species growing on other substrates, such as living or dead plants or dung, was compiled based on the classification of wood rot stages by HEILMANN-CLAUSEN et al. (2005) and POUSKA et al. (2011). Both provide a five-step scale, from dead but still hard to completely disintegrated wood. These five steps were supplemented by three types of living and one step for already (pre-)digested substrates based on remarks by LISIEWSKA (1992) and FRANKLAND (1992).

The impact of human influence was evaluated using a seven-step hemeroby (H) scale (STEINHARDT et al. 1999; KLOTZ & KÜHN 2002; WALZ & STEIN 2014). The hemeroby concept traces back to ideas of SUKOPP (1969) and others. It classifies species, communities, or habitats according to their occurrence completely without or with an increasing degree of human impact (see Table 6). Many species tolerate different hemeroby intensities; therefore, we noted their complete amplitude instead of using an average hemeroby or some extreme value which would remove too much information. This holds true also for the EIVs, but these have always been considered as single-value scores and are commonly used and interpreted as such. For hemeroby, the opposite is the case (S. KLOTZ, pers. comm. 2015). Therefore, we used averaged hemeroby values (H_{mean}) only in calculations and not to describe the features of

a species or for non-mathematical ecological comparisons. To emphasize the amplitude character, the H_{mean} formula is given as (S. KLOTZ, pers. comm. 2015):

$$H_{mean} = (x^{-1} \times H_a) + (x^{-1} \times H_b) + \ldots,$$

where x is the number of H values (= size of the H amplitude) and H_a, H_b, etc. are the single H values of the respective species. The hemeroby concept is applicable at different levels, e.g., for individual substrate particles, landscape units, or map grids (STEINHARDT et al. 1999; ZECHMEISTER & MOSER 2001; KLOTZ & KÜHN 2002; WALZ & STEIN 2014).

Table 2. Compilation of a substrate openness scale (O), which distinguishes the two substrate types "soil" and "other substrates", e.g., living and dead plants or parts of them.

	Inhabiting soil		Inhabiting other substrates
O1	Soil humus-rich (raw humus, peat, etc.)	Dense litter and/or ground vegetation	Living and intact
O2	Soil of medium humus-richness (mull, etc.)		Living and pre-injured (e.g., bark fissures, strong drought stress, pest infestation)
O3	Raw soil with only weak humus formation		Substrate moribund
O4	Soil humus-rich (raw humus, peat, etc.)	Sparse litter and ground vegetation	Substrate dead and still near intact (wood: still hard, ± completely covered with bark, fresh phloem still present at least in parts; herbs: still green and sappy)
O5	Soil of medium humus-richness (mull, etc.)		Substrate dead and weakly disintegrated (wood: quite hard, no fresh phloem left)
O6	Raw soil with only weak humus formation		Substrate dead and disintegrated (wood: partly decayed and becoming soft; herbs: free from intact chlorophyll, beginning to lose their shape)
O7	Soil humus-rich (raw humus, peat, etc.)	Bare soil	Substrate dead and strongly disintegrated (wood: decayed and soft throughout)
O8	Soil of medium humus-richness (mull, etc.)		Substrate dead and completely disintegrated (wood: very soft, disintegrating when lifted; herbs: decayed)
O9	Raw soil with only weak humus formation		Substrate (pre-)digested

The parameters evapotranspiration and air humidity both play an important role in the growth and endurance of fruitbodies (ZOBERI 1972; MCKNIGHT & ESTABROOK 1990) and, together with temperature and air velocity, are important for spore release (ZOBERI 1964; ZOBERI 1972; PASANEN et al. 1991). Furthermore, they are important criteria in the ecology of parasitic species (DICK 1992; HIRSCH & BRAUN 1992). However, these two factors are difficult to handle, in particular at small scales, due to microrelief, shading, wind regime, and other parameters (e.g., see the calculations and estimations applied by KLEYER (1997)).

Classification concepts thus primarily are based on the scale of, e.g., water catchments (ZHANG et al. 2001) or of whole "life zones" (HOLDRIDGE 1967; LUGO et al. 1999), and therefore are primarily or exclusively practical at large scales, but hardly for describing a particular study site. On such a small scale, it seems more reasonable to use a proxy for the conditions of evapotranspiration and air humidity. In the EIV system, light intensity (L), air temperature (T), and substrate moisture (F), and probably also continentality (K) values

evaluated together can be used as a substitute. Therefore, we did not consider evapotranspiration and air humidty and do not propose additional scales.

Table 3. Classification scheme for the hemeroby (H) of different urban and non-urban habitats, compiled using data from the literature (SUKOPP 1969; STEINHARDT et al. 1999; ZECHMEISTER & MOSER 2001; KLOTZ & KÜHN 2002; DIERSCHKE & BRIEMLE 2008; WALZ & STEIN 2014).

		non-urban habitats: woodlands (including coppices and pioneer forest)	non-urban habitats: open landscape	urban habitats
H1	**Ahemerobic**	--	Presumably missing in Central Europe today due to emmision input also in high mountain regions → H2; otherwise: rock faces, glaciers and snow regions in still undisturbed alpine and nival mountain ranges	--
H2	**Oligohemerobic**	Primary or near-natural forests (including alluvial forests, etc.), extensively used forests (tree stock in accordance with the potential natural vegetation)	Coastal areas incl. tidal flats and dunes, unimpaired swamps and bogs, undisturbed alpine grasslands, salt marshes, sea	--
H3	**Mesohemerobic**	Extensively used forests (tree stock not in accordance with the pnv), coppices, hedgerows, avenues in extensively used surroundings	(Semi-)natural or grazed nutrient-poor grasslands, extensive alpine pastures, orchards, hay meadows not or weakly fertilized, heaths, burnt areas, fallow land, unobstructed waters in intact surroudings and their water body	Shrub vegetation, overgrown areas, fallow land on unimpaired soil (i.e., not impaired by soil compaction, soil sealing, overburden, etc.), wooded parts of landscape gardens, arboreta, undisturbed copses
H4	**β-Euhemerobic**	Intensively used forests, avenues in intensively used surroundings	Semi-intensively used pastures and meadows (2-3 cuts per year, fertilized with solid dung and artificial fertilizer), impaired waters and their water body, vegetation adjacent to moderately intensively used plantations or arable land	Green areas cut < 3 times per year, ornamental shrub plantings in landscape gardens, disturbed copses, avenues surrounded by large green areas, multi-annual flower beds
H5	**α-Euhemerobic**	Short-rotation plantations (fuel wood plantations, rotation time < 20-30 years)	Intensively used pastures and meadows (> 3 cuts per year, fertilizing includes liquid manure), moderately intensively used plantations (wine, fruit trees, etc.) and arable land, vegetation adjacent to intensively used plantations or arable land	Ornamental lawns not or only weakly fertilized
H6	**Polyhemerobic**	--	Intensively used plantations and arable land	Scattered settlements/buildings, flower/vegetable beds replanted ≥ once per year, ornamental lawns strongly fertilized and kept clean by weeding and use of herbicides, areas with partly sealed soil, dumps, quarries, vegetation adjacent to railway/street tracks (but excluding track borders themselves → H7)
H7	**Metahemerobic**	--	--	Dense settlement, industrial areas, harbors, airports, contaminated ecosystems, borders of railway/street tracks

Methods for the classification of species

Altogether, ten different scales were used for the classification of macromycete species (see also above): L, T, K, F, R, N, S, M, H, and O.

For L, T, K, F, R, N, S, and O, macromycete species were classified using distributional and ecological data from the literature, our own unpublished observations, and "expert opinions" of the first and second authors. Especially useful were the five volumes of "Die Großpilze Baden-Württembergs" (KRIEGLSTEINER 2000a; KRIEGLSTEINER 2000b; KRIEGLSTEINER 2001; KRIEGLSTEINER 2003; KRIEGLSTEINER & GMINDER 2010), as they provide an abundant set of ecological observations for most basidiomycete species. We used the following approach:

1. We chose 12 model species with well-known ecology and distribution pattern that covered a range of different habitats, fruit body types, and environmental situations (see Table 5).
2. Scale values for the example species were worked out for air temperature (T), substrate moisture (F), substrate reaction (R), and substrate nutrient availability (N), and the values were calibrated; this calibration was used to substantiate the scale values. Mean values of T, F, R, and N calculated from the vascular plant and bryophyte vegetation present at the locations of the respective fungus species (data not shown) thus served as an additional guideline in the development of EIVs for those species.
3. Based on the results for the example species, the remaining species were classified in two steps. First, the ecology of the respective species was checked against that of the example species. Second, based on the similarity (or difference) in the ecological demands, the values for the respective species were chosen;
4. Finally, the species classifications were compared (and reworked, if necessary) in groups of ecologically similar species, p.p. also using additional referencing (see point 2.).

For the preparation of M (frequency) values, we used two different sets of distribution maps: (i) "Die Großpilze Baden-Württembergs" (KRIEGLSTEINER 2000a; KRIEGLSTEINER 2000b; KRIEGLSTEINER 2001; KRIEGLSTEINER 2003; KRIEGLSTEINER & GMINDER 2010); and (ii) the floristic mapping of Germany (www.pilze-deutschland.de). These data sets were complemented by other sources, such as the floristic mapping of Austria (www.austria.mykodata.net) when necessary or useful (e.g., to obtain an insight on the

distribution of species in case of obviously incomplete German maps). From these maps, the number of "Topographische Karten" (topographical maps 1:25,000) occupied by the respective species were counted. As the M scale uses the percentage of occupied Topographische Karten (ELLENBERG 2001), the counts could be directly translated into scale values.

The classification of hemeroby (H) made use of the ranking scheme given in Table 3. In this scheme, different habitat and site types are classified according to their degree of hemeroby. The H values in turn represent the range of habitats in the hemeroby gradient in which the respective species occurs, giving both the minimum and maximum value. This range of occupied habitats was evaluated using published and personal mapping data and distribution maps.

Analysis of the EIV data

The list of EIVs for fungi was explored and comparatively studied in two analyses that used unweighted mean EIV values.

For this purpose, the species set was divided up based on either the species' Red List status (Red List of Bavaria; KARASCH & HAHN 2009) or lifestyle, thereby providing an overview of the distribution of EIV values according to the respective classification. The amplitude of the EIVs was calculated as absolute and relative differences. Differentiation between groups was analyzed using ANOVA and Scheffé's test as a post-hoc test in SPSS 23.0.0.0 (IBM SPSS Statistics 2015).

In addition, to visualise the distribution patterns, we used line charts (species numbers plotted against EIV gradients), as also done by ELLENBERG (2001) for vascular plants.

Results

We used ten different scales (Tables 1-4) in our approach of macromycete classification, including the newly developed indicator value substrate openness (O; Table 2) and hemeroby (H), which was used for the first time for fungi. The other EIVs comprise light intensity (L), air temperature (T), continentality (K), soil moisture (F), soil reaction (R), substrate nutrient availability (N), and substrate salt content (S), and the frequency measure (M). Based on these scales, we compiled a list of EIV values for fungi (Table 7 in Table Appendix). We considered a total of 636 macromycete species, most of which belonged to the basidiomycetes

and have a mycorrhizal or saprobiotic lifestyle (Figure 1D). Our analyses (Table 6) revealed almost constant mean values for the EIVs air temperature (T), continentality (K), and substrate salt content (S) when Red List endangerment classes were compared ($\Delta \leq 0.12$ units).

Comparing not threatened and increasingly endangered species the mean values for the EIVs light intensity (L), frequency measure (M), substrate openness (O), and substrate nutrient availability (N) revealed large differences ($\Delta \geq 1{,}4$ units) and large percent differences (δ = 15,6 - 38,7 %), with differences being significant for L, N, O, H_u (upper boundary of H), and M. When comparing the species' lifestyles, significant differences were found for the EIVs L, T, F, R, N, O, H_u, and M.

Table 4. Definitions of the remaining EIVs used. Taken from ELLENBERG et al. (2001).

	Air temperature		**Continentality**
T1	Indicator of cold conditions, found only in high mountain or boreal-arctic regions, mostly in alpine and nival levels	**K1**	Extremely oceanic species, in Central Europe only in a few outposts
T2	Between T1 and T3	**K2**	Oceanic species, mainly in the west, including western Central Europe
T3	Indicator of cool conditions, mainly subalpine	**K3**	Between K2 and K4
T4	Between T3 and T5	**K4**	Suboceanic species, mainly in Central Europe, but spreading eastward
T5	Indicator of fairly warm conditions, from lowland to montane, but especially in submontane-temperate sites	**K5**	Intermediate species, weakly suboceanic to weakly subcontinental
T6	Between T5 and T7	**K6**	Subcontinental species, mainly in the east of Central Europe and adjoining parts of Eastern Europe
T7	Warmth indicator, in warm lowland sites and colline levels	**K7**	Between K6 and K8
T8	Between T7 and T9	**K8**	Continental species, spreading into Central Europe from the east only exceptionally
T9	Indicator of extreme warm conditions, spreading from the Mediterranean only into the warmest places of the upper Rhine valley	**K9**	Extremely continental species, virtually absent from western Central Europe
	Substrate moisture		**Substrate salt content**
F1	Indicator of xeric conditions, restricted to soils drying out intermittently	**S0**	Glycobiont, tolerating fresh water only
F2	Between F1 and F3	**S1**	Tolerating certain salt concentrations, but mostly on substrates poor in chloride
F3	Indicator of rather xeric conditions, more often found on dry ground than on moist places, never on damp soil	**S2**	Oligohaline (I), mainly on substrates with very low chloride content
F4	Between F3 and F5	**S3**	β-Mesohaline (II), mainly on substrates with low chloride content
F5	Indicator of mesic conditions, mainly on fresh soils of average dampness, absent from both wet and dry ground	**S4**	α/β-Mesohaline (II/III), mainly on substrates with low to moderate chloride content
F6	Between F5 and F7	**S5**	α-Mesohaline (III), mainly on substrates with moderate chloride content
F7	Indicator of rather hygric conditions, mainly on constantly moist or damp, but not on wet soils	**S6**	α-Meso/polyhaline (III/IV), on substrates with moderate to high chloride content
F8	Between F7 and F9	**S7**	Polyhaline (IV), on substrates with high chloride content
F9	Indicator of hygric conditions, often on water-saturated, badly aerated soils	**S8**	Euhaline (IV/V and V), on substrates with very high chloride content
F10	Indicator of occasionally, but only temporary flooded sites	**S9**	Euhaline to hyperhaline (V-VI), on substrates with high and, during drought periods, extreme salt content
F11	Rooting under water, but at least intermittently exposed to the air, or plant floating on the surface		
F12	Submerged, permanently under water or nearly so		

Table 4 ***continued***

	Substrate reaction		Substrate nutrient availability
R1	Indicator of extremely acidic substrate, never found on weakly acidic or basic substrate	**N1**	Indicator of sites extremely poor in available nutrients
R2	Between R1 and R3	**N2**	Between N1 and N3
R3	Indicator of acidic substrate, mainly on acid substrate, but exceptionally also on nearly neutral one	**N3**	Indicator of sites more or less poor in available nutrients
R4	Between R3 and R5	**N4**	Between N3 and N5
R5	Indicator of moderately acidic substrate, only occasionally found on very acidic or on neutral to basic substrate	**N5**	Indicator of intermediate nutrient availability
R6	Between R5 and R7	**N6**	Between N5 and N7
R7	Indicator of weakly acidic to weakly basic substrate, never found on very acidic substrate	**N7**	Species often found in places rich in available nutrients
R8	Between R7 and R9	**N8**	Between N7 and N9
R9	Indicator of basic substrate, always found on calcareous substrate	**N9**	Indicator of extremely rich situations, such as cattle resting places or polluted rivers
	Frequency (occupied squares of topographical map grid)		
M1	Extremely rare, only in a few squares		
M2	Very rare, in about 1% of the squares		
M3	Rare, in about 5%		
M4	Moderately rare, in about 10%		
M5	Neither rare nor frequent, in about 25%		
M6	Between 5 and 7, moderately frequent		
M7	Frequent, but not everywhere, in about 50%		
M8	Very frequent, in about 75%		
M9	Nearly everywhere, lacking only in a few squares		

When we plotted species numbers against the EIV gradients (Figure 1 A-C), different distribution patterns were visible. For the EIVs T, K, F, and the upper boundary of H, the distribution had a marked maximum near or at the center value of 5; for L, M, R, S, and the lower boundary of H the distribution was more skewed to the left or right. For EIVs O and N, the distribution was bimodal or more flattened, respectively.

Discussion

We present the first proposal of Ellenberg indicator values for fungi. For most of the 636 macromycete species considered, all indicator values except continentality (K) were easy to classify. However, a certain proportion of fungi had to be classified as "indifferent" (Table 6; indicated by "×" in the EIV list) at the respective value because the ecological behavior of the species was not distinct or limited enough to describe it by a single value (cf.: ELLENBERG 1974; ELLENBERG 2001). The newly introduced indicator value substrate openness (O) and the hemeroby (H) – applied to fungi for the first time –, were also both easy to classify. By contrast, continentality (K) values were similar for a large part of the species. As described above many fungus species do not exhibit clearly visible preferences within the gradient of continentality, probably owing to their wide distribution areas (SERZANINA 1984; WASSER 1990; VELLINGA 2004), resulting in K values primarily of 5 or occassionally 4 or 6.

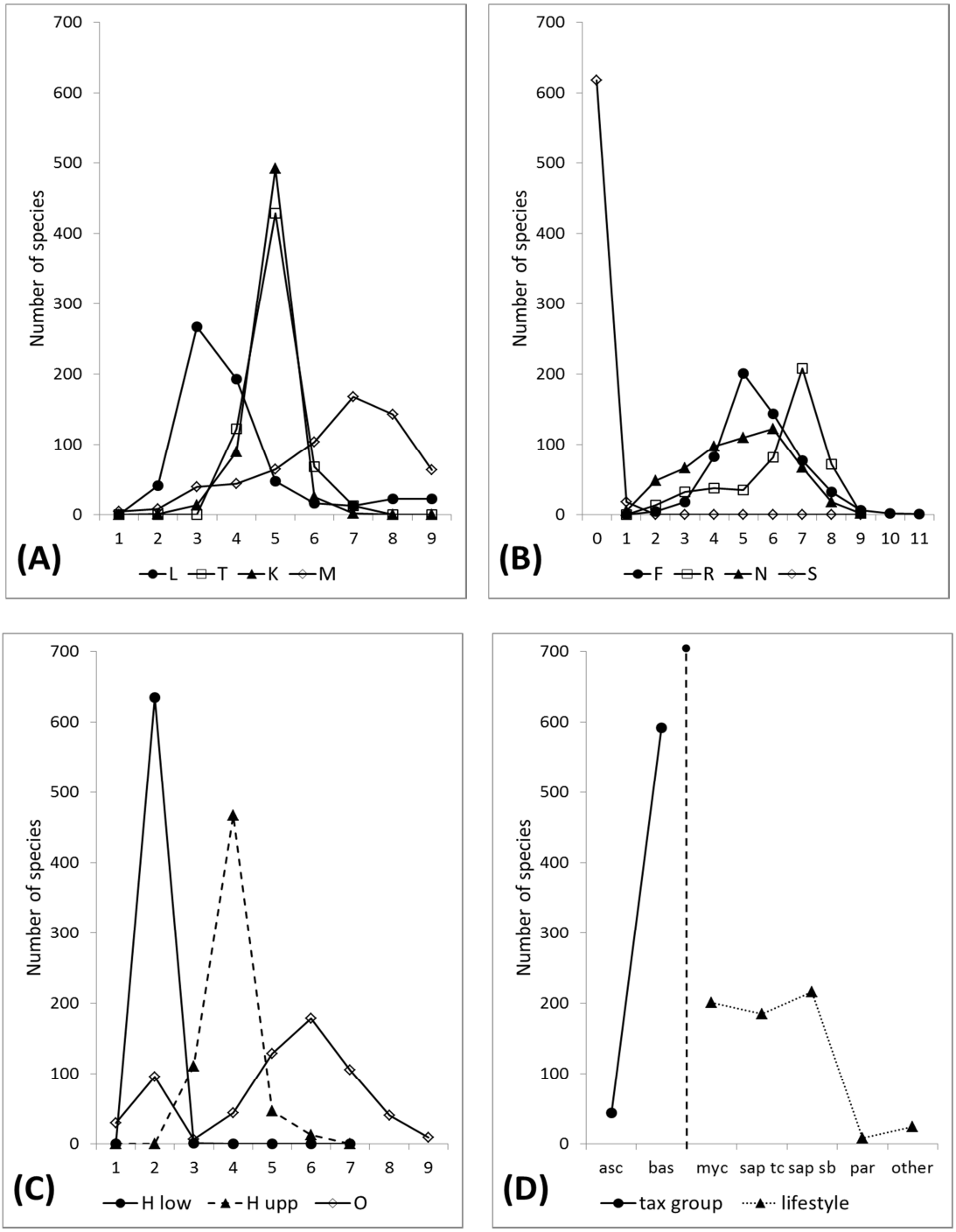

Figure 1. Distribution of the macromycete species evaluated in the present study (n = 636) along the EIV gradients (A-C) and classification according to their taxonomical position and lifestyle (D). L, light intensity; T, air temperature; K, continentality; M, frequency; F, substrate moisture; R, substrate reaction; N, substrate nutrient availability; S, substrate salt content; H low/H upp, lower/upper boundaries of hemeroby; O, substrate openness; taxonomical position (asc, ascomycetes; bas, basidiomycetes); lifestyle (myc, mycorrhizal; sap tc, saprobiotic-terricolous; sap sb, saprobiotic on other substrates; par, parasitic; other, other lifestyle, e.g., saprobiotic-parasitic).

We determined the EIV values using mapping data and literature predominantly covering southern Germany (i.e., from the federal states Baden-Wuerttemberg and Bavaria). It thus has to be tested whether the indicator values presented here can be directly applied in other parts

of Germany and Central Europe, or if they have to be adjusted (DIERSCHKE 1994; ELLENBERG 2001). Such adjustments, for example, have been proposed for indicator values of vascular plants in the former GDR (ZÓLYOMI 1989), the Netherlands (TER BRAAK & GREMMEN 1987; ERTSEN et al. 1998), and the Faroe Islands (LAWESSON et al. 2003).

It has been repeatedly discussed which mathematical operations are allowed for calculating mean indicator values. Indicator values, strictly speaking, are not cardinal numbers, which means that mean values cannot be actually calculated (see also ELLENBERG 2001: 44-48 for further explanations). On the other hand, several authors have concluded that indicator values can be considered as "quasi-cardinal" numbers for practical applications (DURWEN 1982; TER BRAAK & GREMMEN 1987; KOWARIK & SEIDLING 1989). We followed this reasoning and calculated mean indicator values and used correlation analyses.

When we compared the mean indicator values of species in individual Red List endangerment classes, marked differences were found for light intensity (L), frequency measure (M), substrate openness (O), and substrate nutrient availability (N) (Table 6), especially for L and M, where δ constituted nearly 40% or 30%, respectively, of the whole amplitude of the factor (M: 12 steps; L: 9 steps). For the mean values of O and N (9 steps), δ constituted nearly 20% or 15%, respectively, of the whole amplitude of the factor. These four EIVs also showed significant differences in ANOVA analyses. For M, these differences of course are because most endangered species are also rare species. On the other hand, rare macromycete species, in contrast to non-threatened species, seem to favour more intensely sun-lit sites, more nutrient-poor sites, and a more easily accessible substrate.

Our results obtained for L and N are in accordance with the data of H. ELLENBERG (cited in DIERSCHKE 1994: 229-230), with higher or lower values, respectively, for endangered species. Furthermore, the striking combination of high L and O values and low N values reflects the habitat range for a high proportion of endangered macromycete species: (i) open, nutrient-poor grasslands or habitats (on dry as well as on wet or peaty soil); (ii) light, nutrient-poor forests with areas of bare soil; and (iii) large, rotten deadwood (ARNOLDS 1991; BERG et al. 1994; KARASCH & HAHN 2009; BÄSSLER et al. 2012; LÜDERITZ & GMINDER 2014).

Hemeroby (H) classification involves two values, namely the minimum and maximum level of hemeroby under which the respective species occurs. The minimum level of hemeroby for most of the species studied was similar because most of the species occurr in forests and grasslands that are not or extensively used. By contrast, the maximum levels significantly differed, with a δ of 10%, pointing out a certain gradation with respect to the Red List classes.

Specifically, non-threatened species on average reached higher hemeroby values than endangered species.

When we compared lifestyle guilds, substrate moisture (F), substrate reaction (R), and frequency measure (M) only weakly differed ($\delta < 15$ %), whereas the differences of light intensity (L), substrate nutrient availability (N), and substrate openness (O) were greater ($\delta >$ 17 %; Table 6). For these six EIVs as well as for air temperature (T) and hemeroby (H), ANOVA showed significant differences. Soil-inhabiting and parasitic species on average had higher demands on light intensity. Saprobiotic and mycorrhizal fungi depend on the presence of suitable substrate (e.g., dead wood) or partner species (mostly woody species), respectively; therefore, the lower L values obtained for these guilds can at least in part be due to their occurrence in, e.g., forests and under scattered trees. Both mycorrhizal and parasitic species also seemed to favour more nutrient-poor conditions than species of the other guilds. This is in accordance with conclusions of other studies and thereby confirms nutrient enrichment as a main factor causing the decline of mycorrhizal macromycete species (see overview in ARNOLDS (1991)). The lower substrate openness (O) values for parasitic species, and the higher values for saprobionts can be explained by the substrate status, with low O values for fungi growing on living organisms.

In some respects, the distribution of species along the EIV gradients (Figure 1 A, B) is similar to the distribution graphs of vascular plants of Germany given in ELLENBERG (2001: 42). This is especially true for the EIVs substrate moisture (F), substrate reaction (R), and substrate salt content (S), for which the distribution graphs of vascular plants and fungi are identical. For the EIVs air temperature (T) and continentality (K), the distribution graphs of vascular plants and fungi have a similar form, but are shifted to higher or lower values, respectively. For plants, the maximum indicator values are around 6-7 (T) and 4 (K), respectively, whereas the maximum indicator values for fungi are both around 5. These similarities in the EIVs T, K, F, R, and S for vascular plants and fungi are very likely based on their comparable history in Central Europea. For example, the present richness in plants preferring base-rich soils is thought to be the result of a Pleistocene and Holocene dominance of calcareous soils (CHYTRÝ et al. 2003; EWALD 2003).

By contrast, the distributions of vascular plant and fungal species along the gradients of light intensity (L) and substrate nutrient availability (N) differ. The distribution of vascular plants distinctly peaks at low N levels with a broad positive skew, whereas that of fungi is more flattened with a vague peak around the middle. For L, the distributions of plants and fungi were almost the opposite. Thus, the demands of most of the fungal species, especially for the

light regime but also for nutrient levels, clearly differed from the demands of vascular plants. These differences can probably be best explained by the autotrophic or heterotrophic lifestyle of vascular plants and fungi, respectively.

As both lower and upper boundaries of hemeroby (H; Figure 1C) exhibited a marked maximum, the fungal species studied here seem to have comparable limitations dealing with the human influence. The distribution of fungal species with regard to substrate openness (O) was bimodal. For both hemeroby and substrate openness, it should be tested using larger species sets whether the patterns found in the present study are caused by the selection of species or whether they reflect a general rule. For O, such a rule could be that soil-inhabiting macromycetes prefer either soils "closed" by vegetation and/or litter (O value of 2) or more open (O value of 5-7), and that other species prefer living substrates (O value of 1-2) or disintegrated substrates (O value of 5-7).

Outlook

As was said in the introduction, the present study is thought to be only a first step in the development of EIV values for fungi. With about 6,000 species of macromycetes in Germany alone, the EIV list for fungi needs to be expanded. With such a large number of species, the further development of indicator values for additional species, calibrations, and proposals from other researchers would be welcomed.

Other topics for future studies include, e.g., (i) the correlation of soil nutrient content, fruit body mass, and the N value, (ii) small-scale measurements of evapotranspiration and humidity in comparison to mycelial and fruit body properties, and (iii) the deduction or adjustment of conservation measurements based on the indicator values of fungal species.

Acknowledgements

We thank Hans Halbwachs (Amorbach, Germany), Jacob Heilmann-Clausen (University of Copenhagen, Denmark), Stefan Klotz (Helmholtz Centre for Environmental Research UFZ, Halle/Saale, Germany), and Irmgard Krisai-Greilhuber (University of Vienna, Austria) for their comments on the development of indicator values as well as for valuable literature references.

Table 5. Ecology and fruit body morphology of twelve species from two taxonomic groups chosen as examples in the preparation of EIV lists. Taxonomic groups: a, ascomycete; b, basidiomycete.

Species	Taxomonic group	Habitat, ecology	Lifestyle	Fruit body type
Agaricus campestris L. : Fr.	b	Pastures, extensive grasslands	Terricol-saprobiotic	Agaricoid, fleshy, short-lived
Albatrellus ovinus (Schaeff. : Fr.) Kotl. & Pouzar	b	Nutrient-poor and often quite dry forests	Terricol-mycorrhizal	Boletoid, fleshy, short-lived
Armillaria ostoyae (Romagn.) Herink	b	Living and dead coniferous trees	Lignicol-parasitic, lignicol-saprobiotic	Agaricoid, fleshy, short-lived
Bovista pusilla (Batsch : Pers.) Pers.	b	Nutrient-poor, mostly calcareous and dry grasslands	Terricol-saprobiotic	Gastroid, fleshy, short-lived
Elaphomyces muricatus Fr.	a	Woodlands not too rich in nutrients	Hypogeous-mycorrhizal	Cleistothecial, fleshy, short-lived
Fomitopsis pinicola (Sw. : Fr.) P. Karst.	b	Dead wood of numerous tree species	Lignicol-saprobiotic	Pileate ("bracket"), woody, long-lived
Helvella lacunosa Afzel. : Fr.	a	Base- and humus-rich woodlands	Terricol-saprobiotic	Apothecial, fleshy, short-lived
Hygrocybe persistens (Britz.) Sing.	b	Pastures, extensive grasslands	Terricol, most probably biotrophic	Agaricoid, fleshy, short-lived
Hymenochaete cruenta (Pers. : Fr.) Donk	b	Deadwood of *abies* in the airspace, mostly in humid sites	Lignicol-saprobiotic	Corticioid, tenacious, long-lived
Sarcodon imbricatus (L.) P. Karst.	b	Nutrient-poor, light forests, often on sandy soil	Terricol-mycorrhizal	Hydnoid, fleshy, short-lived
Thelephora penicillata (Pers. : Fr.) Fr.	b	Light woodlands, mostly base-rich and wet	Terricol-mycorrhizal	Ramarioid, tenacious, short-lived
Tricholoma auratum (Paul. : Fr.) Gill.	b	Nutrient-poor, bright forests, often on sandy soil	Terricol-mycorrhizal	Agaricoid, fleshy, short-lived

Table 6. Comparison of the ten indicator scales dealt with in the present study.

		n	L	T	K	F	R	N	S	O	H_l	H_u	M
amp	min	636	2	4	2	2	2	1	0	1	2	3	1
	max	636	9	7	7	11	9	9	1	9	3	6	9
	Δ [units]		7	3	5	9	7	8	1	8	1	3	8
	δ [%]		77.78	33.33	55.56	0.75	77.78	88.89	10	88.89	14.29	42.86	88.89
×	total	636	16	2	4	67	149	88	0	2	0	0	0
	%	636	2.52	0.31	0.63	10.53	23.43	13.84	0	0.31	0	0	0
RL	all species	636	3.95^{a}	4.95	4.86	5.54	6.21	4.86^{ab}	0.03	4.95^{ac}	2^{a}	$3,94^{b}$	$6,51^{c}$
	not threat.	553	3.75^{a}	4.95	4.87	5.56	6.22	4.99^{abc}	0.03	4.88^{ac}	2^{a}	$4,01^{b}$	$6,86^{a}$
	R+G+D+V	31	4.48^{ab}	4.97	4.8	5.72	6.27	4.93^{abc}	0.06	5.07^{abc}	2.03^{bc}	$3,52^{a}$	$4,19^{b}$
	3	34	5.45^{b}	4.97	4.79	5.34	5.83	3.59^{c}	0	5.18^{abc}	2.03^{a}	$3,35^{a}$	$4,53^{b}$
	1+2	16	6.5^{c}	5	4.75	5	6.6	3.63^{bc}	0.06	6.5^{ab}	2^{ac}	$3,31^{a}$	$3,38^{b}$
	Δ [units]		2.75	0.05	0.12	0.72	0.77	1.4	0.06	1.62	0.03	0.7	3.48
	δ [%]		30.56	0.56	1.33	6	8.56	15.56	0.67	18	0.43	10	38.67
	ANOVA F-value		19.9	0.04	0.35	1.7	1.05	8.16	0.79	50.3	4.94	22.2	3.88
	significance level		***	n.s.	n.s.	n.s.	n.s.	***	n.s.	***	**	***	**
lst	mycorrh	203	3.47^{b}	4.77^{a}	4.94^{a}	5.56^{b}	5.57^{a}	3.93^{a}	0.01	4.59^{a}	2^{a}	3.79^{a}	6.37^{a}
	saprob soil	185	5.01^{a}	5.04^{b}	4.85^{ab}	5.14^{a}	6.59^{b}	5.21^{b}	0.05	5.59^{b}	2^{a}	4.01^{b}	6.3^{a}
	saprob sub	216	3.41^{b}	5.02^{b}	4.77^{b}	5.8^{b}	6.68^{b}	5.67^{b}	0.02	5.5^{b}	2^{a}	4^{b}	6.82^{a}
	paras	8	4.43^{ab}	5.13^{ab}	4.88^{ab}	5.86^{ab}	5.8^{ab}	4.83^{a}	0	1.75^{c}	2.13^{b}	4.13^{ab}	5.5^{a}
	other	24	4.09^{ab}	5.21^{b}	4.96^{ab}	6.19^{b}	6.82^{ab}	5.8^{b}	0.04	4^{ac}	2^{a}	4.04^{ab}	6.58^{a}
	Δ [units]		1.6	0.45	0.18	1.05	1.25	1.88	0.05	3.84	0.13	0.34	1.32
	δ [%]		17.7	5.02	2.05	8.74	13.9	20.8	0.54	42.63	1.79	4.81	14.7
	ANOVA F-value		39.2	8.46	2.87	7.55	15.0	34.7	1.74	3.33	22.3	5.35	17.5
	significance level		***	***	*	***	***	***	n.s.	**	***	***	***

In the upper third, the size of the amplitude used for the species set (amp) is characterised by the respective minimum and maximum values. The number of "indifferent" species (×) and their percentual share of all cases are given.

In the middle and lower third, mean unweighted EIVs calculated for different Red List endangerment classes (RL; KARASCH & HAHN 2009) and for different lifestyle types (lst) are given.

n, number of species from the present study in the comparison or in the respective class; H_l/H_u, lower/upper boundary of H levels; Δ, amplitude (difference between highest and lowest value); δ, percentual difference [δ = (Δ/s)*100], with s being the scale size [s = 12 (F), 10 (S), 7 (H), 9 (remaining EIVs)]; n.s., not significant; significant differences between groups are indicated using superscript letters.

Endangerment classes: not threatened; R, extremely rare; G, degree of endangerment uncertain; D, data deficient; V, near threatened; 3, vulnerable; 2, endangered; 1, critically endangered.

Lifestyle: mycorrh, mycorrhizal; saprob soil, saprobiotic on soil; saprob sub, saprobiotic on other substrates; paras, parasitic; other, other lifestyle.

Chapter 3 – Lifestyle and threat of macromycetes – are there any functional traits correlated with?

Abstract

Regarding the functional traits of macromycetes, at present there are only few studies available, and these mostly deal with more specific questions or single traits. In the present study we are interested in if any functional trait may explain the lifestyle and threat of these fungi. For this purpose, a database on 31 traits that cover a broad range of features of, e.g., fruit body morphology, hymenial structure, spore morphology, and propagule dispersal of 636 macromycete species was assembled. Lifestyle and the species' Red List classification were used to detect differences in functional trait adaptation of species. Lifestyle types accounted for significant differences in 28 traits, Red List classification only in three traits. We describe the differentiations and discuss them against the background of ecological and morphological research, including the causes of threat and niche adaptation.

Key words: cystidia; fruit body longevity; fruiting season; hymenium area; lifestyle type; Red List; spore ornamentation; surface index; trama; volume index.

Introduction

Unlike other indicator systems like Ellenberg indicator values (EIVs) that are based on ecological observations regarding the target species, functional traits are based on the features of these species themselves. These include, e.g., spatial characteristics (e.g., leaf size, root depth), temporal (e.g., flowering time, longevity of the propagule bank) or reproduction characteristics (e.g., occurrence of vegetative reproduction, number of seeds) (cf. POSCHLOD et al. 2003; HILL et al. 2007; KLEYER et al. 2008). Thus, functional traits allow insights into the adaptations and demands of species, and thereby traits can be used to assess the influence of ecological, abiotical, and man-made parameters. Regarding vascular plants, functional traits are used, e.g., to address general ecological questions (MCGILL et al. 2006), the effect of ecological filters (DÍAZ et al. 1998), the influence of management and succession (KAHMEN et al. 2002; KAHMEN & POSCHLOD 2004), or "simple" questions such as the seed longevity in

soil seed banks (BEKKER et al. 1998). The basic requirements for those analyses, however, are available databases on traits such as in the case of vascular plants BIOPOP (POSCHLOD et al. 2003) and LEDA (KLEYER et al. 2008).

Concerning bryophytes and lichens, functional traits also are applied, and respective trait databases already exist (HILL et al. 2007) which were already applied to answer more special questions (e.g. ELLIS & COPPINS 2006; STOFER et al. 2006). However, as compared to vascular plants, functional traits are quite rarely used in cryptogam research, which is especially true for fungi, e.g. macromycetes. Though there is a number of studies or reviews on the traits of mycorrhizal structures or of micromycetes, only few publications deal with functional traits of the macromycete lifecycle. Moreover, these few publications mostly describe single elements within the fungal lifecycle such as carbon sequestration or exploitation (e.g. MOELLER et al. 2014; FERNANDEZ & KENNEDY 2015), the genetic basis of fruiting (e.g. STAHL & ESSER 1976), or the features of ballistospores formed by agarics (HALBWACHS & BÄSSLER 2015). So far, no comprehensive database on functional traits of macromycetes exists.

To encourage further research in this field this paper is the first attempt to build up a functional trait database as it was done for vascular plants and bryophytes. The database PILZOEK (BRESINSKY et al. 2007) already points in the right direction. It comprises data on ecological and morphological features of fungal species. However, we try to further extend and customise it regarding data retrieval. This would enhance its value and to use also macromycetes in conservation management or restoration planning in the future.

To get a closer insight which functional traits may be especially worthwile in practical use we made a comparison of 31 functional traits for 636 species of macromyctes. This species set also was used in **Chapter 2**. We used the species' lifestyle type and Red List classification to find out if any of the 31 functional traits may explain respective patterns.

Materials and methods

Selection of traits

We took into account a broad selection of macromycete characteristics including traits of mycelia, fruit bodies, spores, and dispersal, using the set of 636 species assembled in **Chapter 2**. As there are quite few studies on functional traits of macromycetes (see above) we were forced to compile most of the classification schemes and of the trait data by ourselves. After

an intense literature screening we chose a set of 31 traits (Table 8 and 9) mainly based on data from HANSEN & KNUDSEN (1992; 1997; 2000), WINTERHOFF (1992), KRIEGLSTEINER (2000a; 2000b; 2001; 2003), KRIEGLSTEINER & GMINDER (2010), and HALBWACHS & BÄSSLER (2015). Most of these traits were handled or classified according to the data given in identification books or monographs on the respective group, and thus they are self-descriptive. For the traits that were classified in a more specific way explanations are

Table 8. Description of 31 functional traits used in the present study.

Trait	Description	Calculation	Classes
Myc longv	Mycelium longevity	--	3
Frb longv	Fruit body longevity	--	3
Frb size	Fruit body size	mean fruit body height (or width) × fruit body type	--
Frb nr	Fruit body number	--	3
Frb cons	Fruit body consistency	--	5
Frb loc	Fruit body location	--	6
Frb type	Fruit body type	--	5
Frb vel	Fruit body velum conditions	--	4
Frb col	Fruit body colour	--	4
Frt seas	Fruiting season	--	5
Nutr type	Nutrition type	--	5
Sub type	Substrate type	--	5
Sub nr	Number of substrates/mycorrhizal partners	--	3
Hym type	Hymenophore type	--	6
Hym area	Hymenium area	--	5
$Surf_i$	Surface index (surface of hymenium : total fruit body surface)	--	3
Vol_i	Volume index (volume of hymenium : total fruit body volume)	--	3
Sp size	Spore size	mean spore length × spore shape	--
Sp shape	Spore shape	--	5
Sp surf	Spore surface	--	7
Sp col	Spore colour	--	4
Sp wall	Spore wall	--	3
Sp pore	Spore porus	--	3
Sp disp	Spore dispersal	--	3
Sp nr	Spore number per basidium/ascus	directly the number	--
Anam	Presence of anamorphe	--	3
Cyst H	Cystidial conditions hymenium	--	4
Cyst adpt	Cystidial adaptations	--	5
Cyst F	Cystidial conditions fruit body	--	4
Hyph type	Types of hyphae present	--	3
Clamp	Presence of clamps	--	3

given in the following, also including explanations on two traits that were omitted from the present study.

Fruit body colour: Based on the results presented by GUEVARA & DIRZO (1999) we classified colours in dull and bright shades. To get an idea how the colour of fruitbodies is seen by animals in contrast to the background, e.g. bare soil or leaf litter, we also distinguished colour shades similar or different to the background colour.

$Surf_i$ and Vol_i: We used these two indices to express the relation between the total surface or volume of the fruit body and the surface or volume that is made up by the hymenium. As

calculation would be difficult owing to the various shapes of fruit bodies and hymenophores we used a first approximation by giving three ratios.

Fruit body size and spore size: The shape of fruit bodies and also the shape of spores is often quite complicate to describe by mathematical terms, especially for spores that have wrinkles, ridges, or protuberations. Therefore, we used a proxy for the calculation of sizes, which was achieved by multiplying the largest spatial expansion (i.e., fruit body height or width; spore length) with the respective class of fruit body type or of the spore shape.

Odour and volatiles: There are quite many studies on the perception and effect of fungal volatiles on fungivores, especially insects (e.g. HEDLUND et al. 1995; FÄLDT et al. 1999; GUEVARA et al. 2000). However, as these studies throughout only deal with one or few animal groups there seems to be no broader understanding of more general effects of these volatiles; furthermore, very little is known concerning the impact of fungal volatiles on vertebrates, with the one exception of truffles and other hypogeous species. A very common volatile present in most fungal species is 1-octen-3-ol which strongly attracts mosquitos (TAKKEN & KLINE 1989). Due to this very incomplete data situation we omitted this trait type from the present study.

Toxicity: Regarding toxicity the data situation is quite similar as for volatiles. While the constituents that are toxic to humans or mammals are well known, the perception (and avoidance) of toxic fungal substances especially in invertebrates is studied only rarely (SHAW 1992). Thus, we also omitted this factor from the present study.

Analysis of the trait data

The list of FTs for fungi was explored and comparatively studied in two analyses that used unweighted mean trait values.

For this purpose, the species set was divided up based on either the species' Red List status (Red List of Bavaria; KARASCH & HAHN 2009) or lifestyle, thereby providing an overview of the distribution of trait characteristics according to the respective classification.

Differences between groups were analysed using ANOVA and Scheffé's test as a post-hoc test in SPSS 23.0.0.0 (IBM SPSS Statistics 2015).

Results

We included 31 functional traits in the present study (Table 8 and 9). These cover a broad range of ecological and morphological characteristics, including mycelial factors, growth and qualities of the fruit body, nutritional factors, and spore characteristics. We compiled data on these 31 traits for 636 species (Table 12 in Table Appendix).

When we divided the trait data by the species' lifestyle (Table 10) we found significant differences for 28 functional traits. The strongest differentiation (ANOVA F-value > 15) was detected for the twelve traits longevity, consistence, location (i.e., position in respect to the soil surface), and type of the fruit body, velum type, fruiting season, hymenium area, surface and volume indices, spore surface, cystidia types present in the hymenium, and hyphal types in the fruit body.

Saprobionts on special substrates on average had longer-lived fruit bodies than species from other guilds, and these were also tougher, more commonly located in aboveground substrates, and more commonly formed during autumn and spring or during the whole year than that of mycorrhizal and soil-saprobiotic species. Furthermore, the fruit bodies of saprobionts on special substrates had more commonly no or only a partial velum than mycorrhizal and soil-saprobiotic species. Saprobionts on special substrates and parasites more often had simple fruit bodies (e.g., resupinate, effuso-reflex, apothecial) as compared to other species.

The fruit bodies of mycorrhizal species on average had a larger hymenial area and a higher ratio of the volume index, while saprobiotic species on special substrates and parasitic species had the smallest hymenial area and the lowest volume ratio. On the other hand, mycorrhizal species and soil-saprobionts had a higher ratio of the surface index as compared to other species.

Mycorrhizal species on average had more commonly pleurocystidia or both pleuro- and cheilocystidia and also more strongly structured spores than species of other guilds, while saprobionts on special substrates more commonly had cheilo- or no cystidia and mostly smooth spores. Mycorrhizal species and saprobionts on special substrates, as compared to soil-saprobionts, more commonly had a complex hyphal structure including skeletal or binding hyphae.

When we analysed the trait data using the species' Red List classification (Table 11) we found only few significant differences. Not threatened species on average more commonly fruited during autumn and spring or the whole year round, while critically endangered species produced fruit bodies predominately in the 'typical' season (i.e., autumn and winter). The

strongly endangered species in turn used more commonly soil as substrate, the less endangered and not threatened species instead more commonly subsisted on living or dead substrates. Threatened species had significantly more often spores with a sculptured surface, whereas not threatened species had smooth spores.

Discussion

In our analysis of the species' lifestyles we found significant differences for 28 traits. In the discussion we address only those twelve traits with the strongest differentiation as given by the highest F-values (ANOVA F-value > 15).

Table 9. Classification used for the functional traits described in Table 8.
Red List classification: 1, critically endangered; 2, endangered; 3, vulnerable; V, near threatened; R, extremely rare; G+D, data deficient; n.t., not threatened.

Trait	Classes						
Myc longv	perennial	annual	temporary				
Frb longv	perennial	annual	temporary				
Frb size	values						
Frb nr	many	several	one-few				
Frb cons	woody	tenacious	cartilaginous	soft, dry	soft, aqueous		
Frb loc	high air space	low air space	soil surface	in substrate aboveground	subterranean	in substrate belowground	
Frb type	resupinate	effuso-reflex, apothecial	clavarioid, ramarioid	gastroid, cleistothecial, perithecial	agaricoid, boletoid, dimidiate		
Frb vel	Velum universale + partiale	Velum universale	Velum partiale	missing			
Frb col	darker than substrate	like substrate	lighter than substrate	brightly coloured			
Frt seas	all year round	spring + autumn	autumn	winter	other		
Nutr type	mycorrhizal	saprobiotic	saprobiotic + parasitic	parasitic	other		
Sub type	living substrate	dead substrate	dung	soil	other		
Sub nr	many	several	one-few				
Hym type	tubes	lamellae, ridges	spines or similar, coralloid or similar	near smooth	smooth	gastroid, perithecial, cleistothecial	
Hym area	very large	large	medium	small	very small		
$Surf_i$	± 1	< 1	<< 1				
Vol_i	± 1	< 1	<< 1				
Sp size	values						
Sp shape	elongate	cylindric	ellipsoid	curved, bean-shaped	sperical		
Sp surf	smooth	fine warts	coarse warts	spines	ridges, grooves	net-shaped	protuberations
Sp col	hyaline	weakly coloured	strongly coloured	± black			
Sp wall	thin	thick	doube layer				

Table 9 *continued*

Trait	Classes				
Sp pore	big and distinct	small	± missing		
Sp disp	without adaptation	epizoochorous	endozoochorous		
Sp nr	values				
Anam	as separate fruit body	associated with teleomorphe	missing		
Cyst H	pleurocystidia + cheilocystidia (or similar)	pleurocystida (or similar)	cheilocystidia (or similar)	missing	
Cyst adpt	basidium-like	larger or other form than basidia	thick-walled	containing oils etc.	encrusted
Cyst F	pileocystidia + caulocystidia	pileocystidia	caulocystidia	missing	
Hyph type	generative hyphae only	generative + skeletal hyphae	generative + skeletal + binding hyphae		
Clamp	present throughout	± only subbasidial (or similar)	(±) missing		

Compared to the fruit bodies of terricolous (mycorrhizal or saprobiotic) fungi, the fruit bodies of saprobiotic species on special substrates were longer-lived, tougher, and more commonly produced in autumn and spring or during the whole year. Furthermore, they had no or only a partial velum, and more commonly were located in aboveground substrate. The first three traits clearly are interrelated, since the fruit bodies can survive longer due to their tougher structure, and due to their longer durability they often are found the whole year round. In contrast to soil, special substrates are limited in size, and thus, when feeding on such substrates it seems to be reasonable and economic to produce tougher and longer surviving fruit bodies instead of repeated production of short-lived fruit bodies. Soil-inhabiting species feed on a more infinite nutrient source (in the case of mycorrhizal species including additional nutrients supplied by the vascular plant host), which is why they can afford it to repeatedly produce fruit bodies at times, when the host's activity also is highest (cf. HALBWACHS & BÄSSLER 2012).

Many wood-inhabiting species of polypores and of Corticiaceae s.l. most actively sporulate in the winter half year (e.g. JÜLICH 1984; RYVARDEN & GILBERTSON 1993; KRIEGLSTEINER 2000a), which is why the fruit bodies of many species mainly are found from autumn to spring. Sporulation during the winter may have two advantages. Firstly, at least in species forming ballistospores sporulation is most active around midnight, when temperature reaches its lowest and humidity its highest values (INGOLD 1966; KRAMER 1982; HALBWACHS & BÄSSLER 2015). Referring to a whole year, the same pattern is achieved during the winter, and thus circumstances for spore dispersal then are best. Secondly, since there are various insect

species feeding even on tough and woody fruit bodies (e.g. FÄLDT et al. 1999; SCHIGEL et al. 2006), sporulation during the winter may minimize spore loss by avoiding the times of insect activity (cf. BODDY & JONES 2008). The velum characteristics as well as the location of fruit bodies in aboveground substrates may simply reflect taxonomical circumstances since these traits are closely linked to the taxonomical group that a species belongs to (CARLILE et al. 2001; MUELLER et al. 2004), and the velum characteristics also evidently are linked to fruit body complexity (see next paragraphs).

In a similar way, the species living as parasites or as saprobionts on special substrates we dealt with in our study on average had simpler fruit bodies than the other guilds, and they had lower values of Vol_i and smaller hymenium areas than mycorrhizal species. Having simple fruit bodies obviously is an advantage for species feeding on limited nutrition sources such as living or dead plants; in different taxonomical lineages similar anatomical reductions can be observed, leading to fruit bodies with reduced stipes and velum or to bracket-like or resupinate fruit body types, and the same holds true regarding gasteromycetation (BINDER et al. 2005; HIBBETT 2006; HAWKSWORTH & LAGRECA 2007; WILSON et al. 2011; HALBWACHS et al. 2016). Thus, our findings unequivocally reflect the data from the literature. However, fruit body simplification also leads to a reduction of the hymenophore, and as a consequence, hymenium area and the ratio of Vol_i become smaller. The opposite is the case with mycorrhizal species since these produce relatively complex fruit bodies with comparatively large hymenia and high Vol_i ratios (cf. BÄSSLER et al. 2015). Due to the high complexity the fruit bodies of mycorrhizal and soil-saprobiotic species also have higher $Surf_i$ ratios than those of other guilds.

Mycorrhizal species on average more often had ornamented spores and also more often had pleurocystidia or pleuro- and cheilocystidia than species from other guilds, which in turn more often had smooth spores and only cheilocystidia or no cystidia at all. In the reproduction of mycorrhizal species it is a crucial step to get their spores placed near the roots of their host species. Thus, strong ornamentation of the spores most probably is an adaptation to enhance dispersal by animals (BRUNDRETT 1991) or by precipitation water trickling through the forest soil and along the root channels (GREGORY 1973; MALLOCH & BLACKWELL 1992). Regarding animals, mammals and small soil-dwelling arthropods probably are the most efficient spore vectors (JOHNSON 1996; LILLESKOV & BRUNS 2005; HALBWACHS & BÄSSLER 2015), the latter also concering deposition of spores near the roots of host species (LILLESKOV & BRUNS 2005; HALBWACHS & BÄSSLER 2015). Hymenial cystidia commonly are thought to have three main functions that can be found in different combinations (cf. HALBWACHS & BÄSSLER

2015), i.e., to function as spacers keeping the lamellae (or pore walls) sufficiently apart (e.g. BULLER 1924; MOORE et al. 1998), as collectors of air humidity (LARGENT et al. 1978), or as defence against sporophagous animals (e.g. BULLER 1909; NAKAMORI & SUZUKI 2007). Since mycorrhizal fungi produce relatively complex fruit bodies (cf. BÄSSLER et al. 2015) this most probably is the reason why they more commonly have pleuro- and/or cheilocystidia than species of other groups, as they have to support and protect comparatively larger hymenial areas.

