Dissertationes Forestales 225

Dead-wood-associated aphyllophoroid fungi: perspectives on the diversity, ecology and conservation biology of species and their habitats

Panu Kunttu

School of Forest Sciences
Faculty of Science and Forestry
University of Eastern Finland

Academic dissertation

To be presented, with the permission of the Faculty of Science and Forestry of the University of Eastern Finland, for public examination in the auditorium AT100 of the University of Eastern Finland, Yliopistokatu 4, Joensuu, on 7th of October 2016, at 12 o’clock noon

Title of dissertation: Dead-wood-associated aphyllophoroid fungi: perspectives on the diversity, ecology and conservation biology of species and their habitats

Author: Panu Kunttu

Dissertationes Forestales 225

http://dx.doi.org/10.14214/df.225

Thesis Supervisors:
Professor Jari Kouki
School of Forest Sciences, University of Eastern Finland, Finland
Dr. Kaisa Junninen
Metsähallitus, Parks & Wildlife Finland

Pre-examiners:
Dr. Jan Holec
Mycological Department
Natural History Museum, Prague, Czech Republic

Docent, Dr. Beatrice Senn-Irlet
Biodiversity and Conservation Biology
Swiss Federal Institute for Forest, Snow and Landscape Research
Birmensdorf, Switzerland

Opponent:
Docent, Dr. Mikael von Numers
Environmental and Marine Biology
Åbo Akademi University

ISSN 1795-7389 (online)
ISBN 978-951-651-540-6 (pdf)

ISSN 2323-9220 (print)
ISBN 978-951-651-541-3 (paperback)

2016

Publishers:
Finnish Society of Forest Science
Natural Resources Institute Finland
Faculty of Agriculture and Forestry at the University of Helsinki
School of Forest Sciences at the University of Eastern Finland

Editorial Office:
The Finnish Society of Forest Science
P.O. Box 18, FI-01301 Vantaa, Finland
http://www.metla.fi/dissertationes

Kunttu P. (2016). Dead-wood-associated aphyllophoroid fungi: perspectives on the diversity, ecology and conservation biology of species and their habitats. Dissertationes Forestales 225. 66 p. http://dx.doi.org/10.14214/df.225

ABSTRACT

This thesis examines the diversity and substrates of aphyllophoroid fungi with implications for their conservation biology. I focused on the distributional patterns of fungi on woody substrates, analyzed the diversity and indicators related to their substrates, and developed fungal monitoring schemes. The main results are:

1) A total of 303 aphyllophoroid fungi species were observed on my study site in the Archipelago Sea National Park, and a total of 331 species from all study sites. These include eight species new to Finland, 30 very rare species in Finland, and seven still undescribed species.

2) Of the five dead wood related indicators of forest naturalness and fungal substrate diversity; volume of dead wood provided the best overall agreement with the other indicators. Not all indicators were correlated and, as such, the selection of a dead wood indicator can considerably affect the output of an assessment.

3) Fungi occurrence was not related to the availability of different types of dead wood substrates, thereby indicating the high importance of specific substrates for species. Polypores and corticioids differed from each other in their occurrence patterns. Variation in dead wood quality is important for the preservation of wood-inhabiting fungi diversity.

4) I observed 138 species on black alder (*Alnus glutinosa*); 27 of which grew solely on that tree species. Many of the alder-associated species are rare. Thus, less common trees can also host highly diverse and specialized fungal assemblages and within-tree substrate variation is ecologically important for fungi.

5) A more effective systematic utilization of citizen science, databases, modern molecular methods and recording sampling information would provide major possibilities for the improvement of monitoring and the conservation of lesser known fungi.

In conclusion, this thesis highlights the ecological significance of diverse substrates for aphyllophoroid fungi. Several coarse wood debris (CWD)-related measures that have been used to describe substrate characteristics, and to measure forest naturalness, are not consistent in their results and are also unlikely to provide consistent indications of fungal substrates. CWD-related measures of forest naturalness are thus not recommended to replace on-site fungal surveys in the assessment of the value of a particular site for fungi.

Keywords: Aphyllophorales, Baltic Sea, corticioids, polypores, substrates, wood-inhabiting fungi, woody debris

PREFACE

My enthusiasm towards both the biodiversity contained within forests, especially on dead wood, and the archipelago drove me to develop a doctoral thesis on aphyllophoroid fungi in the forests of the Baltic Sea archipelago. I could not image something more fascinating than biogeography and the ecology of wood-inhabiting species in the archipelago. I was overwhelmed by the island theory. I got the idea for a large-scale field survey of wood-inhabiting fungi in summer 2007 when I randomly sampled fungal specimens during my long leisure-time kayaking trip to the Archipelago Sea. However, I started field trips to this area at regular intervals already in 1993. Wood-inhabiting fungi came to my life later, in 2003.

I remember well my supervisor Jari Kouki's reaction to my first proposal in August 2008 regarding my study idea. He barely knew me or my skills or my background but he replied rapidly and he was absolutely positive. Jari's interest and his appreciative attitude towards my ideas provided a good starting point for this thesis. It has been a great privilege to work in the Forest Biodiversity and Conservation Research Group led by Jari. For me it was important to undertake a doctoral thesis in the School of Forest Sciences although my Master's thesis had taken place in the Department of Ecology and Environmental Management.

My second supervisor Kaisa Junninen is one of the most experienced polyporologists in Finland and I was very flattered and grateful when she agreed to serve as my second supervisor. I knew Kaisa from my previous time in Joensuu when nature conservation and polypores were already our shared interests. With the high quality expertise and skills of Jari and Kaisa – and their patience too – my data was shaped into this doctoral thesis, for which I thank them deeply.

I am very grateful to Matti Kulju who identified the majority of the corticioid specimens in this dataset. His expertise and willingness to help allowed me to include corticioid species in this work. Heikki Kotiranta's unique expertise with the taxonomy of corticioids was also at my disposal, for which I am very thankful. With the contribution of Matti and Heikki the knowledge of corticioid distribution, ecology and taxonomy has improved considerably.

My beloved wife Sanna-Mari Kunttu assisted me in many ways during the work: she worked as a clerk in the field work, sorted specimens and stored field notes. She also empathized the gained results, found rare species and published articles. Without her support this work would had been much tougher to perform. During the weeks of field work we spent memorable times together on the islands of the Archipelago Sea, which is so dear to us. It was valuable that we could combine our hobbies – sea kayaking and outdoor life – into this research project.

Timo Kosonen, Panu Härmävaara, Oskari Härmä, Elina Manninen and Sinikka Kunttu also assisted me in the collection of species and forest data during field work. I started field work with Timo, and together we pondered the sampling method for fungi. Jorma Pennanen kindly identified many fungal specimens and Urmas Kõljalg several specimens of the difficult *Tomentella*-genus. The staff at the Herbarium of Turku University, the Herbarium of Helsinki University and the Natural History Museum of Central Finland welcomed and handled my thousands of fungal specimens. Pekka Helo kindly provided excellent photographs of aphyllophoroid species for use in this thesis.

I thank Jan Holec and Beatrice Senn-Irlet who kindly and thoroughly pre-reviewed my thesis and provided valuable comments and suggestions that have improved it. David Wilson revised the English language. Grateful thanks to Check List – The Journal of Biodiversity Data, the Finnish Mycological Society, Elsevier and the Finnish Zoological and Botanical Publishing Board for granting permission to include my published articles in this work.

During my Master's degree studies in ecology at the University of Jyväskylä, I had great friends and colleagues within the taxonomy, biogeography and conservation biology. We had a brilliant naturalists' society called Kryptogamen where my closest friends were Panu Halme, Jukka Salmela, Jouni Penttinen, Teemu Nieminen, Oskari Härmä, and Santtu Kareksela. In particular, I worked with Panu – both in the forest and the lab - because we shared a common fascination for polypores. My namesake guided me to the world of fungi. I am grateful to you all for those experiences and for the inspiration to continue my studies.

I started my Master's degree studies in forest ecology at the same time as Mai Suominen, and since then we have been close friends and shared many of the same interests, such as the promotion of forest conservation, forest biodiversity inventories and a devotion to archipelago nature.

Although I spent only a short time at the University of Eastern Finland, Joensuu (for analysis and manuscript preparation), I was fortunate to meet many nice colleagues there and had rewarding lunch and coffee break discussions about environmental politics, our research projects and science in general: Hannes Pasanen, Osmo Heikkala, Harri Lappalainen, Aino Hämäläinen, Aino Korrensalo, Matti Koivula and Olli-Pekka Tikkanen, and of course Kaisa and Jari. These moments were very important to me.

My employer WWF Finland looked kindly on my study leave and the finalizing of my doctoral dissertation of which I am grateful to Liisa Rohweder, Jari Luukkonen and Petteri Tolvanen.

My dear parents Kristina Kunttu and Tapani Kunttu supported and encouraged me to start and complete this doctoral dissertation. They also provided an academic inheritance in my childhood home. My dear grandmother Katarina Piha has shown a huge interest towards my research and she has told me stories of the academic traditions from the past decades.

This thesis has been funded by the Ella and Georg Ehrnrooth Foundation, the Education Fund, the Varsinais-Suomi Regional Fund of the Finnish Cultural Foundation, Nordenskiöld-Samfundet i Finland rf, Societas pro Fauna et Flora Fennica, and the Finnish Union of Environmental Professionals.

I dedicate this doctoral thesis to the pioneers of ecological research of the Archipelago Sea area: Ole Eklund, Börje Olsoni, Ossian Bergroth, Henrik Skult, Leif Lindgren, Torsten Stjernberg, Sakari Hinneri, and Rauno Tenovuo. Their work has been important and motivational to me and I see myself as a continuum of this distinguished group of naturalists.

In Dalsbruk beside the Archipelago Sea, May 2016

Panu Kunttu

"*In the end we will conserve only what we love, we will love only what we understand, and we will understand only what we are taught*." Baba Dioum 1968

LIST OF ORIGINAL ARTICLES

The thesis is based on the following articles, which are referred to in the text by the Roman numerals **I**–**VI**. The articles **I**–**III** and **V**–**VI** are reproduced with the kind permission of publishers, while the **IV** is the author's version of the submitted manuscript.

I Kunttu P., Kulju M., Kotiranta H. (2015). Checklist of aphyllophoroid fungi (Basidiomycota) of the Archipelago Sea National Park, Southwest Finland. Check List 11(2): 1587.
http://dx.doi.org/10.15560/11.2.1587

II Kunttu P., Kulju M., Kotiranta H. (2010). Rare corticioid fungi in Finland – records of new and little collected species (Basidiomycota). Karstenia 50: 35–44.
http://karstenia.fi/index-of-articles/

III Kunttu P., Junninen K., Kouki J. (2015). Dead wood as an indicator of forest naturalness: A comparison of methods. Forest Ecology and Management 353: 30–40.
http://dx.doi.org/10.1016/j.foreco.2015.05.017

IV Kunttu P., Junninen K., Kulju M., Kouki J. Major wood-decayer fungal groups have distinct occurrence patterns on woody substrates. (submitted manuscript)

V Kunttu P., Kotiranta H., Kulju M., Pasanen H., Kouki J. (2016). Occurrence patterns, diversity and ecology of aphyllophoroid fungi on the black alder (*Alnus glutinosa*) in an archipelago in the Baltic Sea. Annales Botanici Fennici 53: 173–189.
http://www.sekj.org/PDF/anb53-free/anbf53-173-189-36231-free.pdf

VI Halme P., Heilmann-Clausen J., Rämä T., Kosonen T., Kunttu P. (2012). Monitoring fungal biodiversity – towards an integrated approach. Fungal Ecology 5: 750–758.
http://dx.doi.org/10.1016/j.funeco.2012.05.005

CONTRIBUTIONS OF THE AUTHORS

The table shows the major contributions of the authors to the original articles and the manuscript. Other contributors are acknowledged in the relevant articles or the manuscript.

	I	**II**	**III**	**IV**	**V**	**VI**
Original idea	PK	PK	JK, KJ, PK	JK, KJ	PK	PH, PK, TK
Study design	PK	PK	JK, KJ, PK	JK, KJ, PK	PK	-
Data collection	PK	PK	PK	PK	PK	TR, JHC, PH, PK, TK
Species identification	MK, PK, HK	MK, HK	-	MK, PK	MK, PK, HK	-
Data analysis	-	-	PK, JK	PK, JK	PK, HP	-
Manuscript preparation	PK, HK	PK, HK	PK, JK, KJ	PK, KJ, JK	PK, JK, HK	PH, JHC, TR, TK, PK

Panu Kunttu (PK), Jari Kouki (JK), Kaisa Junninen (KJ), Matti Kulju (MK), Heikki Kotiranta (HK), Hannes Pasanen (HP), Panu Halme (PH), Jacob Heilmann-Clausen (JHC), TR Teppo Rämä (TR), Timo Kosonen (TK)

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Biodiversity in dead wood in Fennoscandia

Dead wood has a fundamental role in forest ecosystems. In addition to biodiversity (Esseen et al. 1997; Siitonen 2001; Stokland et al. 2004; Jonsson et al. 2005), dead wood contributes to soil formation, nutrient recycling, energy circulation, seedbed creation and also serves as a carbon store (Hyvönen and Ågren 2001; Janisch and Harmon 2002; Lonsdale et al. 2008).

The dynamics of deadwood; volume and quality, are determined by tree mortality and decomposition over time (Grove 2002; Jonsson et al. 2005). In natural boreal forests, recurring disturbances, from small-scale gap perturbations to stand-replacing catastrophic events, kill trees and create dead wood (Jonsson and Kruys 2001). The disturbances are caused by different natural events like forest fires, storms, heavy snow or insect and pathogen outbreaks (Kuuluvainen 1994).

In pine-dominated old-growth forests, the volumes of dead wood in coarse woody debris (CWD; minimum diameter 10 cm, see Enrong et al. 2006 for detailed definitions) vary from ca. 60 to 120 m^3 ha^{-1} in the southern and middle boreal zones in Fennoscandia and ca. 20 m^3 ha^{-1} in the timberline forests in the northern boreal zone (Siitonen 2001). The mean volume of CWD in old-growth Norway spruce (*Picea abies*) forests varies from 19 m^3 ha^{-1} in the north boreal zone near the timberline, to 201 m^3 ha^{-1} in the southern part of the middle boreal zone (Linder et al. 1997; Sippola et al. 1998). The proportion of CWD is often about 20–30% of the total stand wood volume (Sippola et al. 1998; Siitonen et al. 2000; Karjalainen and Kuuluvainen 2002).

Dead wood is important for biodiversity because of the large number of species that are dependent on dead wood (saproxylic species) in boreal forests (Esseen et al. 1997; Jonsson and Kruys 2001; Lassauce et al. 2011). Fungi, invertebrates, lichen and bryophytes are particularly dependent on dead wood as a substrate (Jonsson et al. 2005; Stokland et al. 2012). There are 5800–7000 dead wood dependent species in Fennoscandia (Dahlberg and Stokland 2004; Stokland et al. 2004). The number of wood-decaying fungi species is ca. 2500 and of this, 1270 are the fungal species of Basidiomycota (Stokland et al. 2004). In Finland, 87% of aphyllophoroid fungi grow in various kinds of forests and 75% are decayers (Kotiranta et al. 2009).

Intensive forest management has dramatically reduced the volume of dead wood in Finnish forests, and forests are currently managed so that an even-aged cohort of one tree species is grown on each stand with very little dead wood present (Siitonen et al. 2000; Kouki et al. 2001). Currently, there is, on average, less than 4 m^3 ha^{-1} of dead wood in Southern Finland, with slightly higher values in coastal areas (Juntunen 2014). In protected forests, the average dead wood volume is around 10 m^3 ha^{-1} and 16.7 m^3 ha^{-1} in newly established nature reserves in Southern Finland (Hokkanen et al. 2005; Siitonen et al. 2012). At the landscape level, the average amount of CWD has been reduced by 90–98% in comparison to natural boreal forests (Siitonen 2011; Kuuluvainen 2002).

The dead wood volume represents a measure of substrate and resource availability for saproxylic organisms. Several studies have demonstrated a positive significant correlation between the local quantity of dead wood and the number of saproxylic species (e.g. Økland et al. 1996; Grove 2002; Junninen and Komonen 2011; Lachat et al. 2012). The decline in the amount of dead wood has had major consequences for saproxylic species: the decline in dead wood is at least one of the causes for the decline in over 500 red-listed species in Finland (Rassi et al. 2010) and, furthermore, may even have led to a loss of over 50% of the original saproxylic species in managed forests (Siitonen 2001). For example, one of main threats to 94% of species currently classified as threatened is change relating to forests, and the most significant cause is the decreasing amounts of decaying wood (Kotiranta et al. 2010). According to the large review study by Gao et al. (2015), there is strong evidence for a positive correlation between the volume of dead wood and wood-inhabiting fungal species richness.

1.2 Forest naturalness and its indicators

Forests cover most of the boreal zone, although large, non-fragmented primeval forest areas can currently be found only in Siberia and northern Canada (Aksenov et al. 2002; Lee et al. 2006). Other parts of the taiga zone have been influenced by human activities and have encountered human impacts of variable intensity. Many regions have been used for timber production for decades and modern forestry practices have largely changed forest ecosystems (Bryant et al. 1997).