Compared to the fruit bodies of soil-saprobionts, those of mycorrhizal species and of saprobiontic species on special substrates more often had a di- or trimitic hyphal system. While monomitic trama consists only of generative hyphae and, therefore, in most cases is relatively soft, the additional presence of skeletal hyphae or of skeletal hyphae and binding hyphae (i.e., dimitic or trimitic trama with two or three hyphal types) leads to a more tenacious or woody texture. Mycorrhizal species were shown to have bigger (BÄSSLER et al. 2015) and more complex fruitbodies (see above) than species from other guilds. Thus, strengthening of the fruit bodies by dimitic or trimitic trama very likely relates to their size and complexity. In saprobiotic species on special substrates fruit bodies are more long-lived than in species belonging to other guilds (Table 10). This pronounced longevity commonly is caused by a tenacious or woody texture that inhibits or retards degradation by physical or biological influences, e.g. frost or predators (e.g. LISIEWSKA 1992; HOOD 2006; KÜES & NAVARRO-GONZÁLEZ 2015). In both mycorrhizal species and saprobiotic species on special substrates the strengthened trama thus improves the production of big or long-lived fruit bodies and, thereby, the amount of spores produced by these due to the comparably larger hymenium or prolonged fruiting time. Since both mycorrhizal species and saprobionts on special substrates are connected to (mostly woody) vascular plants, the resinous incrustation of skeletal and binding hyphae found in di- and trimitic hyphal systems (as well as resinous surfaces, which are commonly found in bracket fungi) may play an important role in the disposal of phenolic substances received from the woody host tissues.

When we compared the species using their Red List classification we could show that not threatened or only weakly endangered species typically were characterised by smooth spores, occurrence on living or dead substrates, and fruiting during autumn, spring, or the whole year. On the other hand, strongly endangered species typically had sculptured spores, subsisted on soil, and fruited during autumn and winter.

Table 10. Comparison of 31 functional traits dealt with in the present study using unweighted mean values calculated for different lifestyle types.
n, number of species from the present study in the respective class; n.s., not significant; significant differences between groups are indicated using superscript letters.
Lifestyle types: myc, mycorrhizal; soil, saprobiotic on soil; sub, saprobiotic on other substrates; par, parasitic; other, other lifestyle.
The three traits nutrition type, substrate type, and number of substrates were omitted from the analysis due to their close relationship to the lifestyle guilds.
F, ANOVA F-value; sig, significance level.

	myc	soil	sub	par	other	F	sig
n	203	185	216	8	24		
Myc longv	1.0^{a}	1.1^{a}	1.1^{a}	1.4^{bc}	1.1^{ac}	6.4	***
Frb longv	3.0^{a}	3.0^{a}	2.1^{bc}	2.8^{ac}	2.8^{a}	83.5	***
Frb size	29.4^{a}	20.8^{b}	20.5^{bc}	10.3^{ac}	22.8^{ac}	6.5	***
Frb nr	2.0^{a}	2.0^{a}	2.2^{bc}	2.3^{ac}	2.1^{ac}	13.3	***
Frb cons	4.9^{a}	4.9^{a}	3.3^{bc}	3.9^{ac}	4.3^{ac}	83.1	***
Frb loc	3.0^{a}	3.2^{a}	3.5^{bc}	3.6^{ac}	3.0^{a}	15.3	***
Frb type	3.2^{a}	3.1^{a}	2.0^{b}	2.3^{b}	2.0^{a}	42.9	***
Frb vel	3.5^{a}	3.6^{a}	3.9^{bc}	4.0^{ac}	3.0^{ac}	18.0	***
Frb col	3.1	3.0	2.9	2.9	2.8	3.0	n.s.
Frt seas	3.0^{a}	3.2^{a}	2.3^{bc}	3.0^{ac}	3.1^{a}	41.2	***
Nutr type	--	--	--	--	--	--	--
Sub type	--	--	--	--	--	--	--
Sub nr	--	--	--	--	--	--	--
Hym type	2.0^{a}	2.6^{bc}	2.7^{bc}	3.4^{ac}	2.1^{ac}	9.6	***
Hym area	2.1^{a}	3.1^{b}	3.8^{ce}	6.4^{d}	2.8^{abe}	20.7	***
Surf$_i$	2.9^{a}	2.8^{a}	2.1^{b}	2.0^{bc}	2.7^{ac}	67.0	***
Vol$_i$	2.9^{a}	2.6^{b}	2.1^{cd}	2.0^{ce}	2.4^{bde}	59.1	***
Sp size	29.8	27.5	25.4	37.3	31.6	3.5	n.s.
Sp shape	3.2	3.2	3.0	2.5	3.1	4.0	n.s.
Sp surf	2.8^{a}	1.8^{b}	1.1^{c}	0.9^{bc}	1.3^{bc}	37.2	***
Sp col	1.6^{a}	1.5^{ac}	1.3^{bcd}	0.9^{ad}	1.5^{ad}	4.8	**
Sp wall	1.2^{a}	1.2^{ac}	1.1^{bcd}	0.9^{ad}	1.0^{ad}	4.8	**
Sp pore	3.0^{a}	2.6^{bd}	2.8^{c}	2.6^{acd}	2.8^{acd}	12.2	***
Sp disp	1.0	1.0	1.0	0.9	1.0	1.7	n.s.
Sp nr	4.0^{a}	4.2^{ac}	4.7^{bc}	4.0^{ac}	4.0^{ac}	3.0	*
Anam	3.0^{a}	3.0^{a}	2.9^{bc}	2.8^{bc}	2.9^{ac}	6.8	***
Cyst H	2.2^{a}	3.2^{bd}	2.8^{c}	2.9^{acd}	2.9^{acd}	17.5	***
Cyst adpt	2.0^{a}	1.0^{bc}	1.3^{b}	0.8^{ac}	1.5^{ac}	12.0	***
Cyst F	3.4^{a}	3.7^{bc}	3.9^{b}	3.3^{ac}	3.7^{ac}	9.2	***
Hyph type	1.3^{a}	1.0^{bc}	1.3^{a}	1.0^{ac}	1.2^{ac}	15.5	***
Clamp	2.1^{a}	1.7^{bc}	1.7^{b}	1.5^{ac}	1.8^{ac}	5.8	***

The differences in spore ornamentation clearly indicate considerable differences in the species' ecological strategy. Spore ornamentation was shown to allow a long dormancy (GREGORY 1973) and to support spore dispersal by wind, raindrops, mist, and invertebrates (DAVIES 1961; RUDDICK & WILLIAMS 1972; JENNINGS & LYSEK 1999; LILLESKOV & BRUNS 2005; DIJKSTERHUIS & SAMSON 2007; DÖRFELT & RUSKE 2010; GUBE & DÖRFELT 2011; HALBWACHS & BÄSSLER 2015). Furthermore, ornamented spores frequently also have thick and melanised walls. Thick walls increase the resistence of the spore against environmental influences and thereby also allow a long dormancy (GREGORY 1973; HAWKER & MADELIN 1976; DIX & WEBSTER 1995; GARNICA et al. 2007), while melanisation enhances the resistance against desiccation, UV radiation, and lysis (BLOOMFIELD & ALEXANDER 1967; GARNICA et al. 2007; FERNANDEZ & KOIDE 2013; HALBWACHS & BÄSSLER 2015).

Thus, primarily soil-inhabiting species mostly seemed to be adapted to specific dispersal vectors and to have a persistent spore bank that allows them to survive unfavourable times and disturbance. On the other hand, species with smooth spores as a rule did not exhibit a stronger specialisation regarding a long dormancy or certain dispersal vectors. However, both the species with ornamented and those with smooth spores can be classified as ruderals (cf. GRIME 1979; ANDREWS 1992; KLOTZ & KÜHN 2002). Since special substrates often are available only for a short time at a given site, the missing of a more pronounced dormancy in species colonising these substrates also seems reasonable.

Table 11. Comparison of 31 functional traits dealt with in the present study using unweighted mean values calculated for different Red List endangerment classes (RL; KARASCH & HAHN 2009). n, number of species from the present study in the respective class; n.s., not significant; significant differences between groups are indicated using superscript letters.
Endangerment classes: n.t., not threatened; R, extremely rare; G+D, data deficient; V, near threatened; 3, vulnerable; 2, endangered; 1, critically endangered.
F, ANOVA F-value; sig, significance level.

RL	all	n.t.	R+G+D+V	3	1+2	F	sig
n	636	553	31	34	16		
Myc longv	1.0	1.1	1.0	1.0	1.0	0.9	n.s.
Frb longv	2.7	2.7	2.8	3.0	2.9	2.3	n.s.
Frb size	23.4	23.5	22.9	24.1	18.7	0.2	n.s.
Frb nr	2.1	2.1	2.1	2.1	2.0	0.3	n.s.
Frb cons	4.3	4.3	4.7	4.7	4.8	2.3	n.s.
Frb loc	3.2	3.2	3.1	3.1	3.2	0.9	n.s.
Frb type	2.4	2.3	2.4	3.5	4.0	2.8	n.s.
Frb vel	3.7	3.7	3.5	3.8	3.8	0.5	n.s.
Frb col	3.0	3.0	2.9	3.2	2.9	1.1	n.s.
Frt seas	2.8^{ab}	2.8^{b}	2.9^{ab}	3.2^{ab}	3.5^{a}	5.0	**
Nutr type	1.8	1.8	1.6	1.6	1.8	1.2	n.s.
Sub type	3.1^{ab}	3.0^{a}	3.4^{abc}	3.7^{c}	3.9^{bc}	7.1	***
Sub nr	1.4^{ab}	1.4^{ab}	1.7^{ab}	1.2^{ac}	0.6^{c}	3.6	*
Hym type	2.4	2.4	2.2	2.3	2.3	0.5	n.s.
Hym area	3.1	3.1	2.5	2.5	2.3	1.5	n.s.
$Surf_i$	2.6	2.5	2.7	2.8	2.9	2.9	n.s.
Vol_i	2.5	2.5	2.7	2.7	2.8	2.2	n.s.
Sp size	27.8	27.9	24.9	28.3	28.8	0.3	n.s.
Sp shape	3.1	3.1	3.2	3.4	3.3	1.7	n.s.
Sp surf	1.8^{ab}	1.7^{ab}	2.4^{ac}	3.0^{c}	2.2^{ac}	6.4	***
Sp col	1.5	1.5	1.6	1.5	1.7	0.7	n.s.
Sp wall	1.2	1.2	1.2	1.1	1.2	0.3	n.s.
Sp pore	2.8	2.8	2.9	2.9	2.8	0.6	n.s.
Sp disp	1.0	1.0	1.0	1.0	1.0	0.1	n.s.
Sp nr	4.3	4.3	3.9	3.9	4.2	0.7	n.s.
Anam	3.0	3.0	3.0	3.0	3.0	0.3	n.s.
Cyst H	2.7	2.7	2.6	2.8	3.3	1.0	n.s.
Cyst adpt	1.4	1.5	1.7	1.2	1.1	0.7	n.s.
Cyst F	3.7	3.7	3.6	3.5	3.8	0.6	n.s.
Hyph type	1.2	1.2	1.2	1.2	1.0	0.9	n.s.
Clamp	1.8	1.8	1.6	2.0	1.8	0.6	n.s.

Soil-inhabiting species seem to have a more compressed period of fruiting. Phenologies of fungus species were shown to interact with that of animals (HANSKI 1989). Fungi thereby may be able to avoid predation of their fruit bodies (BODDY & JONES 2008) or to make fruit bodies

in time with the highest acitivity of their main vectors (HALBWACHS et al. 2016). Furthermore, the group of soil-inhabiting fungi comprises a high number of mycorrhizal species, and these have considerably shorter fruiting periods than species on other substrates (BODDY et al. 2014). The high share of mycorrhizal species and the timed fruiting thus very likely are the reasons of the more compressed fruiting period observed for soil-inhabiting species.

The high share of soil-inhabiting species within the group of strongly endangered species seems to reflect a general rule, as 78 % of the critically endangered fungi in the Red List of Bavaria (KARASCH & HAHN 2009) use soil as substrate. The main threats for fungi are deposition of nitrogen and other substances and degradation or destruction of suitable sites (ARNOLDS 1991; KARASCH & HAHN 2009), which also are the main threats in vascular plants (e.g. RÖMERMANN et al. 2008). In addition, it is more difficult for mycorrhizal and soil-saprobiontic macromycete species to reach new sites due to three trait characteristics that have a negative effect in this respect: strong specialisation in specific dispersal vectors, need of suitable soil conditions, and short fruiting periods. In contrast, less specialised species or species with a prolonged fruiting time are at an advantage to reach new sites and to tolerate the impact of eutrophication and similar processes.

Outlook

Referring to the lifestyle types, 28 out of 31 functional traits showed significant differences. Thus, it would be worthwile to have a closer look at smaller sets of related factors, and the present study may be used as a basis of future research, by giving hints in which fields the biggest differentiations (and, in consequence, the strongest adaptations) are to be expected.

In contrast, in the comparison of Red List classification only three functional traits showed a significant differentiation. This result implies that species' traits play only a minor role in their vulnerability, except the nutritional status of the substrate.

Chapter 4 – Does the cryptogam vegetation of calcareous grasslands reflect land-use history?

Abstract

This study was designed to compare the influence of land-use history and continuity on vascular plants and cryptogams. Two study areas of dry calcareous grassland were chosen where ancient and recent calcareous grassland could be differentiated. Ancient was defined that there was a continuous grazing history since at least 200 years. Recent was defined that these grasslands have developed from arable fields during the last 200 years. In these grassland sites, we studied the terricolous cryptogam vegetation (bryophytes, lichens, macromycetes) regarding species composition, occurrence of endangered species, and the applicability of the indicator species concept and Ellenberg indicator values. Species numbers and Ellenberg indicator values were quite similar in ancient and recent grasslands. Nevertheless, we could identify indicator species for both grassland types, with *Cladonia furcata* ssp. *subrangiformis* and *Hygrocybe persistens* var. *persistens* as strongest indicators of ancient grasslands, and *Rhytidiadelphus squarrosus* as strongest indicator of recent grasslands. This was in contrast to the vascular plant vegetation where recent grasslands could be differentiated through many species such as arable weeds and crop species, being residuals of the former land-use type. Thus, land-use history seems to have less influence on the composition of the cryptogam vegetation in grasslands.

Key words: bryophytes; calcareous grasslands; Central Europe; Ellenberg indicator values; fungi; historical ecology; indicator species; lichens; macromycetes; vascular plants; woodlands

Introduction

In Europe there is a long tradition of studies on the vegetation of habitats with different age and land-use history. A great number of these studies focusses on woodlands (cf. HERMY et al. 1999). One major topic is to compare ‘ancient’ and more ‘recent’ or variously managed sites of the same habitat type with respect to their general species pool and the occurrence of rare and endangered taxa (PETERKEN 1974; PETERKEN & GAME 1984; EJRNAES & BRUUN

1995; WULF 1997; POSCHLOD et al. 1998; HERMY et al. 1999; ROSE 1999; POSCHLOD & WALLISDEVRIES 2002). In this context, ancient sites have a continuous habitat history, but may be altered in structure or species composition by man, while recent sites have been newly established displacing other habitat types a certain time ago.

Mainly because of their continuity, ancient sites are thought to hold more rare or threatened species and to be richer in species typical for the particular habitat (EJRNAES & BRUUN 1995; GRAAE & SUNDE 2000; FRITZ et al. 2008). However, there is little consistency in where exactly to draw the line between 'ancient' and 'recent' (EJRNAES & BRUUN 1995; HERMY et al. 1999). The distance between the sites compared regarding their age or history also is a point of much discussion, as recolonisation of newly established habitats from old ones is easier when these are adjacent. Surveys using close-by sites therefore sometimes tend to detect less differences (SCHNEIDER & POSCHLOD 1999; COUSINS et al. 2009). Seeds may, nonetheless, be dispersed over comparably large distances in the course of transhumance and similar husbandry types (POSCHLOD et al. 1998; POSCHLOD 2015) or by rare long-distance effects (NATHAN 2006), thereby linking the vegetation of distant sites. Species traits also can explain some patterns in the dispersal and colonisation process, as species with infrequent seed production or heavy seeds are at a disadvantage to reach newly created sites owing to their limited dispersal potential (HERMY et al. 1999). On the other hand, seeds and other propagules suitable for long-distance dispersal or persistent in soil seed banks can have a pivotal role in the re-colonisation of disturbed sites (INGOLD 1971; PUTWAIN & GILLHAM 1990; SMITH 1993; RYDGREN et al. 1998; KALAMEES & ZOBEL 2002; NATHAN 2006).

While vascular plant vegetation is a recurrent topic in ecological studies, cryptogam vegetation often is neglected due to the sporadic occurrence and minute size of the species or owing to problems in determination and taxonomy. Larger lichen and bryophyte species are among the cryptogam groups more frequently screened in studies of sites of different age or management (HUMPHREY et al. 2002; LÖBEL et al. 2006; FRITZ et al. 2008). Fungi, in contrast, are surveyed very rarely, except macromycetes growing on deadwood (ÓDOR et al. 2006; NORDÉN et al. 2007) and in dry grasslands (EJRNAES & BRUUN 1995). Thus, the effects of history and management on soil-inhabiting vascular plants and cryptogams can hardly be compared, as there are very few studies on both groups.

Against this background our work aimed on the comparison of the terricolous vegetation of vascular plants and cryptogams, studying the cryptogam vegetation (i. e., bryophytes, lichens and macromycetes) of nutrient-poor calcareous grasslands. Comparing recent and ancient grasslands we addressed the following questions: (i) Are there any differences in species

richness, species composition, and Ellenberg indicator values of cryptogams? (ii) Is it possible to identify cryptogams as indicator species for the types? (iii) Are there comparable results for cryptogam and vascular plant vegetation?

Materials and methods

Study sites

Our study was carried out in two areas located in the German part of the Jurassic mountains (Swabian Alb, Franconian Alb; Figure 2). Both study areas comprise sets of calcareous grasslands of different land-use history (Table 13). While ancient grasslands were pastures at least since 1830, recent grasslands were formed from arable land after this time (KARLÍK 2008; KARLÍK & POSCHLOD 2009). The grassland sites of both study areas were characterised regarding main abiotic properties (KARLÍK 2008; KARLÍK & POSCHLOD 2009).

KARLÍK & POSCHLOD (2009) proposed three age groups within the recent grasslands, namely very old (ca. 160 years old), old (ca. 65-160 years old), and young grasslands (less than 65 years old). Due to only minor differences regarding the cryptogam vegetation we united these three types of recent grasslands in one and compared them as a whole with the ancient sites.

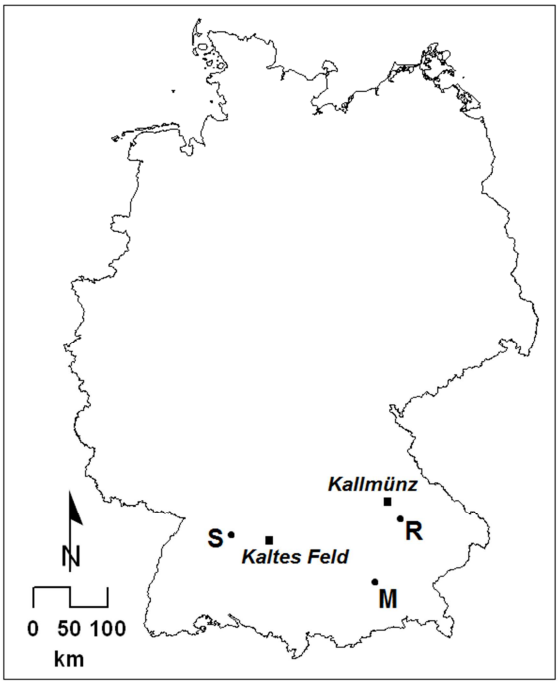

Figure 2. Location of the two study areas Kaltes Feld and Kallmünz in southern Germany. M, Munich; R, Regensburg; S, Stuttgart.

Vegetation survey and data analysis

For all grassland sites, we compiled separate species lists of the terricolous species of bryophytes, lichens, and macromycetes by searching the total extent of each site. We did not use vegetation relevés, mainly owing to the strongly heterogeneous distribution of the cryptogam species. We recorded the bryophyte and lichen vegetation using the abundance-dominance scale by Braun-Blanquet (e.g. DIERSCHKE 1994) and the macromycete vegetation by counting the sporocarps. Vegetation data of acrocarpous mosses also were considered in separate analyses because of their indicator value for well-managed dry calcareous grasslands, where they grow in gaps of the vascular plant vegetation or on exposed ground (DURING 1979; FRAHM 2001). Information on Red List taxa were taken from SAUER & AHRENS (2005) for bryophytes, WIRTH (2008) for lichens, and KARASCH & HAHN (2010) for macromycetes. We used the Red List of macromycetes of Bavaria as the last one published for Baden-Wuerttemberg (WINTERHOFF & KRIEGLSTEINER 1984) is too old and a later compilation by GMINDER was left unpublished. Nomenclature follows FRAHM & FREY (2004) for bryophytes, WIRTH (1995) for lichens, and the Index Fungorum (www.indexfungorum.org) for macromycetes.

Species lists were analysed by univariate and multivariate tests. Univariate analyses were performed in SPSS 17 (SPSS 2009) as comparison of means (Mann-Whitney U test). Multivariate analyses were performed in PC-Ord 5.17 (MCCUNE & MEFFORD 2011) as DCA (Detrended Correspondence Analysis) with rescaling of axes using 26 fragments. We calculated fidelity values for each species in JUICE 7.0 (TICHÝ 2002) to find indicator species for the grassland types. According to KARLÍK & POSCHLOD (2009) we used the Phi coefficient as measure of fidelity and calculated significance of fidelity on basis of presence/absence data with Fisher's exact test ($P < 0.05$).

Based on the species lists we calculated mean Ellenberg indicator values (EIV) to find out if of ancient and recent sites have similar ecological properties or differ. Owing to their different lifestyle, we did separate analyses for macromycetes and for bryophytes and lichens; while terricolous bryophytes and lichens use the soil mainly or exclusively as a basis to grow on, terricolous macromycetes depend on the soil and humus material (HAWKSWORTH & HILL 1984; FRAHM 2001; MUELLER et al. 2004; GOFFINET & SHAW 2008). For the comparison of EIVs we used the values of L (light intensity), T (mean annual temperature), F (soil moisture content), R (soil pH value), N (soil nutrient availability), H_{max} (maximum value of hemeroby), and O (habitat openness). Note that values for H_{max} and O are available only for macromycetes, and that values for N are not available for bryophytes. EIV data were taken

from DÜLL (2001; bryophytes), WIRTH (2001; lichens), and SIMMEL et al. (2016; see **Chapter 2**). We consider as meaningful only percentual differences ≥ 5 %.

Table 13. Environmental data of the two study sites "Kaltes Feld" and Kallmünz, and number of study sites. While "ancient" sites were grasslands since at least 1830, "recent" sites have a habitat tradition of < 170 years. Data compiled from BAUMANN et al. (2005), KARLÍK (2008), KARLÍK & POSCHLOD (2009), and POSCHLOD & BAUMANN (2010).

	"Kaltes Feld"	Kallmünz
Altitude (m a.s.l.)	650-780	340-440
Mean annual precipitation (mm)	1.050	649
Mean annual temperature (°C)	7	7.4-7.8
Main geological substrate	Upper Jurassic Bedrock	Upper Jurassic Bedrock
Main soil type	Rendzina	Rendzina
Vegetation type	Mesobromion s.l.	Mesobromion s.l., partly tending to Xerobromion
N recent sites	12	7
N ancient sites	10	8

Table 14. Mean species numbers (N) of terricolous bryophytes, lichens, macromycetes and Red List cryptogam species in plots of ancient and recent grasslands of the study areas "Kaltes Feld" and Kallmünz. Additionally, mean proportion of acrocarpous mosses of all bryophytes is given. Mann-Whitney U test: U, U-value; p, p-value.

	N Total	N Bryophytes	% Acrocarpous mosses	N Lichens	N Macromyc	N Red List
Kaltes Feld						
Ancient	11.5	8.4	21.5	1.7	1.4	2.7
Recent	10.6	8.4	11.7	0.3	1.9	1
MW U	55.000	59.000	26.500	4.500	54.000	9.000
MW p	0.740	0.947	0.026	0.000	0.680	0.001
Kallmünz						
Ancient	14.5	8.25	20.21	1.88	4.38	2.63
Recent	13.57	8.57	15.48	1.14	3.86	2.71
MW U	23.500	27.000	21.500	18.500	25.000	25.000
MW p	0.600	0.905	0.445	0.242	0.723	0.718

Results

We could observe only few differences between the cryptogam vegetation of ancient and recent calcareous grasslands, with three significant differences regarding the "Kaltes Feld" (Table 14). Ancient grasslands held significantly higher numbers of lichen species, of Red List species, and a higher proportion of acrocarpous mosses of all bryophytes compared to the total number of bryophytes. For Kallmünz, we did not find any significant differences (Table 14).

In the DCA ordination of the grasslands of the "Kaltes Feld", ancient and recent sites were quite strongly intermingled in the diagram center (Figure 3). Main differentiation is explained by the first axis (39.6 %), with an SD of 3.3 and thus an almost complete species turnover. The gradients of *Hygrocybe virginea*, *Pleurozium schreberi*, *Rhytidiadelphus squarrosus*, and *Rhytidium rugosum* exhibit the strongest correlation with the first axis. The second axis only accounts for a minor differentiation of 10.3 %.

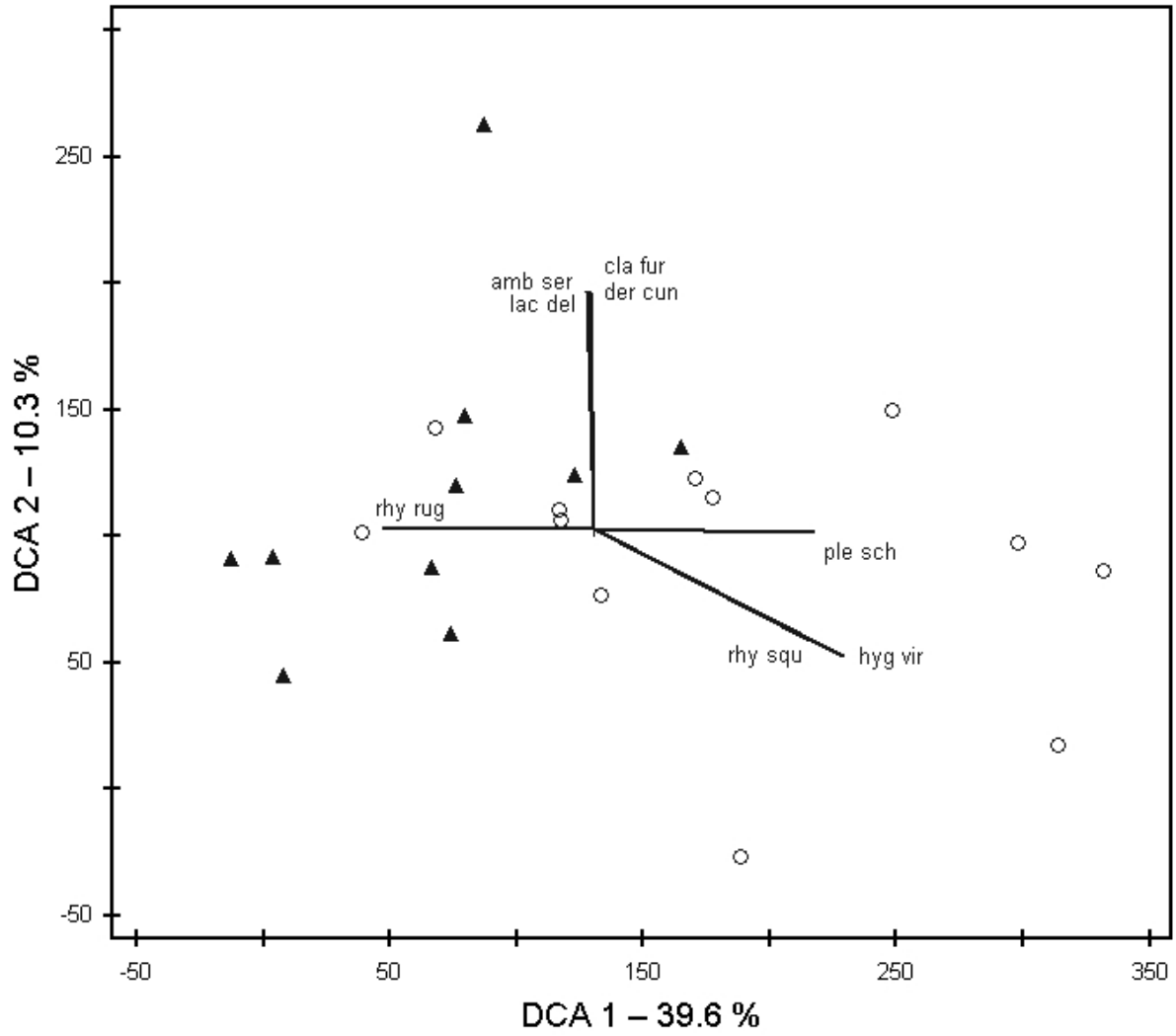

Figure 3. DCA biplot of ten ancient (▲) and twelve recent (○) grassland sites of the study area "Kaltes Feld" with the vegetation data of bryophytes, lichens, and macromycetes. Axis titles give the accounted-for variance. Length of gradient: 3.3 SD; cut-off r^2: 0.4; data set: 22 sites, 55 species. Correlation (Pearson's r) with 1./2. axis for the displayed species: *Amblystegium serpens* (0.2/0.6), *Cladonia furcata* ssp. *subrangiformis* (0.2/0.6), *Dermoloma cuneifolium* (-0.2/0.5), *Hygrocybe virginea* (0.7/-0.04), *Lactarius deliciosus* (-0.2/0.1), *Pleurozium schreberi* (0.6/0.3), *Rhytidium rugosum* (-0.6/-0.3), *Rhytidiadelphus squarrosus* (0.8/-0.04).

Ancient and recent grassland sites were quite well separated in the DCA ordination of Kallmünz (Figure 4). Main differentiation is explained by the first axis (34.1 %), with an SD of 2.7, while the second axis only accounts for a minor differentiation of 14.9 %. The gradients of *Bryum rubens* and *Omphalina pyxidata* exhibit the strongest correlation with the first axis.

Table 15 gives the species with significant fidelity in ancient or recent grasslands. These species can be considered as indicator species. For the "Kaltes Feld", no fungi with significant fidelity could be identified. The strongest indicator species of ancient grasslands was *Cladonia furcata* ssp. *subrangiformis*, missing in recent grasslands.

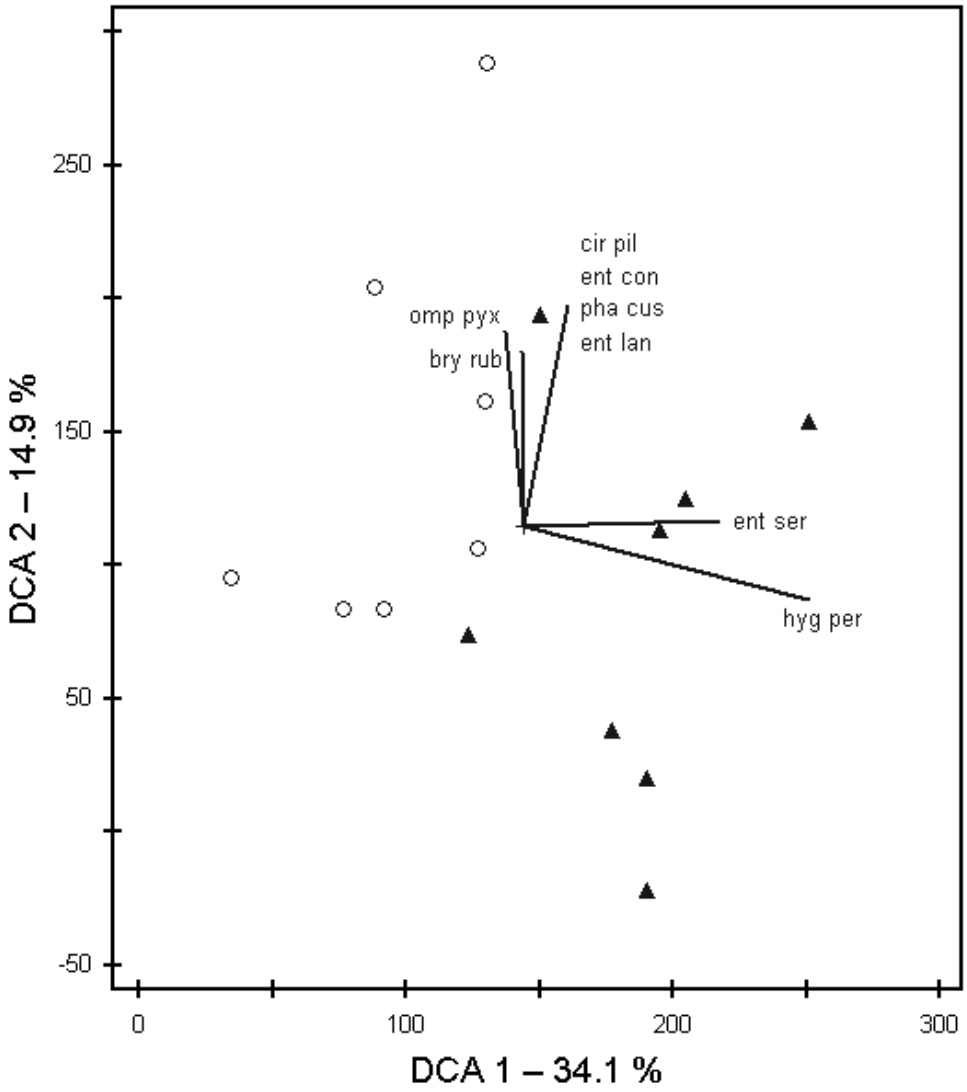

Figure 4. DCA biplot of eight ancient (▲) and seven recent (○) grassland sites of the study area Kallmünz with the vegetation data of bryophytes, lichens, and macromycetes. Axis titles give the accounted-for variance. Length of gradient: 2.7 SD; cut-off r^2: 0.37; data set: 15 sites, 64 species. Correlation (Pearson's r) with 1./2. axis for the displayed species: *Bryum rubens* (0.69/-0.2), *Cirriphyllum piliferum* (0.6/-0.16), *Entodon concinnus* (0.6/-0.55), *Entoloma lanicum* (0.6/-0.16), *Entoloma sericeum* (0.12/-0.45), *Hygrocybe persistens* var. *persistens* (-0.5/-0.6), *Omphalina pyxidata* (0.65/-0.39), *Phascum cuspidatum* (0.6/-0.16).

Similarly, the strongest indicator species of recent grasslands, *Rhytidiadelphus squarrosus*, did not occur in ancient grasslands. For Kallmünz, only indicator species of ancient grasslands could be identified. These were the two macromycetes *Agaricus xanthoderma* and *Hygrocybe persistens* var. *persistens*, both missing in the recent grasslands.

Results of the EIV analysis are given in Table 16. For both the "Kaltes Feld" and Kallmünz, the EIV values of bryophytes and lichens hardly match with those of macromycetes. This holds true also regarding the differences comparing recent and ancient grasslands as calculated for these two groups. We found no strong differences ≥ 5 % for the bryophyte and

lichen vegetation. Regarding the macromycete vegetation, meaningful differences were found for the L, N, H_{max}, and O values ("Kaltes Feld"), and for the L and O values (Kallmünz).

Discussion

Comparing the recent and ancient grasslands, in both study areas total species richness and richness in bryophyte and macromycete species were quite similar. At the study site Kallmünz also the richness in lichen species and in Red List species and the proportion of acrocarpous mosses of all bryophytes did not significantly differ. For the grasslands at the "Kaltes Feld" we found significant differences regarding these three factors, with higher values found throughout for the ancient grasslands. However, as species numbers in general were quite low these differences should not be overrated.

While mean EIV values of the bryophyte and lichen vegetation for recent and ancient sites did not considerably differ in neither of the two study areas, we could find at least some differences for the macromycete vegetation. The recent sites at the "Kaltes Feld" yielded higher L, H_{max}, and O values, but a lower R value than the ancient grasslands. The difference in light intensity is contradicting the PDSI measurements of KARLÍK & POSCHLOD (2009), who found significantly higher insolation values for the ancient sites. Perhaps the spatial distribution of the scattered trees may have an undue effect in this respect. In contrast, the difference in soil reaction is in line with the pH measurements. The differences in both H_{max} and O values met the expectations, as they most probably relate to the different land-use history of ancient and recent grasslands (cf. ZECHMEISTER & TRIBSCH 1999; RÜHS 2001; KIEDRZYNSKI et al. 2014). Regarding the study area Kallmünz the differences in the L value are in line with the actual measurements (cf. KARLÍK 2008), while differences in habitat openness do not match with land-use history. However, they may be due to the differences in moss and stone cover found by KARLÍK (2008).

In the DCA ordination for the "Kaltes Feld", the main differentiation is explained by the first axis, with the two mosses *Rhytidium rugosum* and *Pleurozium schreberi* characterising this separation. Thus, they point out a strong gradient in soil pH as the EIV R for *R. rugosum* and *P. schreberi* is 7 and 2, respectively (DÜLL 2001). This gradient is contradicting the measurements of KARLÍK & POSCHLOD (2009) who found almost identical pH values for ancient and recent sites. However, soil samples of that study were taken from the main rooting horizon, i.e., from a depth of 5-10 cm. As bryophytes are in contact only with the topmost soil layer there may in fact be a gradient in soil reaction due to eluviation and similar processes affecting mainly the upper soil. Separation along the second axis is of minor effect.

Except *Lactarius deliciosus*, being simply a mycorrhizal partner of the *Pinus sylvestris* trees growing scattered on the sites, all further species are common on calcareous and/or acidic grasslands. *Rhytidiadelphus squarrosus* and *Hygrocybe virginea* also tolerate grasslands somewhat richer in nutrients, while especially *Dermoloma cuneifolium* and *Cladonia furcata* ssp. *subrangiformis* prefer nutrient-poor conditions (KRIEGLSTEINER 2001; NEBEL & PHILIPPI 2001; WIRTH 2001). Thus, there may be a weak gradient in nutrient availability along the second axis although there is no signal for such a gradient in the main rooting horizon (KARLÍK & POSCHLOD 2009).

Concerning their demands in soil pH and nutrient availability there are three groups of species in the DCA ordination for Kallmünz (NEBEL & PHILIPPI 2000; DÜLL 2001; KRIEGLSTEINER 2001; NEBEL & PHILIPPI 2001; KRIEGLSTEINER 2003; SIMMEL et al. 2016; see also **Chapter 2**). The first group comprises species preferring moderately acidic to calcareous and relatively nutrient-poor soils (*Entodon concinnus*, *Entoloma lanicum*, *Hygrocybe persistens* var. *persistens*, *Omphalina pyxidata*), the second group species that prefer also weakly acidic to calcareous, but more nutrient-rich soils (*Cirriphyllum piliferum*, *Phascum cuspidatum*). Both, *Bryum rubens* and *Entoloma sericeum*, constituting the third group, are widely indifferent to soil pH and nutrient content. As members of all three groups are intermixed in the biplot, no distinct ecological gradients are visible. This is consistent with KARLÍK (2008) who found only minor differences comparing recent and ancient sites.

Species with significant fidelity could be detected for both ancient and recent grasslands of the "Kaltes Feld". Indicator species of ancient grasslands were two lichens and two mosses, three of which are typical species for dry, nutrient-poor and calcareous grasslands. The fourth species, *Fissidens taxifolius*, also is more common on calcareous soil, but is found in a wide range of dry and wet habitats including forests (NEBEL & PHILIPPI 2000). Indicator species of recent grasslands were the mosses *Plagiomnium affine* and *Rhytidiadelphus squarrosus*, which are both quite indifferent and common species (NEBEL & PHILIPPI 2001). However, other common species prefering base-rich and nutrient-poor habitats like *Abietinella abietina* or *Entodon concinnus* (NEBEL & PHILIPPI 2001) were equally distributed in ancient and recent grasslands. For Kallmünz, indicator species were only found for ancient grasslands. These were two fungi *Agaricus xanthoderma* and *Hygrocybe persistens* var. *persistens* which both are typical species of neutral to basic and nutrient-poor grasslands (CAPELLI 1984; BOERTMANN 1995; KRIEGLSTEINER 2001; KRIEGLSTEINER & GMINDER 2010). Like for the "Kaltes Feld", other species with comparable ecological demands are more equally distributed, or are even more common in the recent grasslands. Thus, regarding grasslands the

indicator species listed in Table 15 may in fact be true indicators of history; however, the 'history' gradient showed very low correlation values in the ordination analyses (see below), which again is highlighting the weak influence of the site age.

Table 15. Synoptic table of bryophyte, lichen, and macromycete species with significant fidelity (i. e., indicator species) in ancient (AN) and recent (RT) grasslands in the study areas "Kaltes Feld" and Kallmünz. Fidelity measure (presence/absence data) given as Phi coefficient ($P < 0.05$, Fisher's exact test).

	Kaltes Feld				Kallmünz			
	Frequency		Fidelity		Frequency		Fidelity	
Species	AN	RT	AN	RT	AN	RT	AN	RT
Bryophytes								
Abietinella abietina	80	75	-	-	100	100	-	-
Entodon concinnus	60	42	-	-	.	.	-	-
Fissidens taxifolius	60	8	54.5	-	.	.	-	-
Homalothecium lutescens	.	.	-	-	57	88	-	-
Hylocomium splendens	.	.	-	-	14	63	-	-
Hypnum lacunosum	.	.	-	-	100	88	-	-
***Plagiomnium affine* s. str.**	20	67	-	47.1	86	63	-	-
Rhytidiadelphus squarrosus	.	50	-	57.7	.	.	-	-
Rhytidiadelphus triquetrus	50	67	-	-	.	.	-	-
Rhytidium rugosum	100	58	51.3	-	71	50	-	-
Scleropodium purum	60	58	-	-	57	88	-	-
Thuidium philibertii	80	83	-	-	.	.	-	-
Lichens								
Cladonia furcata* ssp. *subrangiformis	70	.	73.4	-	71	25	-	-
Cladonia rangiformis	60	8	54.5	-	71	25	-	-
Fungi								
Agaricus xanthoderma	.	.	-	-	57	.	63.2	-
Hygrocybe persistens* var. *persistens	.	.	-	-	71	.	74.5	-

Despite the near neighbourhood of the survey sites in the study areas "Kaltes Feld" and Kallmünz, KARLÍK & POSCHLOD (2009; 2016) found considerable differences in the vascular plant vegetation of recent and ancient grasslands in both areas. Both abiotic habitat properties and history, i.e. former use as arable land in the recent grasslands, significantly influenced species composition. Furthermore, the 'history' gradient was strongly correlated with the ordination axes of the RDA analyses done by KARLÍK (2008) and KARLÍK & POSCHLOD (2009). Recent grassland sites were clearly distinguished by their phytosociological heterogenity and the occurrence of arable weeds, ruderal grassland plants, and crop plants. Ancient sites instead held a homogenous *Festuco-Brometea* vegetation cover typical for calcareous grasslands. Indicator species with high fidelity values were found for both ancient and recent grasslands. While there were former crop plants such as *Onobrychis viciifolia* and arable weeds as well as typical calcareous grassland species among the indicators of recent sites, the latter were almost exclusively found as indicators of ancient sites. Thus, even after 150 years former arable fields could clearly be distinguished from continuous grasslands. Concerning the cryptogam vegetation, we found no such strong differences as ancient and recent sites were quite strongly intermingled in the DCA biplot (Figure 3); the 'history'

gradient was correlated with the DCA axes very weakly (Pearson's r < 0.15; data not shown). Only few species frequent in one and missing in the other type were found (Table 15). Even though arable weed species and the like are still occuring in the sites of recent grassland, land-use history seems to have much less influence on grassland cryptogams.

EJRNAES & BRUUN (1995) found habitat age to be one of the most important factors regarding species composition in grassland and list *Hygrocybe virginea* and *Fissidens adianthoides* as indicators of old, nutrient-poor grasslands. *Rhytidiadelphus squarrosus, Cladonia furcata* and others are classified by them as occasional species having other main habitats than grasslands. In our study area "Kaltes Feld", the ssp. *subrangiformis* of *C. furcata* occurred frequently and exclusively in the ancient grasslands. *Hygrocybe virginea* and *Rhytidiadelphus squarrosus* were commonly found in the recent grasslands, the latter also exclusively. GRIFFITH et al. (2002) give considerably short times for the recovery of nutrient-poor and species-rich grassland. Less demanding species of waxcaps (*Hygrocybe* spec.) may already appear ten years after abandonment of fertilized grasslands or arable fields and subsequent grazing. However, more demanding species are not likely to return before 30 or more years (see also BOERTMANN 1995). In the case of the study areas "Kaltes Feld" and Kallmünz,160 years were not sufficient for a considerable part of the vascular plant species typical for calcareous grassland to resettle the adjacent former arable fields (KARLÍK 2008; KARLÍK & POSCHLOD 2009). However, various rare and endangered species occurred in both ancient and recent grasslands (KARLÍK 2008). In contrast, EJRNAES & BRUUN (1995) could find threatened vascular plants exclusively in grassland sites never ploughed or fertilized. Land-use history and abiotic conditions in summary are influencing species composition and species numbers of both vascular plants and cryptogams, but not the same way. LÖBEL et al. (2006), using fitted generalised linear mixed models, could show that the two factors soil pH and percential cover of bare rock affected the species richness of bryophytes and lichens in a markedly different pattern than the richness of vascular plant species. Moreover, the different lifestyles of species also should be taken in account. Considerable differences can be seen, e.g., in the nutrition modes (autotrophic, heterotrophic, parasitic) or the organisation levels (mycelial, thallus-like, cormophytic) (e.g. HAWKSWORTH & HILL 1984; FRAHM 2001; MUELLER et al. 2004; GOFFINET & SHAW 2008), and comparing such groups regarding their reaction on abiotic and historical effects may be an interesting issue in future research.

Due to their small size the dispersability of propagules produced by cryptogam species in general is considered to be higher than that of vascular plant propagules (INGOLD 1971; HAWKSWORTH & HILL 1984; MALLOCH & BLACKWELL 1992; FRAHM 2001; GOFFINET &

SHAW 2008). This enhanced dispersability is confirmed by the comparably large distribution areas of various cryptogam species (SERZANINA 1984; WASSER 1990; URMI 1999; FRAHM 2001; VELLINGA 2004; FEUERER & HAWKSWORTH 2007) which in many cases considerably exceed the areas of phanerogams (URMI 1999; FEUERER & HAWKSWORTH 2007). Like seeds and fruits, cryptogam propagules may be dispersed by a broad range of vectors. These include, e.g., wind, animals living aboveground or subterranean, clouds of smoke, and also more specialised ways like splash mechanisms or endophytic dispersal (INGOLD 1971; HAWKSWORTH & HILL 1984; AYLOR 1990; MALLOCH & BLACKWELL 1992; RYDGREN et al. 1998; FRAHM 2001; MIMS & MIMS, III 2004; LILLESKOV & BRUNS 2005; GOFFINET & SHAW 2008; TELLO et al. 2013). Although there is a certain time effect, cryptogams forming soil crusts and ruderal species like the bryophyte *Tortula ruraliformis* can reach suitable sites comparably fast (LANGHANS et al. 2010). Thus, the relatively high uniformity concerning the occurrences of cryptogam species found in our study is not as surprising. Furthermore, propagule banks very likely also have an effect on the spatial and temporal distribution of cryptogam species (cf. MILES & WALTON 1993; SMITH 1993; RYDGREN et al. 1998; ROSS-DAVIS & FREGO 2004), but owing to insufficient knowledge such effects can not be properly assessed at present.

Conclusion

In the grasslands of the study areas “Kaltes Feld” and Kallmünz, land-use history strongly influenced the vascular plant vegetation, and former arable fields were distinctly separated from continuous grasslands. Even 150 years after abandonment arable weeds still occurred in the recent sites, and they also held rare and endangered species. Regarding cryptogams we observed much less differences and only very few species may be suitable as indicators of land-use history. Terricolous cryptogam vegetation therefore seems to be less affected by history, given a certain time of recreation and succession. Rare species were found in ancient and recent grasslands in both, ancient and recent grassland sites. Thus, ancient and recent grassland sites considered in this study have a similar conservation value, and species maintenance measures and landscape management can be worthwile in all of these grassland sites.

Table 16. Mean Ellenberg indicator values and species numbers of the bryophyte and lichen vegetation and of the macromycete vegetation of ancient and recent grasslands in the study areas "Kaltes Feld" and Kallmünz.
L, light intensity; T, mean annual temperature; F, soil moisture content; R, soil pH value; N, soil nutrient availability (not available for bryophytes); H_{max}, maximum value of hemeroby; O, habitat openness. Species data on bryophytes and lichens taken from DÜLL (2001) and WIRTH (2001), species data on macromycetes taken from **Chapter 2**.
Δ, difference in units; δ, percentual difference [δ = (Δ/s)*100], with s being the scale size [s = 7 (H_{max}); s = 9 (L, T, R, N, O); s = 12 (F)].

		L	T	F	R	N	H_{max}	O	N species
Kaltes Feld									
Bryophytes+lichens									
Recent		6.8	3.7	4.1	6.1	2.3			25
Ancient		6.9	4.0	3.8	6.4	2.3			24
	Δ	-0.0	-0.3	0.3	-0.3	0.1			
	δ	-0.4	-3.5	2.6	-3.0	0.9			
Macromycetes									
Recent		6.1	4.9	4.8	6.5	4.8	4.4	6.8	14
Ancient		4.7	5.0	4.7	7.0	4.3	4.0	5.6	7
	Δ	1.4	-0.1	0.1	-0.5	0.4	0.4	1.2	
	δ	15.1	-0.8	0.5	-5.1	4.6	5.1	13.3	
Kallmünz									
Bryophytes+lichens									
Recent		7.2	4.1	3.8	6.0	2.3			26
Ancient		7.1	3.8	4.0	6.0	2.0			26
	Δ	0.1	0.2	-0.1	0.0	0.3			
	δ	0.9	2.4	-1.0	0.0	2.8			
Macromycetes									
Recent		5.8	5.1	4.5	6.7	4.3	3.9	5.2	18
Ancient		6.9	5.0	4.7	6.8	4.7	4.1	6.1	20
	Δ	-1.1	0.2	-0.2	-0.1	-0.4	-0.2	-0.8	
	δ	-11.9	1.8	-1.3	-1.2	-4.9	-2.2	-9.1	

Chapter 5 – The cryptogam vegetation of grasslands after 37 years of management and succession – bryophytes, lichens, and macromycetes of the "grassland management project" of Baden-Wuerttemberg

Abstract

After a time span of 37 years, the cryptogam vegetation of eight study sites of the grassland management project of Baden-Wuerttemberg was surveyed for the first time. Composition of the terricolous, saprobiotic, and epiphytic cryptogam vegetation is described. The most species-rich bryophyte vegetation was found for the management types mulching every third year, mowing twice per year, and, for small acrocarpous species only, controlled burning. Macromycete species richness was highest in the successional plots. These, despite the comparably short time for development, also yielded a surprisingly rich epiphytic vegetation. To enhance species diversity it is recommended to leave old trees and to newly create situations of high structural diversity by connecting wooded stands with grassland sites differing in the intensity of maintenance.

Key words: Black Forest; hemeroby; Hohenlohe; land-use; substrate openness; Swabian Alb; vegetation mosaic.

Introduction

Since 1975 different management treatments to maintain species-rich grasslands are tested in the network of the "grassland management project" of Baden-Wuerttemberg. Thus, this project is one of the most prosperous long-term experiments in Europe (SCHREIBER et al. 2009). At 14 sites, distributed over the major areas of Baden-Wuerttemberg, management methods such as grazing (traditional management and reference), mowing, mulching, and controlled burning (alternative management treatments) are applied at adjacent survey plots. As another reference, in an additional plot, succession is allowed to take place. Vascular plant

cover of each survey plot is mapped in a 4-year interval to record changes, and thereby the influence of the management treatments (SCHREIBER 2009). Additionally, effects of the management treatments on various taxonomical groups of animals, as well as on specific soil characteristics, were analysed (SCHREIBER et al. 2009).

Whereas the vascular plant cover and its changes are continuously studied, cryptogam species (i.e., bryophytes, lichens, and fungi) so far were not recorded at all. Moreover, there seem to be quite few studies on the influence of long-term land use or grassland management on cryptogams, and these, in turn, often focus on more specific issues like the influence on mycorrhizal species (BEDINI et al. 2007; BERNHARDT-RÖMERMANN et al. 2009) or sporocarp production (STRAATSMA et al. 2001). On the other hand, at least some studies deal with species composition and related issues (DETTKI & ESSEEN 2003; GERKEN et al. 2008; JESCHKE et al. 2008).

Therefore, in the present study we surveyed the cryptogam vegetation at eight sites of the grassland management project in differently managed plots. To analyse the effect of the management treatments on cryptogams we address the following questions: (i) Which management treatments promoted the most species-rich cryptogam vegetation? (ii) Which management treatments promoted the most species-rich macromycete funga? (iii) Are there differences between the cryptogam vegetations of the managed plots and the succession plots? (iv) How species-rich is the epiphytic vegetation, and are there differences between various host tree species?

Based on these issues, we also give recommendations for conservational measures.

Materials and methods

Study sites and management measures

In the present study we surveyed eight sites of the grassland management project that comprise a broader set of management treatments (SCHREIBER 2009). Figure 5 presents the geographical setting within Baden-Wuerttemberg. Sites are compared regarding some abiotic and biotic features in Table 17. Table 18 lists the management treatments applied on the respective sites. Four plots managed by controlled succession (i.e., removal of surface biomass of woody species, but otherwise free succession) were included since no application of the actual management had been done so far.

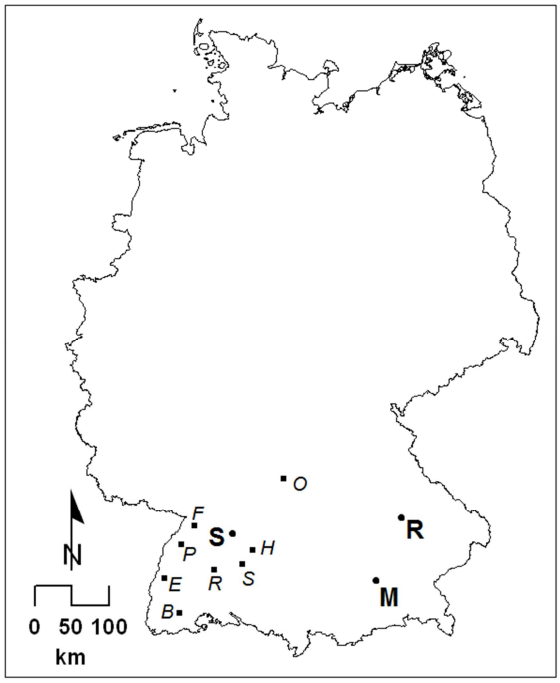

Figure 5. Map of the eight study sites, displaying their location in southwestern Germany. M, Munich; R, Regensburg; S, Stuttgart. Sites: B, Bernau; E, Ettenheimmünster; F, Fischweier; H, Hepsisau; O, Oberstetten; P, Plättig; R, Rangendingen; S, St. Johann.

Table 17. Site-specific and vegetation data of the eight study sites (data from SCHREIBER 2009b).

Study site	Region	Height a.s.l. (m)	Mean annual values		Vegetation type before initiation of the project
			Temp. (° C)	Precipit. (mm)	
Oberstetten	Muschelkalk-Tauberland	ca. 380	8.5-9	ca. 700	Moderately dry Salvio-Arrhenatheretum elatioris, lowland type
Hepsisau	Mittlere Voralb	ca. 560	7.5-8	ca. 900	Mountainous Arrhenatheretum
St. Johann	Mittlere Kuppenalb	ca. 760	6-6.5	ca. 1000	Weakly developed Gentiano-Koelerietum
Rangendingen	Hecken- und Korngäu	ca. 460	7.5-8	ca. 750	Mesobrometum, p.p. including early successional stages
Fischweier	Nordwestliche Schwarzwald-Randplatten	ca. 220	8-8.5	ca. 950	Wetland meadows
Plättig	Grinden-Schwarzwald und Enzhöhen	ca. 740	6-6.5	ca. 1900	Ranunculo aconitifolii-Filipenduletum
Ettenheim-münster	Lahrer Schollen	260-290	8-8.5	ca. 900	Arrhenatheretum
Bernau	Hochschwarzwald	ca. 1100	ca. 5.5	ca. 1800	Festuco-Chamaespartietum sagittalis

Table 18. Overview of the management treatments applied at the respective study sites. Undisturbed succession (US), controlled succession (CS); grazing (G); mulching twice a year (2M), mulching once a year applied early (1Me) or applied late (1Ml), mulching every second year (M2), mulching every third year (M3); mowing twice a year (2Mo) or once a year (1Mo); controlled burning every year (1B) or every second year (B2).

Study site	Succession		Grazing	Mulching					Mowing		Burning	
	US	CS	G	2M	1Me	1Ml	M2	M3	2Mo	1Mo	1B	B2
Oberstetten	x			x	x	x	x	x			x	x
Hepsisau	x		Sheep	x		x	x		x			
St. Johann	x	x	Sheep, horses	x	x	x	x	x		x	x	x
Rangendingen	x	x		x	x	x	x	x			x	x
Fischweier	x			x	x	x	x				x	x
Plättig	x			x		x	x		x			
Ettenheimmünster	x	x		x		x	x	x	x		x	x
Bernau	x	x	Cattle	x		x	x	x			x	x

Survey of cryptogam species

We recorded the terricolous, saprobiotic, and epiphytic vegetation of bryophytes, lichens, and macromycetes. 'Macromycetes' in this context refers to all fungus species producing fruit bodies > 5 mm in size. Small parasitic fungi (e.g., rust fungi, smut fungi, powdery mildews, downy mildews) were excluded from the study, even though they sometimes cause conspicuous damage patterns.

To analyse the vegetation data concerning occurrences of endangered species we used the Red Lists of bryophytes/lichens of Baden-Wuerttemberg (SAUER & AHRENS 2005; WIRTH 2008) and the Red List of macromycetes of Bavaria (KARASCH & HAHN 2009). We used the macromycete list of Bavaria, instead one of Baden-Wuerttemberg, as the last one published for this federal state is outdated (WINTERHOFF & KRIEGLSTEINER 1984) and a later compilation of GMINDER was left unpublished.

Terricolous species; macromycetes on deadwood, herbaceous substrates, and litter

Within the survey plots cryptogams most often were found in very small and isolated patches. Regarding fungi this is due to sporocarp formation, but also because the populations of bryophytes and lichens often consisted of only one or few indivuals. Survey squares, being commonly used in vegetation and succession mapping, therefore were not applicable in a reasonable way. It seemed in fact to be more useful to search the whole survey plot. In doing so, we walked over the plots in a narrow zigzag pattern, recording the small-scale (ca. 20 × 20 cm) cryptogam vegetation after a few steps each. Additionally, based on the species lists we calculated the abundance of small and acrocarpous bryophyte species. These are species growing in ± loose turfs mostly reaching less than 1 cm in height (see Figure 6). DURING (1979) classifies these species to be fugitives, colonists, or annual to short lived shuttle species. Thus, as these species prefer sites with an open and sparse vegetation poor in competitors (see also FRAHM 2001), they can be used as indicators of habitat openness. We also recorded the total cover of bryophytes and lichens, given as percentage of the whole survey plot area, and estimated the proportion of each species. By estimating the species' proportion to the total cover of bryophytes and lichens, and not to the total vegetation cover, it is easier to evaluate the less frequent species as well. We used the scale of HERTEL (1974), giving the species' proportion in percent with regard to the total cover of bryophytes and lichens. These species proportion can be transformed to absolute cover values by

multiplication with the total cover, and then can be classified in the scales of BRAUN-BLANQUET, LONDO, etc. (e.g., see DIERSCHKE 1994)

Compared to the records of bryophytes and lichens growing year-round, detection of the mostly short lived sporocarps of macromycetes is a much more demanding task. As we had only one season for species recording, our study does not represent a complete macromycete survey which would take at least a few years (ARNOLDS 1992b; STRAATSMA et al. 2001; MUELLER et al. 2004). Abundances of species are given as the number of fruit bodies according to the scale of SIMMEL (2011b). Survey plots comprising areas differing in soil humidity as well as in species composition were divided up, and separate species lists (including abundance estimations) for the different areas were compiled.

Figure 6. Sparse 'short turfs', consisting of small acrocarpous bryophytes, in a vegetation gap. Displayed are: *Bryum argenteum* (tight, bud-like foliage), *Bryum rubens* (protruding dark green leaves), and *Ceratodon purpureus* (protruding light green leaves). Photo: J. Simmel. Image width ca. 20 cm.

Epiphytic species

We studied epiphytic bryophytes and lichens only in the succession plots for two reasons. First, except of few tree or shrub individuals growing along the edge of different survey plots,

host species are present only in the successional plots; secondl only there the situation regarding disturbance is comparable. As compared to terricolous species, abundances of epiphytic bryophytes and lichens are more difficult to record due to the irregular form of branch and stem surfaces, and due to different sizes and ages of tree individuals. Moreover, the number of trees as well as host species identities are unequally distributed within the study sites. We recorded therefore the epiphytic species by scanning all trees and shrubs of the respective survey plot up to viewing or reaching height, classifying the species abundances using to the scale by SIMMEL (2011b) and separate recordings for each host species.

'Individuals' were defined as single plants (liverworts and pleurocarpous bryophytes), as single plants or cushions up to 1 cm in diameter (acrocarpous bryophytes), or as single thalli (lichens) (see BARKMAN 1958; WIRTH 1972; HERTEL 1974). Regarding their position on the host, we classified the occurrences of species in four ecological groups: (i) stem base, including exposed roots; (ii) stem; (iii) branches (> 10 mm thick and/or bark deeply fissured); (iv) branchlets (≤ 10 mm thick and bark smooth). The stem base was defined as the zone between soil level and the upper end of the root lugs. Referring to the 'higher cryptogams', in Central Europe as a general rule only lichen and bryophyte species are seen as epiphytes, while fungi are excluded. In the case of *Stenocybe pullatula*, classification is quite unsure. Due to its growth type and fruit body form it is included in the work of WIRTH et al. (2013), which is the reason why we also recorded it.

Indicator value analysis using epiphytic lichens

Based on the mapping of epiphytes (see above) we compiled an additional analysis of Ellenberg indicator values (EIVs), using the values of T (mean annual temperature), F (substrate moisture), R (substrate reaction), N (substrate nutrient availability), and To (toxi-tolerance) as given by WIRTH (2001). In this analysis we could not meaningfully apply the current guidelines [VDI guideline 3957 sheet 13; EU-ForestBIOTA method (both described by FRAHM et al. (2010)], as there are considerable differences in number, species, and size of the woody host plants among the study sites. Thus, no actual mapping of the air quality could be done. Instead of this we calculated mean EIV values based on the data from the successional plots, separated by host species and ecological groups (stem, branch, branchlet; occurrences at the stem base were excluded, as these often are overgrown by taller plants and enriched in nutrients by the run-off water from the stem).

Data analysis

Graphical analyses are given for all parts of the present study. Statistical analyses were not reasonably applicable due to an uneven distribution of numbers and types of the survey plots as well as due to species occurring very rarely (particularly true of macromycetes).

Results

Terricolous species

The results regarding the terricolous species are presented in the Figures 7 and 8. We found the highest mean species numbers of bryophytes in the plot types M3, 1Mo, US. and CS, and the lowest in the plot types 1Me, 1Ml, M2, 2Mo, 1B, and B2. Terricolous lichens only were present in successional plots, which also were most species-rich in macromycetes. While the total cover of cryptogams reached values of 20 % and more in the plot types 2Mo and CS, the respective values of the plot types G, 1B, and B2 lay below 5 %. The proportion of acrocarpous mosses was highest in the plot types G, M3, 1B, and B2. We found only few red listed species, and these grew in the plot types 2M, 1Me, and 1B.

Macromycetes on herbaceous or woody substrates

We found only few lignicolous or herbicolous fungi per plot type. Species numbers were highest in the successional plots (Figure 9).

Epiphytic species

On average, we found nearly 20 species of lichens and about five species of bryophytes growing epiphytic per successional plot (Figure 10), resulting in a total of 68 species of epiphytes. 50 species of this total number were found on *Fraxinus excelsior*, while only one species was found on *Betula pendula* (Figure 11). The proportion of endangered species was highest in the epiphyte communities growing on *Fraxinus excelsior* and *Malus domestica* s. lat. We found the most diverse epiphyte communities to grow on *Fraxinus*, *Malus*, and *Pyrus communis*, regarding both the total species number and the proportion of endangered species (Figure 12). In contrast, no endangered species were found on *Prunus spinosa*. Analysing the niches that epiphytes can colonise on a host plant (Figure 13), most species lived on stems, branches, or branchlets. Of these three niches, the proportion of endangered

species was highest for branchlets, while no endangered species were found at the stem base of the host plants.

Analysis of Ellenberg indicator values of epiphytic lichen vegetation

The values we calculated for the EIVs T, F, R, N, and To are listed in Table 19. Considerable differences are found for the EIVs R, N, and T, while there are quite similar results for F and To.

Table 19. Results of the mapping of Ellenberg indicator values using lichens, given as adjusted mean values of T (temperature value), F (moisture value), R (reaction value), N (nutrient value), and T (toxi-tolerance) according to WIRTH (2001).
For abbreviations of the study sites, see Table 17 and Figure 5. Site P (Plättig) is divided in an open (o) and an fenced (f) part.

	O	H	S	R	F	B	E	P_o	P_f
T	4.71	4.96	5.2	4.58	5.06	5.18	4.03	4.82	4.51
F	3.16	3.31	3.21	3.28	3.33	3.09	3.54	3.22	3.25
R	4.94	5.25	5.29	4.87	4.63	4.5	3.8	4.96	4.91
N	4.09	4.21	4.2	4.21	3.66	3.78	3.04	4.31	4.57
To	6.53	6.18	6.3	6.2	6.14	6.26	6.72	6.41	6.47

Discussion

Terricolous species

Cover values of the bryophyte and lichen layer were highest in the plot type 2Mo, lowest in the plot types G, 1B, and B2, and reached around 10-20 % in the remaining plot types. On average, in the more species-rich plot types (i.e., US, CS, M3, 1Mo) we found about seven species of bryophytes, while we found lichens in only two US plots at all. This pattern roughly is in congruence with the results of other studies, except of the low values found for the G plots. These should be much more species-rich in bropyhytes due to various favorable factors like the presence of extensive areas of bare soil and the disturbance by trampling (GERKEN et al. 2008; JESCHKE et al. 2008). In the G plots, grazing intensity might be too low so that a relatively dense vascular plant vegetation characteristic for pastures has established (POSCHLOD et al. 2009) hindering an additional establishment of bryophytes.

In contrast, the high cover values in the mown plots meet the expectations. Mowing at regular intervals guarantees suitable light conditions for the bryophytes growing close to the soil surface, thereby promoting especially the large pleurocarpous species (VANDERPOORTEN et al. 2004; JESCHKE et al. 2008). Mowing twice a year still seems to be more suitable than mowing only once; however, as we could study but one 1Mo plot, generalisation is hardly possible.

The negative effects of a mulching regime on cryptogams (cf. VON BRACKEL et al. 2008) are well demonstrated by generally quite low cover values in the respective plots. Decomposition of the mulch material takes around three to four weeks during the summer half-year (i.e., first/early mulching), but may last up to several months during the winter half-year (i.e., second/late mulching) (POSCHLOD et al. 2009). During this time the mulch material is covering and shading the soil. At least in individual cases, but probably also more often, the mulch material keeps covering the soil even longer, particularly at wet sites (Figure 14). While vascular plants can grow through the mulch layer quite well, small cryptogam species are not able to do so and suffer from the covering on the long term. This situation is confirmed by the high mean species numbers found in the M3 plots. Due to the infrequent application of the management, processes similar to the conditions in the successional plots can be observed: occurrence of tall grasses, bush encroachment, and increasing patchiness of the lower vegetation. Thus, the species numbers match with those found in the successional plots. Solely the 1Mo plot also reaches this species number.

The proportion of acrocarpous mosses generally was low and their occurrence was largely restricted to disturbance sites like, e.g., molehills or soil disturbances caused by the mulching or mowing vehicles. Therefore, no coincidence with the respective management treatments could be detected, except of the burned plots. In vegetation gaps caused by fire, acrocarpous mosses regularly can be found, even though only very few species occur together at a time. Moreover, the regular application of burning causes a less compact turf which is suitable for the growth of small cryptogam species (POSCHLOD et al. 2009).

In the course of shrub and tree encroachment and the establishment of tall grasses and herbs in the successional plots, a quite species-rich bryophyte vegetation has formed, consisting of pleurocarpous and procumbent acrocarpous species (e.g., *Plagiomnium* spec.). As these species throughout are rather tolerant to shading, even after full development of the canopy hardly any changes in species composition are to expect. The question why terricolous lichens solely were found in successional plots remains unclear based on the present data. Most probably, these lichen individuals had established already before the project was initiated.

The distribution of terricolous macromycetes closely meets the expectations. Species numbers were considerably higher in successional than in managed plots, owing to the additional occurrence of, e.g., mycorrhizal species or saprobionts growing on leaf humus. However, the time available for the mapping of macromycete species was restricted to one season, whereas several years and mapping runs all year round are necessary to record at least the main part of

the macromycete inventory (ARNOLDS 1992b; STRAATSMA et al. 2001; MUELLER et al. 2004). Thus, the present data do not constitute an inventory statistically evaluable.

Regarding both bryophytes and fungi, we found only very few rare or endangered species. It can be assumed that these species also occur in the nearer surroundings of the study sites and have spread into the plots since the initiation of the project.

Finally, it should be noted that the sites surveyed in the present study are representing mainly the mesophilic grassland, which in general is rather poor in bryophytes and lichens (ELLENBERG 1996; DIERSCHKE & BRIEMLE 2008), and that these are reacting on environmental impacts largely independent from the herb layer (HERBEN 1987; PHARO et al. 1999).

Macromycetes on herbaceous or woody substrates

Except for the successional plots, we could find only very few lignicolous or herbicolous species throughout. Regarding lignicolous species the possibilities for establishment are widely restricted due to the lack of dead wood – most of the trees and shrubs have only grown up after inception of the project. When the trees get older, the habitat situation for fungi on dead wood will increasingly improve. Regarding herbicolous species we found fruit bodies in several plot types. However, due to the short study time some plot types are rather under-represented, which certainly does not reflect the actual situation. Therefore, further observations should be carried out, especially during autumn and early winter when larger amounts of dead herbacous material are available for colonisation.

Epiphytic species

We found, on average, 25 species of epiphytes per successional plot, nearly 20 of which are lichens. Numbers of epiphyte species and of phorophyte species show, at least, a rough correlation; the plots most species-rich in hosts also held the most epiphytic species, with the study site Bernau as one exception. While there is only one phorophyte species present in Bernau (*Picea abies*), the number of epiphytic species still reaches an average value. The high relevance of *Picea abies* as a host tree also was shown by KUUSINEN (1996); with increasing age the communities still may become more species-rich, at least regarding lichens (KUUSINEN & SIITONEN 1998; NASCIMBENE et al. 2010).

Another striking fact ist that the proportions of bryophytes of all epiphytic species strongly vary. At the site Hepsisau nearly half of the epiphytic species are bryophytes, while they are, nevertheless, constituting one third of all epiphytes at the sites Fischweier and Ettenheimmünster. In contrast, at the other sites we found only very few epiphytic bryophytes. This pattern is not reasonably explained by the number or identity of phorophyte species at the respective sites. Thus, composition of the epiphytic vegetation perhaps is affected by certain climatic influences or by different regional species pools.

Though most of the phorophyte individuals are rather young (due to establishment after initiation of the project in most cases) they bear a surprisingly rich epiphyte flora. FRITZ et al. (2008), studying *Fagus sylvatica*, on average found twelve epiphytic species (six lichens, six bryophytes) per host tree, with a maximum of 34 species. On *Fraxinus excelsior*, JOHANSSON et al. (2007) on average could detect about 12 to 22 epiphytic lichen species per tree individual, and KUUSINEN (1996) recorded 17 to 28 epiphytic species per *Picea abies* tree individual. In the present study we found quite similar species numbers. Ten phorophyte species yielded 19 or even more epiphytes, three of which (*Fraxinus e.*, *Malus domestica*, *Pyrus communis*) bore up to more than 25 species. The comparatively species-rich epiphyte flora probably is due to rich floras in the surroundings of the respective sites. With increasing age of the phorophytes further increases in species numbers of epiphytes are to expect, in particular regarding lichens (KUUSINEN & SIITONEN 1998; JOHANSSON et al. 2007; NASCIMBENE et al. 2010) and rare and endangered species (JOHANSSON et al. 2007; FRITZ et al. 2008). However, this is not only related to the mere age of the host individuals (and thus an increasing time span available for establishment), but likewise with an increasing number of microhabitats formed by, e.g., a fissured bark or during the development of a closed canopy (BARKMAN 1958; JOHANSSON et al. 2007). Most of the endangered species at present are found on thin branchlets, which is explained by the pioneer character or the low competitive power of various red listed species. Thin branchlets at the margin of the canopy thus are the most favorable sites due to the low age of the branchlets and the comparably harsh ecological conditions. Compared to thicker branches or stems, branchlets at the margin of the canopy on the one hand receive more light and precipitation, but on the other hand are exposed to less constant conditions regarding wind, radiation, and temperatures (cf. BARKMAN 1958; FRAHM 2001).

Analysis of Ellenberg indicator values of epiphytic lichen vegetation

We found a quite interesting pattern of Ellenberg indicator values. The largest differences among the respective study sites can be seen for temperature values, reaction values, and nutrient values. In contrast, moisture values and toxi-tolerance values are quite similar. This is surprising because the sites we studied have a great variation of surrounding environments (e.g., humid river valleys vs. dry southern slopes, close to vs. far from settlements). Thus, most probably the similarity in moisture values is caused by quite similar ages of the phorophytes; the bark of the majority of the host individuals still is ± smooth or only weakly structured, and only few individuals of, e.g., *Pinus sylvestris*, already have developed a fissured or scaly bark. As smooth bark hardly is providing different microhabitats (BARKMAN 1958; HAWKSWORTH & HILL 1984), it promotes the establishment of a quite uniform set of epiphyte species adapted to smooth and rather dry bark surfaces. The toxi-tolerance values do not exhibit a correlation with the nutrient values or the distance of the sites to settlements, which is why the relatively small differences seem to be independent from fertilising or harmful airborne depositions, but probably may be due to different stocks of phorophyte species or different microclimates at the sites. The temperature values clearly reflect the mean annual temperatures calculated from actual measurements, but, interestingly, in reverse order. Thus, the temperature values probably reflect the influence of air humidity at the respective site. In contrast, the reaction values and nutrient values are in congruence with the composition of the set of phorophyte species at the respective sites. The highest values therefore are found for the sites Hepsisau and St. Johann, where the tree stock is rich in *Acer* and *Fraxinus* which both have a base-rich bark, while the lowest values are found for the sites Bernau and Ettenheimmünster, where *Picea* (Bernau) or *Quercus* and *Castanea* are the sole or the dominant tree species, which all have acidic barks (see WIRTH 1995).

Implications for the conservation practice

In the present study, after 37 years of management or succession, the bryophyte layer shows the highest cover values in the 2Mo plots, while it is most species-rich in the plot types M3 and 1Mo. For maintenance of grasslands rich in bryophytes, these three management treatments thus have proved best. Regarding small acrocarpous species, the two types of controlled burning (1B, B2) performed best; if applied intensively enough also grazing (G) can be a good alternative, perhaps in combination with more disturbing treatments such as milling (POSCHLOD 2009). We clearly must advise against the application of frequent

mulching (2M, 1M, M2) which, however, is recommended when taking into account only vascular plant vegetation (POSCHLOD et al. 2009). Accordingly, a recent meta-analysis on grassland management experiments came to the conclusion that grazing is generally better than mowing concering diversity of vascular plant vegetation (TÄLLE et al. 2016).

Species numbers of macromycetes are highest at sites with moasic-like patches of open and dense vascular plant vegetation. It thus may be an interesting option (i) to connect older (and/or younger) trees already present by a loosely arranged set of small 'succession islands' intermingled with managed plots, or (ii) to create a close arrangement of grassland plots differing in their use intensity. The latter also could be applied in bryophyte conservation (see above, combining the measures 2Mo, 1Mo, and M3).

Despite the relatively low age of the phorophytes, these held a surprisingly rich epiphyte flora. Therefore, also single trees or smaller 'succession islands' (see also above) can substantially contribute to the conservation and promotion of epiphyte floras, including rare or endangered epiphytic species (cf. HUNTER et al. 2016).

Acknowledgements

We thank the administration of the federal state Baden-Wuerttemberg for financing and promoting the Fallowland project and the LEL Schwäbisch Gmünd for the good cooperation.

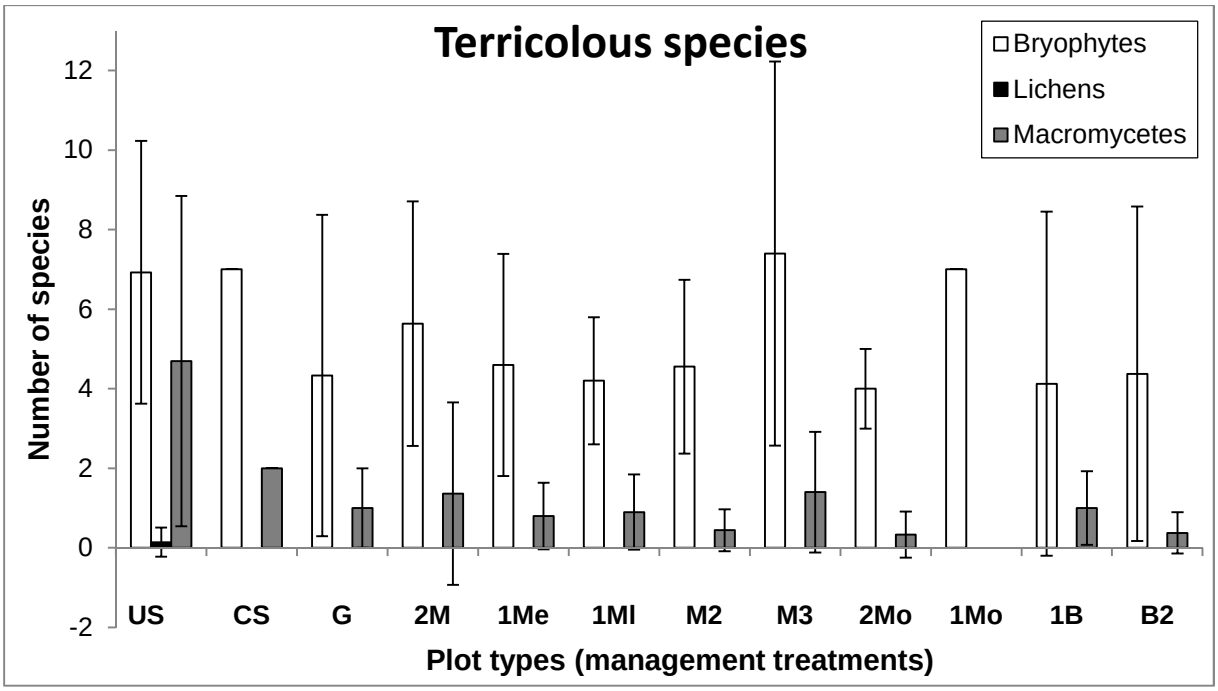

Figure 7. Species numbers of terricolous bryophytes, lichens, and macromycetes in the respective plot types.
For abbreviations of the plot types, see Table 18.

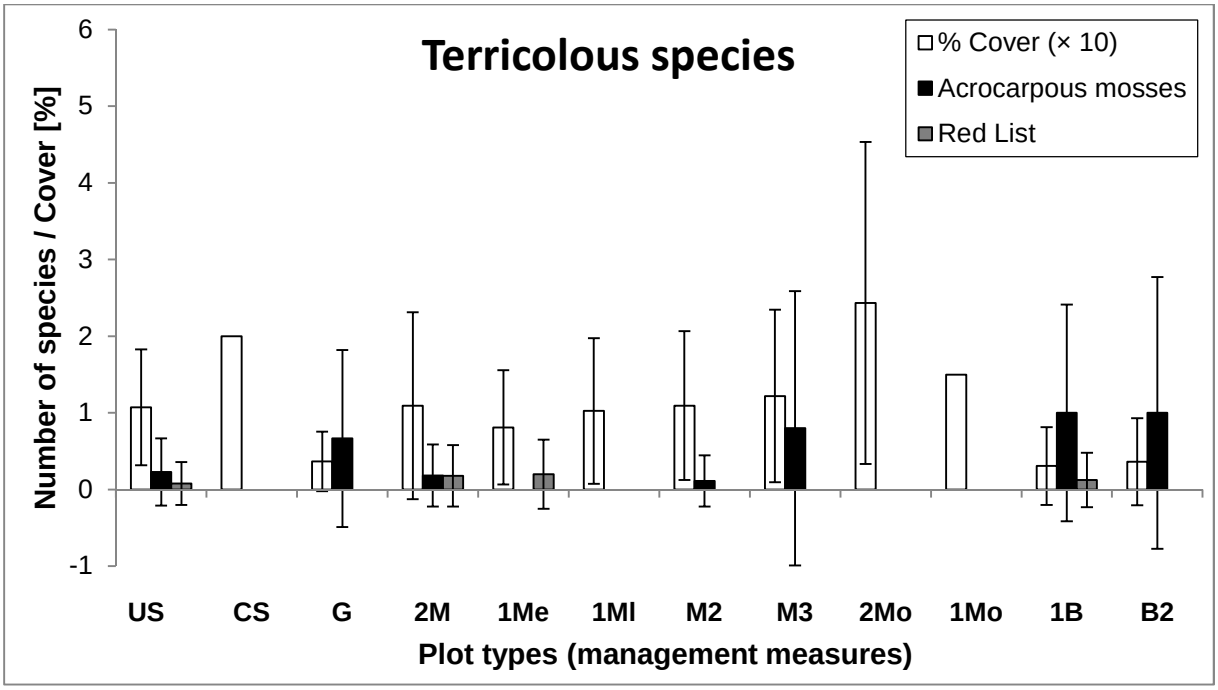

Figure 8. Total cover values (in %) of the terricolous cryptogam vegetation, and species numbers of small acrocarpous bryophytes in the respective plot types
For abbreviations of the plot types, see Table 18.

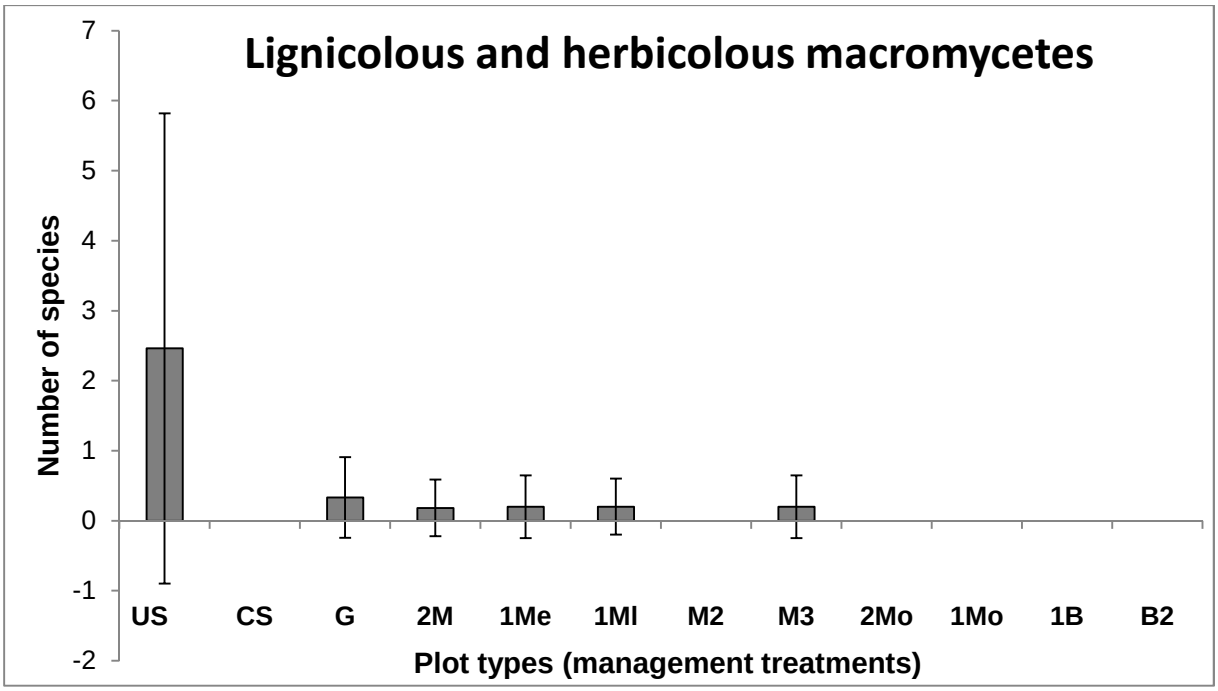

Figure 9. Species numbers of lignicolous and herbicolous macromycetes in the respective plot types.
For abbreviations of the plot types, see Table 18.

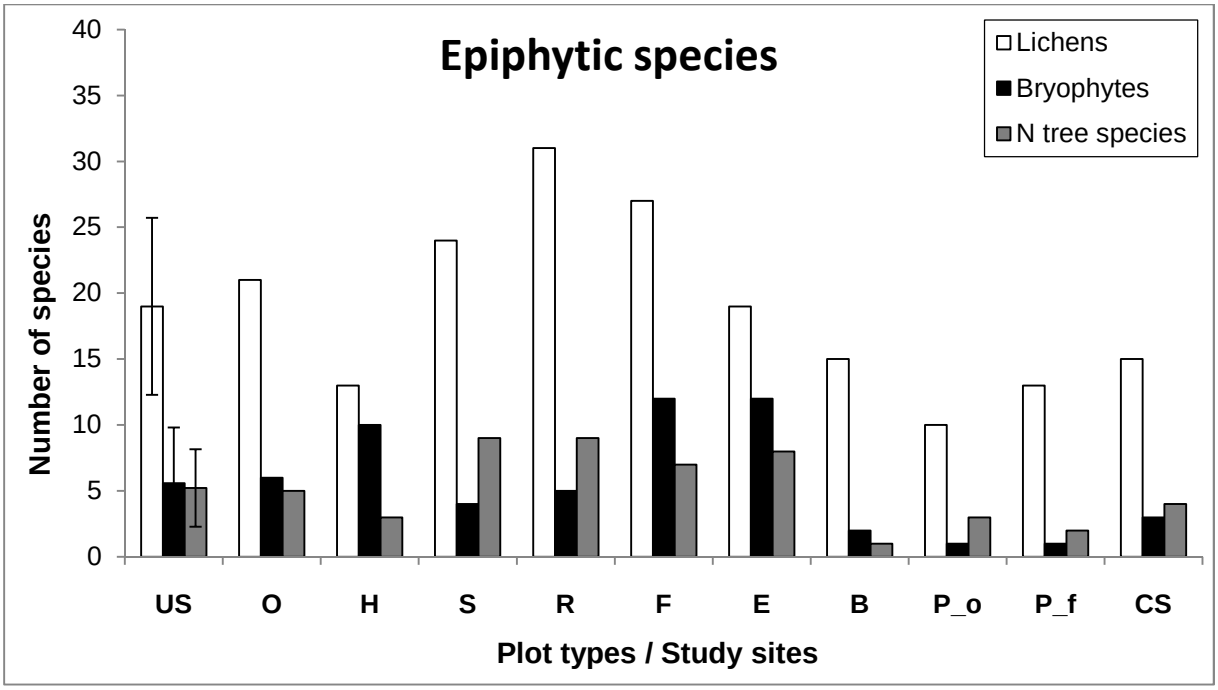

Figure 10. Species numbers of epiphytic lichens and bryophytes, and of phorophyt species present at the respective sites. US, mean value of all US plots.

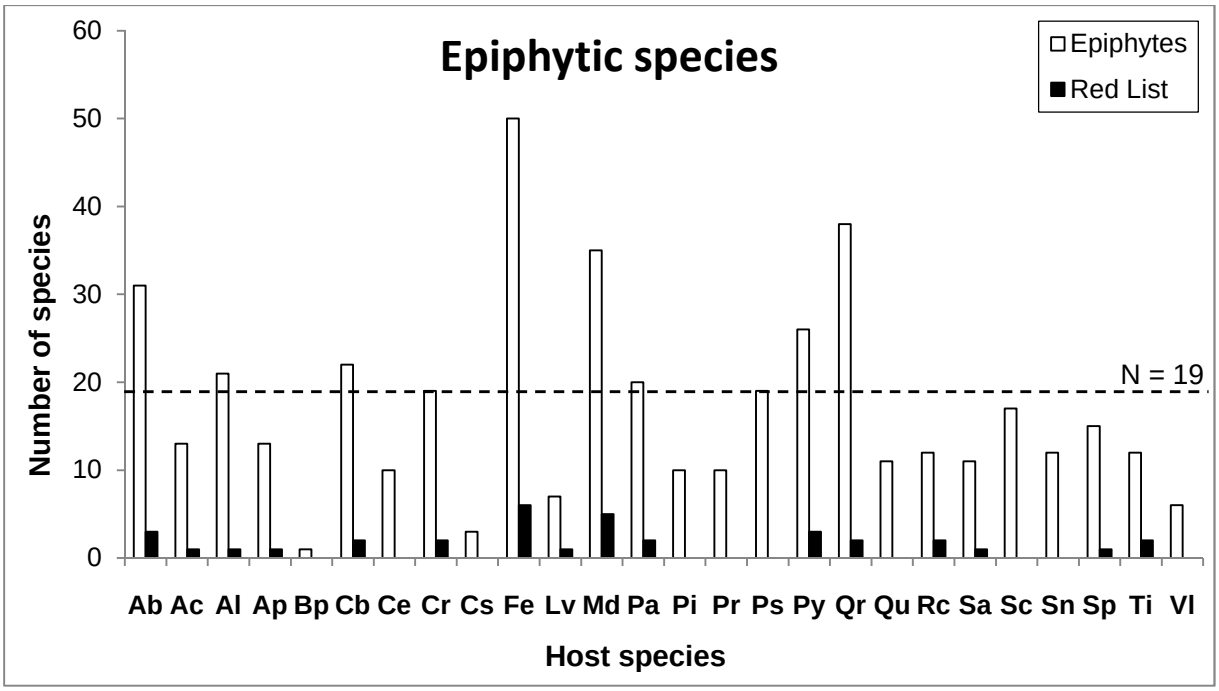

Figure 11. Species numbers of epiphytic species (lichens + bryophytes) and of Red List species thereof, given by their occurrence on the respective phorophyte species. The ten phorophyte species bearing 19 or more epiphyte species (see dashed line) are treated separately in Figure 12. Abbreviations of species names: Ab, *Acer pseudoplatanus*; Ac, *Acer campestre*; Al, *Alnus glutinosa*; Ap, *Acer platanoides*; Bp, *Betula pendula*; Cb, *Carpinus betulus*; Ce, *Castanea sativa*; Cr, *Crataegus* spec.; Cs, *Cornus sanguinea*; Fe, *Fraxinus excelsior*; Lv, *Ligustrum vulgare*; Md, *Malus domestica* ss. lat.; Pa, *Picea abies*; Pi, *Pinus sylvestris*; Pr, *Prunus avium*; Ps, *Prunus spinosa*; Py, *Pyrus communis* ss. lat.; Qr, *Quercus robur*; Qu, *Quercus rubra*; Rc, *Rosa canina*; Sa, *Sorbus aucuparia*; Sc, *Salix caprea*; Sn, *Sambucus nigra*; Sp, *Salix purpurea*; Ti, *Tilia* spec.; Vl, *Viburnum lantana*.

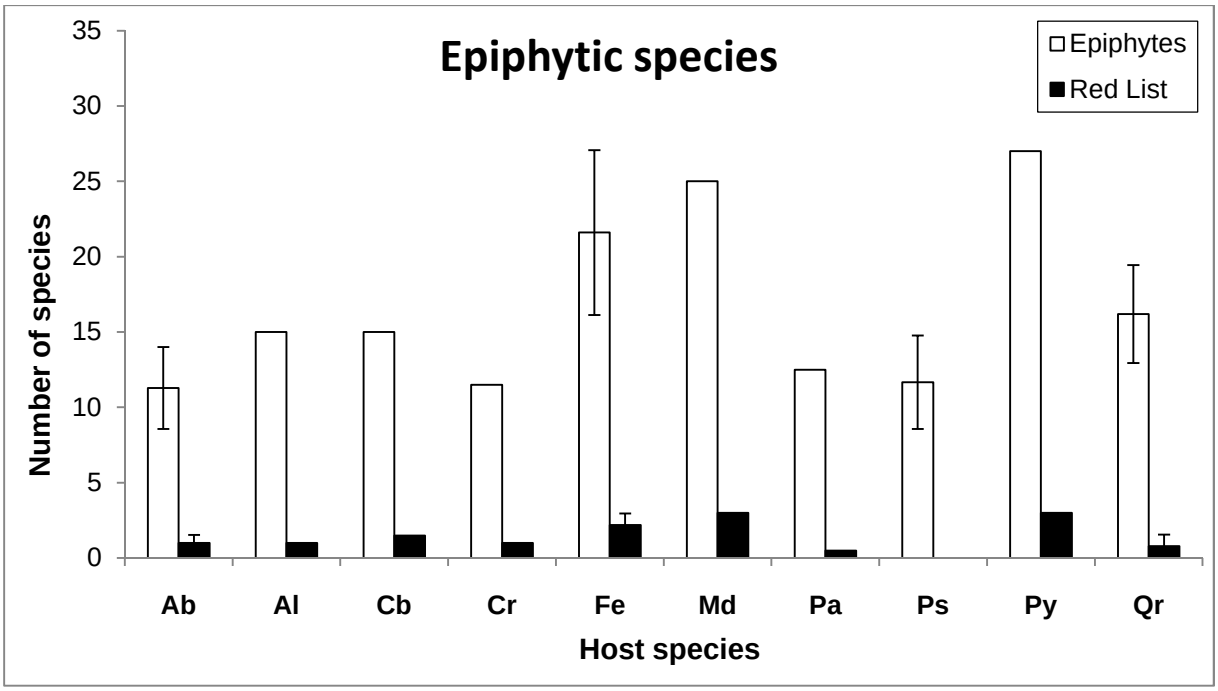

Figure 12. Species numbers of epiphytic species (lichens + bryophytes) and of Red List species thereof, given by their occurrence on the ten phorophyte species bearing the most species-rich epiphytic flora (cf. Figure 11). Mean values and standard deviation are shown for phorophytes with three or more occurrences (Ab, Fr, Ps, Qr).
For abbreviations of the species names, see Figure 11.

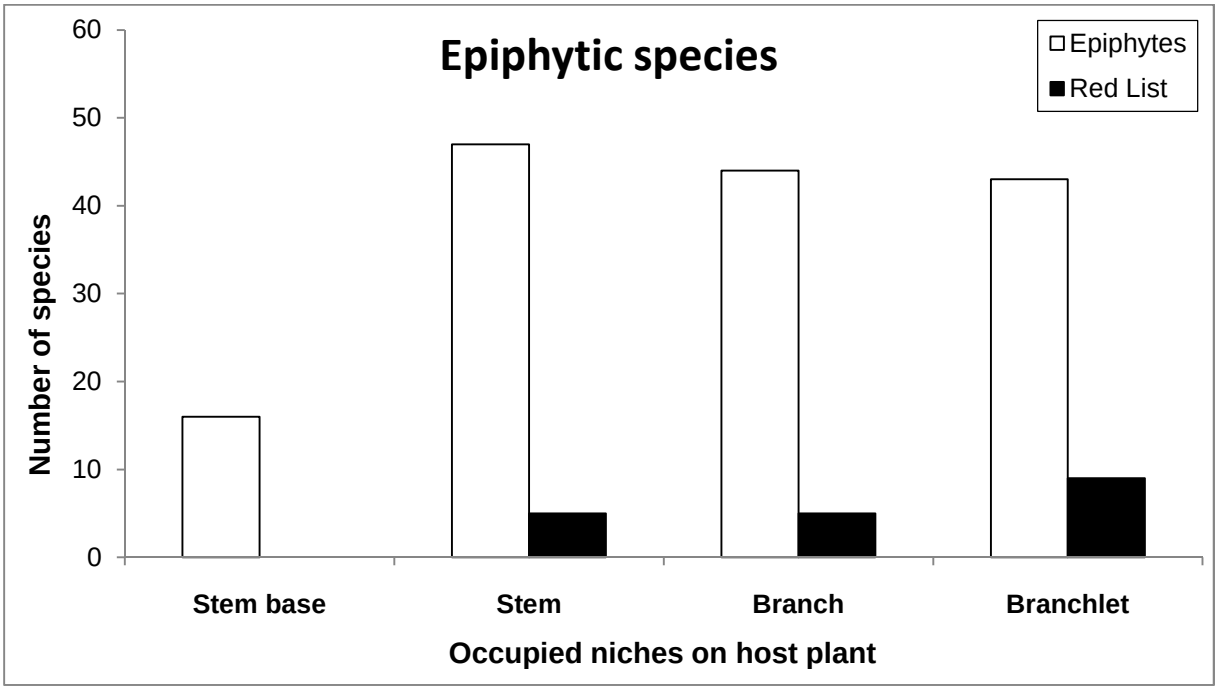

Figure 13. Species numbers of epiphytic species (lichens + bryophytes) and of red listed species thereof, given by their occurrence in four niches on the phorophytes.
Stem base (between soil level and the upper end of the root angles, including exposed roots); stem; branch (> 10 mm thick and/or bark deeply cracked); branchlet (≤ 10 mm thick and bark smooth).

Figure 14. Dense and strongly matted layer of mulch material in the plot 1Ms at the study site Fischweier. While taller plants can grow through this layer, the soil in between is nearly completely covered. Mulching is applied at this study site around the end of August or the begin of September, the mulch layer thus dates back to the year 2012. Photo: 18.07.2013, J. Simmel. Image width ca. 110 cm.

Chapter 6 – Shifts in species composition of macromycete assemblages in the nature reserve "Sippenauer Moor" – an assessment using species identities, Ellenberg indicator values, and functional traits

Abstract

In the present paper we present the results of a monitoring on the macromycete vegetation of the nature reserve "Sippenauer Moor", a calcareous fen comprising areas of different mire types which was affected by land-use changes including darinage and a nearby quarry pumping groundwater for limestone extraction. We used a fungus mapping from 1998 and 1999 as a basis for the comparison and assessed the species identities, Ellenberg indicator values, and functional traits. While species numbers were similar for the *Sphagnum* patches, we found a considerable loss of species and of red listed species for the remaining fen area, and only very few species were found in both studies. Ellenberg indicator values and functional traits did not yield significant differences. However, we found a considerable increase in the number of ubiquitous species. These changes in species composition most probably are caused by an insufficient management, tree encroachment, and effects of the past drainage and groundwater pumping. We recommend to apply a more adapted management to prevent further species losses and to maintain the high quality of the fen.

Key words: draining; fen meadow; karst water; percolation mire; Pruno-Fraxinetum; Sphagnetum magellanici; spring mire; transitional mire

Introduction

Concerning issues of ecology, restoration ecology, and nature conservation, wetlands are regarded as very important ecosystems since they provide habitats for numerous specialised plant and animal species (KAPFER & POSCHLOD 1997; WIEDER & VITT 2006; RYDIN & JEGLUM 2013). Furthermore, they also have more general ecological functions such as

buffering floods and balancing temperature fluctuations (ELLENBERG 1996; RYDIN & JEGLUM 2013). In ecological and geological respects, wetlands are classified by their hydrological status, and in a first step, swamps can be distinguished from mires. While the latter are constantly waterlogged, the former also experience phases of desiccation. Thus, only mires can accumulate peat, whereas the dead organic matter is more or less completely decomposed in swamps (KAPFER & POSCHLOD 1997; SIEGEL & GLASER 2006; RYDIN & JEGLUM 2013). Mires therefore are important sinks of organic carbon, which makes them valuable buffers concerning climate and global change research (ZERBE & WIEGLEB 2009; RYDIN & JEGLUM 2013).

There are several types of mires that can be classified by the origin and pH status of the water that feeds them. Being fed by water originating from the mineral soil, fens are distinguished from bogs that are fed exclusively by precipitation water (KAPFER & POSCHLOD 1997; RYDIN & JEGLUM 2013). Therefore, fens are strongly affected by the quality of the mineral soil water, especially regarding its nutrient and base content. Besides peat mining, fens also were used in agriculture, e.g. as hay meadows or litter meadows, which is why large proportions of fen areas have suffered from draining, fertilization, or even tillage (ELLENBERG 1996; KAPFER & POSCHLOD 1997; POSCHLOD 2015).

Though it is still in a rather good condition, changing land-use but also drainage and pumping of groundwater in a nearby quarry until the beginning of the 21st century affected the habitats and their respective biodiversity in the "Sippenauer Moor", a calcareous fen southwestern of Regensburg. It has a high rarity value owing to two facts. Firstly, it is the only mire in Bavaria that is fed by sulphuric water, and secondly, it is a combination of alluvial forest, forest mire, percolation mire, spring mire, and transitional mire (WARNEKE 1993; BRESINSKY 1999; KRIEGLSTEINER 2002), being the last fen in relatively good state in the catchment area of the Bavarian part of the Danube. Due to its species richness and its unique hydrology, the "Sippenauer Moor" was established as a nature reserve already in 1939 (BRESINSKY 1999). Traditional land-use types were given up in the 1960ies to 1980ies and step by step replaced by an artificial grassland management which tries to simulate the traditional management. Since the end of the 20th century some rare plant species showed a decline or even became extinct (BRESINSKY 1999; BRESINSKY 2001), and as the main cause the lowering of groundwater due to the pumping activities in the nearby quarry was identified. As a result of litigations regarding this matter, the lime works have to operate a karst water injection and other hydrological protective measures (BRESINSKY 2001; SCHMIDT 2009). Fortunately, these measures are successful in keeping the water table at a constant level (SCHMIDT 2009).

Since considerable changes in the composition of the plant and bryophyte vegetation of the "Sippenauer Moor" have been found (BRESINSKY 2001; KRIEGLSTEINER 2002), in the present study we wanted to investigate if there are similar changes in the macromycete vegetation. Therefore, we did a repeat study of the fungus mapping by KRIEGLSTEINER (2002). To analyse if there are changes in species number, species composition, and species characteristics of the macromycete vegetation, we used three different assessment schemes, which were (i) species identities, (ii) Ellenberg indicator values, and (iii) functional traits.

2. Materials and methods

Study site

The nature reserve "Sippenauer Moor" is situated at the border of the natural regions Franconian Jura and Lower Bavarian Upland at ca. 360-370 m a.s.l. (Figure 15). Its main area is a complex of percolation mire, spring mire, and transitional mire (KRIEGLSTEINER 2002). Within Bavaria it is unique in being fed by sulphuric water (BRESINSKY 1999), which mainly pours out of slit springs in the underground, but there is also one large aerial spring (WARNEKE 1993; BRESINSKY 1999). While wet to seasonally flooded alluvial forest and forest mire (*Pruno-Fraxinetum*) as well as fen shrubs are occupying the periphery, different types of fen meadows are found in the central parts of the site. These mainly belong to the associations *Orchio-Schoenetum* and *Juncetum subnodulosi*, and also comprise a few small occurrences of *Sphagnetum magellanici* hummocks (WARNEKE 1993). In the southeastern part there is a small spruce plantation which was excluded from the present study.

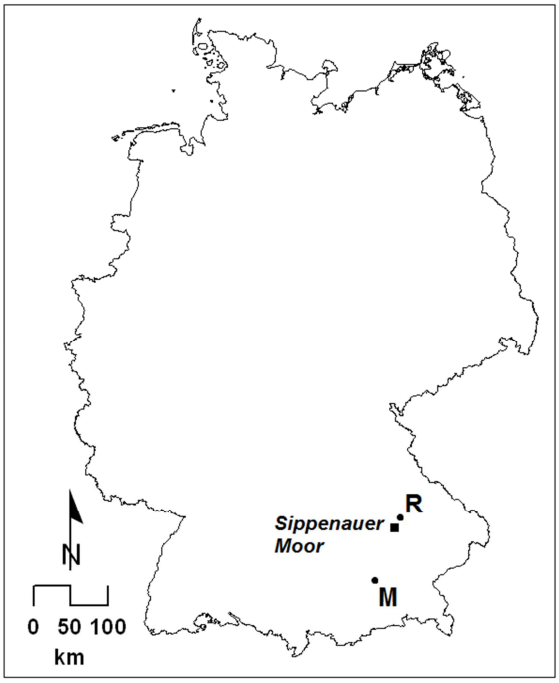

Figure 15. Location of the study site "Sippenauer Moor" near Regensburg (R). M, Munich.

Macromycete surveys

The present study was designed as a comparison with a thorough survey of fungi by KRIEGLSTEINER (2002). This author mapped the funga of macromycetes, micromycetes, and myxomycetes in the years 1998 and 1999, while we carried out our repeat study in 2010 to 2012. Due to practical reasons, we mapped only the macromycete funga, which is why we adapted the species list provided by KRIEGLSTEINER (2002) to our selection of species groups. Species lists were published by KRIEGLSTEINER (2002) and SIMMEL (2011a; 2013b). Like KRIEGLSTEINER, we did not use plots but searched the whole site extent (except of the spruce plantation, see above). For every occurrence of a macromycete species we noted the affiliation to a plant community and data regarding substrate, fruit body number, and habitat quality.