The main threat to forest biodiversity is the loss of naturalness of forest ecosystems as a consequence of intensive ecosystem management (European Environment Agency 2014). To protect forest biodiversity and threatened forest-dwelling species, it is important to recognize the features of naturalness and the characteristics of the forests that species depend on. It is also important to use reliable and time saving methods to assess naturalness and the conservation value of forests when promoting the protection of forests at all levels.

Approximately 75% of Finland’s land area is forest (Kaila and Ihalainen 2014). However, less than 5% of forests can be defined as natural-like old-growth forests (Punttila and Ihalainen 2006). Forestry has changed the natural dynamics of forests and this can be seen as a structural simplification at the stand level. Natural dynamics and disturbances have disappeared and have been replaced by repeated thinnings and clearcuts that maintain structurally monotonous forests (Esseen et al. 1997; Östlund et al. 1997; Kuuluvainen 2009; Kuuluvainen and Aakala 2011). Consequently, 36% of threatened species in Finland are forest species and 67% of forest habitat types are threatened (Raunio et al. 2008; Rassi et al. 2010).

An assessment of forest naturalness can serve simultaneously as a surrogate for biodiversity (Noss 1999; Thompson 2006; Rondeux and Sanchez 2010). Different types of forest biodiversity indicators have been generated (e.g. Jonsson and Jonsell 1999; Noss 1999; Thompson 2006). Dead wood as a forest naturalness indicator appears to be a very practical tool for revealing habitats of dead wood dependent species and assessing the conservation value of new forest conservation areas (Jonsson et al. 2005; Mönkkönen et al. 2008; Siitonen et al. 2012). Nevertheless, there is an urgent need to improve assessment methods and to compare the different methods. This is needed, for example, for forest policy and conservation planning (Winter et al. 2010; European Environment Agency 2014; Machado 2014).

Forest naturalness has three dimensions: structure, species, and processes (Brūmelis et al. 2011; Ikauniece et al. 2012). The most important components of the structural dimension of natural forests include the amount and type of dead wood and their continuity (Stokland et al. 2004). Dead wood is an essential characteristic of natural boreal forests and it is essential resource for saproxylic species. It can be also used as a surrogate for species number and processes (Similä et al. 2006; Lassauce et al. 2011).

Several dead wood based methods have been used to assess naturalness in boreal forests. The *volume of dead wood* is the most widely used measure (e.g. Stokland et al. 2004; Similä et al. 2006; Winter 2012). The *diversity of dead wood* can be expressed as the number of combinations formed by tree species, quality, decay class and diameter classes present on each sample plot (Siitonen et al. 2000). The *number of cut stumps* per hectare has been used as a quickly measured indicator of forest naturalness (Uotila et al. 2002; Rouvinen and Kouki 2008; Wallenius et al. 2010). The *dead wood continuity profile* summarizes the quantitative and qualitative composition of dead lying wood at the stand level (Stokland 2001). The continuity profile is based on diameter and the decay stages of dead wood and results from four main processes: regeneration, tree growth, tree mortality and decomposition. It can provide information in regards to the long-term forest history. *Kelo trees* are a special kind of substrate in old-growth boreal pine forests. A kelo is an old, dead Scots pine (*Pinus sylvestris*) tree with a hard and silver grey, decorticated trunk surface, and its formation and decomposition takes hundreds of years (Sirén 1961; Leikola 1969; Tarasov and Birdsey 2001; Niemelä et al. 2002). Such processes occur in natural forests only, and thus the number of kelo trees may be a good indicator of forest naturalness.

Despite the obvious potential of dead wood for the assessment of forest naturalness and the substrates that it can provide for the sparoxylic organisms, there is no widely used and generally applicable method for carrying out this assessment. In fact, there is an urgent need to understand how the different dead-wood related measures correlate with each other and to what aspects of forest naturalness they may be linked to in the field.

1.3 Aphyllophoroid fungi

1.3.1 Aphyllophoroid fungi in Finland

Aphyllophoroid fungi constitute non-gilled form-groups of the Basidiomycota. They comprise a diverse group of various kinds of fungi, such as corticioids, polypores and clavarioids. These fungal groups are highly diverse and taxonomically polyphyletic (Hibbett et al. 2014). In this thesis, I use the term aphyllophoroid fungi as a synonym of polypores, corticioids, corticioid heterobasidioids and wood-decaying hydnaceous fungi for pragmatic reasons. The species division into polypores and corticioids was based on Niemelä (2005), Kotiranta et al. (2009) and Bernicchia and Gorjón (2010). In general, the two groups differ from each other based on the appearance of sporocarps: polypores have a poroid and corticioids a non-poroid hymenophore. Only the wood-inhabiting species of these groups were included in this study (saprobes, parasites or mycorrhizal). However, the clavarioid taxa were excluded due to their taxonomical uncertainty.

The first Finnish checklist of aphyllophoroid fungi was published in 2009 and contained 980 aphyllophoroid species (Kotiranta et al. 2009). Of these, 756 are species of my target groups and 489 of them also occur (some even solely) on the southwestern coast of Finland where the study sites are situated (Kotiranta et al. 2009). The number of polypore species in Finland is 240 and the number of corticioid species is 422 (Kotiranta et al. 2009; Niemelä 2012). After the publication of the check-lists in 2009, at least 35 species new to Finland have been reported, and abundant biogeographical knowledge has accumulated, especially in regard to corticioids, polypores and clavarioids (e.g. Kunttu et al. 2011, 2012, 2016a,b; Miettinen et al. 2012a,b; Niemelä 2012; Kotiranta and Larsson 2013, Kotiranta and Shiryaev 2013; Spirin et al. 2013a,b; Juutilainen 2016).

To date, only a few intensive inventories covering all or almost all aphyllophoroid species have been carried out in Finland (Kotiranta and Shiryaev 2013). Usually, aphyllophoroid species are divided into morphological groups, such as polypores, corticioids, clavarioids and tremelloids, and the studies usually focus on just one or two of these (e.g. Pippola and Kotiranta 2008; Shiryaev 2008; Juutilainen et al. 2011; Markkanen and Halme 2012). Collection of non-poroid aphyllophoroid fungi is time-consuming: for example the sporocarps of corticioids are small in size and mostly grow underneath the substrate. Most of these species need to be identified with a microscope. It is thus likely that many such species are still unrecognized or inadequately known.

Aphyllophoroid fungi (mainly polypores) are widely used as indicators of ecological value in boreal forests (Karström 1992; Kotiranta and Niemelä 1996, Nitare 2000; Savola 2015). Many of these species are particularly old-growth forest indicators, but some herb-rich forest, deciduous forest and semi-natural habitat species are also included. In particular, red-listed aphyllophoroid fungi are regarded as key biodiversity indicators in forests, and their indicator value has been explored and tested several times (Nilsson et al. 1995; Similä et al. 2006; Djupström et al. 2008, 2010).

1.3.2 Occurrence on substrates

Conservation of wood-inhabiting fungi requires sufficient knowledge of their occurrence on woody substrates and on the habitat factors that affect these species. Of the aphylloporoids included in my study, polypores are probably the most commonly studied dead wood associated fungi (see the review by Junninen and Komonen 2011). Other wood-inhabiting fungal groups remain less studied, although corticioids, for example, have received increasing attention in recent years (Küffer and Senn-Irlet 2005; Küffer et al. 2008; Juutilainen et al. 2011). However, comparative studies of quantitative data on fungal groups other than polypores are still quite rare. Polypores and corticioids have often been considered as one group (e.g. Penttilä and Kotiranta 1996; Heilmann-Clausen 2001) but the ecological justification for this is not usually explicitly stated. Indeed, if occurrence patterns differ between groups, polypores and corticoids may have different roles in the decomposition of wood and, therefore, their roles may also differ in ecosystem functioning (Hakala et al. 2004; Juutilainen 2011).

There are several stand-scale factors that affect the occurrence of wood-inhabiting fungi: the age of the forest, successional stage, state of naturalness, management history, size and connectivity of forest patches, tree species composition, and the amount and quality of dead wood (Junninen et al. 2006; Stokland and Larsson 2011; Ylisirniö et al. 2012; Magnusson et al. 2014). However, in this thesis, I concentrate on the tree level dead wood factors: tree species, decay stage, dead wood type, and diameter of the dead wood units. These all are known to affect species-richness and the abundance of wood-decay fungi (Høiland and Bendiksen 1997; Sippola and Renvall 1999; Heilmann-Clausen and Christensen 2004; Ylisirniö et al. 2012). However, the species-specific occurrence patterns of fungi on different substrates are often based on non-systematic descriptive observations. Moreover, only positive records are available in many studies. In addition, null records or uninhabited substrates and habitats should be reported and analyzed, to provide a comprehensive description of species occurrence.