Nomenclature follows BESL & BRESINSKY (2009) for basidiomycetes and HANSEN & KNUDSEN (2000) for ascomycetes.

Data analysis

We analysed the species composition found by KRIEGLSTEINER (2002) and in the present study by comparing the species set (i) of the whole mire area and (ii) of three separate

habitat/phytosociological units. These three units represent largely homogeneous habitats as we chose the *Sphagnetum magellanici* (SP), the fen meadows at the central fen area (FM), and the *Pruno-Fraxinetum* (PF) stands around the central spring.

In both comparisons we used the total number of macromycete species, the number of endangered species (as classified by KARASCH & HAHN (2009)), the number of species for which Germany has a global responsibility (LÜDERITZ & GMINDER 2014), and the number of species exclusively or primarily growing in fens or bogs. For the latter assessment we used ecological descriptions given in the literature (e.g. HANSEN & KNUDSEN 1992; HANSEN & KNUDSEN 1997; HANSEN & KNUDSEN 2000; KRIEGLSTEINER 2000a; KRIEGLSTEINER 2000b; KRIEGLSTEINER 2001; KRIEGLSTEINER 2003; KRIEGLSTEINER & GMINDER 2010). In comparison (ii) we also used Ellenberg indicator values (EIV) and functional traits (FT) of the macromycete species (see **Chapter 2** and **3**). We included the EIVs L (light intensity), T (mean annual temperature), F (substrate moisture content), R (substrate reaction), N (substrate nutrient availability), O (substrate openness), and M (frequency measure), and omitted the EIVs K (continentality), S (substrate salt content), and H (hemeroby) as these factors are not useful in the analysis of the fen vegetation at a single site (see also ELLENBERG et al. 2001 and **Chapter 2**). Differentiation between groups was analysed using Mann-Whitney U test in SPSS 23.0.0.0 (SPSS 2009).

Table 20. Comparison of the macromycete mapping by KRIEGLSTEINER (2002) and by SIMMEL (2011a; 2013b). Numbers of all species, of red listed species, of German responsibility species, and of species exclusively or primarily growing in fens or bogs. See also Table 4. Mapping of the whole site extent (All), of the *Sphagnetum magellanici* (SP), of the fen meadows (FM), and of the *Pruno-Fraxinetum* (PF).

Site/habitat	**All**		**SP**		**FM**		**PF**	
Author	Kr	Si	Kr	Si	Kr	Si	Kr	Si
No. species	368	195	4	4	35	10	21	19
No. RL	50	13	3	3	22	5	10	2
No. responsib.	4	2	1	1	2	2	2	0
No. fen species	12	7	2	2	5	3	1	0

Table 21. Comparison of mean Ellenberg indicator values calculated for the macromycetes of the *Sphagnetum magellanici* (SP), fen meadows (FM), and *Pruno-Fraxinetum* (PF) habitats, and the results of Mann-Whitney U test analysis (n.s., not significant; *, $p < 0.05$; ***, $p = 0.000$). Kr, mapping by KRIEGLSTEINER (2002); Si, mapping by SIMMEL (2011a; 2013b). EIVs: L, light intensity; T, mean annual temperature; F, soil moisture content; R, substrate moisture content; N, substrate nutrient availability; O, substrate openness. For further explanations, see text.

Habitat	**SP**				**FM**				**PF**			
Author	**Kr**	**Si**	**U**	***p***	**Kr**	**Si**	**U**	***p***	**Kr**	**Si**	**U**	***p***
L	6.50	7.50	-0.87	n.s.	6.42	6.44	-0.27	n.s.	4.52	4.16	0.70	n.s.
T	5.75	4.50	3.27	n.s.	5.00	4.60	1.52	n.s.	4.85	5.00	-0.95	n.s.
F	8.00	6.67	0.92	n.s.	6.57	6.67	-0.15	n.s.	7.42	6.41	2.19	*
R	6.50	7.67	-0.77	n.s.	5.36	5.43	-0.07	n.s.	5.50	5.67	-0.26	n.s.
N	3.00	3.75	-0.74	n.s.	3.41	4.40	-1.85	n.s.	5.10	4.71	0.78	n.s.
O	1.33	7.25	-14.55	***	5.31	6.10	-0.96	n.s.	4.80	4.84	-0.07	n.s.

Table 22. Comparison of mean functional trait values calculated for the macromycetes of the *Sphagnetum magellanici* (SP), fen meadows (FM), and *Pruno-Fraxinetum* (PF) habitats, and the results of Mann-Whitney U test analysis (n.s., not significant; *, $p < 0.05$). Statistical analysis was done exclusively for comparisons with a difference > 5 %.
Kr, mapping by KRIEGLSTEINER (2002); Si, mapping by SIMMEL (2011a; 2013b). FTs: RL B, Red List status for Bavaria (KARASCH & HAHN 2009); Long M, longevity of mycelium; Long F, longevity of fruit body; Season, fruiting season; N type, nutrition type; Frb type, fruit body type; Frb size, fruit body size; Frb col, fruit body colour; H type, hymenium type; Vol_i, fruit body volume index; Sp size, spore size; Sp sh, spore shape; Sp su, spore surface structure; Sp col, spore colour; Sp pore, type of spore pore; Sp disp, spore dispersal mode; Cyst H, cystidial types in hymenium; Cyst F, cystidial types of fruit body. For further explanations, see text.

Habitat	SP				FM				PF			
Author	Kr	Si	U	*p*	Kr	Si	U	*p*	Kr	Si	U	*p*
RL B	3.25	4.00	-0.36	n.s.	4.77	5.40	-0.65	n.s.	6.48	7.63	-2.17	n.s.
Long M	1.00	1.00	--	--	1.07	1.10	--	--	1.05	1.05	--	--
Long F	3.00	3.00	--	--	3.00	3.00	--	--	3.00	3.00	--	--
Season	3.00	3.00	--	--	2.96	3.00	--	--	2.95	2.95	--	--
N type	2.00	2.00	--	--	1.83	1.56	1.68	n.s.	1.24	1.67	-2.03	n.s.
Frb type	3.25	1.00	1.00	n.s.	2.26	1.50	0.47	n.s.	1.89	1.63	0.29	n.s.
Frb size	22.31	12.50	0.72	n.s.	18.20	18.58	-0.06	n.s.	15.43	16.33	-0.29	n.s.
Frb col	2.75	3.50	-1.34	n.s.	3.09	3.40	-0.99	n.s.	3.29	3.21	0.37	n.s.
H type	3.00	2.00	1.00	n.s.	2.57	1.90	1.40	n.s.	2.48	2.16	1.01	n.s.
Vol_i	2.00	3.00	-2.45	*	2.63	2.80	-0.79	n.s.	2.76	2.79	-0.20	n.s.
Sp size	2.50	2.50	--	--	2.26	2.30	--	--	2.50	2.63	--	--
Sp sh	4.50	3.00	3.00	*	3.51	2.90	1.51	n.s.	3.05	2.95	0.52	n.s.
Sp su	5.75	4.75	0.53	n.s.	3.46	3.30	0.16	n.s.	2.52	1.68	1.73	n.s.
Sp col	1.75	2.00	-0.52	n.s.	1.85	1.90	-0.16	n.s.	1.62	1.53	0.46	n.s.
Sp pore	3.00	2.50	1.00	n.s.	2.83	2.40	1.78	n.s.	3.05	3.00	0.95	n.s.
Sp disp	1.00	1.00	--	--	1.00	1.00	--	--	1.00	1.00	--	--
Cyst H	3.75	3.00	3.00	*	3.26	2.60	1.62	n.s.	3.10	2.84	0.78	n.s.
Cyst F	4.00	3.25	1.00	n.s.	3.86	3.60	1.09	n.s.	3.71	3.58	0.64	n.s.

Results

Species numbers and identities

As compared to KRIEGLSTEINER (2002) we found lower numbers of species, of red listed species, and of typical fen or bog species for the total species mapping and for both the FM and PF sites (Table 20). In contrast, we found exactly the same species numbers for the SP sites. As can be seen from Table 23, there are only few (FM, PF) or even no species (SP) that were observed in both studies.

Ellenberg indicator values and functional traits

Table 21 gives the results of the EIV comparison. Only two comparisons showed significant differences which were the O values of the SP sites and the F values of the PF sites. Thus, the present macromycete vegetation of the SP sites has a considerably higher O value, while the present vegetation of the PF sites displays a lower F value. For all other comparison we found no significant differences.

Similarly, only three comparisons concerning the FTs showed significant differences (Table 22). These were the fruit body volume index, the spore shape, and the types of hymenial cystidia. As compared to the mapping by KRIEGLSTEINER (2002) the present macromycete vegetation thus is characterised by a lower hymenium : total volume ratio of the fruit bodies, more elongate spores, and a higher proportion of species with cheilocystidia and/or pleurocystidia.

Discussion

Species numbers and identities

With the exception of the SP sites we almost throughout found lower numbers (and percential shares) of species, of red listed and responsibility species, and of typical fen or bog species than KRIEGLSTEINER (2002) did. Most of the species were found either by KRIEGLSTEINER or in the present study, while only very few species were found in both mappings. Thus, there seems to be a considerable species loss going on, in combination with a strong species turnover – in the course of only 12 to 14 years. As both studies lasted hardly more than two seasons they most probably did not record the complete species set actually present, since macromycete studies should extend over a few to several years, if possible (ARNOLDS 1992b; MUELLER et al. 2004). However, due to the loss of red listed species as well as of species typical for fens or bogs, the macromycete vegetation of the FM and PF sites and of the whole fen area seems to suffer a considerable loss in species diversity. A certain proportion of the species loss is compensated by the new appearance of mostly quite common species like *Bolbitius vitellinus*, *Laccaria tetraspora*, and *Mycena pura*. A similar development can be observed regarding bryophytes, with a strong decline in typical fen species like *Drepanocladus cossonii*, *Homalothecium nitens*, and *Plagiomnium elatum*, while common species like *Calliergonella cuspidata* become more frequent (KRIEGLSTEINER 2002 and own observations). Both macromycetes and bryophytes therefore prove a quite strong vegetation shift driven by an increase in ubiquitous species and an decrease in specialised species.

Concerning the SP sites, despite of a complete species turnover we observed exactly the same numbers of species, of red listed species and of species typical for fens and bogs. The SP sites therefore seem to be more or less stable regarding their ecological situation – even though significant species shifts took place. This ecological stability probably is best explained by a widely independent hydrology and nutrition of the *Sphagnum* hummocks due to their development towards a more rainwater fed peatland (WARNEKE 1993; RYDIN et al. 2006;

RYDIN & JEGLUM 2013) which might be also supported by acid rain depositions until the end of the 20th century (ZOLLER & SELLDORF 1989). This development very likely is the main factor causing the observed species turnover (see also below), even though a certain shift in species composition is observed also in other habitat types (STRAATSMA et al. 2001).

Using a sequence of excursions comparable in number with that applied by KRIEGLSTEINER (2002) and in the present study, EINHELLINGER (1976; 1977) in different Upper Bavarian fens, transitional mires, and bogs found between 181 an 377 macromycete species, while WINTERHOFF & BEGENAT (1993) even found nearly 480 species in the Eriskircher Ried, a fen bordering Lake Constanze. However, in the latter study also some drier and less fen-like habitat types were included; if corrected for this, around 380 species were left. The species composition found by KRIEGLSTEINER (2002) with 368 macromycete species thus equals those found in other studies, while the species number found in the present study only reaches quite low values.

Ellenberg indicator values and functional traits

Despite the extensive species shifts (see above) we could observe only very few significant shifts in EIVs or FTs. The shifts in FTs obviously are only caused by the changes in the species richness of the respective genera present at the sites; thus, they should not be overrated. The O values of the SP rose by nearly six units, thus indicating an increase in bare soil or in vegetation gaps. Very probably the occurrence of such gaps is due to the development of *Sphagnum* hummocks within the SP patches, since this development also leads to a structured surface (KAPFER & POSCHLOD 1997; RYDIN & JEGLUM 2013). This tendency also is proven by a (non significant) decrease in the F value. However, as the R and N values are (non significantly) rising, either aerial nitrogen deposition seems to have a strong effect on the bog vegetation or the management by mowing does not remove enough nutrients or both. It should be tested in some years by a repeat study whether this is an actual development; if so, great shifts in vegetation composition of bryophytes, vascular plants, and macromycetes are to be expected, also including actual ruderalisation effects (cf. AERTS et al. 1992; ARNOLDS 1992a; WINTERHOFF & BEGENAT 1993; AERTS et al. 2001; BERENDSE et al. 2001; LIMPENS et al. 2003). A similar trend can be seen for the FM, with increasing N and O values, and increasing numbers of ubiquitous species already having been detected by KRIEGLSTEINER (2002).

The F values of the PF show a decrease of around one unit. Since the water table is held at a stable height by the karst water injection (SCHMIDT 2009) it is unlikely that a decline of the water table occurs. However, drainage already occurred in the past owing to the groundwater pumping activities by the limestone quarry in Saal a. d. Donau. Probably this former drainage has after-effects leading to the decrease in the F value. In the same way, some vascular plant and bryophyte species typical for the wetter parts of fens also still are declining (see above).

Taken as a whole, though the water table is held constant, some others factors also may influence the vegetation of the Sippenauer Moor, e.g. superficial drainage and the management applied to maintain the fen meadows – as they were used as litter meadows in the past they are managed by mowing during the late autumn or winter. However, application of the actual management varies from year to year, e.g. when some patches cannot be accessed properly due to flooding (data from RBG (2016)). Actually, there are various patches where obviously litter is accumulating (pers. observ.) and where young *Alnus glutinosa* trees have established. Litter accumulation may suppress the low-growth vegetation (including bryophytes and fungi). Furthermore, while litter accumulation, *Alnus-Frankia* symbiosis, and *Alnus* mycorrhiza lead to a nutrient enrichment (TORREY 1978; BENSON & SILVESTER 1993; EKBLAD & HUSS-DANELL 1995) which probably is enhanced even more by aerial nitrogen depositions, the *Alnus* trees also enhance the evaporation due to the enlargement of the plant surface and thereby lead to a superficial draining, as afforestation can lead to an increase in evaporation of about 80 percent as compared to open grasslands (NOSETTO et al. 2005). All of these three hypotheses are supported by the increase in ubiquitous species such as the bryophyte *Calliergonella cuspidata*. This moss species is an indicator for wetland sites rich in nutrients and litter, and in contrast to typical fen species that demand open and strongly illuminated sites, it is widely tolerant to shading as it also occurs in forests (NEBEL & PHILIPPI 2001).

Thus, most likely the vegetation shift (i.e., an increase in ubiquitous species and a decrease in specialised species) is a greater threat to the occurrence of rare and demanding species in the "Sippenauer Moor" than changes in hydrology (see also KRIEGLSTEINER (2002)), making it necessary to take actions against the ongoing vegetation shift. Such measures could be, e.g., (i) a more regularly and probably also more frequent mowing to remove both the litter and the *Alnus* encroachment, (ii) mowing once per year in the late spring or early summer, which showed very positive effects regarding nutrient removal and the creation of an open vegetation structure, including germination sites (KAHMEN & POSCHLOD 1998; SCHREIBER et al. 2009; SIMMEL et al. 2016), (iii) an (artificially) raised water level to compensate for the

superficial drainig using nutrient-poor calcareous water (e.g., karst water), or (iv) the creation of vegetation gaps to promote the establishment of small or low-competitive species (e.g. TIMMERMANN et al. (2009)).

Conclusion

In our study of the "Sippenauer Moor" we could detect considerable shifts and losses in species composition of the macromycete vegetation regarding both species typical for fens and red listed species. These changes in species composition clearly prove a negative influence by ruderalisation processes, most probably caused by an insufficient management, tree encroachment, and after-effects of past draining. To maintain the high quality of the fen vegetation and to prevent further species losses, the management should be adapted in a more specific way, e.g., using a more regular mowing regime applied earlier in the year, combined with the artificial creation of vegetation gaps.

Table 23. Species lists for the mapping of the *Sphagnum magellanici* (SP), fen meadow (FM), and *Pruno-Fraxinetum* (PF) habitats by KRIEGLSTEINER (2002; Kr) and SIMMEL (2011a; 2013b; Si). *, species exclusively or primarily growing in fens or bogs.

	SP	FM	PF
Kr	*Bovista paludosa**	*Agrocybe paludosa**	*Amanita friabilis*
	*Entoloma cuspidiferum**	*Bovista paludosa**	*Clavulina rugosa*
	Entoloma queletii	*Camarophyllopsis foetens*	*Cortinarius alnetorum*
	Entoloma undatum	*Camarophyllopsis phaeophylla*	*Cortinarius anomalus*
		Clavaria falcata	*Cortinarius bibulus*
		Clavulinopsis helveola	*Cortinarius helvelloides*
		Clavulinopsis luteoochracea	*Entoloma dysthales*
		Entoloma chalybaeum	*Hygrocybe cantharellus*
		Entoloma conferendum	*Hygrocybe conica*
		Entoloma corvinum	*Lactarius camphoratus*
		*Entoloma cuspidiferum**	*Lactarius lilacinus**
		Entoloma exile	*Leotia lubrica*
		Entoloma longistriatum	*Lepista flaccida*
		*Entoloma mougeotii**	*Naucoria alnetorum*
		Entoloma poliopus	*Naucoria melinoides*
		Entoloma queletii	*Naucoria scolenica*
		Entoloma rhombisporum	*Naucoria striatula*
		Entoloma sericellum	*Paxillus filamentosus*
		Entoloma sericeum	*Rhodocollybia butyracea*
		Entoloma serrulatum	*Russula alnetorum*
		Geoglossum cookeianum	*Trichoglossum hirsutum*
		Gyrodon lividus	
		Hygrocybe cantharellus	
		Hygrocybe conica	
		Hygrocybe miniata	
		Hygrocybe subminutula	
		Laccaria tetraspora	
		Leccinum scabrum	
		Leccinum variicolor	
		Leotia lubrica	
		Naucoria bohemica	
		*Panaeolus reticulatus**	
		Psathyrella prona	
		Suillus bovinus	
		Trichoglossum hirsutum	
Si	*Entoloma chalybaeum*	*Bolbitius vitellinus*	*Clitocybe rivulosa*
	*Entoloma mougeotii**	*Cantharellus aurora*	*Cortinarius decipiens*
	Laccaria tetraspora	*Entoloma chalybaeum*	*Cortinarius helvelloides*
	*Panaeolus reticulatus**	*Entoloma mougeotii**	*Cortinarius obtusus*
		Hygrocybe cantharellus	*Galerina clavata*
		*Lactarius lilacinus**	*Gymnopus dryophilus*
		Lactarius torminosus	*Hebeloma senescens*
		Leccinum variicolor	*Hygrocybe cantharellus*
		Panaeolus foenisecii	*Laccaria tetraspora*
		*Panaeolus reticulatus**	*Leotia lubrica*
			Lepista flaccida
			Marasmius cohaerens
			Mycena pura
			Mycena rosea
			Naucoria melinoides
			Naucoria scolenica
			Naucoria striatula
			Paxillus filamentosus
			Tricholoma fulvum

Chapter 7 – Conclusions and perspectives

Applicability of Ellenberg indicator values for macromycetes

In ecological research, Ellenberg indicator values (EIVs) are an easy-to-use tool used to describe the realised niche of species and habitat parameters. In **Chapter 2**, I present the first proposal of EIVs for fungi, including two new EIV scales, i.e. substrate openness (O) and hemeroby (H). With the exception of continentality, the majority of macromycete species considered could be classified easily using the 'classic' and new scales.

In most ecological research and species mapping the presence of a species is proven by the presence of its fruit bodies (HALME & KOTIAHO 2012). The same holds true in theoretical and applied issues such as conservation planning or in the evaluation of, e.g., rehabilitation or restoration measures. Moreover, a broad range of data today is gained through Citizen Science or other public activities (DICKINSON et al. 2010; THEOBALD et al. 2015). Thus, most studies on the ecology and distribution of macromycetes indeed are based on fruit bodies.

However, when dealing with ecological niches of species, it is very important to take into account all relevant occurrences of these species, i.e., all occurrences with established individuals. Mycelia are more or less completely hidden inside their substrate, and therefore can be detected only by using a markedly higher sampling effort, e.g. sequencing community DNA (O'BRIEN et al. 2005; LINDAHL et al. 2013); however, these methods utilise all sources of DNA, including propagules, very young mycelial stages, and inactive or dead mycelia (RAJALA et al. 2011; OVASKAINEN et al. 2013; BÄSSLER et al. 2016). As long as no molecular technique can differentiate the types of DNA sources, the ecology of macromycetes at present is best assessed by 'traditional' means, which is why I also used the fruit body-based approach. Future research may yield new techniques applicable in the way described above, which then can be used to review the ecological niches of species.

Significance of Ellenberg indicator values and functional traits for macromycetes

In **Chapters 2** and **3**, I studied the significance of EIVs and functional traits (FTs) for macromycete species belonging to different lifestyle guilds or different Red List endangerment classes.

Comparing lifestyle guilds, eight out of ten EIVs and 28 out of 31 FTs showed significant differences. Regarding EIVs, the strongest differentiation was found for light intensity (L) and substrate nutrient availability (N). Terricolous-saprobiotic and parasitic species on average had higher demands on light intensity, while mycorrhizal and parasitic species favoured more nutrient-poor conditions than species of the other guilds. The gradient in light intensity may simply attribute to different niches in open or forested areas. On the other hand, the preference for nutrient-poor conditions is in accordance with conclusions of other studies and thus confirms nutrient enrichment as a main factor causing the decline of mycorrhizal species (e.g. ARNOLDS 1991). Regarding FTs, characteristics of the fruit body, trama, hymenium, spore-producing cells, and spores were relevant in explaining differences between species belonging to different lifestyle guilds. These are, besides many others, the endurance, size, and complexity of fruit bodies, sporulation periodicity, occurrence of species types of cystidia, and spore ornamentation, which in turn have effects on nutrient utilisation, spore predators, and directed spore dispersal.

Comparing Red List classes, four out of ten EIVs and three out of 31 FTs showed significant differences. Regarding EIVs, light intensity (L), substrate nutrient availability (N), substrate openness (O), and maximum level of hemeroby (H_{max}) exhibited a strong differentiation. A high proportion of endangered species is characterised by the combination of high L and O values and low N values, thus clearly reflecting the respective habitat range: open, nutrient-poor grasslands (or similar habitats); light, nutrient-poor forests with areas of bare soil; large, rotten deadwood (ARNOLDS 1991; BERG et al. 1994; KARASCH & HAHN 2009; BÄSSLER et al. 2012; LÜDERITZ & GMINDER 2014). Furthermore, not threatened species on average reached markedly higher maximum levels of hemeroby than endangered ones. Regarding FTs, spore ornamentation and fruiting periodicity exhibited differences connected to the Red List classes. In contrast to not threatened or only weakly endangered species, strongly endangered species typically were characterised by sculptured spores and a fruiting time during autumn and winter. While spore ornamentation is a factor allowing long dormancy and spore dispersal by specific vectors (e.g. GREGORY 1973; LILLESKOV & BRUNS 2005; HALBWACHS & BÄSSLER 2015), the compressed fruiting time is likely to be due to a timed fruiting adapted to times when the activity of specialised vectors is highest (BODDY et al. 2014; HALBWACHS et al. 2016). However, both the strong specifity in dispersal vectors and the compressed fruiting time are among the main reasons accounting for the species' rarity or endangerment.

In conclusion, both EIVs and FTs can explain several aspects of the ecology and adaptations of macromycete species, and thus, both measures have a high significance for respective studies, particularly regarding endangered species or species on special substrates.

Influence of past and present land-use on cryptogams

The influence of land-use history on terricolous bryophytes, lichens, and macromycetes was studied in **Chapter 4**, using ancient and recent dry calcareous grasslands as study sites. Past land-use seemed to have only a minor or virtually no effect on the present cryptogam vegetation, while abiotic factors as well as structure and composition of the vascular plant vegetation exhibited a stronger influence. Species numbers and EIVs were quite similar in ancient and recent grasslands, and rare or endangered species were found in both ancient and recent sites. Only very few species may be suitable as indicators of land-use, e.g., *Cladonia furcata* ssp. *subrangiformis*, *Hygrocybe persistens* var. *persistens*, and *Rhytidiadelphus squarrosus*.

Chapter 5 focussed on present land-use and its influence on the cryptogam vegetation, also using grasslands as study sites. The bryophyte layer showed the highest cover values in plots managed by mowing, while it was most species-rich in plots managed by mowing or by mulching only every third year. Burning and intensive grazing performed best for the maintenance of small acrocarpous mosses. Frequently applied mulching clearly had negative effects on the bryophyte layer due to the relatively long-lasting cover by mulching material. Regarding macromycetes, highest species numbers were found at sites with mosaic-like patches of open and dense vascular plant vegetation.

After-effects of past draining and maintenance measures used in the management of a calcareous fen were studied in **Chapter 6** regarding their influence on the macromycete funga. Except the Sphagnetum magellanici patches, a considerable loss of species, including Red List species, seems to take place, while the number of ubiquitous species increases. Furthermore, in several parts of the fen intensive tree encroachment can be observed. Thus, both tree encroachment and shifts in the composition of the macromycete funga most probably are caused by an insufficient management and past draining.

In conclusion, given a certain time of recreation and succession, regarding cryptogams past land-use hardly is an obstacle in colonisation processes, with the exception of very invasive measures such as wetland draining. By contrast, present land-use significantly influences the cryptogam vegetation. In most cases, it will be inevitable to specifically adapt the management treatments. However, combining different treatments in a mosaic-like pattern

also may often be a reasonable solution. If possible, such mosaics should include successional sites, as even quite young phorophytes may hold a relatively rich epiphytic flora.

Outlook

Especially regarding the use of EIVs, but also of FTs for macromycetes, the present thesis was intended to be a basis and a catalyst for future research. As there are at least 6,000 species of macromycetes in Germany, both the lists of EIV and FT values have to be continued on a large scale.

Further research topics may be, e.g., (i) comparative ecological studies on fungi, lichens, bryophytes, and vascular plants with respect to management and succession processes, (ii) studies on the biological meaning and background of traits not well understood at present, (iii) integration of fungi in planning tools such as vulnerability analyses or restoration plans, and (iv) the development of molecular techniques that can differentiate established mycelia from other DNA sources.

References

AD-HOC-AG BODEN (2005): Bodenkundliche Kartieranleitung. 5. Ed., Hannover, Bundesanstalt für Geowissenschaften und Rohstoffe und Niedersächsisches Landesamt für Bodenforschung. 438 pp.

AERTS, R., WALLÉN, B., MALMER, N. (1992): Growth-limiting nutrients in *Sphagnum*-dominated bogs subject to low and high atmospheric nitrogen supply. – Journal of Ecology **80**: 131–140.

AERTS, R., WALLÉN, B., MALMER, N., CALUWE, H. de (2001): Nutritional constraints on *Sphagnum*-growth and potential decay in northern peatlands. – Journal of Ecology **89**: 292–299.

AK STANDORTSKARTIERUNG (1996): Forstliche Standortsaufnahme. 5. Ed., Eching, IHW Verlag. 352 pp.

ANDREWS, J. H. (1992): Fungal life-history strategies. – pp. 119-145 in: CARROLL, G. C., WICKLOW, D. T.: The fungal community: Its organization and role in the ecosystem. New York, Marcel Dekker.

ARNOLDS, E. (1981): Ecology and coenology of macrofungi in grasslands and moist heathlands in Drenthe, The Netherlands. Part 1: Introduction and synecology. – Bibliotheca Mycologia **63**: 1–497.

ARNOLDS, E. (1983): Ecology and coenology of macrofungi in grasslands and moist heathlands in Drenthe, The Netherlands. Part 2: Autecology and taxonomy. – Bibliotheca Mycologia **90**: 1–501.

ARNOLDS, E. (1991): Decline of ectomycorrhizal fungi in Europe. – Agriculture, Ecosystems and Environment **35**: 209–244.

ARNOLDS, E. (1992a): Macrofungal communities outside forests. – pp. 113-149 in: WINTERHOFF, W.: Handbook of vegetation science 19/1: Fungi in vegetation science. Dordrecht, Kluwer.

ARNOLDS, E. (1992b): The analysis and classification of fungal communities with special reference to macrofungi. – pp. 7-48 in: WINTERHOFF, W.: Handbook of vegetation science 19/1: Fungi in vegetation science. Dordrecht, Kluwer.

AYLOR, D. E. (1990): The role of intermittent wind in the dispersal of fungal pathogens. – Annual Review of Phytopathology **28**: 73–92.

BARKMAN, J. J. (1958): Phytosociology and ecology of cryptogamic epiphytes. Assen, Van Gorcum & Comp.

BARTELHEIMER, M., POSCHLOD, P. (2015): Functional characterizations of Ellenberg indicator values – a review on ecophysiological determinants. – Functional Ecology **30(4)**: 506-516.

BÄSSLER, C., HEILMANN-CLAUSEN, J., KARASCH, P., BRANDL, R., HALBWACHS, H. (2015): Ectomycorrhizal fungi have larger fruit bodies than saprotrophic fungi. – Fungal Ecology **17**: 205–212.

BÄSSLER, C., MÜLLER, J., CADOTTE, M. W., HEIBL, C., BRADTKA, J. H., THORN, S., HALBWACHS, H. (2016): Functional response of lignicolous fungal guilds to bark beetle deforestation. – Ecological Indicators **65**: 149-160.

BÄSSLER, C., MÜLLER, J., SVOBODA, M., LEPŠOVA, A., HAHN, C., HOLZER, H., POUSKA, V. (2012): Diversity of wood-decaying fungi under different disturbance regimes – a case study from spruce mountain forests. – Biodiversity and Conservation **21**: 33–49.

BAUMANN, A., BLATTNER, S., POSCHLOD, P. (2005): Neuzeitliche Geschichte der Kalkmagerrasen in der Umgebung von Kallmünz (Mittlere Frankenalb, Lkr. Regensburg). – Hoppea, Denkschr. Regensb. Bot. Ges. **66**: 469–487.

BEDINI, S., AVIO, L., ARGESE, E., GIOVANNETTI, M. (2007): Effects of long-term land use on arbuscular mycorrhizal fungi and glomalin-related soil protein. – Agriculture, Ecosystems and Environment **120(2-4)**: 463–466.

BEKKER, R. M., BAKKER, J. P., GRANDIN, U., KALAMEES, R., MILBERG, P., POSCHLOD, P., THOMPSON, K., WILLEMS, J. H. (1998): Seed size, shape and vertical distribution in the soil: indicators of seed longevity. – Functional Ecology **12(5)**: 834–842.

BENSON, D. R., SILVESTER, W. B. (1993): Biology of *Frankia* strains, actinomycete symbionts of actinorhizal plants. – Microbiological Reviews **57(2)**: 293–319.

BERENDSE, F., VAN BREEMEN, N., RYDIN, H., BUTTLER, A., HEIJMANS, M., HOOSBEEK, M. R., LEE, J. A., MITCHELL, E., SAARINEN, T., VASANDER, H., WALLÉN, B. (2001): Raised atmospheric CO_2 levels and increased N deposition cause shifts in plant species composition and production in *Sphagnum* bogs. – Global Change Biology **7(5)**: 591–598.

BERG, Å., EHNSTRÖM, B., GUSTAFSSON, L., HALLINGBÄCK, T., JONSELL, M., WESLIEN, J. (1994): Threatened plant, animal, and fungus species in Swedish forests: distribution and habitat associations. – Conservation Biology **8(3)**: 718–731.

BERG, C., DENGLER, J. (2005): Moose und Flechten als diagnostische Arten von Pflanzengesellschaften – eine Übersicht aus Mecklenburg-Vorpommern. – Herzogia **18**: 145–161.

BERNHARDT-RÖMERMANN, M., BRAUCKMANN, H.-J., BROLL, G., SCHREIBER, K.-F., POSCHLOD, P. (2009): Mycorrhizal infection indicates the suitability of different management treatments for nature conservation in calcareous grassland. – Botanica Helvetica **119**: 87–94.

BESL, H., BRESINSKY, A. (2009): Checkliste der Basidiomycota von Bayern (Agaricomycotina, Urediniomycotina, Ustilaginomycotina). – Regensb. Mykol. Schr. **16**: 1–868.

BINDER, M., HIBBETT, D. S., LARSSON, K.-H., LARSSON, E., LANGER, E., LANGER, G. (2005): The phylogenetic distributioin of resupinate forms across the major clades of mushroom-forming fungi (Hompbasidiomycetes). – Systematics and Biodiversity **3(2)**: 113–157.

BLACKWELL, M., SPATAFORA, J. W. (2004): Fungi and their allies. – pp. 7-22 in: MUELLER, G. M., BILLS, G. F., FOSTER, M. S.: Biodiversity of fungi. Inventory and monitoring methods. Burlington, San Diego, London, Elsevier.

BLOOMFIELD, B. J., ALEXANDER, M. (1967): Melanins and resistance of fungi to lysis. – Journal of Bacteriology **93(4)**: 1276–1280.

BLUME, H.-P., BRÜMMER, G. W., HORN, R., KANDELER, E., KÖGEL-KNABNER, I., KRETZSCHMAR, R., STAHR, K., WILKE, B.-M. (2010): Lehrbuch der Bodenkunde („Scheffer/Schachtschabel“). 16. Ed., Heidelberg, Spektrum Akademischer Verlag. 569 pp.

BODDY, L., BÜNTGEN, U., EGLI, S., GANGE, A. C., HEEGAARD, E., KIRK, P. M., MOHAMMAD, A., KAUSERUD, H. (2014): Climate variation effects on fungal fruiting. – Fungal Ecology **10**: 20–33.

BODDY, L., JONES, T. H. (2008): Interactions between basidiomycota and invertebrates. – pp. 155-179 in: BODDY, L., FRANKLAND, J. C., VAN WEST, P.: Ecology of Saprotrophic Basidiomycetes. Academic Press.

BOERTMANN, D. (1995): Fungi of northern Europe, Vol. 1: The genus Hygrocybe. Greve, Svampetryk. 184 pp.

BOLLER-ELMER, K. C. (1977): Stickstoff-Düngungseinflüsse von Intensiv-Grünland auf Streu- und Moorwiesen. Dissertation, ETH Zürich. 103 pp.

BRESINSKY, A. (1999): Die Verteidigung des Naturschutzgebietes Sippenauer Moor. Musterfall eines Konfliktes zwischen einem Wirtschaftsunternehmen, einer Behörde und dem Naturschutz. – Hoppea, Denkschr. Regensb. Bot. Ges. **60**: 691–724.

BRESINSKY, A. (2001): Das Schicksal des Sippenauer Moores nach Abschluss des Verfahrens vor dem Bayerischen Verwaltungsgerichtshof. – Hoppea, Denkschr. Regensb. Bot. Ges. **62**: 367–391.

BRESINSKY, A., DÜRING, C., AHLMER, W. (2007): Datenbank PILZOEK im Internet. 2. Update. http://www.pilzoek.de.

BRIEMLE, G., NITSCHE, S., NITSCHE, L. (2002): Nutzungswertzahlen für Gefäßpflanzen des Grünlandes. – Schriftenreihe für Vegetationskunde **38**: 203-225.

BROWN, W., WOOD, R. K. S. (1953): Ecological adaptations in fungi. – pp. 326-339 in: DAVIES, R., GALE, E. F.: Adaptations in micro-organisms. Cambridge, Cambridge University Press.

BRUNDRETT, M. C. (1991): Mycorrhizas in natural ecosystems. – pp. 171-313 in: BEGON, M., FITTER, A. H., MACFADYEN, A.: Advances in ecological research. London, Academic Press.

BULLER, A. H. R. (1909): Researches on fungi. London, Longmans, Green & Co.

BULLER, A. H. R. (1924): Researches on fungi, Vol. III. London, Longmans, Green & Co.

CAPELLI, A. (1984): Fungi Europaei, Vol. 1: *Agaricus*. Saronno, Candusso. 558 pp.

CARLILE, M., WATKINSON, S., GOODAY, G. (2001): The fungi. New York, Academic Press.

CARROLL, G. C., WICKLOW, D. T. (1992): The fungal community: Its organization and role in the ecosystem. 2. Ed., New York, Marcel Dekker. 976 pp.

CHIKISHEV, A. (2013): Plant indicators of soils, rocks, and subsurface waters. Heidelberg, Springer. 224 pp.

CHYTRÝ, M., TICHÝ, L., ROLEČEK, J. (2003): Local and regional patterns of species richness in Central European vegetation types along the pH/calcium gradient. – Folia Geobotanica **38**: 429–442.

CONTI, M. E., CECCHETTI, G. (2001): Biological monitoring: lichens as bioindicators of air pollution assessment – a review. – Environmental Pollution **114(3)**: 471–492.

CORNELISSEN, J. H. C., LANG, S. I., SOUDZILOVSKAIA, N. A., DURING, H. J. (2007): Comparative cryptogam ecology: a review on bryophyte and lichen traits that drive biogeochemistry. – Annales of Botany **99(5)**: 987–1001.

CORROCHANO, L., GALLAND, P. (2006): Photomorphogenesis and gravitropism in fungi. – pp. 233-259 in: KÜES, U., FISCHER, R.: The Mycota I: Growth, differentiation and sexuality. Berlin, Heidelberg, Springer.

COUSINS, S. A. O., LINDBORG, R., MATTSSON, S. (2009): Land use history and site location are more important for grassland species richness than local soil properties. – Nordic Journal of Botany **27**: 483–489.

DAVIES, R. (1961): Wettability and the capture, carriage and deposition of particles by raindrops. – Nature **191**: 616–617.

DETTKI, H., ESSEEN, P.-A. (2003): Modelling long-term effects of forest management on epiphytic lichens in northern Sweden. – Forest Ecology and Management **175(1-3)**: 223–238.

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

DICK, M. W. (1992): Patterns of phenology in populations of zoosporic fungi. – pp. 355-382 in: CARROLL, G. C., WICKLOW, D. T.: The fungal community: Its organization and role in the ecosystem. New York, Marcel Dekker.

DICKINSON, J. L., ZUCKERBERG, B., BONTER, D. N. (2010): Citizen Science as an ecological research tool: challenges and benefits. – Annual Review of Ecology, Evolution, and Systematics **41**: 149–172.

DIEKMANN, M. (2003): Species indicator values as an important tool in applied plant ecology – a review. – Basic and Applied Ecology **4**: 493–506.

DIERSCHKE, H. (1994): Pflanzensoziologie. Stuttgart, Ulmer Verlag. 683 pp.

DIERSCHKE, H., BRIEMLE, G. (2008): Kulturgrasland. Stuttgart, Ulmer Verlag. 239 pp.

DIGHTON, J., POSKITT, J. M., HOWARD, D. M. (1986): Changes in occurrence of basidiomycete fruit bodies during forest stand development: with specific reference to mycorrhizal species. – Trans. Br. mycol. Soc. **87(1)**: 163–171.

DIJKSTERHUIS, J., SAMSON, R. A. (2007): Food mycology: a multifaceted approach to fungi and food. Abingdon, Taylor & Francis.

DIX, N., WEBSTER, J. (1995): Fungal ecology. London, Chapman and Hall.

DÖRFELT, H. (1989): Lexikon der Mykologie. Stuttgart - New York, Fischer. 432 pp.

DÖRFELT, H., RUSKE, E. (2010): Hydrophobie von Basidiosporen als Merkmal der Gasteromycetation. – Zeitschrift für Mykologie **76(2)**: 153–170.

DÜLL, R. (2001): Zeigerwerte von Laub- und Lebermoosen. – pp. 175-220 in: ELLENBERG, H., WEBER, H. E., DÜLL, R., WIRTH, V., WERNER, W.: Zeigerwerte von Pflanzen in Mitteleuropa. Göttingen, Erich Goltze GmbH & Co KG.

DÜRHAMMER, O. (2003): Die Flechtenflora von Regensburg. – Hoppea, Denkschr. Regensb. Bot. Ges. **64**: 5–461.

DURING, H. J. (1979): Life strategies of bryophytes: a preliminary review. – Lindbergia **5**: 2–18.

DURWEN, K.-J. (1982): Zur Nutzung von Zeigerwerten und artspezifischen Merkmalen der Gefäßpflanzen Mitteleuropas für Zwecke der Landschaftsökologie und -planung mit Hilfe der EDV - Voraussetzungen, Instrumentarien, Methoden und Möglichkeiten. – Arbeitsber. Lehrstuhl Landschaftsökologie Münster **5**: 1–138.

EGERTON-WARBURTON, L. M., ALLEN, E. B. (2000): Shifts in arbuscular mycorrhizal communities along an antrophogenic nitrogen deposition gradient. – Ecological Applications **10(2)**: 484–496.

EIDENSCHINK, B. (2011): Die Auswirkungen des Landnutzungswandels auf die Kulturlandschaft bei Kallmünz und den Lebensraum Kalkmagerrasen. Zulassungsarbeit zum 1. Staatsexamen, Universität Regensburg.

EINHELLINGER, A. (1976): Die Pilze in primären und sekundären Pflanzengesellschaften oberbayerischer Moore, Teil 1. – Berichte der Bayerischen Botanischen Gesellschaft **47**: 75–149.

EINHELLINGER, A. (1977): Die Pilze in primären und sekundären Pflanzengesellschaften oberbayerischer Moore, Teil 2. – Berichte der Bayerischen Botanischen Gesellschaft **48**: 61–146.

EJRNAES, R., BRUUN, H. H. (1995): Prediction of Grassland Quality for Environmental Management. – Journal of Environmental Management **41**: 171–183.

EKBLAD, A., HUSS-DANELL, K. (1995): Nitrogen fixation by *Alnus incana* and nitrogen transfer from *A. incana* to *Pinus silvestris* influenced by macronutrients and ectomycorrhiza. – New Phytologist **131**: 453–459.

ELLENBERG, H. (1974): Zeigerwerte der Gefäßpflanzen Mitteleuropas. Göttingen, Erich Goltze GmbH & Co KG. 97 pp.

ELLENBERG, H. (1996): Vegetation Mitteleuropas mit den Alpen. 5. Ed., Stuttgart, Ulmer Verlag. 1095 pp.

ELLENBERG, H. (2001): Zeigerwerte der Gefäßpflanzen (ohne Rubus). – pp. 9-166 in: ELLENBERG, H., WEBER, H. E., DÜLL, R., WIRTH, V., WERNER, W.: Zeigerwerte von Pflanzen in Mitteleuropa. Göttingen, Erich Goltze GmbH & Co KG.

ELLENBERG, H., WEBER, H. E., DÜLL, R., WIRTH, V., WERNER, W. (2001): Zeigerwerte von Pflanzen in Mitteleuropa. 3. Ed., Göttingen, Erich Goltze GmbH & Co KG. 262 pp.

ELLIS, C. J., COPPINS, B. J. (2006): Contrasting functional traits maintain lichen epiphyte diversity in response to climate and autogenic succession. – Journal of Biogeography **33(9)**: 1643–1656.

ELLIS, M. B., ELLIS, J. P. (1997): Microfungi on land plants. An identification handbook. New enlarged edition. Slough, U.K., Richmond Publ. 868 pp.

ERTSEN, A. C. D., ALKEMADE, J. R. M., WASSEN, M. J. (1998): Calibrating Ellenberg indicator values for moisture, acidity, nutrient availability and salinity in the Netherlands. – Plant Ecology **135**: 113–124.

EWALD, J. (2003): The calcareous riddle: why are there so many calciphilous species in the Central European flora? – Folia Geobotanica **38**: 357–366.

FACELLI, J. M., PICKETT, S. T. A. (1991): Plant litter: its dynamics and effects on plant community structure. – The Botanical Review **57(1)**: 1–32.

FÄLDT, J., JONSELL, M., NORDLANGER, G., BORG-KARLSON, A.-K. (1999): Volatiles of bracket fungi *Fomitopsis pinicola* and *Fomes fomentarius* and their functions as insect attractants. – Journal of Chemical Ecology **25(3)**: 567–590.

FERNANDEZ, C. W., KENNEDY, P. G. (2015): Moving beyond the black-box: fungal traits, community structure, and carbon sequestration in forest soils. – New Phytologist **205(4)**: 1378–1380.

FERNANDEZ, C. W., KOIDE, R. T. (2013): The function of melanin in the ectomycorrhizal fungus *Cenococcum geophilum* under water stress. – Fungal Ecology **6(6)**: 479–486.

FEUERER, T., HAWKSWORTH, D. L. (2007): Biodiversity of lichens, including a world-wide analysis of checklist data based on Takhtajan's floristic regions. – Biodiversity and Conservation **16**: 85–98.

FRAHM, J.-P. (2001): Biologie der Moose. Heidelberg - Berlin, Spektrum Akademischer Verlag. 357 pp.

FRAHM, J.-P., FREY, W. (2004): Moosflora. 4. Ed., Stuttgart, Ulmer Verlag. 538 pp.

FRAHM, J.-P., SCHUMM, F., STAPPER, N. (2010): Epiphytische Flechten als Umweltgütezeiger. Norderstedt, Books on Demand GmbH.

FRANK, D., KLOTZ, S., WESTHUS, W. (1990): Biologisch-ökologische Daten zur Flora der DDR. 2. Ed., Halle-Wittenberg, 167 pp.

FRANK, J. L., COFFAN, R. A., SOUTHWORTH, D. (2010): Aquatic gilled mushrooms: *Psathyrella* fruiting in the Rogue River in southern Oregon. – Mycologia **102(1)**: 93–107.

FRANKLAND, J. C. (1992): Mechanisms in fungal succession. – pp. 383-402 in: CARROLL, G. C., WICKLOW, D. T.: The fungal community: Its organization and role in the ecosystem. New York, Marcel Dekker.

FRITZ, Ö., GUSTAFSSON, L., LARSSON, K. (2008): Does forest continuity matter in conservation? – A study of epiphytic lichens and bryophytes in beech forests of southern Sweden. – Biological Conservation **141**: 655–668.

FRITZ, Ö., NIKLASSON, M., CHURSKI, M. (2008): Tree age is a key factor for the conservation of epiphytic lichens and bryophytes in beech forests. – Applied Vegetation Science **12**: 93–106.

GARNICA, S., WEISS, M., WALTHER, G., OBERWINKLER, F. (2007): Reconstructing the evolution of agarics from nuclear gene sequences and basidiospore ultrastructure. – Mycological Research **111(9)**: 1019–1029.

GERKEN, B., KRAWCZYNSKI, R., WAGNER, H.-G. (2008): Hutelandschaftspflege und Artenschutz mit großen Weidetieren im Naturpark Solling-Vogler. Teil 2 - Wissenschaftliche Begleitung. – pp. 121-267 in: GERKEN, B., KRANNICH, R., KRAWCZYNSKI, R., SONNENBURG, H., WAGNER, H.-G.: Hutelandschaftspflege und Artenschutz mit großen Weidetieren im Naturpark Solling-Vogler. Bonn-Bad Godesberg, Bundesamt für Naturschutz.

GIORDANI, P., INCERTI, G., RIZZI, G., RELLINI, I., NIMIS, P. L., MODENESI, P. (2014): Functional traits of cryptogams in Mediterranean ecosystems are driven by water, light and substrate interactions. – Journal of Vegetation Science **25**: 778–792.

GOFFINET, B., SHAW, A. J. (2008): Bryophyte biology. Cambridge, Cambridge University Press. 580 pp.

GRAAE, B. J., SUNDE, P. B. (2000): The impact of forest continuity and management on forest floor vegetation evaluated by species traits. – Ecography **23**: 720–731.

GREGORY, P. H. (1973): Microbiology of the atmosphere. 2. Ed., New York, John Wiley & Sons.

GRIFFITH, G. W., EASTON, G. L., JONES, A. W. (2002): Ecology and diversity of Waxcap (*Hygrocybe* spp.) fungi. – Botanical Journal of Scotland **54(1)**: 7–22.

GRIME, J. P. (1979): Plant strategies and vegetation processes. Chichester, Wiley. 222 pp.

GRUNDMANN, G. L., RENAULT, P., ROSSO, L., BARDIN, R. (1994): Differential effects of soil water content and temperature on nitrification and aeration. – Journal of the Soil Science Society of America **59(5)**: 1342–1349.

GUBE, M., DÖRFELT, H. (2011): Gasteromycetation in Agaricales s.l. (Basidiomycota): Morphological and ecological implimentations. – Feddes Repertorium **122(5-6)**: 367–390.

GUEVARA, R., DIRZO, R. (1999): Consumption of macro-fungi by invertebrates in a Mexican tropical forest: do fruit body characteristics matter? – Journal of Tropical Ecology **15**: 603–617.

GUEVARA, R., RAYNER, A. D. M., REYNOLDS, S. E. (2000): Orientation of specialist and generalist fungivorous ciid beetles to host and non-host odours. – Physiological Entomology **25(3)**: 288–295.

HALBWACHS, H., BÄSSLER, C. (2012): Hängt der Wachstumsverlauf der Fruchtkörper der Ektomykorrhizapilze vom Wirtsverhalten ab? Messmethode und erste Ergebnisse. – Zeitschrift für Mykologie **78(2)**: 221-223.

HALBWACHS, H., BÄSSLER, C. (2013): Umweltfaktoren und die Diversität von Großpilzen: eine Analyse mit Ellenbergschen Zeigerwerten. – Zeitschrift für Mykologie **79(2):** 583–600.

HALBWACHS, H., BÄSSLER, C. (2015): Gone with the wind – a review on basidiospores of lamellate agarics. – Mycosphere **6(1)**: 78–112.

HALBWACHS, H., SIMMEL, J., BÄSSLER, C. (2016): Tales and mysteries of fungal fruiting: how morphological and physiological traits affect a pileate lifestyle. – Fungal Biology Reviews **30**: 36–61.

HALME, P., KOTIAHO, J. S. (2012): The importance of timing and number of surveys in fungal biodiversity research. – Biological Conservation **21**: 205–219.

HANSEN, L., KNUDSEN, H. (1992): Nordic Macromycetes Vol. 2: Polyporales, Boletales, Agaricales, Russulales. Kopenhagen, Nordsvamp. 474 pp.

HANSEN, L., KNUDSEN, H. (1997): Nordic Macromycetes Vol. 3: Heterobasidioid, Aphyllophoroid and Gastromycetoid Basidiomycetes. Kopenhagen, Nordsvamp. 444 pp.

HANSEN, L., KNUDSEN, H. (2000): Nordic Macromycetes Vol. 1: Ascomycetes. Kopenhagen, Nordsvamp. 309 pp.

HANSKI, I. (1989): Fungivory: fungi, insects and ecology. – pp. 25-68 in: WILDING, N., COLLINS, N. M., HAMMOND, P. M., WEBBER, J. F.: Insect-fungus interactions. London, Academic Press.

HARLEY, J. L. (1971): Fungi in ecosystems. – Journal of Applied Ecology **8(3)**: 627–642.

HAWKER, L., MADELIN, M. (1976): The dormant spore. – pp. 1-70 in: WEBER, D. J., HESS, W. M.: The fungal spore. New York, John Wiley & Sons.

HAWKSWORTH, D. L. (1991): The fungal dimension of biodiversity, its magnitude, significance, and conservation. – Mycological Research **95(6)**: 641–655.

HAWKSWORTH, D. L. (2001): The magnitude of fungal diversity: the 1.5 million species estimate revisited. – Mycological Research **105(12)**: 1422–1432.

HAWKSWORTH, D. L., HILL, D. J. (1984): The lichen-forming fungi. Glasgow, Blackie & Son. 158 pp.

HAWKSWORTH, D. L., LAGRECA, S. (2007): New bottles for old wine: fruit body types, phylogeny, and classification. – Mycological Research **111(9)**: 999–1000.

HAWKSWORTH, D. L., ROSE, F. (1970): Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens. – Nature **227**: 145–148.

HEDLUND, K., BENGTSSON, G., RUNDGREN, S. (1995): Fungal odour discrimination in two sympatric species of fungivorous collembolans. – Functional Ecology **9**: 869–875.

HEILMANN-CLAUSEN, J., AUDE, E., CHRISTENSEN, M. (2005): Cryptogam communities on decaying deciduous wood – does tree species diversity matter? – Biodiversity and Conservation **14**: 2061–2078.

HEILMANN-CLAUSEN, J., AUDE, E., VAN DORT, K., CHRISTENSEN, M., PILTAVER, A., VEERKAMP, M., WALLEYN, R., SILLER, I., STANDOVÁR, T., ÒDOR, P. (2014): Communities of wood-inhabiting bryophytes and fungi on dead beech logs in Europe – reflecting substrate quality or shaped by climate and forest conditions? – Journal of Biogeography **41**: 2269–2282.

HERBEN, T. (1987): Bryophytes in grassland vegetation sample plots: what is their correlation with vascular plants? – Folia Geobotanica et Phytotaxonomica **22**: 35–41.

HERMY, M., HONNAY, O., FIRBANK, L., GRASHOF-BOKDAM, C., LAWESSON, J. E. (1999): An ecological comparison between ancient and other forest plant species of Europa, and the implications for forest conservation. – Biological Conservation **91**: 9–22.

HERTEL, E. (1974): Epilithische Moose und Moosgesellschaften im nordöstlichen Bayern. – Beihefte zu den Berichten der Naturwissenschaftlichen Gesellschaft Bayreuth **1**: 1-489 + Anhang.

HIBBETT, D. S. (2006): A phylogenetic overview of the Agaricomycotina. – Mycologia **98(6)**: 917–925.

HILL, M. O., CAREY, P. D. (1997): Prediction of yield in the Rothamsted Park Grass Experiment by Ellenberg indicator values. – Journal of Vegetation Science **8(4)**: 579–586.

HILL, M. O., PRESTON, C. D., BOSANQUET, S. D. S., ROY, D. B. (2007): BRYOATT – attributes of British and Irish mosses, liverworts and hornworts. Monks Wood, Abbots Ripton, Huntingdon, Centre for Ecology and Hydrology. 88 pp.

HIRSCH, G., BRAUN, U. (1992): Communities of parasitic microfungi. – pp. 225-250 in: WINTERHOFF, W.: Handbook of vegetation science 19/1: Fungi in vegetation science. Dordrecht, Kluwer.

HOLDRIDGE, L. R. (1967): Life zone ecology. San Jose, Tropical Science Center. 206 pp.

HOOD, I. A. (2006): The mycology of the Basidiomycetes. – pp. 34-59 in: POTTER, K., RIMBAWANTO, A., BEADLE, C.: Heart rot and root rot in tropical *Acacia* plantations. Canberra,

HULTENGREN, S., GRALÉN, H., PLEIJEL, H. (2004): Recovery of the epiphytic lichen flora following air quality improvement in south-west Sweden. – Water, Air, and Soil Pollution **154(1)**: 203–211.

HUMPHREY, J. W., DAVEY, S., PEACE, A. J., FERRIS, R., HARDING, K. (2002): Lichens and bryophyte communities of planted and semi-natural forests in Britain: the influence of site type, stand structure and deadwood. – Biological Conservation **107**: 165–180.

HUNTER, M. L. JR., ACUÑA, V., BAUER, D. M., BELL, K. P., CALHOUN, A. J. K., FELIPE-LUCIA, M. R., FITZSIMONS, J., GONZÁLEZ, E., KINNISON, M., LINDENMAYER, D., LUNDQUIST, C., MEDELLIN, R., NELSON, E. J., POSCHLOD, P. (2016): Conserving small natural features with large ecological roles: a synthetic overview. – Biological Conservation (submitted).

INGOLD, C. T. (1966): Aspects of spore liberation: violent discharge. – pp. 113-132 in: MADELIN, M.: The fungus spore. London, Butterworths.

INGOLD, C. T. (1971): Fungal spores. Their liberation and dispersal. Oxford, Clarendon Press. 302 pp.

JANSSENS, I. A., DIELEMANN, W., LUYSSAERT, S., SUBKE, J.-A., REICHSTEIN, M., CEULEMANS, R., CIAIS, P., DOLMAN, A. J., GRACE, J., MATTEUCCI, G., PAPALE, D., PIAO, S. L., SCHULZE, E.-D., TANG, J., LAW, B. E. (2010): Reduction of forest soil respiration in response to nitrogen deposition. – Nature Geoscience **3**: 315–322.

JENNINGS, D. H., LYSEK, G. (1999): Fungal biology: understanding the fungal lifestyle. 2. Ed., Milton Park, Bios Scientific Publishers.

JESCHKE, M., KIEHL, K., PFADENHAUER, J., GIGON, A. (2008): Langfristige Auswirkungen ehemaliger Bewirtschaftungsvarianten auf die Diversität von Blütenpflanzen, Moosen und Flechten eines Kalkmagerrasens. – Botanica Helvetica **118**: 95–109.

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

JOHNSON, C. N. (1996): Interactions between mammals and ectomycorrhizal fungi. – Trends in Ecology and Evolution **11(12)**: 503–507.

JÜLICH, W. (1984): Die Nichtblätterpilze, Gallertpilze und Bauchpilze (Kleine Kryptogamenflora II b/1). Stuttgart, Gustav Fischer Verlag. 626 pp.

KAHMEN, S., POSCHLOD, P. (1998): Untersuchungen zu Schutzmöglichkeiten von Arnika (*Arnica montana* L.) durch Pflegemaßnahmen. – Jahrbuch Naturschutz in Hessen **3**: 225-232.

KAHMEN, S., POSCHLOD, P. (2004): Plant functional trait responses to grassland succession over 25 years. – Journal of Vegetation Science **15(1)**: 21–32.

KAHMEN, S., POSCHLOD, P., SCHREIBER, K.-F. (2002): Conservation management of calcareous grasslands. Changes in plant species composition and response of functional traits during 25 years. – Biological Conservation **104**: 319–328.

KALAMEES, R., ZOBEL, M. (2002): The role of the seed bank in gap regeneration in a calcareous grassland community. – Ecology **83(4)**: 1017–1025.

KAPFER, A., POSCHLOD, P. (1997): Sümpfe und Moore: Biotope erkennen, bestimmen, schützen. Stuttgart, Wien, Weitbrecht. 164 pp.

KARASCH, P., HAHN, C. (2009): Rote Liste gefährdeter Großpilze Bayerns. Ausgburg, Bayerisches Landesamt für Umwelt. 108 pp.

KARLÍK, P. (2008): Abschlussbericht des Promotionsstipendiums der Deutschen Bundesstiftung Umwelt (DBU): Welche Bedeutung hat das Alter eines anthropogenen Lebensraums, der Kalkmagerrasen, für das Vorkommen von Pflanzenarten und die Zusammensetzung der Vegetation – eine kulturhistorische, vegetations- und standortökologische Analyse. 1-57 pp.

KARLÍK, P., POSCHLOD, P. (2009): History or abiotic filter – which is more important in determining the species composition of calcareous grasslands? – Preslia **81**: 321–340.

KARLÍK, P., POSCHLOD, P. (2016): Using plants as indicators for the differentiation of ancient and recent calcareous grasslands – a comparative analysis. – to be submitted.

KIEDRZYNSKI, M., KIEDRZYNSKA, E., WITOSLAWSKI, M. U., KUROWSKI, J. K. (2014): Historical land use, actual vegetation, and the hemeroby levels in ecological evaluation of an urban river valley in perspective of its rehabilitation plan. – Polish Journal of Environmental Studies **23(1)**: 109–117.

KLEYER, M. (1997): Vergleichende Untersuchungen zur Ökologie von Pflanzengemeinschaften. Eine Grundlage zur Beurteilung der Ersetzbarkeit in der naturschutzfachlichen Planung am Beispiel einer Agrar- und Stadtlandschaft. Berlin, Stuttgart, J. Cramer. 202 pp.

KLEYER, M., BEKKER, R. M., KNEVEL, I. C., BAKKER, J. P., THOMPSON, K., SONNENSCHEIN, M., POSCHLOD, P., VAN GROENENDAEL, J. M., KLIMEŠ, L., KLIMEŠOVA, J., KLOTZ, S., RUSCH, G. M., HERMY, M., ADRIAENS, D., BOEDELTJE, G., BOSSUYT, B., DANNEMANN, A., ENDELS, P., GÖTZENBERGER, L., HODGSON, J. G., JACKEL, A.-K., KÜHN, I., KUNZMANN, D., OZINGA, W. A., RÖMERMANN, C., STADLER, M., SCHLEGELMILCH, J., STEENDAM, H. J., TACKENBERG, O., WILMANN, B., CORNELISSEN, J. H. C., ERIKSSON, O., GARNIER, E., PECO, B. (2008): The LEDA traitbase: a datbase of life-history traits of the Northwest European flora. – Journal of Ecology **96(6):** 1266–1274.

KLOTZ, S., KÜHN, I. (2002): Indikatoren des anthropogenen Einflusses auf die Vegetation. – Schriftenreihe für Vegetationskunde **38**: 241–246.

KLOTZ, S., KÜHN, I. (2002): Ökologische Strategietypen. – Schriftenreihe für Vegetationskunde **38**: 197-201.

KOWARIK, I., SEIDLING, W. (1989): Zeigerwertberechnungen nach ELLENBERG - zu Problemen und Einschränkungen einer sinnvollen Methode. – Landschaft und Stadt **21**: 132–143.

KRAMER, C. (1982): Production, release and dispersal of basidiospores. – pp. 33-49 in: FRANKLAND, J. C., HEDGER, J. N., SWIFT, M. J.: Decomposer basidiomycetes: their biology and ecology. Cambridge, Cambridge University Press.

KRIEGLSTEINER, G. J. (2000a): Die Großpilze Baden-Württembergs, Band 1: Allgemeiner Teil. Gallert-, Rinden-, Stachel- und Porenpilze. Stuttgart, Ulmer Verlag. 632 pp.

KRIEGLSTEINER, G. J. (2000b): Die Großpilze Baden-Württembergs, Band 2: Leisten-, Korallen- und Bauchpilze, Röhrlinge, Täublinge. Stuttgart, Ulmer Verlag. 624 pp.

KRIEGLSTEINER, G. J. (2001): Die Großpilze Baden-Württembergs, Band 3: Blätterpilze, Teil1. Stuttgart, Ulmer Verlag. 638 pp.

KRIEGLSTEINER, G. J. (2003): Die Großpilze Baden-Württembergs, Band 4: Blätterpilze, Teil 2. Stuttgart, Ulmer Verlag. 470 pp.

KRIEGLSTEINER, G. J., GMINDER, A. (2010): Die Großpilze Baden-Württembergs, Band 5: Blätterpilze, Teil 3. Stuttgart, Ulmer Verlag. 671 pp.

KRIEGLSTEINER, L. (2002): Pilze im NSG Sippenauer Moor bei Saal a. d. Donau (südwestlich Regensburg) – Resultate einer einjährigen Untersuchung. – Regensb. Mykol. Schr. **10**: 67–133.

KÜES, U., NAVARRO-GONZÁLEZ, M. (2015): How do Agaricomycetes shape their fruiting bodies? 1. Morphological aspects of development. – Fungal Biology Reviews **29(2)**: 63–97.

KUMMEL, M., LOSTROH, P. (2011): Altering light availability to the plant host determined the identity of the dominant ectomycorrhizal fungal partners and mediated mycorrhizal effects on plant growth. – Botany **89**: 439–450.

KUUSINEN, M. (1996): Importance of spruce swamp-forests for epiphyte diversity and flora on *Picea abies* in southern and middle boreal Finland. – Ecography **19(1)**: 41–51.

KUUSINEN, M., SIITONEN, J. (1998): Epiphytic lichen diversity in old-growth and managed *Picea abies* stands in southern Finland. – Journal of Vegetation Science **9(2)**: 283–292.

LANDOLT, E. (1977): Ökologische Zeigerwerte der Schweizer Flora. Zürich, Geobotanisches Institut der ETH, Stiftung Rübel. 208 pp.

LANGHANS, T. M., STORM, C., SCHWABE, A. (2010): Regeneration processes of biological soil crusts, macro-cryptogams and vascular plant species after fine-scale disturbance in a temperate region: recolonization or successional replacement? – Flora **205(1)**: 46–60.

LARGENT, D., JOHNSON, D., WATLING, R. (1978): How to identify mushrooms to genus III: Microscopic features. Eureka, Mad River Press.

LAWESSON, J. E., FOSAA, A. M., OLSEN, E. (2003): Calibration of Ellenberg indicator values for the Faroe Islands. – Applied Vegetation Science **6(1)**: 53–62.

LEWIS, L. A., MCCOURT, R. M. (2004): Green algae and the origin of land plants. – American Journal of Botany **91(10)**: 1535–1556.

LICHT, W. (2015): Zeigerpflanzen. 2. Ed., Wiebelsheim, Quelle & Meyer. 522 pp.

LILLESKOV, E. A., BRUNS, T. D. (2005): Spore dispersal of a resupinate ectomycorrhizal fungus, *Tomentella sublilacina*, via soil food webs. – Mycologia **97(4)**: 762–769.

LILLESKOV, E. A., FAHEY, T. J., HORTON, T. R., LOVETT, G. M. (2002): Belowground ectomycorrhizal fungal community change over a nitrogen deposition gradient in Alaska. – Ecology **83(1)**: 104–115.

LIMPENS, J., BERENDSE, F., KLEES, H. (2003): N deposition affects N availability in interstitial water, growth of *Sphagnum* and invasion of vascular plants in bog vegetation. – New Phytologist **157(2)**: 339–347.

LINDAHL, B. D., NILSSON, R. H., TEDERSOO, L., ABARENKOV, K., CARLSEN, T., KJØLLER, R., KÕLJALG, U., PENNANEN, T., ROSENDAHL, S., STENLID, J., KAUSERUD, H. (2013): Fungal community analysis by high-throughput sequencing of amplified markers – a user's guide. – New Phytologist **199(1)**: 288–299.

LISIEWSKA, M. (1992): Macrofungi on special substrates. – pp. 151-182 in: WINTERHOFF, W.: Handbook of vegetation science 19/1: Fungi in vegetation science. Dordrecht, Kluwer.

LÖBEL, S., DENGLER, J., HOBOHM, C. (2006): Species richness of vascular plants, bryophytes and lichens in dry grasslands: the effects of environment, landscape structure and competition. – Folia Geobotanica **41**: 377–393.

LUCZAJ, L., SADOWSKA, B. (1997): Edge effect in different groups of organisms: vascular plants, bryophyte and fungi species richness across a forest-grassland border. – Folia Geobotanica et Phytotaxonomica **32**: 343–353.

LÜDERITZ, M., GMINDER, A. (2014): Verantwortungsarten bei Großpilzen in Deutschland. – Beihefte zur Zeitschrift für Mykologie **13**: 1–224.

LUGO, A. E., BROWN, S. L., DODSON, R., SMITH, T. S., SHUGART, H. H. (1999): The Holdridge life zones of the conterminous United States in relation to ecosystem mapping. – Journal of Biogeography **26**: 1025–1038.

MALLOCH, D., BLACKWELL, M. (1992): Dispersal of fungal diaspores. – pp. 147-172 in: CARROLL, G. C., WICKLOW, D. T.: The fungal community: Its organization and role in the ecosystem. New York, Marcel Dekker.

MANACHÈRE, G. (1980): Conditions essential for controlled fruiting of macromycetes – a review. – Trans. Br. mycol. Soc. **75(2)**: 255–270.

MASUCH, G. (1993): Biologie der Flechten. Heidelberg - Wiesbaden, Quelle & Meyer. 430 pp.

MATSON, P., LOHSE, K. A., HALL, S. J. (2002): The globalization of nitrogen deposition: consequences for terrestrial ecosystems. – Ambio **31(2)**: 113–119.

MCCUNE, B., MEFFORD, M. J. (2011): PC-Ord: Multivariate analysis of ecological data. Version 6.08. Glenedon Beach, MjM Software.

MCGILL, B. J., ENQUIST, B. J., WEIHER, E., WESTOBY, M. (2006): Rebuilding community ecology from functional traits. – Trends in Ecology and Evolution **21(4)**: 178–185.

MCKNIGHT, K. B., ESTABROOK, G. F. (1990): Adaptations of sporocarps of the basidiomycete *Flammulina velutipes* (Agaricales) to lower humidity. – Botanical Gazette **151(4)**: 528–537.

MEIER, R. (2002): Pflanzensoziologische Beurteilung ausgewählter Pflanzen von Mooren und Weiden (Sonderwoche Alpstein 2001). Trogen, Kantonsschule Trogen.

MILES, J., WALTON, D. W. H. (1993): Primary succession on land. Oxford, Blackwell. 309 pp.

MIMS, S. A., MIMS, F. M., III (2004): Fungal spores are transported long distances in smoke from biomass fires. – Atmospheric Environment **38**: 651–655.

MOELLER, H. V., PEAY, K. G., FUKAMI, T. (2014): Ectomycorrhizal fungal traits reflect environmental conditions along a coastal California edaphic gradient. – FEMS Microbiology Ecology **87(3)**: 797–806.

MOORE, D. (1998): Fungal morphogenesis. Cambridge, Cambridge University Press. 469 pp.

MOORE, D., WAI CHIU, S., HALIT UMAR, M., SÁNCHEZ, C. (1998): In the midst of death we are in life: further advances in the study of higher fungi. – Transactions and Proceedings of the Botanical Society of Edinburgh and Botanical Society of Edinburgh Transactions **50(2)**: 121–135.

MUELLER, G. M., BILLS, G. F., FOSTER, M. S. (2004): Biodiversity of fungi. Inventory and monitoring methods. Burlington, San Diego, London, Elsevier. 777 pp.

NAKAMORI, T., SUZUKI, A. (2007): Defensive role of cystidia against *Collembola* in the basidiomycetes *Russula bella* and *Strobilurus ohshimae*. – Mycological Research **111(11)**: 1345–1351.

NASCIMBENE, J., MARINI, L., NIMIS, P. L. (2010): Epiphytic lichen diversity in old-growth and managed *Picea abies* stands in Alpine spruce forests. – Forest Ecology and Management **260(5)**: 603–609.

NATHAN, R. (2006): Long-distance dispersal of plants. – Science **313**: 786–788.

NEBEL, M., PHILIPPI, G. (2000): Die Moose Baden-Württembergs, Band 1: Allgemeiner Teil. Spezieller Teil: Bryophyta. Stuttgart, Ulmer Verlag. 512 pp.

NEBEL, M., PHILIPPI, G. (2001): Die Moose Baden-Württembergs, Band 2: Bryophytina II, Schistostegales bis Hypnobryales. Stuttgart, Ulmer Verlag. 529 pp.

NORDÉN, B., PALTTO, H., GÖTMARK, F., WALLIN, K. (2007): Indicators of biodiversity, what do they indicate? Lessons for conservation of cryptogams in oak-rich forest. – Biological Conservation **135**: 369–379.

NOSETTO, M. D., JOBBÁGY, E. G., PARUELO, J. M. (2005): Land-use change and water losses: the case of grassland afforestation across a soil textural gradient in central Argentina. – Global Change Biology **11**: 1101–1117.

O'BRIEN, H. E., PARRENT, J. L., JACKSON, J. A., MONCALVO, J.-M., VILGALYS, R. (2005): Fungal community analysis by large-scale sequencing of environmental samples. – Applied and Environmental Microbiology **71(9)**: 5544–5550.

ÓDOR, P., HEILMANN-CLAUSEN, J., CHRISTENSEN, M., AUDE, E., VAN DORT, K. W., PILTAVER, A., SILLER, I., VEERKAMP, M. T., WALLEYN, R., STANDOVÁR, T., VAN HEES, A. F. M., KOSEC, J., MATOČEC, N., KRAIGHER, H., GREBENC, T. (2006): Diversity of dead wood inhabiting fungi and bryophytes in semi-natural beech forests in Europe. – Biological Conservation **131**: 58–71.

OVASKAINEN, O., SCHIGEL, D., ALI-KOVERO, H., AUVINEN, P., PAULIN, L., NORDÉN, B., NORDÉN, J. (2013): Combining high-throughput sequencing with fruit body surveys reveals contrasting life-history strategies in fungi. – The ISME Journal **7**: 1696–1709.

PAKEMAN, R. J., ATTWOOD, J. P., ENGELEN, J. (1998): Sources of plants colonizing experimentally disturbed patches in acidic grassland, in eastern England. – Journal of Ecology **86**: 1032–1041.

PARTON, W. J., LOGAN, J. A. (1981): A model for diurnal variation in soil and air temperature. – Agricultural Meteorology **23**: 205–216.

PASANEN, A.-L., PASANEN, P., JANTUNEN, M. J., KALLIOKOSKI, P. (1991): Significance of air humidity and air velocity for fungal spore release into the air. – Atmospheric Environment **25A(2)**: 459–462.

PETERKEN, G. F. (1974): A method for assessing woodland flora for conservation using indicator species. – Biological Conservation **6(4)**: 239–245.

PETERKEN, G. F., GAME, M. (1984): Historical factors affecting the number and distribution of vascular plant species in the woodlands of central Lincolnshire. – Journal of Ecology **72**: 155–182.

PHARO, E. J., BEATTIE, A. J., BINNS, D. (1999): Vascular plant diversity as a surrogate for bryophyte and lichen diversity. – Conservation Biology **13(2)**: 282–292.

PHARO, E. J., BEATTIE, A. J., PRESSEY, R. L. (2000): Effectiveness of using vascular plants to select reserves for bryophytes and lichens. – Biological Conservation **96**: 371–378.

PHOENIX, G. K., HICKS, W. K., CINDERBY, S., KUYLENSTIERNA, J. C. I., STOCKS, W. D., DENTENER, F. J., GILLER, K. E., AUSTIN, A. T., LEFROY, R. D. B., GIMENO, B. S., ASHMORE, M. R., INESON, P. (2006): Atmospheric nitrogen deposition in world biodiversity hotspots: the need for a greater global perspective in assessing N deposition impacts. – Global Change Biology **12**: 470–476.

POSCHLOD, P. (2009): Fräsen und Panzerketten für Landschaftspflegemaßnahmen? – pp. 65 in: SCHREIBER, K.-F., BRAUCKMANN, H.-J., BROLL, G., KREBS, S., POSCHLOD, P.: Artenreiches Grünland in der Kulturlandschaft. 35 Jahre Offenhaltungsversuche Baden-Württemberg. Heidelberg - Ubstadt-Weiher - Basel, verlag regionalkultur.

POSCHLOD, P. (2015): Geschichte der Kulturlandschaft. Stuttgart, Ulmer Verlag. 320 pp.

POSCHLOD, P., BAUMANN, A. (2010): The historical dynamics of calcareous grasslands in the central and southern Franconian Jurassic mountains: a comparative pedoanthracological and pollen analytical study. – The Holocene **20(1)**: 13–23.

POSCHLOD, P., KIEFER, S., TRÄNKLE, U., FISCHER, S., BONN, S. (1998): Plant species richness in calcareous grasslands as affected by dispersability in space and time. – Applied Vegetation Science **1**: 75–91.

POSCHLOD, P., KLEYER, M., JACKEL, A.-K., DANNEMANN, A., TACKENBERG, O. (2003): BIOPOP – a database of plant traits and internet application for nature conservation. – Folia Geobotanica **38**: 263–271.

POSCHLOD, P., SCHREIBER, K.-F., MITLACHER, K., RÖMERMANN, C., BERNHARDT-RÖMERMANN, M. (2009): Entwicklung der Vegetation und ihre naturschutzfachliche Bewertung. – pp. 243-288 in: SCHREIBER, K.-F., BRAUCKMANN, H.-J., BROLL, G., KREBS, S., POSCHLOD, P.: Artenreiches Grünland in der Kulturlandschaft. 35 Jahre Offenhaltungsversuche Baden-Württemberg. Heidelberg - Ubstadt-Weiher - Basel, verlag regionalkultur.

POSCHLOD, P., WALLISDEVRIES, M. F. (2002): The historical and socioecomonic perspective of calcareous grasslands – lessons from the distant and recent past. – Biological Conservation **104(3)**: 361–376.

POTT, R. (1995): Die Pflanzengesellschaften Deutschlands. 2. Ed., Stuttgart, Ulmer Verlag. 622 pp.

POUSKA, V., LEPŠ, J., SVOBODA, M., LEPŠOVA, A. (2011): How do log characteristics influence the occurrence of wood fungi in a mountain spruce forest. – Fungal Ecology **4**: 201–209.

PURSCHWITZ, J., MÜLLER, S., KASTNER, C., FISCHER, R. (2006): Seeing the rainbow: light sensing in fungi. – Current Opinion in Microbiology **9**: 566–571.

PUTWAIN, P. D., GILLHAM, D. A. (1990): The significance of the dormant viable seed bank in the restoration of heathlands. – Biological Conservation **52(1)**: 1–16.

RAJALA, T., PELTONIEMI, M., HANTULA, J., MÄKIPÄÄ, R., PENNANEN, T. (2011): RNA reveals a succession of active fungi during the decay of Norway spruce logs. – Fungal Ecology **4**: 437–448.

RAVEN, R. F., EICHHORN, S. E. (2013): Biology of plants. 8. Ed., London, W. H. Freeman. 900 pp.

RBG (REGENSBURGISCHE BOTANISCHE GESELLSCHAFT; 2016): Archiv der Regensburgischen Botanischen Gesellschaft. Regensburg, Regensburgische Botanische Gesellschaft von 1790 e.V.

RÖMERMANN, C., TACKENBERG, O., JACKEL, A.-K., POSCHLOD, P. (2008): Eutrophication and fragmentation are related to species' rate of decline but not to species rarity: results from a functional approach. – Biodiversity and Conservation **17**: 591-604.

ROSE, F. (1999): Indicators of ancient woodland. The use of vascular plants in evaluating ancient woods for nature conservation. – British Wildlife241–251.

ROSS-DAVIS, A. L., FREGO, K. A. (2004): Propagule sources of forest floor bryophytes: spatiotemporal compositional patterns. – The Bryologist **107(1)**: 88–97.

RUDDICK, S. M., WILLIAMS, S. T. (1972): Studies on the ecology of actinomycetes in soil. V. Some factors influencing the dispersal and adsorption of spores in soil. – Soil Biology and Biochemistry **4(1)**: 93–103.

RÜHS, M. (2001): Anwendung des Hemerobie-Konzepts in Agrarlandschaften am Beispiel des Biosphärenreservats Schorfheide-Chorin. Bern, Verlag Agrarökologie vaö.

RYDGREN, K., HESTMARK, G., ØKLAND, R. H. (1998): Revegetation following experimental disturbance in a boreal old-growth *Picea abies* forest. – Journal of Vegetation Science **9**: 763–776.

RYDIN, H., GUNNARSSON, U., SUNDBERG, S. (2006): The role of Sphagnum in peatland development and persistence. – pp. 47-65 in: WIEDER, R. K., VITT, D. H.: Boreal peatland ecosystems. Heidelberg, Springer.

RYDIN, H., JEGLUM, J. K. (2013): The biology of peatlands. 2. Ed., Oxford, Oxford University Press. 432 pp.

RYVARDEN, L., GILBERTSON, R. L. (1993): European polypores, part 1 (= Synopsis Fungorum 6). Oslo, Fungiflora. 387 pp.

SALA, O. E., CHAPIN, F. S., ARMESTO, J. J., BERLOW, E., BLOOMFIELD, J., DIRZO, R., HUBER-SANWALD, E., HUENNEKE, L. F., JACKSON, R. B., KINZIG, A., LEEMANS, R., LODGE, D. M., MOONEY, H. A., OESTERHELD, M., POFF, N. L., SYKES, M. T., WALKER, B. H., WALKER, M., WALL, D. H. (2000): Global biodiversity scenarios for the year 2100. – Science **287**: 1770–1774.

SAUER, M., AHRENS, M. (2005): Rote Liste und Artenverzeichnis der Moose Baden-Württembergs. – Naturschutz-Praxis, Artenschutz **10**: 1–142.

SCHAFFERS, A. P., SÝKORA, K. V. (2000): Reliability of Ellenberg indicator values for moisture, nitrogen and soil reaction – a comparison with field measurements. – Journal of Vegetation Science **11**: 225–244.

SCHIGEL, D. S., NIEMELÄ, T., KINNUNEN, J. (2006): Polypores of western Finnish Lapland and seasonal dynamics of polypore beetles. – Karstenia **46**: 37–64.

SCHMIDT, A. (2009): Die Regensburgische Botanische Gesellschaft in den Jahren 1999-2007. – Hoppea, Denkschr. Regensb. Bot. Ges. **70**: 255–272.

SCHNEIDER, C., POSCHLOD, P. (1999): Die Waldvegetation ausgewählter Flächen der Schwäbischen Alb in Abhängigkeit von der Nutzungsgeschichte. – Zeitschrift für Ökologie und Naturschutz **8**: 135–146.

SCHREIBER, K.-F. (2009): Die Versuchsflächen – von Oberstetten bis Mambach. – pp. 63-222 in: SCHREIBER, K.-F., BRAUCKMANN, H.-J., BROLL, G., KREBS, S., POSCHLOD, P.: Artenreiches Grünland in der Kulturlandschaft. 35 Jahre Offenhaltungsversuche Baden-Württemberg. Heidelberg - Ubstadt-Weiher - Basel, verlag regionalkultur.

SCHREIBER, K.-F., BRAUCKMANN, H.-J., BROLL, G., KREBS, S., POSCHLOD, P. (2009): Artenreiches Grünland in der Kulturlandschaft. 35 Jahre Offenhaltungsversuche Baden-Württemberg. Heidelberg - Ubstadt-Weiher - Basel, verlag regionalkultur. 421 pp.

SERZANINA, G. I. (1984): Shlyapoczje griby Belorussisi. Opredelitelj i konspekte florys. Minsk, Nauka i tekhnika. 407 pp.

SHAW, P. J. A. (1992): Fungi, fungivores, and fungal food webs. – pp. 295-310 in: CARROLL, G. C., WICKLOW, D. T.: The fungal community: Its organization and role in the ecosystem. New York, Marcel Dekker.

SIEGEL, D. I., GLASER, P. (2006): The hydrology of peatlands. – pp. 289-311 in: WIEDER, R. K., VITT, D. H.: Boreal peatland ecosystems. Heidelberg, Springer.

SIMMEL, J. (2011a): IBF Fungi: Großpilz-Kartierung mit Smartphone und GPS. Ein Beispiel aus dem Raum Regensburg. – Hoppea, Denkschr. Regensb. Bot. Ges. **72**: 139–170.

SIMMEL, J. (2011b): Kryptogamen als Indikatoren der Landnutzungsgeschichte in Wäldern und Kalkmagerrasen. Diplomarbeit, Universität Regensburg. 130 pp.

SIMMEL, J. (2013a): Die Kryptogamen in den Versuchsflächen der Offenhaltungsversuche Baden-Württemberg. Ersterfassung der Moose, Flechten und Großpilze. Regensburg, Schwäbisch Gmünd, Gutachten für den Lehrstuhl für Botanik und das Landesamt für Entwicklung der Landwirtschaft und der ländlichen Räume (LEL). 52 pp.

SIMMEL, J. (2013b): IBF Fungi: Großpilz-Kartierung mit Smartphone und GPS. Ergebnisse des zweiten Projektteils. – Hoppea, Denkschr. Regensb. Bot. Ges. **74**: 201–224.

SIMMEL, J., BÄSSLER, C., POSCHLOD, P. (2016): Ellenberg indicator values for macromycetes – a methodological approach and first applications. – Fungal Ecology (under review).

SIMMEL, J., KRONFELDNER, M. (2013): Häufiger werdende Pilzarten an Totholz. – Hoppea, Denkschr. Regensb. Bot. Ges. **74**: 225–233.

SIMMEL, J., RUBANSCHI, S., POSCHLOD, P. (2016): Zustandsbewertung der Populationen von Kennarten des FFH-Grünlands bei unterschiedlichem Management – Ergebnisse aus den Offenhaltungsversuchen des Landes Baden-Württemberg. – Naturschutz und Landschaftspflege Baden-Württemberg **78** (in press).

SITTE, P., WEILER, E. W., KADEREIT, J. W., BRESINSKY, A., KÖRNER, C. (2002): Lehrbuch der Botanik für Hochschulen („Strasburger“). 35. Ed., Heidelberg - Berlin, Spektrum Akademischer Verlag. 1123 pp.

SKEFFINGTON, R. A., WILSON, E. J. (1988): Excess nitrogen deposition: issues for consideration. – Environmental Pollution **54**: 159–184.

SMART, S. M., SCOTT, W. A. (2004): Bias in Ellenberg indicator values – problems with detection of the effect of vegetation type. – Journal of Vegetation Science **15**: 843–846.

SMITH, R. I. L. (1993): The role of bryophyte propagule banks in primary succession: case-study of an Antarctic fellfield soil. – pp. 55-78 in: MILES, J., WALTON, D. W. H.: Primary succession on land. Oxford, Blackwell.

SPSS (2009): The statistical package for social sciences, Version 17. Chicago, SPSS Inc.

STAHL, U., ESSER, K. (1976): Genetics of fruit body production in higher basidiomycetes. I. Monokaryotic fruiting and its correlation with dikaryotic fruiting in *Polyporus ciliatus*. – Molecular and general Genetics **148**: 183–197.

STEINHARDT, U., HERZOG, F., LAUSCH, A., MÜLLER, E., LEHMANN, S. (1999): Hemeroby index for landscape monitoring and evaluation. – pp. 237-254 in: PYKH, Y. A., HYATT, D. E., LENZ, R. J.: Environmental Indices – System analysis approach. Oxford, EOLSS Publications.

STOFER, S., BERGAMINI, A., ARAGÓN, G., CARVALHO, P., COPPINS, B. J., DAVEY, S., DIETRICH, M., FARKAS, E., KÄRKKÄINEN, K., KELLER, C., LÖKÖS, L., LOMMI, S., MÁGUAS, C., MITCHELL, R., PINHO, P., RICO, V. J., TRUSCOTT, A.-M., WOLSELEY, A., WATT, A., SCHEIDEGGER, C. (2006): Species richness of lichen functional groups in relation to land use intensity. – The Lichenologist **38(4)**: 331–353.

STRAATSMA, G., AYER, F., EGLI, S. (2001): Species richness, abundance, and phenology of fungal fruit bodies over 21 years in a Swiss forest plot. – Mycological Research **105(5)**: 515–523.

SUKOPP, H. (1969): Der Einfluss des Menschen auf die Vegetation. – Vegetatio **17(1)**: 360–371.

SYDES, C., GRIME, J. P. (1981): Effects of tree leaf litter on herbaceous vegetation in deciduous woodland. II. An experimental investigation. – Journal of Ecology **69**: 249–262.

TAKKEN, W., KLINE, D. L. (1989): Carbon dioxide and 1-octen-3-ol as mosquito attractants. – Journal of the American Mosquito Control Association **5(3)**: 311–316.

TÄLLE, M., DEÁK, B., POSCHLOD, P., VALKÓ, O., WESTERBERG, L., MILBERG, P. (2016): Grazing vs. mowing: a meta-analysis of biodiversity benefits for grassland management. – Agriculture, Ecosystems and Environment **222**: 200-212.

TELLO, S. A., SILVA-FLORES, P., AGERER, R., HALBWACHS, H., BECK, A., PERŠOH, D. (2013): *Hygrocybe virginea* is a systemic endophyte of *Plantago lanceolata*. – Mycological Progress **13(3)**: 471–475.

TER BRAAK, C. J. F., GREMMEN, N. J. M. (1987): Ecological amplitudes of plant species and the internal consistence of Ellenberg’s indicator values for moisture. – Vegetatio **69**: 79–87.

THEOBALD, E. J., ETTINGER, A. K., BURGESS, H. K., DEBEY, L. B., SCHMIDT, N. R., FROEHLICH, H. E., WAGNER, C., HILLERISLAMBERS, J., TEWKSBURY, J., HARSCH, M. A., PARRISH, J. K. (2015): Global change and local

solutions: tapping the unrealized potential of citizen science for biodiversity research. – Biological Conservation **181**: 236–244.

THOMPSON, K., HODGSON, J. G., GRIME, J. P., RORISON, I. H., BAND, S. R., SPENCER, R. E. (1993): Ellenberg numbers revisited. – Phytocoenologia **23(1-4)**: 277–289.

TICHÝ, L. (2002): JUICE, software for vegetation classification. – Journal of Vegetation Science **13**: 451–453.

TIMMERMANN, T., JOOSTEN, H., SUCCOW, M. (2009): Renaturierung von Mooren. – pp. 55-93 in: ZERBE, S., WIEGLEB, G.: Renaturierung von Ökosystemen in Mitteleuropa. Heidelberg, Spektrum Akademischer Verlag.

TORREY, J. G. (1978): Nitrogen fixation by actinomycete-nodulated angiosperms. – BioScience **28(9)**: 586–592.

URMI, E. (1999): Über die relative Grösse von Arealen bei Kryptogamen und Phanerogamen. – Beihefte zur Haussknechtia **9**: 377–389.

UTSCHICK, H., HELFER, W. (2003): Vergleichende ökologische Untersuchungen mittelschwäbischer Pilzzönosen in Wäldern unterschiedlicher Naturnähe. – Berichte der ANL **27**: 115–145.

VAN DER HEIJDEN, M. G. A. (2002): Arbuscular mycorrhizal fungi as determinant of plant diversity: in search of underlying mechanisms and general principles. – pp. 243-263 in: van der Heijden, M. G. A., SANDERS, I. R.: Mycorrhizal Ecology. Berlin, Heidelberg, Springer.

VAN DER HEIJDEN, M. G. A., KLIRONOMOS, J. N., URSIC, M., MOUTOGLIS, P., STREITWOLF-ENGEL, R., BOLLER, T., WIEMKEN, A., SANDERS, I. R. (1998): Mycorrhizal fungal diversity determines plant biodiversity, ecosystem variability and productivity. – Nature **396(5)**: 69–72.

VANDERPOORTEN, A., DELESCAILLE, L.-M., JACQUEMART, A.-L. (2004): The bryophyte layer in a calcareous grassland after a decade of contrasting mowing regimes. – Biological Conservation **117**: 11–18.

VELLINGA, E. C. (2004): Ecology and distribution of Lepiotaceous fungi (Agaricaceae). A review. – Nova Hedwigia **78(3-4)**: 273–299.

VON BRACKEL, W., WAGNER, A., WAGNER, I., ZEHM, A. (2008): Wenig beachtet aber stark gefährdet: Die Moose und Flechten Bayerns müssen in Artenhilfsmaßnahmen eingebunden werden. – ANLiegen Natur **32(1)**: 47–64.

WALLENDA, T., KOTTKE, I. (1998): Nitrogen deposition and ectomycorrhizas. – New Phytologist **139**: 169–187.

WALZ, U., STEIN, C. (2014): Indicators of hemeroby for the monitoring of landscapes in Germany. – Journal for Nature Conservation **22**: 279–289.

WAMELINK, G. W. W., JOOSTEN, V., VAN DOBBEN, H. F., BERENDSE, F. (2002): Validity of Ellenberg indicator values judged from physico-chemical field measurements. – Journal of Vegetation Science **13**: 269–278.

WARNEKE, M. (1993): Die Flora und Vegetation des Naturschutzgebietes Sippenauer Moor im Landkreis Kelheim. – Hoppea, Denkschr. Regensb. Bot. Ges. **54**: 7–78.

WASSER, S. P. (1990): Plantae non vasculares, Fungi et Bryopsida orientis extremi Sovietici. Fungi, vol. 1: Basidiomycetes. Leningrad, Nauka. 407 pp.

WEBER, H. E. (2001): Zeigerwerte der *Rubus*-Arten. – pp. 167-174 in: ELLENBERG, H., WEBER, H. E., DÜLL, R., WIRTH, V., WERNER, W.: Zeigerwerte von Pflanzen in Mitteleuropa. Göttingen, Erich Goltze GmbH & Co KG.

WIEDER, R. K., VITT, D. H. (2006): Boreal peatland ecosystems. Heidelberg, Springer. 440 pp.

WILSON, A. W., BINDER, M., HIBBETT, D. S. (2011): Effects of gasteroid fruiting body morphology on diversification rates in three independent clades of fungi estimated using binary state speciation and extinction analysis. – Evolutionary Ecology Research **65(5)**: 1305–1322.

WINTERHOFF, W. (1992): Handbook of vegetation science 19/1: Fungi in vegetation science. Dordrecht, Kluwer. 258 pp.

WINTERHOFF, W., BEGENAT, F. (1993): Die Pilzflora des Eriskircher Riedes. – Beihefte der Veröffentlichungen für Naturschutz und Landespflege in Baden-Württemberg **69**: 229–262.

WINTERHOFF, W., KRIEGLSTEINER, G. J. (1984): Rote Liste der gefährdeten Großpilze in Baden-Württemberg. – Beihefte der Veröffentlichungen für Naturschutz und Landespflege in Baden-Württemberg **40**: 1–120.

WIRTH, V. (1972): Die Silikatflechten-Gemeinschaften im außeralpinen Zentraleuropa (Dissertationes Botanicae 17). Lehre, Cramer.

WIRTH, V. (1995): Die Flechten Baden-Württembergs (2 Bände). 2. Ed., Stuttgart, Ulmer Verlag. 1006 pp.

WIRTH, V. (1995): Flechtenflora. 2. Ed., Stuttgart, Ulmer Verlag. 661 pp.

WIRTH, V. (2001): Zeigerwerte von Flechten. – pp. 221-243 in: ELLENBERG, H., WEBER, H. E., DÜLL, R., WIRTH, V., WERNER, W.: Zeigerwerte von Pflanzen in Mitteleuropa. Göttingen, Erich Goltze GmbH & Co KG.

WIRTH, V. (2008): Rote Liste und Artenverzeichnis der Flechten Baden-Württembergs. – Naturschutz-Praxis, Artenschutz **13**: 1–64.

WIRTH, V., HAUCK, M., SCHULTZ, M. (2013): Die Flechten Deutschlands (2 Bände). Stuttgart, Ulmer Verlag. 1220 pp.

WULF, M. (1997): Plant species as indicators of ancient woodland in northwestern Germany. – Journal of Vegetation Science **8**: 635–642.

ZECHMEISTER, H. G., MOSER, D. (2001): The influence of agricultural land-use intensity on bryophyte species richness. – Biodiversity and Conservation **10**: 1609–1625.

ZECHMEISTER, H. G., TRIBSCH, A. (1999): Moose als Indikatoren einer nachhaltigen Nutzung österreichischer Kulturlandschaften. – Abhandlungen der Zoologisch-Botanischen Gesellschaft von Österreich **30**: 179–187.

ZERBE, S., WIEGLEB, G. (2009): Renaturierung von Ökosystemen in Mitteleuropa. Heidelberg, Spektrum Akademischer Verlag.

ZHANG, L., DAWES, W. R., WALKER, G. R. (2001): Response of mean annual evapotranspiration to vegetation changes at catchment scale. – Water Resources Research **37(3)**: 701–708.

ZOBERI, M. H. (1964): Effect of temperature and humidity on ballistospore discharge. – Trans. Br. mycol. Soc. **47(1)**: 109–114.

ZOBERI, M. H. (1972): Transpiration and water uptake in the fruit bodies of some hymenomycetes. – Physiol. Plant. **26**: 215–220.

ZOLLER, H., SELLDORF, P. (1989): Untersuchungen zur kurzfristigen Sukzession von Torf- und Braunmoosgesellschaften in einem Übergangsmoor aus den Schweizer Alpen. – Flora **182**: 127-151.

ZÓLYOMI, B. (1989): Indirekte Methode zur Feststellung des ökologischen Optimums und der ökologischen Amplitude von Pflanzenarten. – Flora **183(5/6)**: 349–357.

Table Appendix

Chapter 2: Table 7 [List of Ellenberg indicator values for 636 species of macromycetes]

Appendix Page A – I

Chapter 3: Table 12 [List of functional trait data for 636 species of macromycetes]

Appendix Page J – X

Table Appendix

Table 7 (Chapter 2). Ellenberg indicator values for 636 macromycete species.
Indicator scales: L, light intensity/habitat openness; T, mean annual temperature; K, continentality; F, substrate moisture content; R, substrate reaction; N, substrate nutrient availability; S, substrate salt content; M, frequency value; H_l, lower boundary of hemeroby; H_u, upper boundary of hemeroby; O, substrate openness.

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Abortiporus biennis		5	7	3	6	7	7	0	5	2	4	3
Agaricus aestivalis	A. albosericellus	3	5	5	4	8	6	0	6	2	4	2
Agaricus bitorquis	A. edulis	7	6	5	4	7	6	1	6	2	6	9
Agaricus campestris	A. flocculosus	9	5	5	4	7	5	1	7	2	4	7
Agaricus silvaticus	A. haemorrhoidarius (p.p.)	2	5	5	5	7	5	0	8	2	4	6
Agaricus silvicola	A. essettii	3	5	5	5	7	5	0	8	2	4	5
Agaricus xanthoderma		8	5	5	5	7	3	0	7	2	4	7
Agrocybe dura	A. molesta	8	6	5	3	7	6	0	7	2	6	7
Albatrellus ovinus		4	6	6	5	7	3	0	4	2	3	6
Aleuria aurantia		4	×	5	5	6	6	0	8	2	5	8
Aleurodiscus amorphus		3	4	5	6	×	6	0	6	2	4	4
Amanita battarrae	A. fuscoolivacea, A. umbrinolutea	3	4	5	5	7	5	0	7	2	3	5
Amanita citrina	A. mappa	2	5	5	6	3	2	0	8	2	4	2
Amanita excelsa	A. ampla, A. spissa	2	5	5	6	4	4	0	8	2	4	5
Amanita fulva		3	5	5	6	4	3	0	7	2	4	5
Amanita muscaria		3	5	5	6	5	3	0	8	2	4	5
Amanita pantherina		3	5	5	4	7	4	0	8	2	3	5
Amanita phalloides	A. viridis	3	5	4	6	7	6	0	8	2	3	5
Amanita porphyria		3	4	5	5	3	3	0	7	2	3	2
Amanita rubescens		3	5	5	6	5	4	0	8	2	4	2
***Amanita vaginata* s. str.**	A. plumbea	3	4	5	6	×	5	0	7	2	4	5
Amylostereum areolatum		3	4	5	×	×	6	0	7	2	4	5
Antrodia serialis		×	5	?	5	×	6	0	7	2	4	4
Antrodiella semisupina		3	6	5	5	7	6	0	4	2	4	4
Armillaria borealis	Korhonen "Species A"	4	5	5	6	?	?	0	5	2	4	4
Armillaria gallica	A. bulbosa ss. Romagn., A. lutea, Korhonen "Species E"	4	6	5	7	7	×	0	7	2	4	4
***Armillaria mellea* s. str.**	Korhonen "Species D"	5	6	5	5	7	?	0	5	2	4	4
Armillaria ostoyae	A. obscura, A. polymyces ss. auct. eur., Korhonen "Species C"	2	5	5	5	×	5	0	8	2	4	4
Ascocoryne cylichnium		3	5	3	6	6	×	0	8	2	3	5
Ascocoryne sarcoides	Coryne sarcoides	3	5	3	7	5	×	0	8	2	3	5
Astraeus hygrometricus		4	5	×	3	2	2	0	5	2	3	6
Aurantiporus fissilis	Tyromyces fissilis	5	7	5	4	8	7	0	3	3	4	6
Auricularia auricula-judae		4	6	4	6	8	8	1	7	2	4	5
Auricularia mesenterica		5	7	4	5	7	7	0	5	2	3	5
Auriscalpium vulgare		4	5	5	4	7	2	0	7	2	4	5
Baeospora myosurus		2	5	5	6	×	×	0	8	2	4	5
Basidioradulum radula	Hyphoderma radula	4	5	4	5	×	7	0	6	2	4	6
Bisporella citrina		3	5	3	5	×	×	0	9	2	4	×
Bjerkandera adusta		×	5	×	×	×	6	0	9	2	4	5
Bjerkandera fumosa		4	6	4	8	8	8	0	4	2	3	5
Bolbitius vitellinus	B. fragilis, B. titubans, incl. B. lacteus, B. variicolor	×	5	5	6	×	9	0	8	2	6	9
***Boletus edulis* s. str.**		2	4	5	5	5	2	0	8	2	4	8
Boletus erythropus	B. luridiformis, B. miniatoporus, incl. B. junquilleus	3	4	5	5	5	4	0	7	2	4	8
Boletus luridus		5	5	5	5	8	5	0	7	2	4	7
Boletus pulverulentus	Xerocomus pulverulentus	2	5	6	5	6	2	0	6	2	4	8
Bovista limosa		9	5	3	2	9	4	1	1	2	3	7
Bovista plumbea		8	6	5	4	×	×	0	6	2	4	7
Bovista pusilla	B. dermoxantha	9	5	5	3	6	4	0	2	2	3	7
Bulbillomyces farinosus		4	7	4	9	8	8	0	3	2	4	6
Calloria neglecta		5	6	5	6	7	8	0	8	2	5	4
Calocera cornea	C. palmata, C. striata	4	5	5	5	7	6	0	8	2	3	6
Calocera furcata	C. cornea f. furcata	4	4	5	5	5	5	0	6	2	3	6
Calocera viscosa	C. flammea, C. stricta	3	4	5	5	×	×	0	9	2	4	7
Calocybe carnea	C. persicolor, Rugosomyces carneus	6	5	5	5	×	5	0	7	2	4	7
Calocybe gambosa	Tricholoma georgii, T. graveolens	4	5	5	5	7	5	0	8	2	4	6
Calvatia excipuliformis	C. saccata, Handkea excipuliformis	6	5	4	4	6	5	0	8	2	4	6
Calvatia utriformis	Handkea utriformis	8	4	5	3	6	5	0	6	2	3	7
Calyptella capula	Cyphella capula	5	5	5	7	7	8	0	6	2	5	4
Cantharellula umbonata		4	4	4	7	2	1	0	3	2	3	1
Cantharellus cibarius* var. *c.		3	4	5	5	5	4	0	8	2	4	5
Cantharellus cibarius* var. *amethysteus	C. amethysteus	3	4	5	5	3	3	0	5	2	4	5
Cantharellus tubaeformis	C. infundibuliformis, incl. var. lutescens	2	4	4	6	4	4	0	7	2	4	5
Ceriporia reticulata		4	5	5	8	8	7	0	4	2	4	7
Ceriporia viridans		4	5	5	7	7	7	0	4	2	4	7
Cerrena unicolor	Daedalea unicolor, Trametes u.	4	4	?	5	×	5	0	4	2	3	5
Chalciporus piperatus	Boletus piperatus	3	4	5	6	6	3	0	7	2	4	8
Chlorociboria aeruginascens	Chlorosplenium aeruginascens	4	5	5	8	7	7	0	8	2	3	5
Chondrostereum purpureum	Stereum purpureum	3	5	3	7	7	7	0	7	2	4	6
Chroogomphus rutilus		4	5	5	4	7	4	0	7	2	3	5
Clavaria fragilis	C. vermicularis	3	5	5	5	6	5	0	5	2	3	5