Finally, our knowledge of how less common host tree species affect fungal diversity is rather unclear. High volumes and large qualitative variation of dead wood in common species is likely to be important but it is not clear whether less common hosts also show the same patterns. For example, non-dominant aspen in boreal zones is known to be a key host for many saproxylic species (Junninen et al. 2007; Lõhmus 2011), while rare substrates can host highly specific species (e.g. Niemelä et al. 2002; Yurchenko 2006). If this is more widely true, then rare hosts may contribute significantly to regional fungal diversity and have a major role in the conservation of fungal diversity. In Finland, black alder is common only on the coast and archipelagos of the Baltic Sea where it is one of the dominant broadleaved tree species, but elsewhere it mainly grows intermixed.

Black alder often occur in riparian habitats, sea shores and wooded swamps (Mäkinen 1978). These habitats are classified in many cases as habitats of high conservation value (Ingerpuu et al. 2001; Raunio et al. 2008). However, in regard to wood-inhabiting fungi, black alder has received little study in Europe. In Western Eurasia, a small number of studies have concentrated on the ecology of wood-inhabiting fungi of black alder (or its close relative grey alder *Alnus incana*) (Strid 1975; Keizer and Arnolds 1990; Safonov 2014). In addition to these, field notes of species found on black alder can be traced from Kotiranta and Niemelä (1996), Niemelä (2005), Kotiranta et al. (2009) and Safonov (2006). Naturally, alders are included in many general polypore surveys (e.g. Küffer and Senn-Irlet 2000, 2005; Junninen and Kouki 2006; Hottola and Siitonen 2008; Komonen et al. 2008).

In general, different fungi have a different role in the wood decay process (Hakala et al. 2004; Fukasawa et al. 2011; Rajala et al. 2015), and the occurrence patterns of fungal groups may indicate that they have a distinct role in these processes. In fact, numerous studies have shown that a succession of fungal species is involved in the wood decomposition process (Renvall 1995, Fukasawa et al. 2009; Rajala et al. 2011), although these studies have rarely looked at the whole fungal decay-assemblage simultaneously. To understand better the decay process under natural conditions in forest ecosystems and the role of the different fungal groups in it, there is a need to analyze whether specific decayer groups are associated with specific substrate types.

1.4 Fungal monitoring

Conservation of biodiversity requires reliable data on species occurrence over time and space. Normally, monitoring is based on observations that were either randomly made or were conducted in a systematic field survey. Such data are useful, for example, in the selection of new nature conservation areas, red-list evaluations and even to assess global change of forest ecosystems (Pressey et al. 1993; Dahlberg and Mueller 2011). However, this occurrence data is not always accurate, and this may seriously undermine conservation priorities and scientific conclusions (Molina et al. 2011; Jetz et al. 2012). Complete or highly representative species surveys are expensive, and often there are no experts available that could make these surveys. Consequently, fungi are often under-represented in the conservation literature (Heilmann-Clausen and Vesterholt 2008).

Macrofungi records have been mainly derived from fungal forgaying, i.e. random walks by mycologists. A similar common method includes the opportunistic search for species, which means a careful walk through a study site to collect visible sporocarps, and emphasis is laid on sampling many habitats and substrate qualities to collect a high number of species and presumably get a representative picture of the species composition of the study site (Stokland and Sippola 2004). However, the estimation of population sizes and trends based on traditional observation data is often difficult or impossible (Pyke and Ehrlich 2010), because fungarium specimens and database records do not include information on the extent and nature of the collection effort. Furthermore, they lack information of negative records, which are as important as positive ones in the evaluation of population trends (Rhodes et al. 2006).

Many fungal groups do not produce visible sporocarps or otherwise they cannot be detected in traditional surveys. However, these can now be studied using molecular methods (e.g. Jones et al. 2011; Liu et al. 2011). Moreover, macrofungi are difficult to survey due to unpredictable sporulation patterns, such as a short or non-annual sporulation cycle (Straatsma et al. 2001; Lagana et al. 2002; Halme and Kotiaho 2012; van der Linde et al. 2012). Molecular analysis of environmental samples might overcome these shortcomings and provide a more realistic or at least a different insight into macrofungal community structure than offered by field observations of sporocarps (Porter et al. 2008; Geml et al. 2009).

Globally, more than 600 biodiversity information databases exist for data storage (Borges et al. 2010). However, most are taxonomically or regionally restricted. Moreover, the development of the databases has not been coordinated. Even though the Biodiversity Information Standards (2016) has attempted to standardize the databases, there is a high variation in the database structure and usability. Within mycology, a rapid development of molecular databases has exacerbated the situation further. Currently, the molecular information is spread over dozens of databases with different levels of accuracy in the nomenclature and quality of the included sequences (e.g. Abarenkov et al. 2010; Öpik et al. 2010; Benson et al. 2011).

Clearly, there is a need to improve and develop fungal databases that can be used for population trend monitoring and conservation purposes. Databases should also collect information on the sampling effort, utilize modern molecular methods and the efforts of citizen science.

1.5 Aims of the thesis

Studies **I** and **II** deal with species richness and the diversity of aphyllophoroid fungi. The aim was to explore what species occur in the forest of the Baltic Sea islands, SW Finland. According to earlier inventories of other taxa carried out in this area, it was expected to find a high number of species, although the diversity of aphyllophoroid fungi has never been extensively studied there before. Furthermore, the taxonomy, ecology and distribution of some corticioids species new to Finland were explored.

Several measures related to dead wood i.e. the substrate for wood-associated fungi, have been used as indicators of forest naturalness, but their general applicability and comparability is unclear. In study **III**, I explored the relationships between the five different dead wood related indicators of forest naturalness: volume of dead wood, dead wood diversity index, number of cut stumps, dead wood continuity profile and number of kelo trees (specific type of dead pine trees) to answer the following questions: Do the different methods used to assess forest naturalness provide similar indications of naturalness? Do the different indicators rank sites similarly? If the indicators provide inconsistent results, they are unlikely to be equally useful indicating fungal diversity patterns.

In study **IV**, I connect fungi occurrence to their substrates and, in particular, compare the groups of wood decay fungi; polypores and corticioids. The objective was to analyze whether these two groups have similar ecological roles in relation to dead wood substrates. Therefore, I made a comparison of the occurrence of the two fungal groups among all surveyed dead wood material (including empty units), with special emphasis on the species of conservation concern.

To explore within-host tree substrate patterns, study **V** was conducted to reveal if a regionally uncommon host tree that is locally quite common can act as a habitat for large or specialized fungal assemblages. The study focused on black alder. All fungal species were analyzed for their occurrence on substrates: type, diameter, and decay stage, as well as the proportion of records made on black alder. I also aimed to identify generalist and specialist species associated with black alder.

Finally, in study **VI** I used the experiences what I accumulated in sampling and handling the fungal material of studies **I, II, IV** and **V**. This article analyzed and reviewed the methods used for gathering information on species occurrences in mycology in study **VI**. In this study, I reviewed the ways that fungal records have been obtained and documented in the past, and investigated how more recently developed molecular methods and online database platforms may boost fungal monitoring in the future. Based on this analysis, the potential to improve the quality of fungal recording databases was evaluated so that they can be used to draw reliable conclusions in regard to fungal diversity and improve population trend monitoring.

2. MATERIALS AND METHODS

2.1 Study area

The fungal and dead wood data were collected from 40 islands (Fig. 1) in the eastern part of the Archipelago Sea within the Baltic Sea, SW Finland (approx. 60° N, 22° E; 0–42 m a.s.l.). The islands were selected based on their size, dominant forest habitat type and location in the archipelago zone. The size of the study islands were 8–191 ha (median 23 ha), and the total area of the 40 islands was 1731 ha. The forest area of the islands ranged from 3 to 159 ha (median 20 ha) and covered 1442 ha of the total area. The characteristics of the study islands are given in study **III**. Of these, 27 islands were sampled for both polypores and corticioids, and on 13 islands only polypores were sampled. In study **IV**, 27 islands and in study **V** 38 islands were included in the analyses.

The islands were classified as being located within the outer or middle archipelago zones (Stjernberg et al. 1974; Lindgren and Stjernberg 1986). The zonation is based on the relative prevalence of the sea and land and also on general features of the vegetation. The forests in the study area are dominated by Scots pine (*Pinus sylvestris*), black alder (*Alnus glutinosa*) and downy birch (*Betula pubescens*). Norway spruce (*Picea abies*), aspen (*Populus tremula*) common hazel (*Corylus avellana*), and rowan (*Sorbus aucuparia*) also occur fairly commonly. Silver birch (*Betula pendula*) grows mostly in the middle archipelago zone, but rarely in the outer zone. In regard to study **V**, black alder grows typically in this area either in herb-rich forests or on stony shores. The islands can be classified into three groups based on their habitat types: herb-rich, mesic heath and xeric/barren heath forests (**III**). The group was determined according to the dominant habitat type on each island (at least 40% of the area).