Table 7 *continued*

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Clavariadelphus pistillaris	Clavaria herculeana	3	5	5	5	8	6	0	7	2	3	5
Clavulina cinerea	Clavulina grisea	2	5	4	6	7	6	0	8	2	4	5
Clavulina coralloides	Clavulina cristata	3	5	5	6	7	6	0	9	2	4	5
Clavulina rugosa		2	4	4	6	7	6	0	7	2	4	5
Climacocystis borealis	Spongipellis borealis	3	4	6	6	×	×	0	6	2	4	5
Clitocybe candicans	C. tenuissima, incl. C. gallinacea	3	5	5	6	8	6	0	6	2	4	2
Clitocybe clavipes		2	5	5	6	6	6	0	8	2	4	2
Clitocybe ditopa		3	5	5	5	×	6	0	8	2	4	2
Clitocybe fragrans	C. suaveolens, excl. C. obsoleta	3	5	5	6	7	7	0	8	2	4	6
Clitocybe gibba	C. infundibuliformis ss. auct.	3	5	5	6	7	6	0	8	2	4	6
Clitocybe glareosa	C. bresadoliana ss. auct.	9	6	4	3	8	2	0	1	2	3	7
Clitocybe metachroa	C. decembris, C. dicolor	4	5	5	6	6	5	0	7	2	4	5
Clitocybe nebularis	Lepista nebularis	3	5	5	6	7	7	0	9	2	4	3
Clitocybe odora		3	5	5	6	8	5	0	8	2	4	2
Clitocybe phaeophthalma	C. hydrogramma	3	6	6	6	8	6	0	7	2	4	5
Clitocybe phyllophila	C. cerrusata, C. pithyophila	3	5	5	6	7	6	0	8	2	4	2
Clitocybe rivulosa	C. augeana, C. dealbata, C. ruderalis	7	6	5	5	×	×	0	8	2	4	7
Clitocybe subspadicea	C. umbilicata (Schaeff.) Singer ss. auct. plur., non ss. Fr.	3	5	5	5	8	6	0	7	2	4	2
Clitocybe vibecina		3	5	5	5	6	4	0	8	2	4	5
Clitocybula platyphylla	Megacollybia platyphylla	3	5	5	6	×	6	0	9	2	4	6
Clitopilus prunulus		5	5	5	6	×	4	0	8	2	4	6
Collybia cookei		3	5	5	5	×	?	0	7	2	4	7
Colpoma quercinum		5	6	3	4	×	×	0	7	2	4	4
Conocybe aporos	Pholiotina aporos, Pholiota togularis ss. Lange	4	5	4	5	7	7	0	7	2	4	6
Conocybe arrhenii	Pholiotina arrhenii, C. blattaria ss. auct.	4	6	5	7	7	7	0	7	2	6	6
***Conocybe dumetorum* s. lat.**		×	6	5	4	×	?	0	5	2	3	7
Conocybe lactea	Bolbitius albipes, Conocybe a., C. huijsmanii	9	5	5	4	7	8	0	5	2	5	7
Conocybe mesospora		8	6	5	4	×	×	0	4	2	4	7
Conocybe pilosella	C. piloselloides	5	5	5	5	6	6	0	4	2	4	7
Conocybe pulchella	C. pseudopilosella	6	7	4	4	5	4	0	2	2	4	7
Conocybe semiglobata		7	6	5	4	7	6	0	5	2	6	7
Conocybe tenera	(Schaeff. : Fr.) Fayod, non ss. Lange	6	5	5	5	×	5	0	7	2	6	7
Conocybe vestita	Pholiotina vestita	4	6	4	7	7	7	0	3	2	4	7
Coprinus atramentarius	Coprinopsis atramentaria	4	5	5	6	×	7	0	8	2	4	6
Coprinus comatus		8	5	5	6	7	8	1	9	2	5	7
Coprinus lagopus	Coprinopsis lagopus, Coprinus phlyctidosporus	3	5	5	5	7	6	0	7	2	4	6
Coprinus leiocephalus	Coprinus galericuliformis p.p., Parasola leiocephala	3	5	4	5	7	7	0	7	2	4	7
Coprinus micaceus	Coprinellus micaceus	3	5	5	×	×	8	0	8	2	4	6
Coprinus plicatilis	Parasola plicatilis	8	5	5	×	6	×	0	8	2	5	7
Cordyceps ophioglossoides		3	5	5	5	4	?	0	6	2	3	1
Cortinarius acutus	C. acutorum	3	4	5	7	4	4	0	5	2	3	6
Cortinarius albovariegatus		3	4	5	9	3	2	0	3	2	4	6
Cortinarius alboviolaceus		3	5	5	4	6	3	0	7	2	4	5
Cortinarius alnetorum	C. iliopodius ss. auct.	4	5	5	8	6	6	0	5	2	3	6
***Cortinarius anomalus* s. str.**		3	5	5	7	5	4	0	8	2	3	5
Cortinarius bibulus	C. americanus, C. pulchellus	4	5	5	9	7	6	0	5	2	3	6
Cortinarius bulbosus		2	4	5	5	×	4	0	2	2	3	2
Cortinarius caninus		3	4	5	4	5	3	0	6	2	4	2
Cortinarius caperatus	Rozites caperata	3	4	5	6	3	2	0	7	2	4	5
Cortinarius cinnamomeus	Dermocybe cinnamomea	3	4	5	6	4	3	0	8	2	4	5
Cortinarius croceus	C. cinnamomeoluteus, Dermocybe crocea	3	4	5	5	4	3	0	6	2	4	5
Cortinarius decipiens	(Pers. : Fr.) Fr., non ss. Lange	4	5	5	6	×	3	0	5	2	3	6
Cortinarius delibutus* var. *d.		4	4	5	×	6	3	0	7	2	3	6
Cortinarius flexipes	C. paleaceus ss. auct., C. paleiferus	4	4	5	7	4	4	0	5	2	3	6
Cortinarius helvelloides		4	4	6	8	7	5	0	4	2	3	6
Cortinarius hemitrichus		3	5	5	6	5	4	0	7	2	4	5
Cortinarius hinnuleus		3	5	5	6	7	5	0	7	2	4	6
Cortinarius infractus		3	5	5	5	8	5	0	7	2	4	2
Cortinarius obtusus		4	4	5	6	4	2	0	5	2	3	6
Cortinarius orellanus		5	6	4	3	5	3	0	5	2	3	6
Cortinarius purpureus	C. phoeniceus ss. auct., Dermocybe purpurea, Dermocybe sanguinea var. vitiosa	3	4	4	5	6	3	0	5	2	4	5
Cortinarius sanguineus	C. puniceus, Dermocybe sanguinea	3	4	5	7	5	2	0	7	2	4	5
Cortinarius semisanguineus	Dermocybe semisanguinea	3	4	5	×	5	3	0	7	2	4	5
Cortinarius sertipes		4	6	5	7	5	6	0	4	2	3	6
Cortinarius speciosissimus	C. henrici, C. rubellus	4	4	5	8	3	2	0	6	2	3	6
Cortinarius torvus		3	5	5	5	6	4	0	6	2	4	5
Cortinarius traganus		2	5	5	5	4	3	0	7	2	4	1
Cortinarius varius		3	4	5	6	8	5	0	8	2	4	5
Cortinarius vibratilis		3	5	5	5	6	4	0	6	2	4	1
Craterellus cornucopioides		3	5	5	5	7	4	0	7	2	4	5
Crepidotus applanatus	C. scalaris ss. Ricken	4	5	5	6	7	7	0	7	2	4	6
Crepidotus cesatii	C. sphaerosporus, C. subepibryus	3	5	5	×	×	×	0	8	2	4	5
Crepidotus epibryus	(Bull. : Fr.) Quél., non ss. Moser; C. chioneus, C. graminicola, C. herbarum, C. hypnophilus, Pleurotellus herbarum	4	6	5	6	7	4	0	6	2	5	5

Table 7 *continued*

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Crinipellis scabellus	C. stipitarius	8	5	5	4	7	4	0	6	2	5	6
Crucibulum laeve	C. vulgare	4	5	5	6	×	6	0	8	2	5	6
Cudoniella clavus		2	5	4	11	7	6	0	6	2	4	7
Cyathus olla	C. laevis	7	5	5	5	7	8	1	6	2	6	7
Cyathus striatus	C. hirsutus	4	5	5	5	7	7	0	8	2	5	6
Cyphellostereum laeve		5	4	4	6	4	3	0	2	2	5	1
Cystoderma amianthinum		4	4	5	5	6	4	0	8	2	4	3
Cystoderma carcharias		3	4	6	5	7	5	0	8	2	4	3
Cystoderma granulosum		4	5	5	5	7	4	0	5	2	4	3
Cystoderma jasonis	C. amianthinum var. longisporum	4	4	5	6	4	3	0	6	2	4	2
Cystolepiota bucknallii	Lepiota lilacina	4	5	5	5	8	8	0	5	2	4	2
Cystolepiota hetieri	Lepiota hetieri, L. langei, L. rufescens	3	6	5	6	7	7	0	3	2	4	2
Cystolepiota seminuda	excl. C. sororia	4	5	5	5	7	7	0	8	2	4	3
Dacrymyces lacrymalis		4	4	3	5	7	5	0	3	2	4	6
Dacrymyces stillatus		×	5	5	×	×	×	0	9	2	4	6
Daedalea quercina		4	6	×	5	7	×	0	6	2	4	5
Daedaleopsis confragosa		4	5	5	8	8	×	0	7	2	4	6
Daedaleopsis confragosa* var. *tricolor		5	7	5	6	8	7	0	5	2	3	5
Datronia mollis		4	5	5	7	7	6	0	7	2	3	5
Delicatula integrella	Mycena integrella	4	6	5	7	7	7	0	6	2	4	6
Dendrothele acerina		5	5	3	6	8	6	0	5	2	4	4
Dendrothele alliacea		5	5	3	5	7	6	0	3	2	4	4
Dermoloma cuneifolium	D. atrocinereum, D. fuscobrunneum	9	5	4	4	8	3	0	4	2	3	7
Diatrype bullata		4	6	5	8	6	4	0	6	2	4	4
Diatrype disciformis		×	5	4	5	6	5	0	9	2	4	4
Diatrype stigma		4	5	4	5	7	5	0	9	2	4	4
Diatrypella favacea		5	5	5	5	×	3	0	9	2	4	4
Echinoderma asperum	Lepiota acutesquamosa, L. friesii	4	5	6	6	7	8	0	8	2	4	2
Elaphomyces muricatus		3	5	5	5	4	2	0	7	2	3	1
***Entoloma cetratum* s. str.**		3	4	5	×	3	2	0	7	2	4	2
Entoloma chalybaeum	E. chalybaeum var. lazulinum, E. lazulinum	8	5	5	4	7	3	0	3	2	3	7
Entoloma conferendum	E. staurosporum	4	5	5	7	4	3	0	8	2	4	2
Entoloma exile	E. pyrospilum	8	4	4	4	3	3	0	2	2	3	7
Entoloma griseocyaneum		9	4	5	4	4	3	0	3	2	3	7
Entoloma lampropus		5	5	5	7	8	5	0	3	2	4	8
Entoloma lanicum		7	5	4	5	7	4	0	3	2	3	7
Entoloma mougeotii		8	4	5	8	8	3	0	4	2	3	7
Entoloma nitidum		2	4	5	6	4	3	0	6	2	4	5
Entoloma politum		4	5	4	7	6	6	0	5	2	3	8
Entoloma prunuloides	E. autumnale, E. inocybeforme, E. inopiliforme	9	4	5	5	8	2	0	5	2	3	7
Entoloma rhodopolium	E. nidorosum	3	5	5	6	7	6	0	8	2	4	2
Entoloma sericeum		7	5	5	×	×	4	0	7	2	4	7
Entoloma turci		8	5	4	×	8	3	0	3	2	3	7
Exidia cartilaginea		4	5	5	5	7	×	0	3	2	3	5
Exidia glandulosa		4	5	5	×	×	×	0	7	2	4	5
Exidia plana	incl. var. pithya	4	5	5	×	×	×	0	7	2	4	5
Exidia recisa		4	4	5	7	7	×	0	5	2	4	5
Flammulaster granulosus		4	5	4	7	7	6	0	3	2	4	6
***Flammulina velutipes* s. str.**		×	5	5	8	?	?	0	8	2	5	6
Fomes fomentarius		×	5	×	×	×	×	0	6	2	4	5
Fomitopsis pinicola		×	4	5	×	×	×	0	9	2	4	4
Galerina clavata	G. heterocystis (ss. auct. eur.)	3	5	5	7	×	6	0	6	2	4	4
Galerina hypnorum	G. decipiens	5	5	5	5	×	×	0	8	2	4	1
Galerina marginata		3	4	5	×	×	?	0	8	2	4	6
Galerina mniophila		6	5	5	9	×	×	0	4	2	4	1
Galerina pumila	G. mycenopsis	4	5	5	×	×	×	0	6	2	4	7
Galerina triscopa		4	5	5	×	×	×	0	5	2	4	1
Galerina vittiformis	s. l. (incl. G. vittiformis var. atkinsoniana, G. rubiginosa ss. auct., G. subannulata)	3	5	5	6	×	5	0	8	2	5	1
Gamundia striatula	Collybia pseudoclusilis, Fayodia leucophylla, Fayodia p., Gamundia p., Rhodocybe striatula	4	5	5	4	?	4	0	4	2	4	2
Ganoderma applanatum		×	5	5	×	×	×	0	8	2	4	5
Ganoderma lucidum		4	6	5	×	8	5	0	5	2	4	5
Geastrum fimbriatum	G. sessile	4	5	5	5	7	6	0	7	2	4	6
Geastrum nanum	G. schmidelii	9	6	4	2	6	2	1	2	2	3	7
Gloeophyllum abietinum		3	5	5	4	×	×	0	5	2	6	4
Gloeophyllum odoratum	Osmoporus odoratus	3	4	7	×	6	×	0	7	2	4	6
Gloeophyllum sepiarium		×	5	5	4	×	×	0	7	2	6	5
Gloeoporus dichrous		6	7	5	6	7	4	0	3	2	4	4
Gomphidius glutinosus	Leucogomphidius glutinosus	3	4	5	6	6	4	0	8	2	3	1
Gymnopilus penetrans	G. hybridus, G. liquiritiae	3	5	5	×	6	×	0	9	2	4	7
Gymnopilus picreus	G. satur	2	5	5	8	4	3	0	3	2	4	7
Gymnopus aquosus	Collybia aquosa var. aquosa	3	6	4	6	×	5	0	7	2	4	2
Gymnopus confluens	Collybia confluens, C. ingrata	3	5	5	5	4	3	0	9	2	4	2

Table 7 *continued*

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Gymnopus dryophilus	Collybia aquosa var. dryophila	3	5	5	6	×	6	0	9	2	4	1
Gymnopus peronatus	Collybia peronata, C. urens	3	5	5	6	5	4	0	9	2	4	1
Hapalopilus nidulans	H. rutilans	4	6	5	5	×	?	0	6	2	4	5
Hebeloma crustuliniforme	(Bull. : Fr.) Quél., non ss. Ricken, Bres.	4	5	5	5	×	4	0	8	2	4	7
Hebeloma edurum	H. senescens, H. sinuosum ss. Ricken, ss. Konrad & Maubl.	4	5	5	4	8	3	0	6	2	4	7
Hebeloma helodes		4	5	5	8	7	6	0	3	2	3	2
Hebeloma incarnatulum	H. bryogenes, H. longicaudum ss. auct. p.p.	3	5	5	8	3	1	0	6	2	3	2
Hebeloma mesophaeum	H. fastibile ss. auct. p.p., non Lange, Bruchet	3	5	5	6	×	6	0	8	2	4	7
Hebeloma radicosum	Myxocybe radicosa	3	5	4	5	7	4	0	7	2	4	5
Hebeloma sinapizans		4	5	5	5	8	5	0	8	2	4	5
Hebeloma theobrominum	H. truncatum	4	5	5	6	7	4	0	5	2	4	6
Helvella lacunosa		4	5	4	6	8	7	0	7	2	4	8
Helvella macropus		4	5	5	5	7	7	0	6	2	4	8
Hemimycena cucullata	H. gypsea	4	5	5	6	6	5	0	6	2	4	6
Hemimycena delectabilis	Omphalia nitrosa	6	?	5	6	×	5	0	4	2	4	6
Hemimycena lactea	H. delicatella	4	5	5	6	5	5	0	6	2	4	6
Hemimycena pseudolactea		6	5	5	5	5	4	0	2	2	4	6
Heterobasidion annosum		3	4	5	5	×	×	0	9	2	5	6
Heteromycophaga glandulosae		4	5	5	×	?	?	0	7	2	4	1
Humaria hemisphaerica		4	5	5	7	8	5	0	6	2	4	8
Hydnum repandum	incl. var. rufescens	3	4	5	5	×	4	0	7	2	4	6
Hygroaster asterosporus		3	5	4	6	4	5	0	4	2	3	1
Hygrocybe cantharellus	H. lepida	8	5	5	8	2	3	0	3	2	3	4
Hygrocybe colemanniana	Camarophyllus colemanniana	9	5	5	4	7	2	0	5	2	3	7
Hygrocybe conica* var. *c.		8	5	5	×	7	4	0	8	2	5	7
Hygrocybe insipida	H. reai var. insipida, H. subminutula	9	5	5	4	7	3	0	4	2	3	7
Hygrocybe persistens		9	4	5	4	8	4	0	4	2	5	7
Hygrocybe pratensis	Camarophyllus pratensis	9	5	5	×	6	3	0	6	2	3	7
Hygrocybe psittacina		9	5	5	×	7	4	0	7	2	5	7
Hygrocybe virginea	Camarophyllus virginea, Hygrophorus v., incl. var. fuscescens	6	5	5	5	6	4	0	7	2	5	7
Hygrophoropsis aurantiaca		4	4	5	5	5	4	0	8	2	4	2
Hygrophorus chrysodon		3	4	5	7	8	5	0	6	2	4	2
Hygrophorus discoxanthus	H. chrysaspis, H. cossus, H. eburneus var. discoxanthus	4	5	5	5	8	6	0	7	2	4	2
Hygrophorus hypothejus		4	5	5	4	3	3	0	7	2	4	6
Hygrophorus latitabundus		4	4	5	4	7	3	0	5	2	4	6
Hygrophorus olivaceoalbus		4	4	5	7	4	3	0	7	2	4	6
Hygrophorus penarius		3	5	4	5	7	6	0	6	2	4	2
Hygrophorus pustulatus		4	5	5	6	7	5	0	8	2	4	1
Hymenochaete cruenta	H. mougeotii	4	4	6	×	6	×	0	5	2	3	4
Hymenochaete rubiginosa		4	6	4	×	7	6	0	7	2	4	5
Hymenoscyphus calyculus		3	5	?	6	8	7	0	7	2	4	6
Hymenoscyphus caudatus		4	5	?	6	×	6	0	8	2	4	6
Hymenoscyphus fructigenus		4	6	4	5	×	×	0	7	2	4	5
Hymenoscyphus lutescens		3	?	6	4	4	×	0	7	2	4	6
Hypholoma capnoides		3	4	5	×	×	×	0	9	2	4	6
Hypholoma fasciculare		×	5	5	×	×	×	0	9	2	5	6
Hypholoma lateritium		3	5	5	×	×	×	0	9	2	4	7
Hypholoma polytrichi	H. dispersum ss. Bres.	3	4	5	6	3	3	0	6	2	4	1
Hypholoma radicosum	H. epixanthum ss. Ricken	3	4	5	×	4	×	0	8	2	4	6
Hypoxylon cohaerens		3	5	3	5	4	3	0	6	2	4	4
Hypoxylon deustum	Kretschmaria deusta, Ustulina d.	3	5	3	5	×	6	0	8	2	4	5
Hypoxylon fragiforme		3	5	4	5	×	×	0	9	2	4	4
Hypoxylon fuscum		4	5	4	5	6	6	0	8	2	4	4
Hypoxylon howeianum		4	5	4	5	7	5	0	7	2	4	4
Hypoxylon rubiginosum		4	6	4	5	7	5	0	7	2	4	4
Inocybe adaequata	I. deducta, I. jurana, I. rhodiola	3	5	5	5	8	7	0	7	2	4	6
Inocybe auricoma	I. pallidipes	5	4	5	5	7	6	0	3	2	4	6
Inocybe bongardii* var. *b.		4	5	5	5	7	6	0	6	2	4	6
Inocybe corydalina		4	5	5	5	8	6	0	6	2	4	2
Inocybe flocculosa	incl. var. crocifolia, incl. var. ferruginea	3	5	5	6	7	5	0	7	2	4	2
Inocybe fuscidula		3	5	5	×	7	5	0	6	2	4	6
Inocybe geophylla* var. *g.		4	5	5	5	7	7	0	9	2	5	6
Inocybe geophylla* var. *lilacina		4	6	5	5	7	5	0	7	2	5	6
Inocybe glabrescens	I. abietis, I. metrodii	3	4	5	5	7	4	0	4	2	4	2
Inocybe glabripes	I. microspora, I. parvispora	5	5	5	4	7	4	0	3	2	4	2
Inocybe godeyi		4	5	5	5	8	6	0	6	2	4	2
Inocybe griseolilacina	I. personata	3	5	5	5	7	5	0	5	2	4	2
Inocybe hirtella		4	6	5	6	7	5	0	6	2	4	6
Inocybe hirtelloides		4	5	5	5	6	4	0	2	2	4	6
Inocybe lacera		5	5	5	5	4	2	0	6	2	3	6
Inocybe mixtilis	I. trechispora ss. Bres.	4	4	5	5	7	5	0	6	2	4	6
Inocybe muricellata	I. scabella ss. auct. plur., I. scabelliformis	3	5	5	5	8	4	0	4	2	4	6
Inocybe napipes		2	5	5	8	3	3	0	7	2	4	6
Inocybe nitidiuscula	I. friesii, I. tarda	4	5	5	5	7	5	0	8	2	4	6

Table 7 *continued*

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Inocybe petiginosa		3	5	5	4	7	6	0	7	2	4	2
Inocybe phaeocomis	I. cincinnata, incl. var. major	3	5	5	6	7	4	0	7	2	4	2
Inocybe rimosa		×	5	5	5	7	6	0	8	2	5	2
Inocybe sindonia	I. eutheles ss. auct., I. kuehneri	4	5	5	×	6	5	0	7	2	5	2
Inocybe splendens* var. *s.	I. alluvionis	4	5	5	5	8	7	0	4	2	4	6
Inocybe splendens* var. *phaeoleuca	I. brunnea ss. auct.	4	5	6	5	8	7	0	4	2	4	6
Inonotus radiatus		4	5	6	8	×	7	0	7	2	4	4
Irpex lacteus		4	6	5	7	7	7	0	3	2	4	5
Ischnoderma resinosum	I. benzoinum	4	5	5	×	×	6	0	6	2	3	6
Junghuhnia nitida		4	6	5	7	8	5	0	6	2	4	6
Laccaria amethystea	L. amethystina	4	5	5	6	×	4	0	9	2	4	8
Laccaria proxima	L. laccata var. proxima	4	4	4	7	3	3	0	6	2	4	8
Laccaria tetraspora	L. laccata var. pallidifolia	6	5	5	×	×	4	0	9	2	5	8
Lacrymaria lacrymabunda	Psathyrella velutina	4	5	5	5	8	7	0	8	2	4	6
Lactarius acerrimus		8	5	4	4	8	5	0	5	2	3	6
Lactarius aurantiacus	L. mitissimus, L. aurantiofulvus	3	4	5	6	7	5	0	8	2	4	5
Lactarius blennius	L. viridis	3	5	5	×	×	4	0	9	2	4	1
Lactarius camphoratus	L. cimicarius	3	5	5	7	4	3	0	8	2	4	2
Lactarius deliciosus	L. lateritius	4	5	6	4	7	4	0	7	2	4	6
Lactarius deterrimus	L. deliciosus var. piceus	3	4	5	×	×	4	0	8	2	4	5
Lactarius fuliginosus	(Fr.) Fr., non ss. Bon, L. romagnesii, L. speciosus	3	5	4	6	7	5	0	7	2	4	2
Lactarius glyciosmus	L. mammosus, non ss. Fr.	3	5	5	4	6	4	0	7	2	4	2
Lactarius helvus		4	4	5	7	2	2	0	6	2	4	5
Lactarius hortensis	L. pyrogalus (Bull. : Fr.) Fr. ss. auct. plur., non ss. Bull.	5	5	5	×	6	5	0	8	2	4	6
Lactarius lacunarum	L. decipiens var. lacunarum	4	?	5	10	7	7	0	3	2	3	8
Lactarius lignyotus		3	4	5	5	4	2	0	7	2	4	2
Lactarius lilacinus	L. cyathula	7	5	4	9	6	6	0	4	2	3	2
Lactarius pallidus		3	5	5	5	7	5	0	7	2	4	2
Lactarius pubescens* var. *p.	L. albus, L. blumii	5	5	5	4	×	3	0	7	2	4	6
Lactarius pyrogalus	(Bull. : Fr.) Fr. ss. Fr., L. circellatus Fr. ss. auct. plur., non Fr.	5	6	5	5	7	6	0	7	2	4	8
Lactarius quietus		4	5	5	6	×	4	0	8	2	4	2
Lactarius rufus		3	4	5	4	3	2	0	7	2	4	5
Lactarius scrobiculatus		4	4	5	7	8	5	0	7	2	4	6
Lactarius subdulcis	L. hradecensis	3	5	5	5	7	3	0	8	2	4	6
Lactarius tabidus	Fr. ss. auct., L. theiogalus	3	5	5	8	2	3	0	7	2	4	5
Lactarius torminosus	L. necator (Bull. : Fr.) Karst. p.p.	4	5	7	4	×	3	0	7	2	4	5
Lactarius turpis	L. necator (Bull. : Fr.) Karst. p.p., L. plumbeus	3	5	6	7	3	2	0	7	2	4	6
Lactarius vellereus	(Fr.) Fr., non ss. Romagn., L. albivellus, L. velutinus	4	5	5	5	7	5	0	8	2	4	2
Lactarius volemus	L. ichoratus	4	5	5	5	6	2	0	7	2	4	6
Laeticorticium roseum	Corticium roseum	4	4	4	6	×	6	0	6	2	4	6
Laetiporus sulfureus		4	5	5	7	7	6	0	7	2	4	4
Leccinum aurantiacum	L. leucopodium, L. rufum ss. auct.	5	5	6	6	5	5	0	7	2	4	8
Leccinum duriusculum	L. nigellum	4	4	5	7	4	2	0	5	2	3	8
Leccinum variicolor	L. oxydabile	4	4	6	7	3	2	0	4	2	3	8
Lentinellus vulpinus	incl. L. piceinum	3	4	6	4	5	4	0	4	2	4	6
Leotia lubrica		4	×	5	5	5	5	0	7	2	4	6
Lepiota alba	incl. L. erminea	9	6	5	3	7	2	0	4	2	3	7
***Lepiota castanea* s. str.**	excl. L. ignicolor ss. auct. p.p., excl. L. rufidula, excl. L. ignipes	4	5	5	5	7	5	0	8	2	4	6
Lepiota clypeolaria		4	5	5	5	7	5	0	8	2	4	2
Lepiota cristata		5	5	5	×	7	7	0	9	2	4	2
Lepiota ignivolvata		3	5	5	5	7	6	0	7	2	4	2
***Lepiota subincarnata* s. str.**		4	6	4	4	8	8	0	3	2	4	8
Lepista flaccida	L. gilva, L. inversa	4	5	5	6	×	6	0	9	2	5	2
Lepista nuda		4	5	5	6	×	6	0	9	2	5	2
Lepista panaeolus		9	5	4	4	8	3	0	6	2	3	7
Lepista saeva		6	5	5	4	7	5	0	7	2	4	6
Lepista sordida		4	5	5	4	7	7	0	6	2	5	6
Leucoagaricus leucothites	L. naucinus, L. pudicus	7	5	5	5	7	7	0	7	2	4	7
Leucogyrophana mollusca	L. pseudomollusca	3	6	4	3	6	4	0	4	2	4	7
Lycoperdon echinatum		8	5	5	5	7	6	0	7	2	4	2
Lycoperdon lividum	L. fuscum, L. spadiceum Pers., non (Schaeff. : Pers.) Poiret	8	5	4	2	7	4	0	3	2	3	7
Lycoperdon molle		3	4	5	4	6	6	0	6	2	4	6
Lycoperdon perlatum	L. gemmatum, L. hirtum	5	5	5	5	×	×	0	9	2	5	6
Lycoperdon pyriforme	L. serotinum	3	5	5	5	6	×	0	9	2	5	6
Lyomyces sambuci	Hyphoderma sambuci, Hyphodontia s.	4	5	5	×	×	×	0	8	2	5	6
Lyophyllum decastes	L. loricatum	5	5	5	4	7	7	0	8	2	4	6
Lyophyllum fumosum		5	5	5	4	7	7	0	7	2	4	6
Lyophyllum gangraenosum	L. leucophaeatum	4	5	5	6	7	6	0	6	2	4	8
Lyophyllum ozes	(Fr.) Singer ss. Großpilze Baden-Württembergs 3, Tephrocybe ozes ss. Ricken, Moser	3	4	5	6	8	6	0	4	2	3	8
Lyophyllum putidum	Tephrocybe putida	4	5	5	7	7	5	0	1	2	3	8
Lyophyllum rancidum	Tephrocybe rancida	4	5	5	6	8	6	0	7	2	4	6
Macrocystidia cucumis		3	5	5	7	8	8	0	7	2	5	8
Macrolepiota excoriata		8	5	5	4	7	4	0	6	2	5	9

Table 7 *continued*

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Macrolepiota procera* var. *fuliginosa	M. fuliginosa, M. procera f. permixta (p. p.)	5	5	6	5	7	5	0	6	2	4	6
Macrolepiota procera* var. *p.		5	5	5	5	7	5	0	9	2	4	7
***Macrolepiota rachodes* s. str.**	Chlorophyllum rachodes, incl. C. olivieri (= M. r. var. olivieri), excl. C. brunneum (= M. r. var. hortensis)	4	5	5	5	×	6	0	9	2	4	5
Macrotyphula fistulosa	Clavariadelphus fistulosus, M. rigida	3	5	5	5	7	7	0	6	2	4	6
Marasmiellus perforans	Micromphale perforans	3	4	5	4	3	4	0	8	2	4	5
Marasmiellus ramealis		3	5	5	×	×	4	0	9	2	4	5
Marasmius alliaceus		3	5	5	5	7	6	0	6	2	4	2
Marasmius androsaceus	Setulipes androsaceus	3	5	5	4	×	4	0	8	2	4	5
Marasmius bulliardii		3	5	5	6	7	6	0	7	2	4	5
Marasmius cohaerens		3	5	5	5	8	6	0	8	2	4	2
Marasmius limosus		7	6	5	10	7	7	0	3	2	3	5
Marasmius oreades		7	5	6	×	×	×	0	8	2	4	×
Marasmius rotula		3	5	5	6	6	5	0	8	2	4	5
Marasmius scorodonius		3	5	5	4	5	4	0	7	2	4	2
Marasmius wettsteinii	M. bulliardii f. acicola	3	5	5	6	7	3	0	7	2	4	5
Marasmius wynnei		3	5	6	5	8	6	0	6	2	4	2
***Melanoleuca brevipes* s. str.**	(Bull. : Fr.) Pat. ss. Konrad & Maubl., Kühner, Münzmay	6	5	5	5	6	8	0	6	2	3	7
Melanoleuca grammopus	(Bull. : Fr.) Pat. ss. Bres. etc.	5	5	5	4	8	6	0	7	2	3	7
Melanoleuca kuehneri	M. exscissa	8	5	4	4	7	6	0	4	2	3	7
Melanoleuca polioleuca	M. melaleuca ss. auct. plur., M. oreina, M. vulgaris	5	5	5	5	7	6	0	7	2	4	7
Melanoleuca stridula	(Fr.) Singer ss. Fr., Kühner, Fontenla & al., M. graminicola ss. auct. p.p.	3	5	5	5	7	6	0	7	2	4	7
Meripilus giganteus		3	6	4	5	7	7	0	6	2	4	6
Meruliopsis corium	Byssomerulius corium	2	5	5	5	7	4	0	8	2	4	7
Merulius tremellosus		2	5	5	5	7	5	0	7	2	4	7
Morchella esculenta		3	6	4	5	8	6	0	7	2	4	8
Mucronella bresadolae	M. alba	3	4	6	?	?	?	0	5	2	4	7
Mycena abramsii	M. nitrata	2	5	5	7	7	6	0	7	2	4	7
Mycena acicula		3	5	5	6	×	×	0	8	2	4	5
Mycena aetites		3	5	5	4	7	2	0	6	2	4	6
Mycena aurantiomarginata		3	5	5	5	7	5	0	8	2	4	1
Mycena capillaripes		4	4	5	5	7	4	0	4	2	4	5
Mycena cinerella		3	5	5	6	7	3	0	6	2	4	1
Mycena crocata		2	5	5	5	7	6	0	8	2	4	6
Mycena diosma		3	5	5	6	8	6	0	6	2	4	6
Mycena epipterygia		3	4	5	×	×	4	0	9	2	5	6
Mycena filopes		3	5	5	6	7	4	0	7	2	4	2
Mycena flavescens		5	5	5	5	7	5	0	7	2	4	6
Mycena flavoalba		4	4	5	5	7	6	0	7	2	4	7
Mycena galericulata		3	5	5	×	×	×	0	9	2	5	7
Mycena galopus		2	5	5	7	×	4	0	9	2	4	7
Mycena haematopus		3	5	5	7	7	6	0	8	2	4	7
Mycena hiemalis		3	6	5	7	7	7	0	5	2	3	7
Mycena inclinata		3	5	5	5	×	5	0	8	2	4	6
Mycena leptocephala		4	5	5	6	×	×	0	8	2	4	2
Mycena metata	(Fr.) P. Kumm., non ss. Kühner	3	5	5	×	6	4	0	7	2	4	2
Mycena mirata		3	5	4	6	6	5	0	4	2	4	2
Mycena niveipes		3	5	5	7	6	5	0	5	2	4	7
Mycena olida		3	6	5	7	7	7	0	4	2	3	7
Mycena pearsoniana		2	5	4	6	7	7	0	3	2	3	2
Mycena polyadelpha	Delicatula polyadelpha	4	6	4	5	×	×	0	6	2	4	2
Mycena polygramma		4	5	5	6	6	5	0	8	2	4	6
Mycena pseudocorticola	M. corticola Schumacher p.p.	4	5	5	7	7	×	0	6	2	3	4
Mycena pura		3	5	5	×	×	×	0	9	2	5	2
Mycena rosea		3	5	5	5	8	5	0	8	2	4	2
Mycena rubromarginata		3	4	5	6	×	×	0	8	2	4	5
Mycena sanguinolenta		3	5	5	5	6	4	0	9	2	4	7
Mycena speirea		3	5	5	6	7	5	0	8	2	4	6
Mycena stipata	M. alcalina ss. auct. plur.	3	5	5	6	5	3	0	7	2	4	7
Mycena tintinabulum		4	5	5	7	7	6	0	5	2	4	6
Mycena vitilis		3	5	5	6	7	6	0	7	2	4	7
Mycena zephirus		3	5	5	5	7	6	0	8	2	4	2
Naucoria bohemica	Alnicola bohemica	4	5	5	8	5	4	0	5	2	3	6
Naucoria melinoides	(Bull. : Fr.) P. Kumm. ss. Kühner, Alnicola escharioides, Naucoria e.	4	5	5	8	6	7	0	8	2	4	6
Naucoria scolenica	(Fr.) Quél. ss. Romagn., Alnicola scolenica	4	5	5	8	4	4	0	5	2	4	6
Naucoria striatula	Orton, non ss. Reid, Alnicola paludosa, Alnicola striatula	4	6	5	8	6	6	0	4	2	4	6
Nectria cinnabarina		×	5	5	×	×	×	1	9	2	5	5
Nectria episphaeria		4	5	4	4	7	5	0	9	2	4	5
Oligoporus caesius	Postia caesia, Spongiporus c., Tyromyces c.	4	4	5	5	×	?	0	8	2	4	5
Oligoporus fragilis	Postia fragilis, Tyromyces f.	3	4	5	7	×	6	0	4	2	4	6
Oligoporus guttulatus	Tyromyces guttulatus	4	5	?	5	6	5	0	2	2	4	4
Oligoporus ptychogaster	Ptychogaster albus, P. fuliginoides	2	5	3	6	×	7	0	5	2	4	6
Oligoporus stipticus	Postia stiptica, Spongiporus s., Tyromyces s.	3	5	5	5	6	×	0	8	2	4	4
Oligoporus subcaesius	Postia subcaesia, Spongiporus s., Tyromyces s.	4	5	?	6	8	5	0	7	2	4	5

Table 7 ***continued***

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Omphalina pyxidata		9	5	5	3	8	2	0	4	2	3	9
Orbilia delicatula		2	5	5	7	×	5	0	7	2	4	7
Orbilia xanthostigma		2	5	5	7	×	6	1	8	2	4	7
Otidea alutacea		4	5	4	5	7	7	0	5	2	4	8
Otidea onotica		4	5	5	6	7	6	0	7	2	4	8
Otidea umbrina		4	5	4	5	5	4	0	4	2	4	8
Oudemansiella mucida		3	5	5	6	7	6	0	8	2	4	6
Oxyporus corticola	O. ravidus	3	5	5	4	7	6	0	3	2	3	4
Panaeolus fimicola		6	5	5	×	×	8	1	5	2	5	7
Panaeolus foenisecii	Panaeolina foenisecii	9	5	5	×	×	6	1	8	2	5	7
Panaeolus papillionaceus	P. sphinctrinus	8	5	5	6	×	9	1	8	2	6	7
Panaeolus reticulatus	P. uliginosus	8	4	6	8	8	5	0	3	2	3	7
Panellus mitis		4	5	5	5	×	×	0	9	2	4	5
Panellus serotinus	Sarcomyxa serotina	4	5	5	6	×	×	0	9	2	4	4
Panellus stipticus		3	5	5	5	×	×	0	9	2	4	4
Paxillus filamentosus	P. rubicundulus	4	5	5	9	7	7	0	6	2	3	6
***Paxillus involutus* s. str.**		3	5	5	5	5	3	0	8	2	4	1
Peniophora incarnata		3	5	5	×	×	×	0	9	2	4	7
Peziza badia		4	5	5	5	6	6	0	7	2	4	8
Peziza succosa		4	5	5	6	6	7	0	7	2	4	8
Phaeolus spadiceus	P. schweinitzii	3	5	5	4	6	4	0	7	2	4	6
Phallus impudicus	excl. var. pseudoduplicatus	2	5	5	5	7	7	0	8	2	4	6
Phanerochaete sanguinea		3	4	5	7	×	×	0	3	2	4	7
Phellinus ferruginosus	Fuscoporia ferruginea	3	5	5	7	7	5	0	7	2	4	6
***Phellinus igniarius* s. str.**	Ochroporus igniarius	5	5	5	7	7	6	0	7	2	3	5
Phellinus punctatus	Fomitiporia punctata	3	5	5	7	×	5	0	7	2	4	6
Phlebia radiata	P. aurantiaca, P. merismoides	3	5	4	6	8	7	0	8	2	4	6
Phlebia rufa		3	6	4	5	7	7	0	5	2	4	6
Pholiota alnicola		4	5	5	8	7	6	0	7	2	3	5
Pholiota flammans		3	4	5	6	5	6	0	8	2	4	6
Pholiota flavida	ss. Großpilze Baden-Württembergs 4	3	5	5	7	7	4	0	5	2	4	5
Pholiota lenta		3	5	5	?	×	5	0	8	2	4	5
Pholiota lucifera		3	5	5	5	6	4	0	7	2	4	5
Pholiota mutabilis	Kuehneromyces mutabilis	3	4	5	6	×	6	0	9	2	4	5
Pholiota squarrosa		3	4	5	×	×	5	0	9	2	4	6
Phylloporus pelletieri	P. rhodoxanthus var. europaeus, Xerocomus pelletieri	2	5	5	4	5	4	0	5	2	4	5
Phyllotopsis nidulans		4	4	5	5	×	6	0	7	2	4	6
Physisporinus vitreus	Rigidoporus vitreus	2	5	4	6	×	6	0	5	2	4	7
Piptoporus betulinus		5	5	5	6	×	×	0	7	2	4	4
Pleurotus ostreatus		5	5	5	5	×	5	0	8	2	4	4
Plicatura crispa	P. faginea, Plicaturopsis crispa	5	4	5	7	7	×	0	8	2	4	6
Pluteus cervinus		3	5	5	×	×	×	1	9	2	4	6
Pluteus pellitus		3	5	5	5	7	5	0	4	2	4	6
Pluteus plautus		3	5	5	7	8	6	0	7	2	4	6
Pluteus podospileus	P. minutissimus	3	5	5	7	7	6	0	5	2	4	7
Pluteus romellii		2	5	5	6	8	7	0	8	2	4	7
Pluteus thomsonii		3	6	5	7	×	6	0	6	2	4	7
Polyporus alveolaris	Favolus europaeus, P. mori	6	7	5	6	×	7	0	5	2	4	4
Polyporus arcularius		3	7	?	3	7	5	0	3	2	4	6
Polyporus brumalis	?P. subarcularius	2	5	5	5	×	6	0	8	2	4	6
Polyporus ciliatus	P. lepideus	3	5	5	7	7	6	0	7	2	4	6
Polyporus leptocephalus	P. elegans, P. varius	4	4	5	5	×	×	0	8	2	4	6
Porostereum spadiceum	Lopharia spadicea	3	5	4	5	7	7	0	6	2	4	6
Porphyrellus porphyrosporus	P. pseudoscaber, Tylopilus porphyrosporus	2	4	5	7	5	3	0	5	2	4	2
Psathyrella candolleana	P. appendiculata	3	5	5	7	×	6	0	9	2	4	6
Psathyrella conopilus	Parasola conopilus	4	5	5	7	8	7	0	8	2	4	6
Psathyrella piluliformis	P. hydrophila	3	5	5	6	7	5	0	8	2	4	7
***Psathyrella prona* s. lat.**		3	6	5	7	7	6	0	8	2	4	6
Psathyrella spadiceogrisea		4	6	5	7	7	6	0	8	2	4	6
Pseudoclitocybe cyathiformis		3	5	5	6	7	6	0	8	2	4	7
Pseudohydnum gelatinosum		3	4	4	6	?	×	0	7	2	4	7
Psilocybe montana		9	6	5	4	3	2	0	5	2	3	9
Psilocybe semilanceata		7	4	5	5	4	7	0	5	2	3	9
Pycnoporus cinnabarinus	Trametes cinnabarina	5	6	6	4	7	4	0	6	2	3	4
Radulomyces confluens	Cerocorticium confluens	3	6	5	5	×	6	0	7	2	4	6
Radulomyces molaris	Cerocorticium molaris	3	6	4	4	×	×	0	6	2	4	6
Ramaria gracilis	R. palmata	3	4	4	5	8	4	0	4	2	4	7
Ramaria myceliosa		2	5	5	4	6	5	0	3	2	4	7
Ramaria stricta		3	5	5	5	7	6	0	6	2	4	6
Resupinatus applicatus		3	5	5	6	×	×	0	7	2	4	7
Rhizopogon roseolus	R. obtextus, R. rubescens	4	5	4	3	×	2	0	3	2	3	8
Rhodocollybia butyracea		3	5	5	5	3	4	0	8	2	5	2
Rhodocollybia butyracea* f. *asema		3	5	5	5	7	5	0	9	2	5	2
Rhodocollybia maculata		3	5	5	4	3	3	0	9	2	4	2

Table 7 *continued*

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Rhodocollybia prolixa	incl. var. distorta	2	4	5	6	3	4	0	7	2	4	2
Rhodocybe gemina	R. truncata p.p.	5	5	4	5	6	4	0	7	2	3	7
Rhodocybe nitellina	R. cuprea	3	5	5	5	8	5	0	6	2	4	2
Rhodocybe popinalis	R. mundula	5	5	5	4	7	3	0	5	2	3	8
Rickenella fibula		×	5	5	6	×	5	0	9	2	5	1
Rickenella swartzii	R. setipes ss. auct., non Fr.	7	5	5	7	×	4	0	7	2	4	1
Rimbachia arachnoidea	Mniopetalum globisporum	4	5	5	7	7	6	0	3	2	4	1
Ripartites tricholoma	incl. R. helomorphus, R. metrodii	3	5	5	5	8	6	0	8	2	4	2
Russula adusta		4	5	5	4	3	2	0	6	2	4	5
Russula aeruginea	R. graminicolor (Secr.) Quél. nom. illeg.	4	5	5	4	3	2	0	6	2	4	6
Russula alnetorum	R. pumila	4	5	4	8	7	5	0	3	2	3	6
Russula amara	R. caerulea (Pers.) Fr. ss. auct.	3	5	5	3	4	2	0	6	2	4	2
Russula atrorubens	R. fragilis ss. Melzer, R. laccata, R. olivaceoviolascens	3	4	5	6	2	2	0	5	2	4	2
Russula azurea		3	4	5	6	4	2	0	5	2	4	2
Russula badia	R. friesii	3	5	5	6	2	2	0	6	2	4	5
Russula cyanoxantha		3	5	5	6	7	4	0	8	2	4	6
Russula decolorans		4	4	4	8	2	2	0	5	2	3	6
Russula densifolia	R. densissima, ?R. fuliginosa	3	5	5	6	3	1	0	7	2	4	2
***Russula emetica* s. str.**		4	4	5	8	2	2	0	6	2	4	2
Russula fellea		3	5	4	6	7	5	0	8	2	4	2
***Russula foetens* s. str.**		3	5	5	6	7	4	0	8	2	4	2
Russula fragilis	R. emetica var. fragilis	3	5	5	7	5	3	0	7	2	3	2
Russula grata	R. laurocerasi	3	5	5	5	7	5	0	7	2	4	2
Russula mairei	R. fageticola	3	4	5	4	6	3	0	7	2	4	2
Russula nigricans		3	5	5	6	×	4	0	8	2	4	6
Russula ochroleuca		3	5	5	×	5	4	0	8	2	4	2
Russula olivacea	R. alutacea (Pers.) Fr. ss. auct., non Fr.	4	5	4	4	7	4	0	8	2	4	1
Russula paludosa	R. elatior	4	4	4	8	2	1	0	6	2	3	2
Russula puellaris		3	5	5	4	3	3	0	7	2	4	2
Russula queletii		3	4	5	6	×	4	0	7	2	4	1
Russula rhodopus		2	4	5	8	2	1	0	4	2	3	1
Russula rosea	R. lepida, R. rosacea (Pers.) Gray, non Fr.	3	5	5	4	7	4	0	8	2	4	2
Russula sanguinaria	R. rosacea Fr., R. sanguinaria	3	5	5	×	×	5	0	6	2	4	6
Russula sylvestris	R. emetica var. sylvestris	4	5	5	4	3	3	0	6	2	4	4
Russula turci	R. amethystina	3	5	4	4	6	3	0	8	2	4	2
Russula variegatula		4	?	?	6	7	5	0	1	2	3	6
Russula velenovskyi		4	6	5	7	5	×	0	5	2	4	5
Russula velutipes	R. aurora	3	5	4	6	5	3	0	6	2	4	5
Russula vesca		3	5	5	6	6	3	0	8	2	4	2
Russula vinosa		3	4	6	7	2	2	0	6	2	4	5
Russula virescens		4	6	5	4	6	2	0	7	2	4	6
Russula viscida		2	4	?	6	8	5	0	6	2	4	6
Russula xerampelina	R. ameonipes, R. atrosanguinea, R. erythropus	3	5	4	4	3	2	0	7	2	4	2
Rutstroemia echinophila		4	7	2	5	4	×	0	4	2	4	4
Sarcodon imbricatus		4	5	5	3	×	2	0	5	2	3	1
Schizophyllum commune		6	5	5	3	×	×	0	9	2	6	4
Schizopora flavipora	S. carneolutea	3	7	5	4	?	5	0	5	2	4	6
Schizopora paradoxa	Irpex deformis	3	5	5	6	×	5	0	8	2	4	5
Schizopora radula		3	6	5	5	×	6	0	5	2	4	5
Scleroderma areolatum	S. lycoperdon, S. verrucosum ss. auct. p.p. (ante 1966)	4	5	4	5	7	4	0	6	2	4	8
Scleroderma citrinum	S. aurantium ss. auct.	3	5	5	×	3	2	0	7	2	4	8
Scutellinia scutellata		4	5	4	7	7	7	0	7	2	5	8
Scutellinia subhirtella		5	6	4	7	6	8	0	6	2	5	9
Serpula himantoides		2	6	?	7	×	?	0	4	2	4	7
Simocybe centunculus	Ramicola centunculus	3	6	5	5	7	7	0	7	2	4	7
Simocybe haustellaris	Crepidotus haustellaris, Ramicola rubi, Simocybe r.	3	5	5	8	7	7	0	4	2	4	6
Sistotrema confluens		4	5	5	6	?	2	0	3	2	3	8
Skeletocutis amorpha	Gloeoporus amorphus	3	5	5	3	6	×	0	7	2	4	6
Skeletocutis nivea	Incrustoporia nivea, I. semipileata	3	5	5	7	7	7	0	7	2	4	6
Skeletocutis subincarnata		3	4	4	4	6	5	0	3	2	4	6
Sparassis crispa		3	5	5	6	6	4	0	7	2	4	2
Steccherinum fimbriatum		3	5	4	6	8	7	0	7	2	4	5
Steccherinum ochraceum		3	5	4	6	8	7	0	7	2	4	5
Stereum hirsutum		4	4	5	×	×	×	0	9	2	4	5
Stereum rameale		3	6	4	5	×	×	0	6	2	4	6
Stereum rugosum		3	4	5	7	×	6	0	9	2	4	4
Stereum sanguinolentum		3	5	5	7	×	×	0	9	2	4	5
Stereum subtomentosum		4	6	4	7	7	6	0	7	2	3	5
Strobilomyces floccopus	S. strobilaceus	2	5	5	5	6	5	0	7	2	4	5
Strobilurus esculentus		3	5	5	×	×	×	0	9	2	4	5
Strobilurus stephanocystis		4	5	5	×	7	×	0	6	2	4	5
Strobilurus tenacellus		4	5	5	×	7	×	0	8	2	4	5
Stropharia aeruginosa		3	5	5	5	4	4	0	8	2	4	6
Stropharia coronilla		8	5	5	5	7	5	1	8	2	5	9
Stropharia cyanea	ss. auct. plur., S. caerulea	5	5	4	5	8	8	1	8	2	5	7

Table 7 *continued*

Species	Nomenclatural information (where necessary)	L	T	K	F	R	N	S	M	H_l	H_u	O
Stropharia squamosa	incl. S. thrausta	3	5	5	5	8	7	0	7	2	4	6
Suillus fluryi	S. collinitus ss. auct., S. roseobasis	5	5	5	3	9	3	0	5	2	4	6
Suillus granulatus		4	4	5	5	7	5	0	7	2	4	6
Suillus grevillei	S. elegans, S. flavus ss. auct.	4	4	5	5	×	×	0	8	2	4	5
Suillus luteus		4	5	5	4	6	2	0	7	2	4	5
Suillus variegatus		4	4	5	×	3	3	0	7	2	3	5
Tapinella atrotomentosa	Paxillus atrotomentosus	2	5	5	×	6	5	0	8	2	4	7
Thelephora palmata		3	5	4	5	3	4	0	7	2	4	2
Thelephora penicillata	T. mollissima, T. spiculosa	6	5	4	8	8	7	0	3	2	3	2
Thelephora terrestris	T. laciniata	2	4	5	4	4	4	0	7	2	4	8
Trametes gibbosa	Pseudotrametes gibbosa	3	5	5	5	×	×	0	8	2	4	5
Trametes hirsuta	Coriolus hirsutus	4	5	5	3	×	×	0	9	2	4	5
Trametes multicolor	Coriolus zonatus, T. ochracea, T. zonatella	3	5	6	8	×	×	0	6	2	4	5
Trametes pubescens	Coriolus pubescens	4	4	5	8	×	×	0	3	2	3	5
Trametes versicolor	Coriolus versicolor	3	5	5	×	×	×	0	9	2	4	6
Trechispora hymenocystis	T. mollusca	3	5	4	5	7	6	0	6	2	4	5
Tremella foliacea		3	5	5	7	7	7	0	6	2	3	5
Tremella mesenterica	T. lutescens	3	5	5	5	×	×	0	8	2	4	4
Trichaptum abietinum	Hirschioporus abietinus	3	4	5	×	×	×	0	8	2	4	5
***Tricholoma album* s. str.**	excl. Tricholoma pseudoalbum, T. stiparophyllum	4	5	5	5	6	4	0	6	2	4	2
Tricholoma argyraceum	incl. Tricholoma inocybeoides, T. scalpturatum	4	5	5	5	7	6	0	7	2	4	6
Tricholoma atrosquamosum		3	5	5	5	7	5	0	7	2	4	5
Tricholoma auratum	(Paul. : Fr.) Gill. s. str., T. equestre p.p.	5	5	4	3	2	2	1	4	2	3	8
Tricholoma fulvum	T. flavobrunneum, T. nictitans ss. Fr.	3	5	5	5	3	2	0	7	2	4	5
Tricholoma saponaceum		3	5	5	5	×	5	0	8	2	4	6
Tricholoma stiparophyllum	T. pseudoalbum	4	5	5	4	4	4	0	6	2	4	6
Tricholoma sulfureum		3	5	5	5	7	6	0	8	2	4	1
Tricholoma terreum		4	5	5	4	8	6	0	7	2	4	6
Tricholoma ustale		3	5	5	5	6	5	0	8	2	4	1
Tricholoma vaccinum		4	4	5	5	6	3	0	7	2	3	5
Tricholoma virgatum		3	4	5	5	6	3	0	6	2	3	5
Tricholomopsis decora		3	4	5	5	4	4	0	6	2	4	6
Tricholomopsis rutilans		3	5	5	5	6	×	0	9	2	4	6
Tubaria furfuracea	incl. T. hiemalis	5	5	5	6	×	5	0	9	2	6	7
Tulostoma brumale	T. mammosum, T. pdeunculatum	9	6	4	2	7	2	0	4	2	3	7
Tylopilus felleus		3	5	5	5	4	3	0	7	2	4	2
Typhula erythropus		2	5	5	7	7	7	0	6	2	4	6
Vascellum pratense	Lycoperdon pratense, V. depressum	9	5	5	4	6	5	0	6	2	4	7
Volvariella gloiocephala	V. speciosa	8	6	5	7	7	8	0	7	2	5	9
***Volvariella pusilla* s. str.**		5	7	5	×	6	5	0	5	2	3	7
***Vuilleminia comedens* s. lat.**		3	5	5	×	×	×	0	8	2	4	5
Xerocomus badius	Boletus badius	3	4	5	6	5	2	0	8	2	4	8
Xerocomus chrysenteron		3	5	5	6	6	×	1	9	2	4	8
Xerocomus porosporus	X. truncatus ss. auct. eur.	4	6	5	5	7	6	0	5	2	4	5
Xerocomus pruinatus	Boletellus pruinatus, X. fragilipes	3	5	5	6	6	5	0	6	2	4	5
Xerocomus rubellus	(Krombh.) Quél. ss. auct. plur., Boletus sanguineus, B. versicolor, X. communis, X. quercinus	4	6	5	5	6	6	1	6	2	4	8
Xerocomus subtomentosus		3	5	5	5	6	4	0	8	2	4	5
Xeromphalina campanella		3	4	6	6	×	?	0	7	2	4	7
Xerula radicata	Oudemansiella radicata, O. pseudoradicata	3	5	5	6	7	×	0	9	2	4	6
Xylaria hypoxylon		×	5	5	×	×	×	0	9	2	4	6
Xylaria longipes		3	5	5	6	6	7	0	7	2	4	6
Xylaria polymorpha		3	5	5	6	7	6	0	8	2	4	6

Table 12 (Chapter 3). List of functional trait data of 636 macromycete species.
For nomenclatural information on species, see Table 7 (Table Appendix). For abbreviations and descriptions of functional traits, see Tables 8 and 9 (Chapter 3).

Species	Mycel longy	Frb longy	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Abortiporus biennis	1	1	50	2	2	3	5	4	3	1	2	2	2	1	1	2	3	16.5	3	1	1	2	3	1	2	2	2	2	4	1	1
Agaricus aestivalis	1	3	35	2	5	3	5	3	3	5	2	4	0	2	2	3	3	21	3	1	3	2	1	1	2	3	4	0	4	1	3
Agaricus bitorquis	1	3	35	2	5	3	5	3	3	3	2	4	0	2	2	3	3	17.25	3	1	3	2	1	1	2	3	3	1	4	1	3
Agaricus campestris	1	3	32.5	2	5	3	5	3	3	5	2	4	0	2	2	3	3	24	3	1	3	2	1	1	2	3	4	0	4	1	3
Agaricus silvaticus	1	3	30	2	5	3	5	3	3	3	2	4	0	2	2	3	3	16.5	3	1	3	2	1	1	2	3	3	2	4	1	3
Agaricus silvicola	1	3	45	2	5	3	5	3	3	3	2	4	0	2	2	3	3	21	3	1	3	2	1	1	2	3	3	2	4	1	3
Agaricus xanthoderma	1	3	45	2	5	3	5	3	3	3	2	4	0	2	2	3	3	17.25	3	1	3	2	1	1	2	3	3	2	4	1	3
Agrocybe dura	2	3	25	2	5	3	5	3	3	3	2	4	0	2	3	3	3	36	3	1	3	2	1	1	2	3	1	2	4	1	2
Albatrellus ovinus	1	3	70	2	4	3	5	4	3	3	2	4	0	1	2	3	3	11.25	3	1	1	1	3	1	2	3	4	0	4	1	3
Aleuria aurantia	2	3	13	2	5	3	2	4	4	3	2	4	0	5	9	2	1	42	3	6	1	1	3	1	2	3	4	0	4	1	2
Aleurodiscus amorphus	1	2	0.3	2	2	1	1	4	3	1	2	2	2	5	3	1	1	69	3	2	1	1	3	1	2	3	4	0	4	1	3
Amanita battarrae	1	3	42.5	2	5	3	5	1	3	3	1	4	2	2	2	3	3	55	5	1	1	1	3	1	2	3	4	0	4	1	3
Amanita citrina	1	3	37.5	2	5	3	5	1	4	3	1	4	1	2	2	3	3	45	5	1	1	1	3	1	2	3	3	2	4	1	3
Amanita excelsa	1	3	62.5	2	5	3	5	1	3	3	1	4	1	2	2	3	3	28.5	3	1	1	1	3	1	2	3	3	2	4	1	3
Amanita fulva	1	3	32.5	2	5	3	5	1	4	3	1	4	1	2	2	3	3	55	5	1	1	1	3	1	2	3	4	0	4	1	3
Amanita muscaria	1	3	75	2	5	3	5	1	4	3	1	4	2	2	2	3	3	27	3	1	1	1	3	1	2	3	4	0	4	1	3
Amanita pantherina	1	3	50	2	5	3	5	1	3	3	1	4	2	2	2	3	3	33	3	1	1	1	3	1	2	3	4	0	4	1	3
Amanita phalloides	1	3	45	2	5	3	5	1	4	3	1	4	2	2	2	3	3	24.75	3	1	1	1	3	1	2	3	4	0	4	1	3
Amanita porphyria	1	3	37.5	2	5	3	5	1	3	3	1	4	1	2	2	3	3	45	5	1	1	1	3	1	2	3	3	2	4	1	3
Amanita rubescens	1	3	50	2	5	3	5	1	4	3	1	4	1	2	2	3	3	25.5	3	1	1	1	3	1	2	3	3	2	4	1	3
***Amanita vaginata* s. str.**	1	3	40	2	5	3	5	1	3	3	1	4	1	2	2	3	3	52.5	5	1	1	1	3	1	2	3	4	0	4	1	3
Amylostereum areolatum	1	1	5.5	3	2	4	1	4	3	1	2	2	2	4	6	1	1	19.5	3	1	1	1	3	1	2	3	3	5	4	2	1
Antrodia serialis	1	1	40	3	2	4	2	4	3	1	2	2	2	1	3	2	3	22.5	3	1	1	1	3	1	2	3	4	0	4	2	1
Antrodiella semisupina	1	1	30	3	2	4	2	4	3	1	2	2	1	1	3	2	3	9	3	1	1	1	3	1	2	3	4	0	4	2	1
Armillaria borealis	1	3	26.25	2	5	3	5	3	3	3	3	2	1	2	2	3	3	22.5	3	1	1	1	3	1	2	3	3	2	4	1	1
Armillaria gallica	1	3	26.25	2	5	3	5	3	3	3	3	2	1	2	2	3	3	24	3	1	1	1	3	1	2	3	3	2	4	1	2
***Armillaria mellea* s. str.**	1	3	32.5	2	5	3	5	3	3	3	3	2	1	2	2	3	3	24.75	3	1	1	1	3	1	2	3	3	2	4	1	3
Armillaria ostoyae	1	3	17.5	2	5	3	5	3	3	3	3	2	2	2	2	3	3	27	3	1	1	1	3	1	2	3	3	2	4	1	2
Ascocoryne cylichnium	1	2	3.5	2	3	2	2	4	4	3	2	2	2	5	12	2	2	76.5	3	1	1	1	3	1	2	3	4	0	4	1	2
Ascocoryne sarcoides	1	2	1.4	2	3	2	2	4	4	3	2	2	2	5	12	2	2	45	3	1	1	1	3	1	2	3	4	0	4	1	2
Astraeus hygrometricus	1	3	7	3	4	3	4	4	3	3	1	4	2	6	4	2	2	45	5	3	3	1	3	1	2	3	4	0	4	1	1
Aurantiporus fissilis	1	2	9	3	5	2	1	4	3	1	4	1	2	1	2	2	2	15	3	1	1	1	3	1	2	2	4	0	4	1	1
Auricularia auricula-judae	1	3	11	2	3	2	2	4	2	3	2	2	2	5	9	2	2	56	4	1	1	1	3	1	2	3	4	0	4	1	1
Auricularia mesenterica	1	3	11	2	3	2	2	4	2	3	2	2	2	5	6	2	2	66	4	1	1	1	3	1	2	3	4	0	4	1	1
Auriscalpium vulgare	1	3	5	3	2	4	5	4	2	5	2	2	1	3	3	3	3	15	3	2	1	1	3	1	2	3	4	0	4	2	1
Baeospora myosurus	1	3	6.25	2	5	4	5	4	3	3	2	2	2	2	3	3	2	7	2	1	1	1	3	1	2	3	1	2	4	1	1
Basidioradulum radula	1	1	5	3	2	4	1	4	3	1	2	2	2	3	2	1	1	20	2	1	1	1	3	1	2	3	1	2	4	1	1
Bisporella citrina	1	3	0.035	1	5	4	2	4	4	3	2	2	1	5	12	2	1	34.5	3	1	1	1	3	1	2	3	4	0	4	1	3
Bjerkandera adusta	1	1	12.5	2	2	2	5	4	2	1	2	2	1	1	2	2	2	14.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Bjerkandera fumosa	1	1	52.5	3	2	2	5	4	2	1	2	2	2	1	2	2	2	20.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Bolbitius vitellinus	2	3	15	2	5	3	5	4	4	3	2	4	0	2	3	3	2	34.5	3	1	3	2	1	1	2	3	3	2	4	1	3
***Boletus edulis* s. str.**	1	3	62.5	2	5	3	5	4	3	3	1	4	2	1	2	3	3	31	2	1	2	2	3	1	2	3	1	2	4	1	3
Boletus erythropus	1	3	50	2	5	3	5	4	4	3	1	4	2	1	2	3	3	45	3	1	2	2	3	1	2	3	1	2	4	1	3

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Boletus luridus	1	3	52.5	2	5	3	5	4	4	3	1	4	2	1	2	3	3	39	3	1	2	2	3	1	2	3	1	2	4	1	3
Boletus pulverulentus	1	3	30	2	5	3	5	4	3	3	1	4	2	1	2	3	3	26	2	1	2	2	3	1	2	3	1	2	4	1	3
Bovista limosa	1	3	3	2	4	3	4	4	2	3	2	4	0	6	8	2	1	23.75	5	2	1	1	3	1	2	3	4	0	4	1	3
Bovista plumbea	1	3	12	2	4	3	4	4	2	3	2	4	0	6	6	2	1	17.25	3	1	1	1	3	1	2	3	4	0	4	1	3
Bovista pusilla	1	3	5.6	2	4	3	4	4	2	3	2	4	0	6	8	2	1	22.5	5	2	1	1	3	1	2	3	4	0	4	1	3
Bulbillomyces farinosus	1	2	7	3	2	4	1	4	3	1	2	2	2	5	6	1	1	24	3	1	1	1	3	1	2	1	1	5	4	1	1
Calloria neglecta	3	3	1.6	1	5	4	2	4	2	3	2	2	2	5	12	1	1	22	2	1	1	1	3	1	2	2	4	0	4	1	3
Calocera cornea	1	3	1.5	1	3	4	2	4	4	3	2	2	2	3	4	1	2	18	2	1	1	1	3	1	2	3	4	0	4	2	3
Calocera furcata	1	3	1.5	2	3	4	2	4	4	3	2	2	2	3	4	1	2	42	4	1	1	1	3	1	2	3	4	0	4	2	3
Calocera viscosa	1	3	15	2	3	4	2	4	4	3	2	2	2	3	3	1	2	45	4	1	1	1	3	1	2	3	4	0	4	2	3
Calocybe carnea	1	3	18	2	5	3	5	4	4	5	2	4	0	2	3	3	3	16.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Calocybe gambosa	1	3	37.5	2	5	3	5	4	3	5	2	4	0	2	2	3	3	16.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Calvatia excipuliformis	1	3	46	2	4	3	4	4	3	3	2	4	0	6	4	2	2	23.75	5	3	1	1	3	1	2	3	4	0	4	1	1
Calvatia utriformis	1	3	48	2	4	3	4	4	3	3	2	4	0	6	4	2	2	25	5	1	1	1	3	1	2	3	4	0	4	1	1
Calyptella capula	3	3	7	2	4	4	2	4	3	3	2	2	2	5	12	2	2	27	3	1	1	1	3	1	2	3	4	0	4	1	1
Cantharellula umbonata	1	3	16.25	2	5	3	5	4	3	3	4	1	2	2	3	3	2	18	2	1	1	1	3	1	2	3	4	0	4	1	1
Cantharellus cibarius* var. *c.	1	3	19.5	2	5	3	3	4	3	3	1	4	2	2	2	2	3	22.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Cantharellus cibarius* var. *amethysteus	1	3	19.5	2	5	3	3	4	3	3	1	4	2	2	2	2	3	22.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Cantharellus tubaeformis	1	3	15	2	5	3	3	4	3	3	1	4	2	2	2	2	2	34.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Ceriporia reticulata	1	2	7	3	4	4	1	4	3	3	2	2	1	1	3	1	1	16	2	1	1	1	3	1	2	3	4	0	4	1	3
Ceriporia viridans	1	2	7	3	4	4	1	4	3	3	2	2	1	1	3	1	1	8	2	1	1	1	3	1	2	3	4	0	4	1	3
Cerrena unicolor	1	1	42.5	3	1	2	5	4	2	1	2	2	1	1	2	2	2	16.5	3	1	1	1	3	1	2	3	4	0	4	3	1
Chalciporus piperatus	1	3	20	2	5	3	5	4	3	3	1	4	2	1	2	3	2	19	2	1	2	2	3	1	2	3	1	5	4	1	3
Chlorociboria aeruginascens	1	3	0.1	2	5	2	2	4	4	3	2	2	2	5	12	2	2	12	2	1	1	1	3	1	2	3	4	0	4	1	3
Chondrostereum purpureum	1	1	8	3	2	2	2	4	4	1	3	2	1	4	6	1	1	14	2	1	1	1	3	1	2	3	1	2	4	1	1
Chroogomphus rutilus	1	3	40	2	5	3	5	3	2	3	1	4	2	2	2	3	3	37	2	1	3	1	3	1	2	3	1	5	4	1	1
Clavaria fragilis	1	3	18	2	5	3	3	4	3	3	2	4	0	5	9	1	2	15.75	3	1	1	1	3	1	2	3	4	0	4	1	3
Clavariadelphus pistillaris	1	3	31.5	2	5	3	3	4	3	3	1	4	2	5	6	1	3	40.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Clavulina cinerea	1	3	19.5	2	5	3	3	4	3	3	2	4	0	5	9	1	2	37.5	5	1	1	1	3	1	3	3	4	0	4	1	1
Clavulina coralloides	1	3	15	2	5	3	3	4	3	3	2	4	0	5	9	1	2	22.5	3	1	1	1	3	1	3	3	4	0	4	1	1
Clavulina rugosa	1	3	16.5	2	5	3	3	4	3	3	2	4	0	5	9	1	2	52.5	5	1	1	1	3	1	3	3	4	0	4	1	1
Climacocystis borealis	1	2	62.5	3	2	2	5	4	3	1	2	2	2	1	1	2	2	16.5	3	1	1	1	3	1	2	3	1	3	4	1	1
Clitocybe candicans	1	3	11.25	2	5	3	5	4	3	3	2	2	1	2	3	3	2	26.25	5	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe clavipes	1	3	37.5	2	5	3	5	4	3	3	2	2	1	2	3	3	3	21.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe ditopa	1	3	20	2	5	3	5	4	2	3	2	2	1	2	3	3	2	17.5	5	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe fragrans	1	3	15.5	2	5	3	5	4	3	3	2	2	1	2	3	3	2	22.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe gibba	1	3	32.5	2	5	3	5	4	3	3	2	2	1	2	3	3	3	20.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe glareosa	1	3	15	2	5	3	5	4	3	3	2	4	0	2	3	3	2	21	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe metachroa	1	3	21.25	2	5	3	5	4	2	3	2	4	0	2	3	3	2	21	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe nebularis	1	3	67.5	2	5	3	5	4	3	3	2	2	1	2	2	3	3	21.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe odora	1	3	25	2	5	3	5	4	4	3	2	2	1	2	3	3	2	21	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe phaeophthalma	1	3	17.5	2	5	3	5	4	2	3	2	2	1	2	3	3	2	17.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe phyllophila	1	3	37.5	2	5	3	5	4	3	3	2	2	1	2	3	3	2	15	3	1	1	1	3	1	2	3	4	0	4	1	1

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Clitocybe rivulosa	1	3	15	2	5	3	5	4	3	3	2	4	0	2	3	3	2	15	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe subspadicea	1	3	27.5	2	5	3	5	4	2	3	2	2	3	2	3	3	2	19.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybe vibecina	1	3	20	2	5	3	5	4	2	3	2	2	1	2	3	3	2	18	3	1	1	1	3	1	2	3	4	0	4	1	1
Clitocybula platyphylla	1	3	50	2	5	4	5	4	3	3	2	2	1	2	2	3	3	22.5	3	1	1	1	3	1	2	3	3	2	4	1	1
Clitopilus prunulus	1	3	32.5	2	5	3	5	4	3	3	2	4	0	2	3	3	3	31.5	3	7	1	1	3	1	2	3	4	0	4	1	3
Collybia cookei	1	3	4.25	2	5	3	5	4	3	3	2	5	2	2	3	3	2	15	3	1	1	1	3	1	2	3	3	2	4	1	3
Colpoma quercinum	1	2	3.6	2	2	1	2	4	2	1	2	2	3	5	12	1	1	80	1	1	1	1	3	1	2	2	4	0	4	1	2
Conocybe aporos	1	3	12.5	2	5	3	5	3	3	3	2	4	0	2	3	3	2	27	3	1	3	2	3	1	2	3	3	2	4	1	2
Conocybe arrhenii	1	3	10	2	5	3	5	3	3	3	2	4	0	2	3	3	2	24	3	1	3	2	2	1	2	3	3	2	4	1	2
***Conocybe dumetorum* s. lat.**	1	3	2.75	2	5	3	5	3	3	3	2	4	0	2	3	3	2	18	3	2	3	2	1	1	2	3	3	2	1	1	3
Conocybe lactea	1	3	25	2	5	3	5	3	3	3	2	4	0	2	3	3	2	37.5	3	1	2	2	1	1	2	3	3	2	1	1	3
Conocybe mesospora	1	3	15	2	5	3	5	3	3	3	2	4	0	2	3	3	2	26.25	3	1	3	1	1	1	2	3	3	2	1	1	3
Conocybe pilosella	1	3	16.25	2	5	3	5	3	3	3	2	4	0	2	3	3	2	21.75	3	1	2	1	2	1	2	3	3	2	1	1	3
Conocybe pulchella	1	3	4.25	2	5	3	5	3	3	3	2	4	0	2	3	3	2	43.5	3	1	3	2	1	1	2	3	3	2	1	1	3
Conocybe semiglobata	1	3	75	2	5	3	5	3	3	3	2	4	0	2	3	3	2	39	3	1	3	2	1	1	2	3	3	2	1	1	3
Conocybe tenera	1	3	100	2	5	3	5	3	3	3	2	4	0	2	3	3	2	34.5	3	1	3	2	1	1	2	3	3	2	1	1	3
Conocybe vestita	1	3	8.25	2	5	3	5	3	3	3	2	4	0	2	3	3	2	21.75	3	1	3	1	2	1	2	3	3	2	4	1	1
Coprinus atramentarius	1	3	45	2	5	4	5	2	3	3	2	2	1	2	2	3	3	27	3	1	4	1	1	1	2	3	1	2	4	1	1
Coprinus comatus	1	3	75	2	5	3	5	2	3	3	2	4	0	2	2	3	3	36	3	1	3	1	1	1	2	3	3	2	4	1	3
Coprinus lagopus	1	3	15	2	5	3	5	2	3	3	2	4	0	2	2	3	2	33.75	3	1	4	1	1	1	2	3	1	2	4	1	3
Coprinus leiocephalus	1	3	9	2	5	3	5	2	3	3	2	4	0	2	3	3	2	36	3	1	4	1	1	1	2	3	1	2	4	1	3
Coprinus micaceus	1	3	25	2	5	4	5	2	3	3	2	2	1	2	2	3	3	24.75	3	1	3	1	1	1	2	3	1	2	4	1	3
Coprinus plicatilis	1	3	9	2	5	3	5	2	3	3	2	4	0	2	2	3	2	29.25	3	1	4	1	1	1	2	3	1	2	4	1	3
Cordyceps ophioglossoides	1	3	6	3	2	4	4	4	1	5	4	2	2	6	6	2	3	200	1	1	1	1	3	1	2	3	4	0	4	1	3
Cortinarius acutus	1	3	7.5	2	5	3	5	3	3	3	1	4	3	2	2	3	3	23.25	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius albovariegatus	1	3	13.75	2	5	3	5	3	3	3	1	4	2	2	2	3	3	23.25	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius alboviolaceus	1	3	25	2	5	3	5	3	3	3	1	4	2	2	2	3	3	24	3	2	2	1	3	1	2	3	3	1	4	1	1
Cortinarius alnetorum	1	3	10	2	5	3	5	3	3	3	1	4	2	2	2	3	2	29.25	3	2	2	1	3	1	2	3	3	1	4	1	1
***Cortinarius anomalus* s. str.**	1	3	22.5	2	5	3	5	3	3	3	1	4	1	2	2	3	3	24	3	2	2	1	3	1	2	3	3	1	4	1	1
Cortinarius bibulus	1	3	5	2	5	3	5	3	4	3	1	4	2	2	2	3	2	27.75	3	2	2	1	3	1	2	3	3	1	4	1	1
Cortinarius bulbosus	1	3	25	2	5	3	5	3	3	3	1	4	2	2	2	3	3	22.5	3	2	2	1	3	1	2	3	3	1	4	1	1
Cortinarius caninus	1	3	32.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	24	3	2	2	1	3	1	2	3	3	1	4	1	1
Cortinarius caperatus	1	3	35	2	5	3	5	3	3	3	1	4	1	2	2	3	3	37.5	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius cinnamomeus	1	3	12.5	2	5	3	5	3	4	3	1	4	1	2	2	3	3	21.75	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius croceus	1	3	12.5	2	5	3	5	3	4	3	1	4	2	2	2	3	3	23.25	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius decipiens	1	3	12.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	27	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius delibutus var. d.	1	3	20	2	5	3	5	3	4	3	1	4	2	2	2	3	3	40	5	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius flexipes	1	3	15	2	5	3	5	3	4	3	1	4	1	2	2	3	2	25.5	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius helvelloides	1	3	10	2	5	3	5	3	3	3	1	4	3	2	2	3	2	27	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius hemitrichus	1	3	12.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	24	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius hinnuleus	1	3	22.5	2	5	3	5	3	3	3	1	4	1	2	2	3	3	30	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius infractus	1	3	27.5	2	5	3	5	3	2	3	1	4	1	2	2	3	3	23.25	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius obtusus	1	3	12.5	2	5	3	5	3	3	3	1	4	1	2	2	3	3	23.25	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius orellanus	1	3	28.75	2	5	3	5	3	4	3	1	4	2	2	2	3	3	30.75	3	2	2	1	3	1	2	3	3	1	4	1	1

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Cortinarius purpureus	1	3	20	2	5	3	5	3	4	3	1	4	2	2	2	3	3	21	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius sanguineus	1	3	12.5	2	5	3	5	3	4	3	1	4	2	2	2	3	3	22.5	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius semisanguineus	1	3	22.5	2	5	3	5	3	4	3	1	4	2	2	2	3	3	19.5	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius sertipes	1	3	13.75	2	5	3	5	3	2	3	1	4	2	2	2	3	3	27	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius speciosissimus	1	3	27.5	2	5	3	5	3	4	3	1	4	2	2	2	3	3	28.5	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius torvus	1	3	37.5	2	5	3	5	3	2	3	1	4	2	2	2	3	3	28.5	3	2	2	1	3	1	2	3	3	1	4	1	1
Cortinarius traganus	1	3	32.5	2	5	3	5	3	4	3	1	4	2	2	2	3	3	27	3	2	2	1	3	1	2	3	3	2	4	1	1
Cortinarius varius	1	3	35	2	5	3	5	3	4	3	1	4	2	2	2	3	3	31.5	3	2	2	1	3	1	2	3	3	1	4	1	1
Cortinarius vibratilis	1	3	20	2	5	3	5	3	3	3	1	4	2	2	2	3	3	22.5	3	2	2	1	3	1	2	3	3	2	4	1	1
Craterellus cornucopioides	1	3	19.5	2	5	3	3	4	2	3	1	4	2	4	6	2	2	36	3	1	1	1	3	1	3	3	4	0	4	1	3
Crepidotus applanatus	1	3	4.5	2	5	2	2	4	3	3	2	2	1	2	4	2	2	28.75	5	2	2	1	3	1	2	3	3	2	4	1	1
Crepidotus cesatii	1	3	2.5	2	5	2	2	4	3	3	2	2	1	2	4	2	2	45	5	2	2	1	3	1	2	3	3	2	4	1	1
Crepidotus epibryus	1	3	2	2	5	2	2	4	3	3	2	2	1	2	4	2	2	20.5	2	1	2	1	3	1	2	3	3	2	4	1	3
Crinipellis scabellus	2	3	42.5	2	5	4	5	4	3	3	2	2	1	2	3	3	2	24	3	1	1	1	3	1	2	3	1	2	1	1	1
Crucibulum laeve	1	3	2.8	2	4	4	4	4	2	3	2	2	1	6	8	2	2	28.5	3	1	1	2	3	2	2	3	4	0	4	1	1
Cudoniella clavus	1	3	1.6	2	5	4	2	4	3	3	2	2	2	5	12	2	2	40.5	3	1	1	1	3	1	2	3	4	0	4	1	2
Cyathus olla	1	3	50	2	2	3	4	4	2	3	2	2	1	6	8	2	2	30	3	1	1	2	3	2	2	3	4	0	4	1	1
Cyathus striatus	1	3	50	2	2	4	4	4	2	3	2	2	1	6	6	2	2	57	3	1	1	2	3	2	2	3	4	0	4	1	1
Cyphellostereum laeve	2	2	1.5	2	2	4	2	4	3	5	4	1	1	5	12	2	1	13.5	3	1	1	1	3	1	2	3	1	2	4	1	3
Cystoderma amianthinum	1	3	16.25	2	5	3	5	2	4	3	2	4	0	2	3	3	3	18	3	1	1	1	3	1	2	3	4	0	4	1	1
Cystoderma carcharias	1	3	21.25	2	5	3	5	2	3	3	2	4	0	2	3	3	3	14.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Cystoderma granulosum	1	3	16.25	2	5	3	5	2	4	3	2	4	0	2	2	3	3	12.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Cystoderma jasonis	1	3	16.25	2	5	3	5	2	4	3	2	4	0	2	3	3	3	20.25	3	1	1	1	3	1	2	2	4	0	4	1	1
Cystolepiota bucknallii	1	3	15	2	5	3	5	2	4	3	2	4	0	2	3	3	3	15.5	2	1	1	2	3	1	2	3	4	0	4	1	3
Cystolepiota hetieri	1	3	12.5	2	5	3	5	2	3	3	2	4	0	2	3	3	3	10	2	1	1	2	3	1	2	3	3	2	4	1	1
Cystolepiota seminuda	1	3	7.5	2	5	3	5	2	4	3	2	4	0	2	3	3	3	9	2	1	1	2	3	1	2	3	4	0	4	1	3
Dacrymyces lacrymalis	1	2	6	2	3	4	2	4	3	3	2	2	2	5	12	1	2	52	4	1	1	1	3	1	2	3	4	0	4	1	3
Dacrymyces stillatus	1	2	6	1	3	4	2	4	4	1	2	2	1	5	12	1	2	52	4	1	1	1	3	1	2	1	4	0	4	1	3
Daedalea quercina	1	1	57.5	3	1	4	5	4	3	1	2	2	3	1	1	2	2	18.75	3	1	1	1	3	1	2	3	4	0	4	3	1
Daedaleopsis confragosa	1	1	42.5	2	1	2	5	4	3	1	2	2	1	1	2	2	2	18	2	1	1	1	3	1	2	3	4	0	4	3	1
Daedaleopsis confragosa* var. *tricolor	1	1	42.5	3	1	2	5	4	3	1	2	2	2	1	2	2	2	18	2	1	1	1	3	1	2	3	4	0	4	3	1
Datronia mollis	1	1	20	3	1	2	5	4	2	1	2	2	1	1	2	2	2	17.5	2	1	1	1	3	1	2	3	4	0	4	2	1
Delicatula integrella	1	3	3.25	2	5	3	5	4	3	3	2	2	2	2	4	3	2	22.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Dendrothele acerina	1	1	3	3	2	2	1	4	3	1	2	2	2	5	6	2	1	33	3	1	1	2	3	1	2	3	1	2	4	1	3
Dendrothele alliacea	1	1	3	3	2	2	1	4	3	1	2	2	2	5	6	2	1	40.5	3	1	1	2	3	1	2	3	1	2	4	1	1
Dermoloma cuneifolium	1	3	16.25	2	5	3	5	4	3	3	2	4	0	2	2	3	3	15.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Diatrype bullata	1	1	12	2	1	4	4	4	1	1	2	2	3	6	8	2	2	26	4	1	2	1	3	1	2	3	4	0	4	1	3
Diatrype disciformis	1	1	9	2	1	4	4	4	1	1	2	2	2	6	8	2	2	26	4	1	2	1	3	1	2	3	4	0	4	1	3
Diatrype stigma	1	1	20	3	1	4	4	4	1	1	2	2	2	6	4	2	2	32	4	1	2	1	3	1	2	3	4	0	4	1	3
Diatrypella favacea	1	1	0.8	2	1	4	4	4	1	1	2	2	2	6	8	2	2	12	4	1	2	1	3	1	1	3	4	0	4	1	3
Echinoderma asperum	1	3	37.5	2	5	3	5	2	4	3	2	4	0	2	2	3	3	16	2	1	1	1	3	1	2	3	3	2	4	1	1
Elaphomyces muricatus	1	3	9	2	5	5	4	4	2	1	1	4	2	6	6	2	1	145	5	3	3	3	3	3	2	3	4	0	4	1	2
***Entoloma cetratum* s. str.**	1	3	10	2	5	3	5	4	2	3	2	4	0	2	2	3	2	58.75	5	7	2	1	3	1	3	3	4	0	4	1	3

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Entoloma chalybaeum	1	3	12.5	2	5	3	5	4	4	3	2	4	0	2	2	3	3	30.75	3	7	2	1	3	1	2	3	3	1	4	1	3
Entoloma conferendum	1	3	15	2	5	3	5	4	2	3	2	4	0	2	2	3	2	50	5	7	2	1	3	1	2	3	4	0	4	1	3
Entoloma exile	1	3	8.75	2	5	3	5	4	3	3	2	4	0	2	2	3	2	52.5	5	7	2	1	3	1	2	3	3	2	4	1	3
Entoloma griseocyaneum	1	3	16.25	2	5	3	5	4	4	3	2	4	0	2	2	3	3	56.25	5	7	2	1	3	1	2	3	4	0	4	1	3
Entoloma lampropus	1	3	12.5	2	5	3	5	4	4	3	2	4	0	2	2	3	3	50	5	7	2	1	3	1	2	3	3	1	4	1	1
Entoloma lanicum	1	3	62.5	2	5	3	5	4	4	3	2	4	0	2	2	3	3	24	3	7	2	1	3	1	2	3	4	0	4	1	1
Entoloma mougeotii	1	3	15	2	5	3	5	4	4	3	2	4	0	2	2	3	3	30.75	3	7	2	1	3	1	2	3	3	2	4	1	3
Entoloma nitidum	1	3	15	2	5	3	5	4	4	3	2	4	0	2	2	3	3	41.25	5	7	2	1	3	1	2	3	4	0	4	1	1
Entoloma politum	1	3	11.25	2	5	3	5	4	2	3	?1	4	2	2	2	3	3	45	5	7	2	1	3	1	2	3	4	0	4	1	1
Entoloma prunuloides	1	3	22.5	2	5	3	5	4	3	3	2	4	0	2	2	3	3	36.25	5	7	2	1	3	1	2	3	4	0	4	1	1
Entoloma rhodopolium	1	3	40	2	5	3	5	4	3	3	1	4	2	2	2	3	3	43.75	5	7	2	1	3	1	2	3	4	0	4	1	1
Entoloma sericeum	1	3	22.5	2	5	3	5	4	3	3	2	4	0	2	2	3	3	43.75	5	7	2	1	3	1	2	3	4	0	4	1	2
Entoloma turci	1	3	15	2	5	3	5	4	4	3	2	4	0	2	2	3	3	32.25	3	7	2	1	3	1	2	3	4	0	4	1	3
Exidia cartilaginea	1	3	1.6	2	3	2	2	4	3	3	2	2	1	5	9	1	2	46	4	1	1	1	3	1	2	3	4	0	4	1	1
Exidia glandulosa	1	3	2	2	3	2	2	4	1	3	2	2	1	5	9	2	2	46	4	1	1	1	3	1	2	3	4	0	4	1	1
Exidia plana	1	3	7	2	3	2	2	4	1	5	2	2	1	5	9	2	2	62	4	1	1	1	3	1	2	3	4	0	4	1	1
Exidia recisa	1	3	4	2	3	2	2	4	2	3	2	2	1	5	9	1	2	56	4	1	1	1	3	1	2	3	4	0	4	1	1
Flammulaster granulosus	1	3	5	2	5	3	5	2	2	3	2	2	1	2	3	3	3	27	3	1	3	2	3	1	2	3	3	2	4	1	1
***Flammulina velutipes* s. str.**	1	3	17.5	2	5	4	5	4	3	4	2	2	1	2	2	3	3	23.25	3	1	1	1	3	1	2	3	3	2	1	1	1
Fomes fomentarius	1	1	100	3	1	2	5	4	3	1	2	2	1	1	1	2	2	37	2	1	1	1	3	1	2	3	4	0	4	3	1
Fomitopsis pinicola	1	1	100	3	1	2	5	4	4	1	2	2	1	1	1	2	2	14	2	1	1	1	3	1	2	3	4	0	4	3	1
Galerina clavata	1	3	8.75	2	5	4	5	1	3	3	4	5	2	2	3	3	2	39	3	2	2	1	3	1	2	3	3	2	3	1	3
Galerina hypnorum	1	3	5	2	5	3	5	1	2	3	2	4	0	2	3	3	2	27	3	2	2	1	3	1	2	3	3	2	4	1	1
Galerina marginata	1	3	8.75	2	5	4	5	1	3	3	2	2	2	2	2	3	3	26.25	3	2	2	1	3	1	2	3	1	2	4	1	1
Galerina mniophila	1	3	5	2	5	3	5	1	3	3	4	5	2	2	3	3	2	32.25	3	2	2	1	3	1	2	3	3	2	4	1	1
Galerina pumila	1	3	7.5	2	5	3	5	1	3	3	4	5	2	2	3	3	2	35.25	3	2	2	1	3	1	2	3	3	2	4	1	1
Galerina triscopa	1	3	4	2	5	4	5	1	2	3	4	5	2	2	3	3	2	22.5	3	2	2	1	3	1	2	3	3	2	4	1	1
Galerina vittiformis	1	3	4.5	2	5	3	5	1	3	3	4	5	2	2	3	3	2	31.5	3	2	2	1	3	1	2	3	1	2	3	1	1
Gamundia striatula	1	3	14.25	2	5	3	5	4	2	3	2	4	0	2	3	3	3	21.75	3	2	1	1	3	1	2	3	1	2	3	1	1
Ganoderma applanatum	1	1	175	3	1	2	5	4	2	1	2	2	1	1	1	2	2	22.5	3	1	2	3	3	1	2	3	4	0	4	3	1
Ganoderma lucidum	1	2	87.5	3	1	4	5	4	4	3	2	2	1	1	2	2	2	28.5	3	1	2	3	3	1	2	3	4	0	4	3	1
Geastrum fimbriatum	1	3	10	2	4	5	4	4	2	5	2	4	0	6	4	2	2	16.25	5	2	2	1	3	1	2	3	4	0	4	1	1
Geastrum nanum	1	3	6	2	4	5	4	4	2	5	2	4	0	6	4	2	2	30	5	2	3	1	3	1	2	3	4	0	4	1	1
Gloeophyllum abietinum	1	1	25	2	1	2	5	4	2	1	2	2	2	1	2	2	2	21	2	1	1	1	3	1	2	3	1	3	4	3	1
Gloeophyllum odoratum	1	1	57.5	3	1	4	5	4	4	1	2	2	2	1	2	2	2	14	2	1	1	1	3	1	2	3	1	2	4	3	1
Gloeophyllum sepiarium	1	1	22.5	2	1	2	5	4	4	1	2	2	2	1	2	2	2	22	2	1	1	1	3	1	2	3	1	2	4	3	1
Gloeoporus dichrous	1	1	6	3	2	1	2	4	3	1	2	2	2	1	2	1	1	13.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Gomphidius glutinosus	1	3	42.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	37	2	1	2	1	3	1	2	3	1	5	4	1	3
Gymnopilus penetrans	1	3	25	2	5	4	5	3	3	3	2	2	1	2	2	3	3	24	3	2	2	1	3	1	2	3	1	2	3	1	1
Gymnopilus picreus	1	3	11.25	2	5	4	5	3	4	3	2	2	2	2	2	3	3	28.5	3	2	2	1	3	1	2	3	3	2	3	1	1
Gymnopus aquosus	1	3	22.5	2	5	3	5	4	3	3	2	2	2	2	2	3	3	19.5	3	1	1	1	3	1	2	3	3	2	4	1	1
Gymnopus confluens	1	3	13.75	2	5	3	5	4	3	3	2	2	2	2	2	3	3	21.75	3	1	1	1	3	1	2	3	1	2	4	1	1
Gymnopus dryophilus	1	3	17.5	2	5	3	5	4	3	3	2	2	1	2	2	3	3	16.5	3	1	1	1	3	1	2	3	3	2	4	1	1
Gymnopus peronatus	1	3	21.25	2	5	3	5	4	3	3	2	2	1	2	2	3	3	27	3	1	1	1	3	1	2	3	1	2	4	1	1

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Hapalopilus nidulans	1	2	30	3	2	2	5	4	4	1	2	2	1	1	2	2	2	12.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Hebeloma crustuliniforme	1	3	30	2	5	3	5	4	3	3	1	4	1	2	2	3	3	33	3	2	2	1	3	1	2	3	3	2	3	1	1
Hebeloma edurum	1	3	22.5	2	5	3	5	4	3	3	1	4	2	2	2	3	3	29.25	3	2	2	1	3	1	2	3	3	2	3	1	1
Hebeloma helodes	1	3	11.25	2	5	3	5	4	3	3	1	4	2	2	2	3	3	30	3	2	2	1	3	1	2	3	3	2	3	1	1
Hebeloma incarnatulum	1	3	20	2	5	3	5	4	3	3	1	4	3	2	2	3	3	29.25	3	2	2	1	3	1	2	3	3	2	3	1	1
Hebeloma mesophaeum	1	3	16.25	2	5	3	5	4	3	3	1	4	1	2	2	3	3	28.5	3	2	2	1	3	1	2	3	3	2	3	1	1
Hebeloma radicosum	1	3	33.75	2	5	3	5	4	3	3	1	4	2	2	2	3	3	27	3	2	2	1	3	1	2	3	3	2	3	1	1
Hebeloma sinapizans	1	3	37.5	2	5	3	5	4	3	3	1	4	1	2	2	3	3	34.5	3	2	2	1	3	1	2	3	3	2	3	1	1
Hebeloma theobrominum	1	3	22.5	2	5	3	5	4	2	3	1	4	2	2	2	3	3	28.5	3	2	2	1	3	1	2	3	3	2	3	1	1
Helvella lacunosa	1	3	6.5	2	5	3	2	4	2	5	2	4	0	2	2	2	2	51	3	1	1	1	3	1	2	3	4	0	4	1	2
Helvella macropus	1	3	5	3	5	3	2	4	2	5	2	4	0	5	6	2	3	69	3	2	1	1	3	1	2	3	4	0	4	1	2
Hemimycena cucullata	1	3	8.75	2	5	4	5	4	3	3	2	2	1	2	4	3	2	24	2	1	1	1	3	1	2	3	3	2	3	1	1
Hemimycena delectabilis	1	3	5	2	5	4	5	4	3	3	2	2	1	2	4	3	2	24	3	1	1	1	3	1	2	3	3	2	3	1	1
Hemimycena lactea	1	3	6	2	5	4	5	4	3	3	2	2	2	2	4	3	2	22	2	1	1	1	3	1	2	3	3	2	1	1	1
Hemimycena pseudolactea	1	3	7.5	2	5	4	5	4	3	3	2	2	1	2	4	3	2	21	3	1	1	1	3	1	2	3	1	2	1	1	1
Heterobasidion annosum	1	1	50	3	1	4	5	4	3	1	3	2	1	1	1	1	2	15.75	3	2	1	1	3	1	2	3	1	2	4	2	3
Heteromycophaga glandulosae	3	3	0.4	2	3	4	2	4	3	3	4	5	3	5	12	1	1	0	0	0	0	0	0	0	0	2	4	0	4	1	1
Humaria hemisphaerica	2	3	3.5	2	5	3	2	4	2	3	2	4	0	5	9	2	2	70.5	3	3	1	1	3	1	2	3	4	0	4	1	2
Hydnum repandum	1	3	35.25	2	5	3	3	4	3	3	1	4	2	3	2	2	3	23.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygroaster asterosporus	1	3	8.75	2	5	3	5	4	2	3	2	2	2	2	3	3	3	32.5	5	4	1	1	3	1	2	3	4	0	4	1	3
Hygrocybe cantharellus	1	3	10.75	2	5	3	5	4	4	3	?2	4	0	2	2	3	3	32.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrocybe colemanniana	1	3	14.25	2	5	3	5	4	1	3	?2	4	0	2	2	3	3	24.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrocybe conica* var. *c.	1	3	26.25	2	5	3	5	4	4	3	?2	4	0	2	2	3	3	27.75	3	1	1	1	3	1	3	3	4	0	4	1	1
Hygrocybe insipida	1	3	6.25	2	5	3	5	4	4	3	?2	4	0	2	2	3	3	20.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrocybe persistens	1	3	15	2	5	3	5	4	4	3	?2	4	0	2	2	3	3	33.75	3	1	1	1	3	1	2	3	4	0	4	1	3
Hygrocybe pratensis	1	3	27.5	2	5	3	5	4	3	3	?2	4	0	2	2	3	3	18	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrocybe psittacina	1	3	16.25	2	5	3	5	4	4	3	?2	4	0	2	2	3	3	24.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrocybe virginea	1	3	20	2	5	3	5	4	3	3	?2	4	0	2	2	3	3	23.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrophoropsis aurantiaca	1	3	27.5	2	5	3	5	4	4	3	2	4	0	2	2	3	3	18	3	1	2	1	3	1	2	3	4	0	4	1	1
Hygrophorus chrysodon	1	3	27.5	2	5	3	5	4	3	3	1	4	1	2	2	3	3	24	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrophorus discoxanthus	1	3	30	2	5	3	5	4	3	3	1	4	3	2	2	3	3	24	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrophorus hypothejus	1	3	17.5	2	5	3	5	4	2	3	1	4	2	2	2	3	3	24	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrophorus latitabundus	1	3	38.75	2	5	3	5	4	2	3	1	4	3	2	2	3	3	31.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrophorus olivaceoalbus	1	3	20	2	5	3	5	4	2	3	1	4	3	2	2	3	3	39	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrophorus penarius	1	3	30	2	5	3	5	4	3	3	1	4	2	2	2	3	3	22.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Hygrophorus pustulatus	1	3	22.5	2	5	3	5	4	3	3	1	4	3	2	2	3	3	25.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Hymenochaete cruenta	1	1	16	3	2	1	1	4	4	1	2	2	3	5	6	1	1	14	2	1	1	1	3	1	2	3	1	3	4	1	3
Hymenochaete rubiginosa	1	1	4	3	2	2	1	4	2	1	2	2	2	5	6	1	1	15.75	3	1	1	1	3	1	2	3	1	3	4	1	3
Hymenoscyphus calyculus	1	3	0.56	2	5	4	2	4	3	5	2	2	1	5	12	2	2	64	4	1	1	1	3	1	2	3	4	0	4	1	2
Hymenoscyphus caudatus	3	3	0.2	2	5	4	2	4	3	3	2	2	1	5	12	2	2	43.5	2	1	1	1	3	1	2	3	4	0	4	1	3
Hymenoscyphus fructigenus	2	3	0.4	2	5	4	2	4	3	3	2	2	2	5	12	2	2	47.25	3	1	1	1	3	1	2	3	4	0	4	1	3
Hymenoscyphus lutescens	1	3	0.2	2	5	4	2	4	4	5	2	2	2	5	12	2	2	37.5	3	1	1	1	3	1	2	3	4	0	4	1	2
Hypholoma capnoides	1	3	21.25	2	5	4	5	3	3	4	2	2	2	2	2	3	3	24	3	1	2	2	1	1	2	3	1	4	4	1	3

Table 12 ***continued***

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Hypholoma fasciculare	1	3	16.25	2	5	4	5	3	3	3	2	2	1	2	2	3	3	21	3	1	2	2	1	1	2	3	1	4	4	1	3
Hypholoma lateritium	1	3	30	2	5	4	5	3	4	3	2	2	2	2	2	3	3	21	3	1	2	2	1	1	2	3	1	4	4	1	3
Hypholoma polytrichi	1	3	8.75	2	5	4	5	3	3	3	2	2	2	2	2	3	3	24	3	1	2	2	1	1	2	3	1	4	4	1	3
Hypholoma radicosum	1	3	16.25	2	5	4	5	3	3	3	2	2	2	2	2	3	3	18.75	3	1	2	2	1	1	2	3	1	4	4	1	3
Hypoxylon cohaerens	1	1	1.2	1	1	4	4	4	1	1	2	2	3	6	6	2	2	31.5	3	1	4	1	1	1	2	2	4	0	4	1	3
Hypoxylon deustum	1	1	32	2	1	4	4	4	1	1	2	2	2	6	8	2	2	60	2	1	4	1	1	1	2	2	4	0	4	1	3
Hypoxylon fragiforme	1	1	2.4	1	1	4	4	4	2	1	2	2	3	6	8	2	2	39	3	1	4	1	1	1	2	2	4	0	4	1	3
Hypoxylon fuscum	1	1	1.2	1	1	4	4	4	1	1	2	2	2	6	8	2	2	40.5	3	1	4	1	1	1	2	2	4	0	4	1	3
Hypoxylon howeianum	1	1	1.2	1	1	4	4	4	1	1	2	2	2	6	8	2	2	22.5	3	1	4	1	1	1	2	2	4	0	4	1	3
Hypoxylon rubiginosum	1	1	32	1	1	4	4	4	2	1	2	2	1	6	6	2	2	33	3	1	4	1	1	1	2	3	4	0	4	1	3
Inocybe adaequata	1	3	27.5	2	5	3	5	3	2	3	1	4	2	2	2	3	3	33	3	1	2	2	3	1	2	3	3	2	3	1	1
Inocybe auricoma	1	3	8.75	2	5	3	5	3	3	3	1	4	2	2	2	3	3	26.25	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe bongardii var. ***b.***	1	3	20	2	5	3	5	3	3	3	1	4	1	2	2	3	3	40.5	3	1	2	2	3	1	2	3	3	2	3	1	1
Inocybe corydalina	1	3	27.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	25.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe flocculosa	1	3	17.5	2	5	3	5	3	2	3	1	4	2	2	2	3	3	28.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe fuscidula	1	3	15	2	5	3	5	3	2	3	1	4	2	2	2	3	3	27.75	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe geophylla var. ***g.***	1	3	11.25	2	5	3	5	3	3	3	1	4	1	2	2	3	3	27	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe geophylla var. ***lilacina***	1	3	11.25	2	5	3	5	3	4	3	1	4	1	2	2	3	3	27	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe glabrescens	1	3	20	2	5	3	5	3	3	3	1	4	2	2	2	3	3	28.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe glabripes	1	3	8.75	2	5	3	5	3	3	3	1	4	2	2	2	3	3	21.75	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe godeyi	1	3	17.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	31.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe griseolilacina	1	3	11.25	2	5	3	5	3	4	3	1	4	2	2	2	3	3	28.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe hirtella	1	3	15	2	5	3	5	3	3	3	1	4	2	2	2	3	3	31.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe hirtelloides	1	3	15	2	5	3	5	3	3	3	1	4	2	2	2	3	3	24	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe lacera	1	3	12.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	37.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe mixtilis	1	3	22.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	25.5	3	7	2	2	3	1	2	3	1	5	3	1	1
Inocybe muricellata	1	3	8.75	2	5	3	5	3	3	3	1	4	2	2	2	3	3	30	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe napipes	1	3	12.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	28.5	3	7	2	2	3	1	2	3	1	5	4	1	1
Inocybe nitidiuscula	1	3	12.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	31.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe petiginosa	1	3	6.25	2	5	3	5	3	3	3	1	4	3	2	2	3	3	21	3	7	2	2	3	1	2	3	1	5	3	1	1
Inocybe phaeocomis	1	3	15	2	5	3	5	3	2	3	1	4	2	2	2	3	3	28.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe rimosa	1	3	26.25	2	5	3	5	3	3	3	1	4	1	2	2	3	3	36	3	1	2	2	3	1	2	3	3	5	3	1	1
Inocybe sindonia	1	3	20	2	5	3	5	3	3	3	1	4	2	2	2	3	3	26.25	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe splendens var. ***s.***	1	3	25	2	5	3	5	3	3	3	1	4	2	2	2	3	3	31.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inocybe splendens var. ***phaeoleuca***	1	3	17.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	31.5	3	1	2	2	3	1	2	3	1	5	3	1	1
Inonotus radiatus	1	2	30	2	2	2	5	4	2	5	2	2	1	1	2	2	2	17.25	3	1	2	1	3	1	2	3	1	3	1	1	3
Irpex lacteus	1	1	5	2	2	4	1	4	3	1	2	2	2	3	2	1	2	11.5	2	1	1	1	3	1	2	3	1	3	4	2	3
Ischnoderma resinosum	1	1	45	3	2	2	5	4	1	1	2	2	2	1	2	2	2	11	2	1	1	1	3	1	2	3	4	0	4	2	1
Junghuhnia nitida	1	1	9	3	2	4	1	4	3	1	2	2	1	1	2	1	1	12.75	3	1	1	1	3	1	2	3	1	3	4	2	1
Laccaria amethystea	1	3	12.5	2	5	3	5	4	4	3	2	4	0	2	2	3	3	27	3	4	1	1	3	1	2	3	3	2	4	1	1
Laccaria proxima	1	3	20	2	5	3	5	4	3	3	2	4	0	2	2	3	3	27.75	3	4	1	1	3	1	2	3	3	2	4	1	1
Laccaria tetraspora	1	3	12.5	2	5	3	5	4	3	3	2	4	0	2	2	3	3	28.5	3	4	1	1	3	1	2	3	3	2	4	1	1

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Lacrymaria lacrymabunda	1	3	21.25	2	5	3	5	3	3	3	2	4	0	2	2	3	3	28.5	3	3	4	1	1	1	2	3	3	2	3	1	1
Lactarius acerrimus	1	3	41.25	2	5	3	5	4	3	3	1	4	3	2	2	3	3	58.75	5	5	1	1	3	1	3	3	1	2	4	2	3
Lactarius aurantiacus	1	3	15	2	5	3	5	4	4	3	1	4	2	2	2	3	3	24	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius blennius	1	3	32.5	2	5	3	5	4	2	3	1	4	2	2	2	3	3	20.25	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius camphoratus	1	3	17.5	2	5	3	5	4	3	3	1	4	2	2	2	3	3	36.25	5	6	1	1	3	1	2	3	3	2	4	2	3
Lactarius deliciosus	1	3	37.5	2	5	3	5	4	4	3	1	4	3	2	2	3	3	27.75	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius deterrimus	1	3	33.75	2	5	3	5	4	4	3	1	4	3	2	2	3	3	29.25	3	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius fuliginosus	1	3	42.5	2	5	3	5	4	2	3	1	4	2	2	2	3	3	41.25	5	6	1	1	3	1	2	3	3	2	4	2	3
Lactarius glyciosmus	1	3	13.75	2	5	3	5	4	2	3	1	4	3	2	2	3	3	21	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius helvus	1	3	45	2	5	3	5	4	3	3	1	4	2	2	2	3	3	21.75	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius hortensis	1	3	28.75	2	5	3	5	4	3	3	1	4	3	2	2	3	3	31.25	5	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius lacunarum	1	3	18.75	2	5	3	5	4	4	5	1	4	2	2	2	3	3	36.25	5	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius lignyotus	1	3	33.75	2	5	3	5	4	1	3	1	4	3	2	2	3	3	48.75	5	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius lilacinus	1	3	18.75	2	5	3	5	4	4	3	1	4	3	2	2	3	3	23.25	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius pallidus	1	3	33.75	2	5	3	5	4	3	3	1	4	2	2	2	3	3	22.5	3	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius pubescens var. *p.*	1	3	33.75	2	5	3	5	4	4	3	1	4	3	2	2	3	3	21.75	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius pyrogalus	1	3	32.5	2	5	3	5	4	3	3	1	4	3	2	2	3	3	33.75	5	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius quietus	1	3	26.25	2	5	3	5	4	3	3	1	4	3	2	2	3	3	38.75	5	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius rufus	1	3	28.75	2	5	3	5	4	3	3	1	4	2	2	2	3	3	24.75	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius scrobiculatus	1	3	65	2	5	3	5	4	4	3	1	4	3	2	2	3	3	42.5	5	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius subdulcis	1	3	18.75	2	5	3	5	4	3	3	1	4	3	2	2	3	3	41.25	5	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius tabidus	1	3	12.5	2	5	3	5	4	3	3	1	4	2	2	2	3	3	36.25	5	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius torminosus	1	3	37.5	2	5	3	5	4	2	3	1	4	3	2	2	3	3	25.5	3	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius turpis	1	3	42.5	2	5	3	5	4	2	3	1	4	2	2	2	3	3	23.25	3	6	1	1	3	1	2	3	1	2	4	2	3
Lactarius vellereus	1	3	87.5	2	5	3	5	4	3	3	1	4	2	2	2	3	3	48.75	5	5	1	1	3	1	2	3	1	2	4	2	3
Lactarius volemus	1	3	55	2	5	3	5	4	3	3	1	4	2	2	2	3	3	50	5	5	1	1	3	1	2	3	1	3	4	2	3
Laeticorticium roseum	1	1	15	2	2	4	1	4	4	1	2	2	2	5	3	1	1	37.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Laetiporus sulfureus	1	2	100	3	2	4	5	4	4	3	3	2	1	1	1	2	3	18.75	3	1	1	1	3	1	2	1	4	0	4	2	3
Leccinum aurantiacum	1	3	45	2	5	3	5	4	4	3	1	4	3	1	2	3	3	31	2	1	2	2	3	1	2	3	1	5	3	1	3
Leccinum duriusculum	1	3	45	2	5	3	5	4	3	3	1	4	2	1	2	3	3	30.5	2	1	2	2	3	1	2	3	1	5	4	1	3
Leccinum variicolor	1	3	38.75	2	5	3	5	4	3	3	1	4	3	1	2	3	3	31	2	1	2	2	3	1	2	3	1	5	4	1	3
Lentinellus vulpinus	1	3	22.5	2	5	4	5	4	3	3	2	2	2	2	2	3	2	22.5	5	2	1	1	3	1	2	3	1	2	4	1	1
Leotia lubrica	2	3	4.5	2	3	3	2	4	4	2	2	4	0	5	12	2	2	45	2	1	1	1	3	1	2	3	4	0	4	1	2
Lepiota alba	1	3	20	2	5	3	5	3	3	5	2	4	0	2	2	3	3	45	3	1	1	1	3	1	2	3	3	2	4	1	1
Lepiota castanea s. str.	1	3	12.5	2	5	3	5	3	3	3	2	4	0	2	2	3	3	21	2	1	1	1	3	1	2	3	3	2	4	1	1
Lepiota clypeolaria	1	3	32.5	2	5	3	5	3	3	3	2	4	0	2	2	3	3	29	2	1	1	1	3	1	2	3	3	2	4	1	1
Lepiota cristata	1	3	22.5	2	5	3	5	3	3	3	2	4	0	2	2	3	3	14	2	1	1	1	3	1	2	3	3	2	4	1	1
Lepiota ignivolvata	1	3	35	2	5	3	5	3	4	3	2	4	0	2	2	3	3	29.25	3	1	1	1	3	1	2	3	3	2	4	1	1
Lepiota subincarnata s. str.	1	3	16.25	2	5	3	5	3	4	3	2	4	0	2	2	3	3	20.25	3	1	1	1	3	1	2	3	3	2	4	1	1
Lepista flaccida	1	3	40	2	5	3	5	4	4	3	2	4	0	2	2	3	3	13.5	3	2	1	1	3	1	2	3	4	0	4	1	1
Lepista nuda	1	3	50	2	5	3	5	4	4	3	2	4	0	2	2	3	3	21.75	3	2	1	1	3	1	2	3	4	0	4	1	1
Lepista panaeolus	1	3	42.5	2	5	3	5	4	3	5	2	4	0	2	2	3	3	16.5	3	2	1	1	3	1	2	3	4	0	4	1	1
Lepista saeva	1	3	62.5	2	5	3	5	4	4	3	2	4	0	2	2	3	3	22.5	3	2	1	1	3	1	2	3	4	0	4	1	1
Lepista sordida	1	3	27.5	2	5	3	5	4	3	3	2	4	0	2	2	3	3	18.75	3	2	1	1	3	1	2	3	4	0	4	1	1