The area is located in the hemiboreal zone and is part of the biogeographic province of Regio aboënsis (Varsinais-Suomi) (Ahti et al. 1968; Knudsen and Vesterholt 2008).The archipelago of the Archipelago Sea is the largest archipelago in the world in regard to the number of islands. There are 41,000 islands and skerries with a minimum size of 100 m^2. The area is characterized by its geographical location in the Baltic Sea (brackish water), geological history with glacial period and its formations, a long history of both open and wooded pastures, and a fragmented mosaic of different biotopes (Lindgren and Stjernberg 1986; von Numers 1995; Lindgren 2000). The area of the Archipelago Sea is 8300 km^2. After the glacial period, most of the islands have emerged from the sea over the past 4000–5000 years, and land uplift is still an ongoing process; 3-5 mm a^{-1} (Skult 1956; Kakkuri 1987). The islands consist mainly of gneiss and granite bedrock with soil layers of moraine, sand or gravel deposition (GTK 2015).

The study area is located mostly inside the Archipelago Sea National Park (founded 1983), but I also included some study sites from islands that surround the national park. In total, the study area covers 151 km^2 of land and 2896 km^2 of sea, and contains 8384 islands or skerries (size at least 100 m^2). However, only 23% of land area is protected, and the remainder located inside of the boundary (see **I**), is unprotected privately owned land.

The area is a particularly good environment for studies on structural characteristics and naturalness of forests. For example, when comparing the average volume of dead wood in the archipelago to the national-level average volume of dead wood, it is clear that there is more dead wood here than in Southern Finland in general (Juntunen 2014; **III**). It is essential

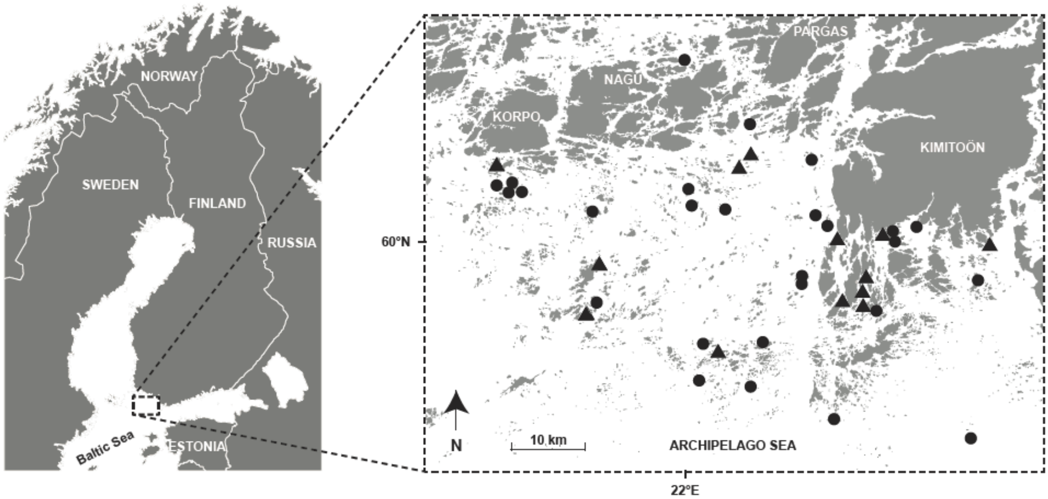

Figure 1. Location of the study sites. Round symbol refers to the study site with survey of polypores and corticioids, and triangle symbol refers to the study site only with polypore survey.

to note that the structure and forest types are very diverse in the archipelago forest due to environmental factors, and despite high levels of CWD there is also a historic human influence on many of these island ecosystems. Herb-rich forests and xeric or barren heath forests are more common here than elsewhere in Southern Finland (Kuusipalo 1996). In general, archipelago forests are rather little studied: studies have been done on eutrophic deciduous woods (Hinneri 1972), forest resources (Simojoki 1975), and on the distribution of conifer and deciduous forests (Koskinen 2011) and a number of studies have been carried out in relation to forests and tree stands (Tenovuo 1955; Skult 1956; Korvenpää et al. 2003). Nevertheless, forest vegetation and botany have been studied in the area of Archipelago Sea for over 100 years (Bergroth 1894; Eklund 1931; Olsoni 1939; von Numers and Korvenpää 2007).

2.2 Sampling of fungal data (I, II, IV, V)

Polypores and corticioids were surveyed and sampled in 2008–2010 between late July and early November, which corresponds to the peak sporocarp (fruit body) formation season for these fungal groups in Finland (Halme and Kotiaho 2012). Each study site (island) was visited once, and each fungal species found on one dead wood unit was considered as one record. The fungal survey was based on the detection of the sporocarps and is a widely-used and established method to survey wood-inhabiting fungi in field studies (e.g. studies described in Halme et al. 2009).

The search effort of fungi was proportional to the size of the island (i.e. substrates were inventoried in relation to island area): one dead wood unit was surveyed for every two hectares for four tree species and five diameter categories (see Tables 1 and 2 for division). The aim was to have an equal number of dead wood units in each category within an island, but not enough dead wood was available for all wood categories on all islands. Every inventoried dead wood unit was classified or measured based on dead wood type (Tonteri and Siitonen 2001), diameter, decay stage (McCullough 1948; Renvall 1995) and tree species.

In total, 10,874 dead wood units were surveyed (Table 1 and 2), although the number of analyzed dead wood units was different between studies, and none of the studies included all units.

Table 1. Number of investigated units of dead wood for polypores (40 islands) according to their diameter category (cm) and tree species.

Tree species	Downed 3–9 cm	Downed 10–19 cm	Downed 20–29 cm	Downed ≥ 30 cm	Dead standing trees ≥10 cm	Total
Scots pine	760	739	686	543	745	3473
Black alder	728	713	533	273	718	2965
Birches	582	510	352	195	457	2096
Other tree species	702	490	357	286	505	2340
Total	2772	2452	1928	1297	2425	10 874

Table 2. Investigated units of dead wood for corticioids (27 islands) according to their diameter category (cm) and tree species.

Tree species	Downed 3–9 cm	Downed 10–19 cm	Downed 20–29 cm	Downed ≥ 30 cm	Dead standing trees ≥10 cm	Total
Scots pine	464	456	412	351	466	2149
Black alder	414	399	279	156	405	1653
Birches	317	277	193	112	256	1155
Other tree species	393	294	215	147	285	1334
Total	1588	1426	1099	766	1412	6291

In total, 8532 fungal records at species or genus level were made. The fungi were identified *in situ* or collected for microscopic identification (3632 specimens): 96 specimens remained at the genus-level and it was not possible to identify 114 specimens. The specimens were identified by Matti Kulju, Panu Kunttu, Heikki Kotiranta, Jorma Pennanen, and Urmas Kõljalg. Voucher specimens were deposited in the herbaria of the Universities of Turku (TUR), Helsinki (H) or Jyväskylä (JYV).

The nomenclature of the genus *Hyphodontia sensu lato* follows Hjortstam and Ryvarden (2009), the polypores mainly follow Niemelä (2005), and the other groups mainly follow Kotiranta et al. (2009). Some names and combinations are presented in Singer (1944), Nilsson and Hallenberg (2003), Bernicchia and Gorjón (2010), Miettinen and Larsson (2010), Miettinen et al. (2012b) and Spirin et al. (2013b). The Finnish national red-listing evaluation of the IUCN Red List Categories is in accordance with Kotiranta et al. (2010), studies **I** and **IV** are also in accordance with Rassi et al. (2001). Indicator species of old-growth forest (**I**, **IV**, **V**) are in accordance with Kotiranta and Niemelä (1996) and with Savola (2015) in study **IV**.

2.3 Sampling of dead wood data (III)

I used line intersect sampling (LIS) and sector sampling (also called belt sampling) (Van Wagner 1968; Shiver and Borders 1996; Kangas et al. 2004) to measure the above-ground dead wood on the islands. The length of the line was determined in relation to the size of the forested area of each island: 50 m of line was surveyed for each forested hectare. A total of 8667 units of dead wood were measured along the study lines, with a total length of 72.1 km. In total, 12 tree species or genera were observed. The field work was carried out in 2009–2010.

Every intersected dead wood unit with a minimum diameter of 3 cm and a minimum length of 30 cm was measured. Measured characteristics were dead wood type (Tonteri and Siitonen 2001), tree species, length, decay stage and diameter. Decay stage was determined using five classes according to Renvall (1995). Kelo trunks of Scots pines were recorded, although Juniper (*Juniperus communis*), a common shrub in the archipelago, was excluded.

Forest and other habitat types were recorded along the line according to Kuusipalo (1996) and Laine and Vasander (1998). Standing dead trees and stumps were counted using the belt sampling method with a transect of 1 m width on both sides of the study line. A more detailed method description can be found in study **III**.

2.4 Data classification and analyses

2.4.1 Indicators of forest naturalness (III)

In study **III**, the rank-based Spearman's correlation were used to explore the pair-wise correlations of continuous naturalness variables (volume of dead wood, dead wood diversity index and number of cut stumps) and the one-way analysis of variance (ANOVA) was used to compare whether dead wood continuity patterns were reflected in the other naturalness indicators. In addition, Kendall's coefficient of concordance (Kendall's W-test) was used to test whether the indicators provided similar ranking of the sites. To check if the results differed between the two archipelago zones, the same analyses were carried out separately for the islands in the middle and the outer archipelago zones. Rarefaction estimates for the dead wood diversity indices were calculated by the software package Analytic Rarefaction (Holland 2003).

2.4.2 Occurrence patterns on substrates (IV)

For the analyses of fungal occurrence patterns on substrates and hosts, the tree species of the dead wood units were divided into four species groups: black alder, birches, other deciduous trees and conifers. Dead wood types were divided into four classes 1) dead standing trees and snags, 2) fallen trunks and logs, 3) fallen branches and logging residues, and 4) natural and cut stumps. Diameter classes are presented in Table 1. In the kelo-class, I included all dead wood units that originated from kelo trees, i.e. not only dead standing or whole fallen trunks but also cut logs, fallen branches and stumps. The distribution of records of these kelo species was compared only to dead wood units in the kelo category.

In the analyses, the fungal species were divided into five, partly overlapping groups: polypores, corticioids, species of conservation concern, rare species, and species on kelo trees. The substrate material was divided into three groups: polypore-rich substrates, corticioid-rich substrates, and species-rich substrates. Empty dead wood units constituted one group. The proportional frequency distributions of fungal records or substrates were compared to the distributions of all surveyed dead wood within each dead wood variable. Detailed definitions of groups and the number of units in each of the categories can be found in study **IV**.

The G-test of goodness-of-fit was used to determine whether the relative frequency distributions of fungal records on the available substrates followed the availability of dead wood categories, or if they appeared more than expected on specific substrates. The independence of the frequency distributions of the attribute categories between polypores and corticoids was tested using the Goodman-Kruskal Tau -test (G-K τ).

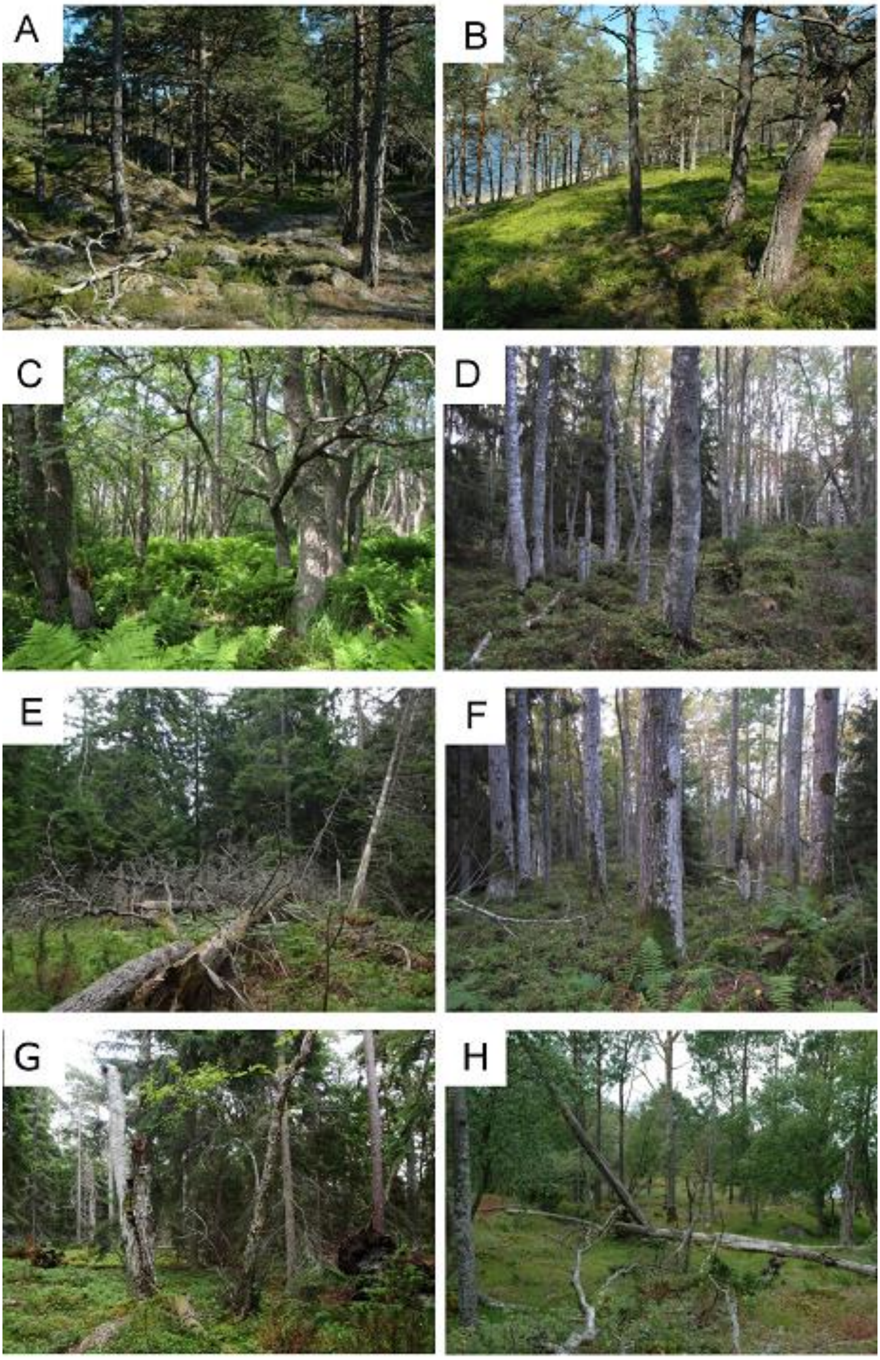

Figure 2. Typical forest habitat types in the study area: A) barren pine forest, B) mesic heath pine forest, C) herb-rich black alder forest, D) mesic heath birch forest, E) mesic heath spruce forest, F) mesic heath aspen forest, G) mesic heath mixed forest, H) semi-natural herb-rich wooded pasture. Photos: Panu Kunttu.

2.4.3 Aphyllophoroid fungi on black alder (V)

For each species, the proportion of records on black alder was counted and compared to all data of aphyllophoroid fungi on the study islands. Substrate patterns were more thoroughly analyzed for the species with at least seven records in the substrate material. The purpose was to identify species with a restricted or a wide substrate range. The following occurrence patterns were compared: the highest proportions of records found on black alder, species with the largest and the smallest median substrate diameter, species with the widest substrate diameter range, species on the most decayed and the hardest-surfaced substrate according to the median decay stage, the number of dead wood types (highest and lowest) and species that were most concentrated on some dead wood type.

The G–test of goodness-of-fit was used to determine whether the relative frequency distributions of fungal records on the substrates followed the availability of dead wood substrates. The G–tests were run using McDonald's (2014) algorithm. To explore the overall coverage of sampling and data, species accumulation curves (Soberón and Llorente 1993) were estimated for polypores and corticoids.

3 RESULTS AND DISCUSSION

3.1 The islands of the Archipelago Sea sustain a high diversity of aphyllophoroid fungi (I, II)

The recorded number of aphyllophoroid species in the Archipelago Sea National Park was 303 species (**I**). This is 40% of all known species in these species groups in Finland and ca. 62% of species found earlier from the coastal region of southwestern Finland. The list comprises 106 polypores, 195 corticioids sensu lato and two wood-inhabiting hydnaceous fungi (**I**). Moreover, the species diversity of the whole study in this area, not only in the national park, covers 331 aphyllophoroid species. All recorded species and their numbers found on the host trees are listed in the Appendix.

Eight species new to Finland were found: *Peniophorella tsugae, Phlebia cremeoalutacea, Tomentella albomarginata, Tomentella cinereoumbrina, Tomentella fuscocinerea, Trechispora araneosa, Tubulicium vermiferum* and *Tulasnella danica* (see also Kunttu et al. 2011, 2012; **II**). Four of these are also globally rare species. The list includes 30 species that can be defined as rare, or at least rarely collected, with five or less previous records in Finland (Kotiranta et al. 2009). In addition, at least seven still undescribed species were found, such as species in genera *Thelephora* and *Xylodon* (*Hyphodontia*), as well as some cryptic species in genera *Piloderma* and *Tomentellopsis*. The most species-rich genera were *Trechispora* (19 species), *Phellinus* (13), *Tomentella* (13), *Hypochnicium* (10) *Postia* (10), *Botryobasidium* (8), *Hyphoderma* (8), *Phlebia* (8), and *Tubulicrinis* (8). Preliminary studies of macrofungi in this area by Vauras (2000) reported 119 species of my target groups.