Table 12 ***continued***

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Leucoagaricus leucothites	1	3	50	2	5	3	5	3	3	5	2	4	0	2	2	3	3	27	3	1	1	2	1	1	2	3	3	2	4	1	3
Leucogyrophana mollusca	1	2	6	3	3	4	1	4	4	1	2	2	2	2	2	1	1	20.25	3	1	2	2	3	1	2	3	4	0	4	1	1
Lycoperdon echinatum	1	3	16	2	4	4	4	4	2	3	2	4	3	6	6	2	2	22.5	5	3	1	1	3	1	2	3	4	0	4	1	1
Lycoperdon lividum	1	3	11	2	4	4	4	4	2	3	2	4	0	6	6	2	2	20	5	2	1	1	3	1	2	3	4	0	4	1	1
Lycoperdon molle	1	3	14	2	4	4	4	4	2	3	2	4	0	6	6	2	2	23.75	5	3	1	1	3	1	2	3	4	0	4	1	1
Lycoperdon perlatum	1	3	14	2	4	4	4	4	3	3	2	4	0	6	4	2	2	18.75	5	3	1	1	3	1	2	3	4	0	4	1	1
Lycoperdon pyriforme	1	3	11	2	4	4	4	4	3	3	2	4	0	6	4	2	2	20	5	1	1	1	3	1	2	3	4	0	4	1	1
Lyomyces sambuci	1	1	15	3	2	4	1	4	3	1	2	2	1	5	3	1	1	17.25	3	1	1	1	3	1	2	3	1	2	4	1	1
Lyophyllum decastes	1	3	35	2	5	3	5	4	3	3	2	4	0	2	2	3	3	28.75	5	1	1	1	3	1	2	3	4	0	4	1	1
Lyophyllum fumosum	1	3	22.5	2	5	3	5	4	2	3	2	4	0	2	2	3	3	28.75	5	1	1	1	3	1	2	3	4	0	4	1	1
Lyophyllum gangraenosum	1	3	25	2	5	3	5	4	2	3	2	2	2	2	2	3	3	21	3	2	1	1	3	1	2	3	3	2	4	1	1
Lyophyllum ozes	1	3	11.25	2	5	3	5	4	2	3	2	2	1	2	2	3	3	19.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Lyophyllum putidum	1	3	22.5	2	5	3	5	4	2	3	2	4	0	2	2	3	3	16.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Lyophyllum rancidum	1	3	15	2	5	3	5	4	2	3	2	4	0	2	2	3	3	23.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Macrocystidia cucumis	1	3	15	2	5	3	5	4	3	3	2	4	0	2	2	3	3	24.75	3	1	1	2	3	1	2	3	1	2	1	1	1
Macrolepiota excoriata	1	3	42.5	2	5	3	5	3	3	5	2	4	0	2	2	3	3	42	3	1	1	2	1	1	2	3	3	1	4	1	3
Macrolepiota procera* var. *fuliginosa	1	3	70	2	5	3	5	3	3	3	2	4	0	2	2	3	3	32	2	1	1	2	1	1	2	3	3	1	4	1	3
Macrolepiota procera* var. *p.	1	3	100	2	5	3	5	3	3	3	2	4	0	2	2	3	3	30.5	2	1	1	2	1	1	2	3	3	1	4	1	3
***Macrolepiota rachodes* s. str.**	1	3	57.5	2	5	3	5	3	3	3	2	4	0	2	2	3	3	22	2	1	1	2	1	1	2	3	3	2	4	1	2
Macrotyphula fistulosa	1	3	75	2	2	4	3	4	3	3	2	2	1	5	6	1	2	49.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Marasmiellus perforans	2	3	5	3	5	4	5	4	3	3	2	2	2	2	3	3	2	25.5	3	1	1	1	3	1	2	3	1	2	4	1	1
Marasmiellus ramealis	1	3	6.25	2	5	4	5	4	3	3	2	2	1	2	3	3	2	27.75	3	1	1	1	3	1	2	3	3	2	4	1	1
Marasmius alliaceus	1	3	11.25	2	5	4	5	4	3	3	2	2	2	2	2	3	3	27.75	3	1	1	1	3	1	2	3	1	2	4	1	1
Marasmius androsaceus	1	3	45	3	5	4	5	4	3	3	2	2	1	2	3	3	2	21.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Marasmius bulliardii	2	3	27.5	3	5	4	5	4	3	3	2	2	2	2	3	3	2	26.25	3	1	1	1	3	1	2	3	3	2	4	1	1
Marasmius cohaerens	1	3	11.25	2	5	4	5	4	3	3	2	2	1	2	3	3	3	27.75	3	1	1	1	3	1	2	3	1	3	1	1	1
Marasmius limosus	1	3	1.15	2	5	4	5	4	3	3	2	2	2	2	3	3	2	27	3	1	1	1	3	1	3	3	3	2	4	1	1
Marasmius oreades	1	3	15	2	5	3	5	4	3	3	2	4	0	2	2	3	3	28.5	3	1	1	1	3	1	2	3	4	0	3	1	1
Marasmius rotula	2	3	6	3	5	4	5	4	3	3	2	2	1	2	3	3	2	23.25	3	1	1	1	3	1	2	3	1	2	4	1	1
Marasmius scorodonius	1	3	6.25	2	5	4	5	4	3	3	2	2	1	2	3	3	3	25.5	3	1	1	1	3	1	2	3	3	3	4	1	1
Marasmius wettsteinii	2	3	1.4	3	5	4	5	4	3	3	2	2	2	2	3	3	2	30	3	1	1	1	3	1	2	3	3	2	4	1	1
Marasmius wynnei	1	3	15	2	5	4	5	4	3	3	2	2	1	2	2	3	3	22.5	3	1	1	1	3	1	2	3	3	3	4	1	1
***Melanoleuca brevipes* s. str.**	1	3	35	2	5	3	5	4	3	5	2	4	0	2	2	3	3	25.5	3	2	1	1	3	1	2	3	3	5	3	1	3
Melanoleuca grammopus	1	3	50	2	5	3	5	4	3	3	2	4	0	2	2	3	3	26.25	3	2	1	1	3	1	2	3	3	5	4	1	3
Melanoleuca kuehneri	1	3	22.5	2	5	3	5	4	3	3	2	4	0	2	2	3	3	25.5	3	2	1	1	3	1	2	3	1	5	3	1	3
Melanoleuca polioleuca	1	3	25	2	5	3	5	4	2	3	2	4	0	2	2	3	3	22.5	3	2	1	1	3	1	2	3	1	5	3	1	3
Melanoleuca stridula	1	3	16.25	2	5	3	5	4	3	3	2	4	0	2	2	3	3	21	3	2	1	1	3	1	2	3	4	0	4	1	3
Meripilus giganteus	1	2	250	3	2	4	5	4	2	3	2	2	2	1	1	2	3	19.5	3	1	1	1	3	1	2	3	4	0	4	1	3
Meruliopsis corium	1	1	9	3	3	4	1	4	3	1	2	2	1	4	3	1	1	12	2	1	1	1	3	1	2	3	4	0	4	1	3
Merulius tremellosus	1	2	10	3	3	4	1	4	3	1	2	2	1	2	1	1	1	8	2	1	1	1	3	1	2	3	1	2	4	1	1
Morchella esculenta	1	3	10	2	5	3	2	4	3	5	?1	4	?2	2	2	2	2	63	3	1	1	1	3	1	2	3	4	0	4	1	2
Mucronella bresadolae	1	2	3	2	3	4	1	4	3	3	2	5	1	3	4	1	1	20.25	3	2	1	1	3	1	2	3	1	4	4	1	1
Mycena abramsii	1	3	10	2	5	4	5	4	3	5	2	2	1	2	2	3	3	20.5	2	1	1	1	3	1	2	3	1	2	4	1	1

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Mycena acicula	1	3	22.5	2	5	4	5	4	3	3	2	2	1	2	3	3	2	20	2	1	1	1	3	1	2	3	1	2	4	1	1
Mycena aetites	1	3	8.75	2	5	3	5	4	3	3	2	4	0	2	3	3	3	27.75	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena aurantiomarginata	1	3	7.5	2	5	4	5	4	4	3	2	2	2	2	2	3	3	26.25	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena capillaripes	1	3	8.75	2	5	4	5	4	3	3	2	2	2	2	3	3	2	30	3	1	1	1	3	1	2	3	1	2	3	1	1
Mycena cinerella	1	3	4.75	2	5	4	5	4	3	3	2	4	0	2	3	3	3	32.25	3	1	1	1	3	1	2	3	3	2	4	1	1
Mycena crocata	1	3	75	2	5	4	5	4	3	3	2	2	1	2	2	3	3	22.5	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena diosma	1	3	15	2	5	3	5	4	3	3	2	2	3	2	2	3	3	25.5	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena epipterygia	1	3	10	2	5	4	5	4	3	3	2	2	1	2	3	3	3	27	3	1	1	1	3	1	2	3	3	2	4	1	1
Mycena filopes	1	3	6.25	2	5	4	5	4	3	3	2	2	1	2	3	3	2	27	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena flavescens	2	3	5.5	2	5	4	5	4	4	3	2	4	0	2	3	3	3	30	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena flavoalba	2	3	6.25	2	5	4	5	4	3	3	2	2	1	2	3	3	3	21.75	3	1	1	1	3	1	2	3	1	2	3	1	1
Mycena galericulata	1	3	13.75	2	5	4	5	4	3	3	2	2	1	2	2	3	3	31.5	3	1	1	1	3	1	3	3	3	2	4	1	3
Mycena galopus	1	3	7.5	2	5	4	5	4	3	3	2	2	1	2	2	3	3	33	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena haematopus	1	3	10	2	5	4	5	4	3	3	2	2	1	2	2	3	3	27	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena hiemalis	1	3	30	2	5	4	5	4	3	3	2	2	2	2	3	3	3	24	3	1	1	1	3	1	3	3	3	2	4	1	3
Mycena inclinata	1	3	11.25	2	5	4	5	4	3	3	2	2	2	2	2	3	3	27	3	1	1	1	3	1	2	3	3	2	4	1	1
Mycena leptocephala	1	3	6.75	2	5	4	5	4	3	3	2	2	1	2	3	3	3	28.5	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena metata	1	3	7.5	2	5	4	5	4	3	3	2	2	1	2	3	3	3	28.5	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena mirata	1	3	2	2	5	4	5	4	3	3	2	2	1	2	3	3	3	30	3	1	1	1	3	1	3	3	3	2	4	1	1
Mycena niveipes	1	3	18.75	2	5	4	5	4	3	3	2	2	1	2	3	3	3	27	3	1	1	1	3	1	2	3	3	2	3	1	1
Mycena olida	1	3	4.25	2	5	4	5	4	3	3	2	2	1	2	2	3	3	22.5	3	1	1	1	3	1	3	3	3	2	3	1	3
Mycena pearsoniana	1	3	7.25	2	5	3	5	4	4	3	2	2	2	2	2	3	3	20.25	3	1	1	1	3	1	2	3	3	2	4	1	1
Mycena polyadelpha	2	3	1.25	2	5	4	5	4	3	3	2	2	2	2	3	3	3	28.5	3	1	1	1	3	1	2	3	3	2	3	1	3
Mycena polygramma	1	3	12.5	2	5	4	5	4	2	3	2	2	2	2	2	3	3	27	3	1	1	1	3	1	2	3	3	2	3	1	1
Mycena pseudocorticola	1	3	2.5	2	5	2	5	4	4	3	2	2	2	2	3	3	2	57.5	5	1	1	1	3	1	2	3	3	2	4	1	1
Mycena pura	1	3	15	2	5	3	5	4	4	3	2	4	0	2	2	3	3	19.5	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena rosea	1	3	21.25	2	5	3	5	4	4	3	2	2	3	2	2	3	3	24	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena rubromarginata	1	3	7.5	2	5	4	5	4	3	3	2	2	2	2	2	3	3	30	3	1	1	1	3	1	2	3	3	2	4	1	1
Mycena sanguinolenta	1	3	5	2	5	4	5	4	2	3	2	2	1	2	2	3	3	25.5	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena speirea	1	3	3	2	5	4	5	4	2	3	2	2	1	2	3	3	3	24.75	3	1	1	1	3	1	2	3	3	2	3	1	1
Mycena stipata	1	3	11.25	2	5	4	5	4	3	3	2	2	2	2	2	3	3	30	3	1	1	1	3	1	2	3	1	2	4	1	1
Mycena tintinabulum	1	3	10	2	5	4	5	4	2	3	2	2	1	2	2	3	3	13.5	3	1	1	1	3	1	2	3	3	2	4	1	1
Mycena vitilis	1	3	6.25	2	5	4	5	4	3	3	2	2	1	2	3	3	3	29.25	3	1	1	1	3	1	2	3	3	2	4	1	3
Mycena zephirus	1	3	12.5	2	5	4	5	4	3	3	2	2	2	2	2	3	3	20	2	1	1	1	3	1	2	3	1	2	3	1	1
Naucoria bohemica	1	3	102.5	2	5	3	5	3	3	3	1	4	2	2	2	3	3	36	3	3	´2	1	3	1	3	3	3	2	3	1	3
Naucoria melinoides	1	3	8.75	2	5	3	5	3	3	3	1	4	3	2	2	3	3	31.5	3	3	2	1	3	1	2	3	3	2	3	1	1
Naucoria scolenica	1	3	8.75	2	5	3	5	3	3	3	1	4	3	2	2	3	3	36.75	3	2	2	1	3	1	2	3	3	2	3	1	1
Naucoria striatula	1	3	8.75	2	5	3	5	3	3	3	1	4	3	2	2	3	3	33.75	3	2	2	1	3	1	2	3	3	2	3	1	1
Nectria cinnabarina	1	2	0.2	1	2	4	4	4	4	3	1	2	1	6	8	2	1	48	3	1	1	1	3	1	2	2	4	0	4	1	3
Nectria episphaeria	1	2	0.08	1	2	4	4	4	4	3	3	2	2	6	8	2	1	25.5	3	1	2	1	3	1	2	3	4	0	4	1	3
Oligoporus caesius	1	2	25	2	5	4	5	4	4	3	2	2	2	1	2	2	2	9	2	1	1	1	3	1	2	3	4	0	4	1	1
Oligoporus fragilis	1	2	30	2	5	4	5	4	3	3	2	2	2	1	2	2	2	10	2	1	1	1	3	1	2	3	4	0	4	1	1
Oligoporus guttulatus	1	2	57.5	3	5	4	5	4	3	3	2	2	2	1	2	2	2	9	2	1	1	1	3	1	2	3	4	0	4	1	1
Oligoporus ptychogaster	1	2	12.5	3	5	4	5	4	3	3	2	2	2	1	2	2	2	14.25	3	1	1	1	3	1	2	1	4	0	4	1	1

Table 12 ***continued***

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Oligoporus stipticus	1	2	25	2	5	4	5	4	3	3	2	2	2	1	2	2	2	9	2	1	1	1	3	1	2	3	4	0	4	1	1
Oligoporus subcaesius	1	2	40	2	5	4	5	4	3	3	2	2	1	1	2	2	2	9	2	1	1	1	3	1	2	3	4	0	4	1	1
Omphalina pyxidata	1	3	8.75	2	5	3	5	4	2	5	2	4	0	2	3	3	3	22.5	3	1	1	1	3	1	2	3	3	2	4	1	1
Orbilia delicatula	1	3	0.16	1	5	4	2	4	3	3	2	2	1	5	12	1	1	11	4	1	1	1	3	1	2	3	4	0	4	1	2
Orbilia xanthostigma	1	3	0.2	1	5	4	2	4	3	3	2	2	1	5	12	1	1	14	4	1	1	1	3	1	2	3	4	0	4	1	2
Otidea alutacea	1	3	6	2	5	3	2	4	3	3	2	4	0	5	6	2	2	45	3	1	1	1	3	1	2	3	4	0	4	1	3
Otidea onotica	1	3	8	2	5	3	2	4	3	3	2	4	0	5	6	2	2	37.5	3	1	1	1	3	1	2	3	4	0	4	1	3
Otidea umbrina	1	3	6	2	5	3	2	4	2	3	2	4	0	5	6	2	2	46.5	3	1	1	1	3	1	2	3	4	0	4	1	3
Oudemansiella mucida	1	3	23.75	2	5	4	5	3	3	3	2	2	2	2	2	3	3	80	5	1	1	2	3	1	2	3	1	3	4	1	1
Oxyporus corticola	1	1	130	3	1	2	5	4	3	1	2	2	2	1	2	2	2	11	2	1	2	1	3	1	2	3	1	5	4	1	3
Panaeolus fimicola	2	3	8.75	2	5	3	5	3	2	3	2	4	0	2	2	3	3	39	3	1	3	2	1	1	2	3	3	2	2	1	1
Panaeolus foenisecii	1	3	12.5	2	5	3	5	3	3	3	2	4	0	2	2	3	3	46.5	3	3	3	2	1	1	2	3	3	2	3	1	3
Panaeolus papillionaceus	2	3	15	2	5	3	5	3	3	3	2	4	0	2	2	3	3	49.5	3	1	3	2	1	1	2	3	3	2	1	1	3
Panaeolus reticulatus	1	3	10	2	5	3	5	3	3	3	2	4	0	2	2	3	3	29.25	3	1	3	2	1	1	2	3	3	2	1	1	3
Panellus mitis	1	3	7.5	1	4	4	5	4	3	2	2	2	2	2	3	2	2	19	4	1	1	1	3	1	2	3	4	0	4	1	1
Panellus serotinus	1	3	32.5	1	4	4	5	4	3	2	2	2	2	2	3	2	2	21	4	1	1	1	3	1	2	3	1	2	3	1	1
Panellus stipticus	1	3	8.75	1	4	4	5	4	3	2	2	2	2	2	3	2	2	13.5	3	1	1	1	3	1	2	3	3	2	4	1	1
Paxillus filamentosus	1	3	32.5	2	5	3	5	4	3	3	1	2	3	2	2	3	3	21	3	1	3	1	3	1	2	3	1	2	4	1	1
***Paxillus involutus* s. str.**	1	3	47.5	2	5	3	5	4	3	3	1	2	1	2	2	3	3	27	3	1	2	1	3	1	2	3	1	2	4	1	1
Peniophora incarnata	1	1	10	3	2	4	1	4	4	1	2	2	1	5	3	1	1	20	2	1	1	1	3	1	2	3	1	5	4	1	1
Peziza badia	2	3	11	2	5	3	2	4	2	5	2	4	0	5	6	2	2	54.75	3	6	1	1	3	1	2	3	4	0	4	1	3
Peziza succosa	2	3	8	2	5	3	2	4	2	5	2	4	0	5	6	2	2	61.5	3	3	1	1	3	1	2	3	4	0	4	1	3
Phaeolus spadiceus	1	2	100	3	1	4	5	4	2	3	2	2	2	1	2	2	3	19.5	3	1	2	1	3	1	2	3	1	5	4	1	3
Phallus impudicus	1	3	20	2	5	5	4	4	3	3	2	4	0	6	2	2	3	8.5	2	1	2	1	3	3	2	3	4	0	4	1	1
Phanerochaete sanguinea	1	1	8	3	2	3	1	4	4	1	2	2	2	5	3	1	1	10.5	2	1	1	1	3	1	2	3	1	2	4	1	3
Phellinus ferruginosus	1	1	25	3	1	2	1	4	2	1	2	2	1	1	1	1	2	9	2	1	1	1	3	1	2	3	1	3	4	2	3
***Phellinus igniarius* s. str.**	1	1	52.5	3	1	2	5	4	2	1	2	2	2	1	1	2	2	31.25	5	1	1	2	3	1	2	3	1	3	4	2	3
Phellinus punctatus	1	1	25	3	1	4	1	4	2	1	2	2	1	1	1	1	2	35	5	1	2	2	3	1	2	3	4	0	4	2	3
Phlebia radiata	1	2	7	3	3	4	1	4	4	1	2	2	1	2	2	1	1	19	4	1	1	1	3	1	2	3	1	2	4	1	1
Phlebia rufa	1	2	7	3	3	4	1	4	4	1	2	2	1	2	2	1	1	10.5	2	1	1	1	3	1	2	3	1	2	4	1	1
Pholiota alnicola	1	3	25	2	5	2	5	3	4	3	2	2	2	2	2	3	3	26.25	3	1	2	1	1	1	2	3	3	2	4	1	1
Pholiota flammans	1	3	25	2	5	4	5	3	4	3	2	2	2	2	2	3	3	13.5	3	1	2	1	2	1	2	3	1	4	4	1	1
Pholiota flavida	1	3	25	2	5	2	5	3	4	3	2	2	2	2	2	3	3	26.25	3	1	2	1	1	1	2	3	1	2	4	1	1
Pholiota lenta	1	3	27.5	2	5	4	5	3	3	3	2	2	1	2	2	3	3	21	3	1	2	2	3	1	2	3	1	2	4	1	1
Pholiota lucifera	1	3	26.25	2	5	2	5	3	4	3	2	2	1	2	2	3	3	24	3	1	2	2	3	1	2	3	3	2	4	1	1
Pholiota mutabilis	1	3	20	2	5	4	5	3	4	3	2	2	2	2	2	3	3	20.25	3	1	2	1	1	1	2	3	3	2	4	1	1
Pholiota squarrosa	1	3	60	2	5	4	5	3	3	3	2	2	1	2	2	3	3	21	3	1	2	1	1	1	2	3	1	4	4	1	1
Phylloporus pelletieri	1	3	27.5	2	5	3	5	4	3	3	1	4	2	2	2	3	3	24	2	1	2	1	3	1	2	3	1	2	3	1	3
Phyllotopsis nidulans	1	2	25	2	5	2	5	4	4	2	2	2	1	2	2	2	2	20	4	1	1	1	3	1	2	3	4	0	4	1	1
Physisporinus vitreus	1	2	20	3	4	4	1	4	3	1	2	2	1	1	2	1	1	23.75	5	1	1	1	3	1	2	3	1	5	4	1	3
Piptoporus betulinus	1	1	5	2	1	4	5	4	2	1	2	2	3	1	1	2	2	6	2	1	1	1	3	1	2	3	1	2	4	3	1
Pleurotus ostreatus	1	3	50	2	5	2	5	4	3	4	2	1	2	2	2	2	2	19.5	2	1	1	1	3	1	2	3	4	0	4	1	1
Plicatura crispa	1	2	3	1	4	2	2	4	3	5	2	2	1	2	3	2	2	7.5	2	1	1	1	3	1	2	3	4	0	4	1	1
Pluteus cervinus	1	3	42.5	2	5	4	5	4	3	3	2	2	1	2	2	3	3	21.75	3	1	2	1	3	1	2	3	1	3	4	1	3

Table 12 ***continued***

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Pluteus pellitus	1	3	27.5	2	5	4	5	4	3	3	2	2	3	2	2	3	3	23.25	3	1	2	1	3	1	2	3	1	3	4	1	3
Pluteus plautus	1	3	16.25	2	5	4	5	4	3	3	2	2	2	2	2	3	3	30	5	1	2	1	3	1	2	3	1	2	4	1	3
Pluteus podospileus	1	3	9.5	2	5	4	5	4	1	3	2	2	1	2	2	3	3	32.5	5	1	2	1	3	1	2	3	1	2	4	1	3
Pluteus romellii	1	3	17.5	2	5	4	5	4	3	3	2	2	1	2	2	3	3	33.75	5	1	2	1	3	1	2	3	1	2	4	1	3
Pluteus thomsonii	1	3	9.5	2	5	4	5	4	1	3	2	2	1	2	2	3	3	41.25	5	1	2	1	3	1	2	3	1	2	4	1	3
Polyporus alveolaris	1	2	22.5	2	2	1	5	4	3	5	2	2	2	1	2	2	2	28.5	3	1	1	1	3	1	2	3	4	0	4	2	3
Polyporus arcularius	1	2	12.5	3	2	4	5	4	3	5	2	2	2	1	2	3	3	24	3	1	1	1	3	1	2	3	4	0	4	2	1
Polyporus brumalis	1	2	22.5	3	2	4	5	4	3	4	2	2	1	1	2	3	3	12	2	1	1	1	3	1	2	3	4	0	4	2	1
Polyporus ciliatus	1	2	32.5	3	2	4	5	4	3	5	2	2	1	1	2	3	3	12.5	2	1	1	1	3	1	2	3	4	0	4	2	1
Polyporus leptocephalus	1	2	20	3	2	4	5	4	4	5	2	2	1	1	3	3	3	15.5	2	1	1	1	3	1	2	3	4	0	4	2	1
Porostereum spadiceum	1	1	18	3	2	4	2	4	2	1	2	2	1	5	6	1	1	19.5	3	1	1	1	3	1	2	3	1	5	4	2	1
Porphyrellus porphyrosporus	1	3	50	2	5	3	5	4	2	3	1	4	2	1	2	3	3	31	2	1	2	2	3	1	2	3	1	2	4	1	3
Psathyrella candolleana	1	3	25	2	5	3	5	3	3	3	2	2	1	2	2	3	3	24.75	3	1	2	1	1	1	2	3	3	2	4	1	2
Psathyrella conopilus	2	3	17.5	2	5	3	5	3	3	3	2	2	1	2	2	3	3	45.75	3	1	3	1	1	1	2	3	3	2	2	1	3
Psathyrella piluliformis	1	3	25	2	5	4	5	3	3	3	2	2	1	2	2	3	3	16.5	3	1	2	1	2	1	2	3	1	2	4	1	3
***Psathyrella prona* s. lat.**	1	3	8.75	2	5	3	5	3	3	3	2	2	1	2	2	3	3	44.25	3	1	3	1	1	1	2	3	1	2	4	1	2
Psathyrella spadiceogrisea	1	3	22.5	2	5	3	5	3	3	5	2	2	2	2	2	3	3	24.75	3	1	3	1	2	1	2	3	1	2	4	1	2
Pseudoclitocybe cyathiformis	1	3	32.5	2	5	4	5	4	1	4	2	2	1	2	2	3	3	30	3	1	1	1	3	1	2	3	4	0	4	1	3
Pseudohydnum gelatinosum	1	3	9	2	5	4	2	4	3	4	2	2	2	3	2	2	2	33.75	5	1	1	1	3	1	2	3	4	0	4	1	1
Psilocybe montana	1	3	5	2	5	3	5	3	2	3	2	4	0	2	3	3	3	24	3	1	2	2	1	1	2	3	3	2	4	1	2
Psilocybe semilanceata	1	3	8.75	2	5	3	5	3	2	3	2	4	0	2	3	3	3	36.75	3	1	2	2	1	1	2	3	3	2	4	1	1
Pycnoporus cinnabarinus	1	2	30	2	1	2	5	4	4	1	2	2	1	1	2	2	2	11	2	1	1	1	3	1	2	3	4	0	4	3	1
Radulomyces confluens	1	1	5	3	2	4	1	4	3	1	2	2	1	3	2	1	1	27	3	1	1	2	3	1	2	3	4	0	4	1	1
Radulomyces molaris	1	1	5	3	2	4	1	4	3	1	2	2	2	3	2	1	1	30	3	1	1	2	3	1	2	3	4	0	4	1	1
Ramaria gracilis	1	3	16.5	2	4	4	3	4	3	3	2	2	2	2	2	1	2	18	3	2	3	1	3	1	2	3	4	0	4	1	1
Ramaria myceliosa	1	3	9.75	2	4	4	3	4	3	3	2	2	2	2	2	1	2	15	3	4	3	1	3	1	2	3	4	0	4	1	1
Ramaria stricta	1	3	21	2	4	4	3	4	3	3	2	2	1	2	2	1	2	25.5	3	2	3	1	3	1	2	3	4	0	4	1	1
Resupinatus applicatus	1	3	1	2	5	2	2	4	2	3	2	2	1	2	4	1	1	25	5	1	1	1	3	1	2	3	4	0	4	1	1
Rhizopogon roseolus	1	3	10	2	5	5	4	4	2	1	1	2	2	6	6	2	2	30	3	1	2	1	3	3	2	3	4	0	4	1	1
Rhodocollybia butyracea	1	3	27.5	2	5	3	5	4	3	3	2	4	0	2	2	3	3	22.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Rhodocollybia butyracea* f. *asema	1	3	25	2	5	3	5	4	3	3	2	4	0	2	2	3	3	24.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Rhodocollybia maculata	1	3	35	2	5	3	5	4	3	3	2	4	0	2	2	3	3	18	5	1	1	1	3	1	2	3	3	2	4	1	1
Rhodocollybia prolixa	1	3	38.75	2	5	3	5	4	3	3	2	2	2	2	2	3	3	15	3	1	1	1	3	1	2	3	4	0	4	1	1
Rhodocybe gemina	1	3	32.5	2	5	3	5	4	2	5	2	4	0	2	2	3	3	17.25	3	3	2	1	3	1	2	3	1	2	4	1	3
Rhodocybe nitellina	1	3	8.75	2	5	3	5	4	4	3	2	4	0	2	2	3	3	22.5	3	3	2	1	3	1	2	3	4	0	4	1	1
Rhodocybe popinalis	1	3	25	2	5	3	5	4	3	3	2	4	0	2	2	3	3	28.75	5	3	1	1	3	1	2	3	4	0	4	1	3
Rickenella fibula	1	3	4.5	2	5	4	5	4	4	2	4	1	2	2	3	3	3	12.5	2	1	1	1	3	1	2	3	1	2	1	1	1
Rickenella swartzii	1	3	4.75	2	5	4	5	4	3	2	4	1	2	2	3	3	3	18	3	1	1	1	3	1	2	3	1	2	1	1	1
Rimbachia arachnoidea	1	3	2	2	4	4	2	4	3	3	4	1	2	4	12	2	1	22.5	5	1	1	1	3	1	2	3	4	0	4	1	1
Ripartites tricholoma	1	3	20	2	5	3	5	4	2	3	2	4	0	2	2	3	3	14.25	3	3	2	1	3	1	2	3	4	0	4	1	1
Russula adusta	1	3	47.5	2	5	3	5	4	2	3	1	4	2	2	2	3	3	24.75	3	6	1	1	3	1	2	3	1	2	2	2	3

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Russula aeruginea	1	3	32.5	2	5	3	5	4	4	3	1	4	2	2	2	3	3	23.25	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula alnetorum	1	3	16.25	2	5	3	5	4	4	3	1	4	3	2	2	3	3	28.5	3	6	1	1	3	1	2	3	1	2	2	2	3
Russula amara	1	3	27.5	2	5	3	5	4	4	3	1	4	3	2	2	3	3	25.5	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula atrorubens	1	3	30	2	5	3	5	4	4	3	1	4	2	2	2	3	3	21	3	6	1	1	3	1	2	3	1	2	2	2	3
Russula azurea	1	3	27.5	2	5	3	5	4	4	3	1	4	2	2	2	3	3	27	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula badia	1	3	45	2	5	3	5	4	4	3	1	4	2	2	2	3	3	28.5	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula cyanoxantha	1	3	50	2	5	3	5	4	4	3	1	4	1	2	2	3	3	24	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula decolorans	1	3	35	2	5	3	5	4	4	3	1	4	2	2	2	3	3	34.5	3	4	1	1	3	1	2	3	1	2	2	2	3
Russula densifolia	1	3	30	2	5	3	5	4	2	3	1	4	2	2	2	3	3	21.75	3	5	1	1	3	1	2	3	1	2	2	2	3
***Russula emetica* s. str.**	1	3	30	2	5	3	5	4	4	3	1	4	2	2	2	3	3	28.5	3	4	1	1	3	1	2	3	1	2	2	2	3
Russula fellea	1	3	27.5	2	5	3	5	4	3	3	1	4	2	2	2	3	3	24.75	3	5	1	1	3	1	2	3	1	2	2	2	3
***Russula foetens* s. str.**	1	3	52.5	2	5	3	5	4	2	3	1	4	1	2	2	3	3	43.75	5	4	1	1	3	1	2	3	1	2	2	2	3
Russula fragilis	1	3	20	2	5	3	5	4	4	3	1	4	2	2	2	3	3	41.25	5	6	1	1	3	1	2	3	1	2	2	2	3
Russula grata	1	3	37.5	2	5	3	5	4	2	3	1	4	2	2	2	3	3	26.25	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula mairei	1	3	22.5	2	5	3	5	4	4	3	1	4	3	2	2	3	3	21.75	3	6	1	1	3	1	2	3	1	2	2	2	3
Russula nigricans	1	3	65	2	5	3	5	4	2	3	1	4	1	2	2	3	3	21.75	3	6	1	1	3	1	2	3	1	2	2	2	3
Russula ochroleuca	1	3	42.5	2	5	3	5	4	4	3	1	4	1	2	2	3	3	27	3	4	1	1	3	1	2	3	1	2	2	2	3
Russula olivacea	1	3	52.5	2	5	3	5	4	4	3	1	4	2	2	2	3	3	28.5	3	4	1	1	3	1	2	3	1	2	2	2	3
Russula paludosa	1	3	47.5	2	5	3	5	4	4	3	1	4	2	2	2	3	3	28.5	3	6	1	1	3	1	2	3	1	2	2	2	3
Russula puellaris	1	3	21.25	2	5	3	5	4	4	3	1	4	2	2	2	3	3	38.75	5	5	1	1	3	1	2	3	1	2	2	2	3
Russula queletii	1	3	25	2	5	3	5	4	4	3	1	4	2	2	2	3	3	41.25	5	4	1	1	3	1	2	3	1	2	2	2	3
Russula rhodopus	1	3	37.5	2	5	3	5	4	4	3	1	4	2	2	2	3	3	41.25	5	5	1	1	3	1	2	3	1	2	2	2	3
Russula rosea	1	3	40	2	5	3	5	4	4	3	1	4	2	2	2	3	3	25.5	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula sanguinaria	1	3	37.5	2	5	3	5	4	4	3	1	4	2	2	2	3	3	23.25	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula sylvestris	1	3	18.75	2	5	3	5	4	4	3	1	4	2	2	3	3	3	25.5	3	6	1	1	3	1	2	3	1	2	2	2	3
Russula turci	1	3	35	2	5	3	5	4	4	3	1	4	2	2	2	3	3	24.75	3	6	1	1	3	1	2	3	1	2	2	2	3
Russula variegatula	1	3	30	2	5	3	5	4	3	3	1	4	3	2	2	3	3	21	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula velenovskyi	1	3	27.5	2	5	3	5	4	4	3	1	4	2	2	2	3	3	23.25	3	4	1	1	3	1	2	3	1	2	2	2	3
Russula velutipes	1	3	35	2	5	3	5	4	4	3	1	4	2	2	2	3	3	21	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula vesca	1	3	37.5	2	5	3	5	4	3	3	1	4	1	2	2	3	3	21.75	3	3	1	1	3	1	2	3	1	2	2	2	3
Russula vinosa	1	3	40	2	5	3	5	4	4	3	1	4	2	2	2	3	3	30	3	4	1	1	3	1	2	3	1	2	2	2	3
Russula virescens	1	3	37.5	2	5	3	5	4	4	3	1	4	1	2	2	3	3	22.5	3	3	1	1	3	1	2	3	1	2	2	2	3
Russula viscida	1	3	30	2	5	3	5	4	4	3	1	4	2	2	2	3	3	28.5	3	5	1	1	3	1	2	3	1	2	2	2	3
Russula xerampelina	1	3	45	2	5	3	5	4	4	3	1	4	2	2	2	3	3	27	3	5	1	1	3	1	2	3	1	2	2	2	3
Rutstroemia echinophila	2	3	1.8	2	5	4	2	4	2	3	2	2	2	5	12	2	2	66	4	1	1	1	3	1	2	3	4	0	4	1	2
Sarcodon imbricatus	1	3	60	2	4	3	5	4	2	3	1	4	2	3	2	3	3	23.1	3	3	3	2	3	1	2	3	4	0	4	1	1
Schizophyllum commune	1	2	5	2	4	4	2	4	3	1	2	2	1	2	3	2	2	9	2	1	1	1	3	1	2	3	4	0	4	1	1
Schizopora flavipora	1	2	12	3	2	4	1	4	3	1	2	2	1	1	2	1	2	12	3	1	1	1	3	1	2	3	4	0	4	2	1
Schizopora paradoxa	1	1	25	3	2	4	1	4	3	1	2	2	1	3	2	1	2	18	3	1	1	1	3	1	2	3	4	0	4	2	1
Schizopora radula	1	1	25	3	2	4	1	4	3	1	2	2	1	3	2	1	2	14.25	3	1	1	1	3	1	2	3	4	0	4	2	1
Scleroderma areolatum	1	3	10	2	4	3	4	4	2	3	1	4	2	6	4	2	2	57.5	5	4	3	1	3	1	2	3	4	0	4	1	3
Scleroderma citrinum	1	3	30	2	4	3	4	4	4	3	1	4	2	6	4	2	2	52.5	5	6	3	1	3	1	2	3	4	0	4	1	1
Scutellinia scutellata	1	3	1.8	2	5	4	2	4	4	3	3	1	2	5	12	2	2	60.75	3	2	1	1	3	1	2	3	4	0	4	1	3
Scutellinia subhirtella	2	3	1	2	5	4	2	4	4	3	3	1	2	5	12	2	2	61.5	3	2	1	1	3	1	2	3	4	0	4	1	3

Table 12 *continued*

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Serpula himantoides	1	2	25	3	3	4	1	4	2	1	2	2	2	2	2	1	1	30	3	1	3	2	3	1	2	3	4	0	4	2	1
Simocybe centunculus	1	3	6.25	2	5	4	5	4	2	3	2	2	2	2	3	3	3	21.75	3	1	2	2	3	1	2	3	3	2	1	1	1
Simocybe haustellaris	1	3	2.2	2	5	4	2	4	2	3	2	2	1	2	4	2	2	25.5	3	1	2	2	3	1	2	3	3	2	1	1	1
Sistotrema confluens	1	2	7	2	2	3	5	4	3	5	1	4	2	3	3	2	2	12.75	3	1	1	1	3	1	1	3	4	0	4	1	1
Skeletocutis amorpha	1	1	16	3	2	4	2	4	3	1	2	2	2	1	2	1	2	8	2	1	1	1	3	1	2	3	1	2	4	2	1
Skeletocutis nivea	1	1	3	3	2	4	1	4	3	1	2	2	1	1	2	1	2	7	2	1	1	1	3	1	2	3	1	2	4	3	1
Skeletocutis subincarnata	1	1	20	3	2	4	2	4	3	1	2	2	2	1	2	1	2	10.5	2	1	1	1	3	1	2	3	1	2	4	2	1
Sparassis crispa	1	3	54	2	5	3	3	4	3	3	3	1	2	2	1	1	2	17.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Steccherinum fimbriatum	1	1	4	3	2	4	1	4	3	1	2	2	1	3	2	1	1	10.95	3	1	1	1	3	1	2	3	1	5	4	2	1
Steccherinum ochraceum	1	1	8	3	2	4	2	4	3	1	2	2	1	3	2	1	1	9.75	3	1	1	1	3	1	2	3	4	5	4	2	1
Stereum hirsutum	1	2	6	2	2	2	2	4	4	1	2	2	1	5	6	2	2	13	2	1	1	1	3	1	2	3	4	0	4	2	3
Stereum rameale	1	2	2	2	2	2	2	4	3	1	2	2	1	5	9	2	2	14.5	2	1	1	1	3	1	2	3	4	0	4	2	3
Stereum rugosum	1	2	10	2	2	2	1	4	2	1	2	2	1	5	6	1	1	19	2	1	1	1	3	1	2	3	4	0	4	2	3
Stereum sanguinolentum	1	2	10	2	2	2	2	4	2	1	2	2	2	5	6	2	2	33	3	1	1	1	3	1	2	3	4	0	4	2	3
Stereum subtomentosum	1	2	12	2	2	2	2	4	4	1	2	2	1	5	6	2	2	12.5	2	1	1	1	3	1	2	3	1	3	4	2	3
Strobilomyces floccopus	1	3	52.5	2	5	3	5	3	2	3	1	4	2	1	2	3	2	55	5	6	3	1	3	1	2	3	1	2	4	1	3
Strobilurus esculentus	1	3	12.5	2	5	4	5	4	3	2	2	2	2	2	2	3	3	16.5	3	1	1	1	3	1	2	3	1	5	1	1	3
Strobilurus stephanocystis	1	3	8.75	2	5	4	5	4	3	2	2	2	3	2	2	3	3	18	3	1	1	1	3	1	2	3	1	5	1	1	3
Strobilurus tenacellus	1	3	8.75	2	5	4	5	4	3	2	2	2	3	2	2	3	3	15	3	1	1	1	3	1	2	3	1	5	1	1	3
Stropharia aeruginosa	1	3	22.5	2	5	3	5	3	4	3	2	4	0	2	2	3	3	24	3	1	2	2	1	1	2	3	1	4	4	1	1
Stropharia coronilla	1	3	15	2	5	3	5	3	4	3	2	4	0	2	2	3	3	24.75	3	1	2	2	1	1	2	3	1	4	4	1	1
Stropharia cyanea	1	3	32.5	2	5	3	5	3	4	3	2	4	0	2	2	3	3	25.5	3	1	2	2	1	1	2	3	1	4	4	1	1
Stropharia squamosa	1	3	18.75	2	5	3	5	3	4	3	2	4	0	2	2	3	3	36	3	1	2	2	1	1	2	3	3	2	4	1	1
Suillus fluryi	1	3	35	2	5	3	5	3	3	3	1	4	3	1	2	3	3	18	2	1	2	2	3	1	2	3	3	2	3	1	3
Suillus granulatus	1	3	25	2	5	3	5	3	3	3	1	4	3	1	2	3	3	18	2	1	2	2	3	1	2	3	1	2	3	1	3
Suillus grevillei	1	3	32.5	2	5	3	5	3	4	3	1	4	3	1	2	3	3	19	2	1	2	2	3	1	2	3	1	2	3	1	3
Suillus luteus	1	3	40	2	5	3	5	3	3	3	1	4	3	1	2	3	3	17	2	1	2	2	3	1	2	3	3	2	3	1	3
Suillus variegatus	1	3	47.5	2	5	3	5	3	3	3	1	4	3	1	2	3	3	18.5	2	1	2	2	3	1	2	3	1	2	3	1	3
Tapinella atrotomentosa	1	3	57.5	2	5	3	5	4	2	3	2	2	2	2	2	2	3	16.5	3	1	2	1	3	1	2	3	4	0	4	1	1
Thelephora palmata	1	3	21	2	2	3	3	4	2	3	1	4	2	2	2	1	2	30	3	4	3	1	3	1	2	3	4	0	4	1	1
Thelephora penicillata	1	3	7.5	2	2	3	3	4	2	3	1	4	2	2	2	1	2	25.5	3	4	3	1	3	1	2	3	4	0	4	1	1
Thelephora terrestris	1	3	10	2	2	3	2	4	2	3	1	4	2	2	2	2	2	30	3	4	3	1	3	1	2	3	4	0	4	1	1
Trametes gibbosa	1	1	62.5	2	1	2	5	4	3	1	2	2	1	1	2	2	2	13.5	3	1	1	1	3	1	2	3	4	0	4	3	1
Trametes hirsuta	1	1	35	2	2	2	5	4	3	1	2	2	1	1	2	2	2	12	2	1	1	1	3	1	2	3	4	0	4	3	1
Trametes multicolor	1	2	22.5	2	2	2	5	4	3	1	2	2	1	1	2	2	2	12.5	2	1	1	1	3	1	2	3	4	0	4	3	1
Trametes pubescens	1	1	27.5	2	2	2	5	4	3	1	2	2	1	1	2	2	2	12	2	1	1	1	3	1	2	3	4	0	4	3	1
Trametes versicolor	1	2	30	2	2	2	5	4	4	1	2	2	1	1	2	2	2	11	2	1	1	1	3	1	2	3	4	0	4	3	1
Trechispora hymenocystis	1	2	8	3	2	4	1	4	3	1	2	2	1	1	2	1	1	9.75	3	4	1	1	3	1	2	3	4	0	4	1	1
Tremella foliacea	1	3	15	2	3	2	2	4	3	3	2	2	1	2	2	1	2	30	3	1	1	1	3	1	2	3	4	0	4	1	1
Tremella mesenterica	1	3	10.5	2	3	2	2	4	4	3	2	2	1	2	2	1	2	25.5	3	1	1	1	3	1	2	3	4	0	4	1	1
Trichaptum abietinum	1	2	5	1	2	2	2	4	4	1	2	2	2	1	3	2	2	15	2	1	1	1	3	1	2	3	1	5	4	2	1
Tricholoma album **s. str.**	1	3	27.5	2	5	3	5	4	3	3	2	4	3	2	2	3	3	18	3	1	1	1	3	1	2	3	4	0	4	1	2
Tricholoma argyraceum	1	3	23.75	2	5	3	5	4	3	3	2	4	1	2	2	3	3	15	3	1	1	1	3	1	2	3	4	0	4	1	3
Tricholoma atrosquamosum	1	3	30	2	5	3	5	4	2	3	2	4	2	2	2	3	3	16.5	3	1	1	1	3	1	2	3	3	2	4	1	3

Table 12 ***continued***

Species	Mycel longv	Frb longv	Frb size	Frb nr	Frb consist	Frb locat	Frb type	Frb velum	Frb colour	Fruit season	Nutr type	Nutr subst	Subst nr	Hym type	Hym area	Surf index	Vol index	Sp size	Sp shape	Sp surf	Sp colour	Sp wall	Sp pore	Sp disp	Sp nr	Ana/Teleo	Cyst type H	Cyst form	Cyst type F	Hyph type	Hyph clamp
Tricholoma auratum	1	3	42.5	2	5	3	5	4	4	3	2	4	3	2	2	3	3	21	3	1	1	1	3	1	2	3	4	0	4	1	3
Tricholoma fulvum	1	3	37.5	2	5	3	5	4	2	3	2	4	3	2	2	3	3	17.25	3	1	1	1	3	1	2	3	4	0	4	1	3
Tricholoma saponaceum	1	3	32.5	2	5	3	5	4	3	3	2	4	1	2	2	3	3	15.75	3	1	1	1	3	1	2	3	4	0	4	1	1
Tricholoma stiparophyllum	1	3	35	2	5	3	5	4	3	3	2	4	2	2	2	3	3	18	3	1	1	1	3	1	2	3	4	0	4	1	2
Tricholoma sulfureum	1	3	23.75	2	5	3	5	4	4	3	2	4	1	2	2	3	3	29.25	3	1	1	1	3	1	2	3	3	2	4	1	2
Tricholoma terreum	1	3	20	2	5	3	5	4	2	3	2	4	2	2	2	3	3	18.75	3	1	1	1	3	1	2	3	4	0	4	1	3
Tricholoma ustale	1	3	32.5	2	5	3	5	4	3	3	2	4	3	2	2	3	3	20.25	3	1	1	1	3	1	2	3	4	0	4	1	3
Tricholoma vaccinum	1	3	30	2	5	3	5	4	3	3	2	4	2	2	2	3	3	18	3	1	1	1	3	1	2	3	4	0	4	1	3
Tricholoma virgatum	1	3	26.25	2	5	3	5	4	3	3	2	4	2	2	2	3	3	21	3	1	1	1	3	1	2	3	3	2	4	1	3
Tricholomopsis decora	1	3	23.75	2	5	4	5	4	4	3	2	2	2	2	2	3	3	23.25	3	1	1	1	3	1	2	3	3	2	4	1	1
Tricholomopsis rutilans	1	3	42.5	2	5	4	5	4	4	3	2	2	2	2	2	3	3	33.75	5	1	1	1	3	1	2	3	3	2	4	1	1
Tubaria furfuracea	1	3	10.75	2	5	4	5	3	2	2	2	2	1	2	3	3	3	24.75	3	1	2	1	3	1	2	3	3	2	4	1	1
Tulostoma brumale	1	3	3.2	2	4	3	4	4	2	3	2	4	0	6	6	3	2	24	5	3	3	1	3	1	2	3	4	0	4	1	1
Tylopilus felleus	1	3	50	2	5	3	5	4	2	3	1	4	2	1	2	3	3	27	2	1	2	2	3	1	2	3	1	2	4	1	3
Typhula erythropus	1	3	4.5	2	2	4	3	4	3	3	2	2	2	5	9	1	2	20.25	3	1	1	1	3	1	2	3	4	0	4	1	1
Vascellum pratense	1	3	17	2	4	3	4	4	3	3	2	4	0	6	4	2	2	18.75	5	2	3	1	3	1	2	3	4	0	4	1	1
Volvariella gloiocephala	1	3	47.5	2	5	3	5	2	3	5	2	4	0	2	2	3	3	42	3	1	2	2	3	1	2	3	1	2	4	1	3
Volvariella pusilla **s. str.**	1	3	10	2	5	3	5	2	3	3	2	4	0	2	2	3	3	20.25	3	1	2	2	3	1	2	3	1	2	4	1	3
Vuilleminia comedens **s. lat.**	1	1	20	3	3	4	1	4	3	1	2	2	1	5	3	1	1	70	4	1	1	1	3	1	2	3	4	0	4	1	1
Xerocomus badius	1	3	50	2	5	3	5	4	2	3	1	4	2	1	2	3	3	27	2	1	3	2	3	1	2	3	1	2	4	1	3
Xerocomus chrysenteron	1	3	37.5	2	5	3	5	4	3	3	1	4	1	1	2	3	3	27.5	2	1	3	2	3	1	2	3	1	2	4	1	3
Xerocomus porosporus	1	3	25	2	5	3	5	4	2	3	1	4	2	1	2	3	3	28	2	1	2	2	3	1	2	3	1	2	4	1	3
Xerocomus pruinatus	1	3	31.25	2	5	3	5	4	2	3	1	4	2	1	2	3	3	27.5	2	5	2	2	3	1	2	3	1	2	4	1	3
Xerocomus rubellus	1	3	18.75	2	5	3	5	4	4	3	1	4	2	1	2	3	3	24	2	1	2	2	3	1	2	3	1	2	4	1	3
Xerocomus subtomentosus	1	3	37.5	2	5	3	5	4	3	3	1	4	1	1	2	3	3	24	2	1	3	2	3	1	2	3	1	2	4	1	3
Xeromphalina campanella	1	3	6	1	5	4	5	4	4	4	2	2	2	2	3	3	3	14	2	1	1	1	3	1	2	3	3	2	3	1	1
Xerula radicata	1	3	33.75	2	5	4	5	4	3	3	2	2	2	2	2	3	3	43.5	3	1	1	1	3	1	2	3	1	2	3	1	1
Xylaria hypoxylon	1	2	10	1	1	4	4	4	1	1	2	2	1	6	6	2	2	56	4	1	4	1	1	1	2	2	4	0	4	1	3
Xylaria longipes	1	2	20	2	1	4	4	4	1	1	2	2	2	6	4	2	2	56	4	1	4	1	1	1	2	3	4	0	4	1	3
Xylaria polymorpha	1	2	30	2	1	4	4	4	1	1	2	2	2	6	4	2	2	102	4	1	4	1	1	1	2	3	4	0	4	1	3