The reasons behind the high species diversity may be that the area is characterized by its geographical location in the hemiboreal vegetation zone, which entails a long growing season compared to the boreal zone and a diversity of host tree species, a mosaic and diversity of different habitats, several environmental gradients, largely unmanaged or non-intensively managed forests, and a long pasture history with domestic animals (semi-natural biotopes).

It is not possible to directly compare the number of species with other areas since surveys of aphyllophoroid fungi in other national parks or other areas in Southern Finland include only polypores or a very limited group of corticioids, or because different inventory methods make direct comparisons difficult (e.g. Schigel 2007; Kunttu et al. 2015; Savola and Kolehmainen 2015).

I found 13 old-growth forest indicator species for pine dominated forests in the Archipelago Sea National Park and the indicator value was 14 points (the value for the whole study area was 18 points), according to the classification of Kotiranta and Niemelä (1996) (**I**). If this is compared to some other polypore inventories of pine dominated forests in other national parks along the southern coast of Finland, it is clear that the amount is relatively high (Kunttu et al. 2015; Savola and Kolehmainen 2015). The remote location has saved these areas from large-scale intensive forestry and this may explain why many forests in the archipelago have a high degree of naturalness (**III**). Many of these old-growth forest species are today common only in protected areas in northern or eastern Finland (e.g. Renvall 1995; Lindgren 2001; Sippola et al. 2005). It is obvious that these species had earlier covered almost the whole of Finland (Kotiranta and Niemelä 1996).

The species diversity and distribution of aphyllophoroid fungi is still inadequately known in Finland. It is highly likely that dozens of species remain undiscovered, and many species have a wider distribution than has been recognized thus far. This study contributed to knowledge base of fungi in the larger geographical perspective as well: the results reveal that knowledge gaps in regard to fungi also remain in Europe. However, some substrates and fungal groups were excluded from this study, such as juniper a common shrub in this area, very fine woody debris (diameter < 1 cm), drift wood logs on shores, all soil-dwelling aphyllophoroid fungi (including some polypore species also) and wood-inhabiting clavarioids. The inclusion of these in future studies would reveal more about the true species richness of aphyllophoroid fungi in the study area.

3.2 The volume of dead wood provides the best overall agreement with other indicators of forest naturalness (III)

The volume of dead wood was most often related to other indicators of forest naturalness (**III**). It is thus likely that the volume of dead wood could provide a measure that is the most reliable overall. The volume of dead wood is often used to describe the main characteristics and conservation value of natural or managed forests (Stokland et al. 2004; Mönkkönen et al. 2008; Müller and Bütler 2010). However, the volume of dead wood also varies considerably within natural forests (Siitonen 2001) and, thus, it cannot provide an unambiguous measure of naturalness. Thus, when dead wood volumes of separate forest areas are compared, the forests should represent the same forest habitat type and be located within the same vegetation zone.

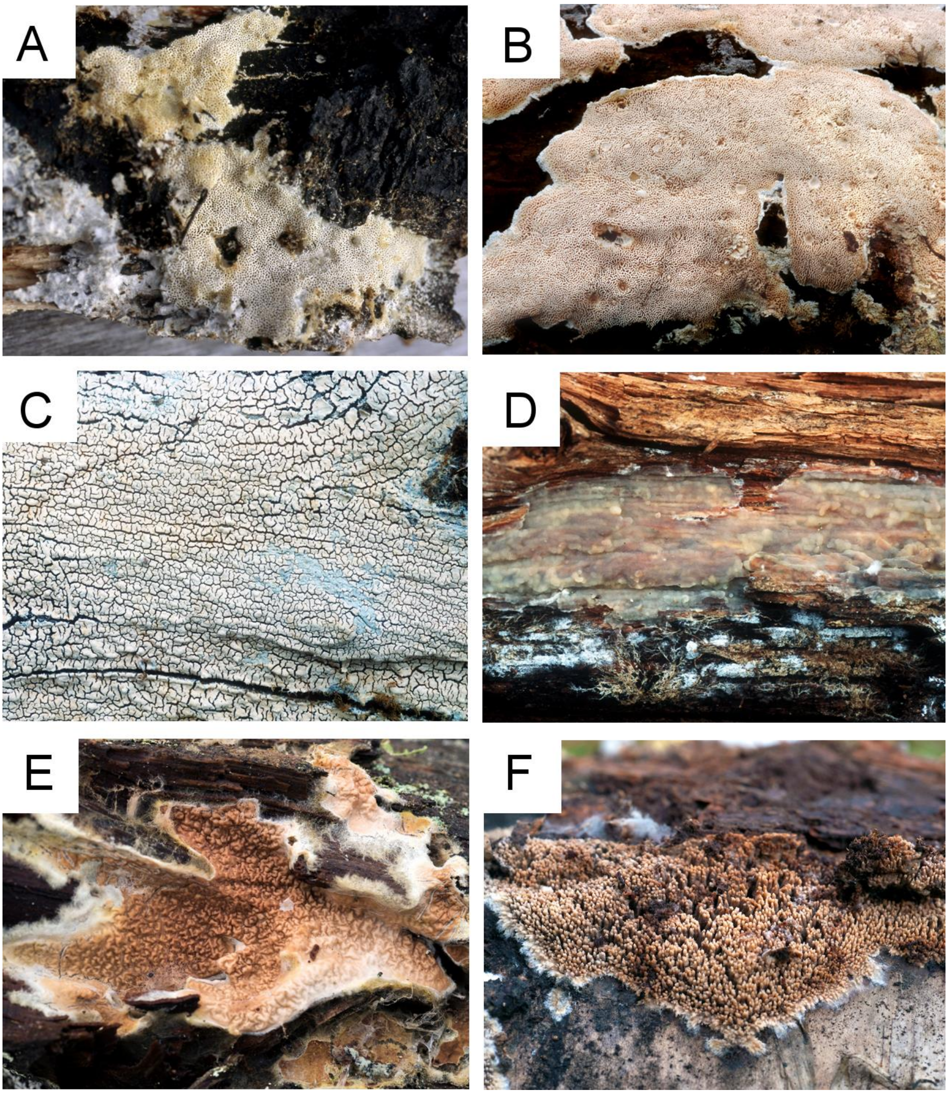

Figure 3. Selected rare aphyllophoroid species found in this study: A) *Gelatoporia subvermispora*, B) *Postia hibernica*, C) *Sistotremastrum suecicum*, D) *Crustoderma corneum*, E) *Pseudomerulius montanus*, and F) *Mycoacia fuscoatra*. Photos: Pekka Helo.

The dead wood diversity index was related to the volume of dead wood (**III**). Obviously, the number of tree species and forest habitat type affect the dead wood diversity index. Consequently, on barren islands with mostly pine as a dominant tree species, this index can be expected to be low even if the forest is in a natural state. In more productive forests where the richness of tree species is higher, dead wood diversity can also be higher naturally. Due to this natural variation, it is more likely to be useful as an explanatory variable of the species richness in forests (Martikainen et al. 2000; Similä et al. 2003; Penttilä et al. 2004; Ylläsjärvi et al. 2011). However, the dead wood diversity index is clearly higher in natural old-growth forests than in mature managed forests (Siitonen et al. 2000).

The number of cut stumps was related to the volume of dead wood. A similar correlation has been found earlier by Karjalainen and Kuuluvainen (2002). The number of cut stumps is easy to measure in a forest and it can, therefore, be easily applied in practical forest inventories (Uotila et al. 2002; Rouvinen and Kouki 2008). If the previously used criteria of stumps are applied to current study sites (Siitonen et al. 2000; Rouvinen et al. 2002; Uotila et al. 2002; Okland et al. 2003; Ylläsjärvi et al. 2011), 12–30% of my study islands would support natural forests. Nevertheless, forests with few or no cut stumps can still have a low dead wood diversity, such as barren forests with only one major tree species. Furthermore, the number of cut stumps is not a reliable indicator of very old management operations.

The volume of dead wood and the dead wood diversity index varied significantly along with the dead wood continuity patterns (**III**). The dead wood continuity profile is a practical indicator of forest history in all types of forests, as it provides data on the dead wood continuity over past centuries, and also reveals the historical intensive human impact (Stokland 2001). Moreover, the historic continuity of dead wood, rather than the current amount of dead wood, predicts species diversity of the present-day (Sverdrup-Thygeson and Lindenmayer 2003; Paltto et al. 2006; Penttilä et al. 2006). Continuity patterns vary naturally in different forest habitat types mainly due to their productivity (Stokland and Larsson 2011).

The number of kelo trees had hardly any relationship to the other naturalness indicators (**III**) despite the fact that kelos are known to occur only in natural forests (Niemelä et al. 2002). However, due to the formation history of kelos (Leikola 1969; Niemelä et al. 2002), they can be used as an indicator of naturalness in specific cases, i.e. in xeric and barren forests with pine as a dominant tree species.

A practical indicator is easy and rapid to use, and the presented indicators described here require varying amounts of effort. The volume of dead wood, the dead wood diversity index and the dead wood continuity profile are the most laborious, whereas the number of cut stumps and the number of kelos per hectare are quick to measure. Moreover, the number of cut stumps is directly related to human activity and can thus be easily used to indicate the lack of naturalness. Aside from the continuity profile, the other indicators can only be used to assess rather recent changes in forest naturalness.

Importantly, however, the results of my studies show that different CWD-related indicators do not always produce consistent results when applied to the same forests. The volume of dead wood was most often correlated with other naturalness indicators and can thus be regarded as the most consistent measure, whereas the dead wood diversity index may provide the best surrogate for species diversity. As the different indicators are inconsistent, it is unlikely that all of them are applicable to reveal species diversities either, and that we need more documentation on how the various naturalness indicators relate to species diversity patterns.

3.3 The occurrence of fungi does not follow exactly dead wood availability, and polypores and corticoids have several distinct occurrence patterns – a diversity of substrates is needed (IV)

The results showed that the occurrence of fungi and their species-rich substrates did not follow the availability of dead wood in forests. The only exception among the dead wood variables was for their distribution on tree species where observations followed closely the availability of hosts (**IV**). The results indicate the high importance of substrate quality and of specific substrate types on wood-inhabiting fungi. Polypores and corticioids showed occurrence patterns distinct from each other. There was a clear difference in their record based occurrence on dead wood, as they differed from each other in all four dead wood variables (**IV**). This reveals the ecological differences of these fungal groups and possibly their different role as wood-decayers.

According to my results, the records of corticioids seemed to follow the availability of the different tree species fairly closely (**IV**). Likewise, Lindhe et al. (2004) found that the number of fungal records was similar when the number of surveyed dead wood units of different tree species was equal. However, polypores were more common on birch but this pattern was largely caused by two very common species that occur on birch. On conifer trees, fungi occurred less often than could be expected from the availability of these tree species. While black alder hosts a high fungal diversity (**V**), the ocurrence pattern followed the availability of substrate closely. In general, most wood-inhabiting fungi favour specific tree species or species groups (Lindner et al. 2006; Boddy and Heilmann-Clausen 2008; Küffer et al. 2008; Junninen and Komonen 2011).

Logs were clearly found to be the most important substrate for all studied groups (**IV**). Logs were especially important as species-rich and polypore-rich substrates for rare species and for kelo species. The importance of downed dead wood, especially logs or fallen trunks, has been recognized in several other studies as well (Sippola and Renvall 1999; Sippola et al. 2005; Junninen and Komonen 2011). Of the other substrate types, only dead standing trees seemed to be of importance for polypores (**IV**), mainly as a few very common species were found on dead standing deciduous trees. However, most of the species that grow on dead standing trees can also grow on downed dead wood (Lindhe et al. 2004; Sippola and Renvall 1999). Thus, I conclude that dead standing trees have a smaller role as substrates for wood-inhabiting fungi (Rydin et al. 1997; Heilmann-Clausen and Christensen 2004; Sippola et al. 2005; Pasanen et al. 2014).

The importance of large-diameter dead wood for polypores was clearly seen in the distribution of the polypore records, polypore-rich substrates and even corticioid-rich substrates. However, corticioid-rich substrates were mainly the smallest fraction of the CWD (**IV**). The importance of large-diameter dead wood for wood-inhabiting fungi has been shown in several studies (e.g. Ohlson et al. 1997; Nilsson et al. 2001; Siitonen et al. 2001). Nevertheless, fine woody debris and very fine woody debris also play an essential role for wood-decaying fungi, many of whom are rare or at least seldom collected (Nordén et al. 2004; Küffer et al. 2008; Juutilainen et al. 2011, 2014; Abrego and Salcedo 2013). However, the current study highlights the importance of the smallest fraction of CWD (10–19 cm) for corticioids (**IV**). Surprisingly, species of conservation concern, rare species or species living on kelo trees were not overrepresented on the largest dead wood diameters but were overrepresented on the 10–19 cm class. In total, 90% of fungal records of rare species were corticioids, and this at least partly explains the result.

Polypores followed the availability of the different decay stages fairly closely, whereas corticioids were found on slightly more decayed wood (**IV**). The corticioid-rich substrates were more concentrated on the later decay stages than the polypore-rich substrates. The species-rich substrates were concentrated on slightly and intermediately decayed wood (**IV**).

The results of this study revealed the important role of slightly decayed wood for fungi, although many other studies have shown that the majority of wood-inhabiting aphyllophoroid species favour intermediately decayed wood, (Groven et al. 2002; Heilmann-Clausen et al.

2005; Siitonen et al. 2005; Sippola et al. 2005; Junninen et al. 2006; Jönsson et al. 2008). In my study, the relative importance of less decayed wood was probably due to a few numerous species that were concentrated on fresh or slightly decayed wood. The occurrences of species of conservation concern were found on earlier decay stages (**IV**). This resulted from several old-growth forest indicator species on pine that commonly grew on fresh dead wood also. In general, red-listed species have been found to favour wood on intermediately or advanced decay stages (Tikkanen et al. 2006; Pouska et al. 2011; Magnusson et al. 2014).

The kelo species were found most often on slightly and intermediately decayed wood but this may result from the fact that the continuity of kelo trees may have been broken on some study islands (**III**). The final decomposition stage had only a minor role for the studied fungi, and this result agrees with earlier studies (e.g. Høiland and Bendiksen 1997; Renvall 1995). Nevertheless, in molecular studies it has been found that the number of wood decay fungi generally increase as the log becomes more decomposed (Rajala et al. 2015; Hoppe et al. 2016).

My findings indicate the importance of maintaining the variation in dead wood quality when preserving the diversity of wood-decaying fungi. Moreover, according to the results of this study, species-empty substrates were overrepresented within dead standing trees and stumps, as well as on dead wood in early and late decay stages (**IV**). Recognizing the dead wood quality associations of fungi can contribute to the success of ecological forest restoration from a fungal perspective. Dead wood creation is one of the key restoration activities (Halme et al. 2013) in forests but restoration does not automatically lead to high fungal species diversity (Pasanen et al. 2014). My results also indicate that if dead wood is restored in forest ecosystems, special attention must be paid to the restoration of different dead wood types and not to focus primarily on restoring a specific volume of dead wood.

3.4 Black alder hosts a diverse fungal assemblage with a range of occurrence on substrates of fungal species, many of them also rare (V)

Several species growing on black alder were restricted to specific dead wood types while others had a remarkably wide substrate utilization. Based on this, potential generalist and specialist species were identified (**V**). Many of the alder-associated species are also rare. The results revealed that black alder also hosts a diverse fungal assemblage and that the preservation of it in forest management helps to maintain the diversity of saproxylic fungi.

Black alder hosted over 40% of all aphyllophoroid species found in the whole study of all tree species carried out on these islands. In total, 27 species were found solely on black alder (**V**). Mostly these species had only one or two occurrences and records may be random; however *Phlebia subochracea*, *Hypochnicium erikssonii* and *Tomentella ellisii* for example displayed several occurrences. Other alder-favoured species were *Stereum subtomentosum*, *Inonotus radiatus*, *Antrodiella serpula*, and *Botryobasidium candicans*, all with over 80% of records on black alder (**V**). In general, most of the species growing on black alder are generalists in regard to host tree species and occur also on other deciduous trees. However, alders host tens of species that appear to be dependent or at least strongly favour alder as a substrate (Strid 1975; Niemelä and Kotiranta 1983; Keizer and Arnolds 1990; Kotiranta et al. 2009; Safonov 2014).

While black alder does not host many red-listed species according this study (**V**), it has an important role as a host for many deciduous tree-dependent fungal species (Keizer and Arnolds 1990; Safonov 2014; **V**). Moreover, many new or rare species have been recently collected from black alder in other studies (e.g. Miettinen 2012; **II**). Of course many species of conservation concern can grow on alders and according to Kotiranta and Niemelä (1996) alder was listed as the fourth most important host tree genus among red-listed aphyllophoroid fungi at that time. Even though black alder or grey alder are not especially rare trees, they do host many rare or at least seldom collected aphyllophoroid species, and some of them appear to be dependent or at least highly favour alder as a substrate, including red-listed fungi and indicator fungi of conservation value (Strid 1975; Keizer and Arnolds 1990; Kotiranta et al. 2009; **V**).

The majority of the records on alder were derived from fallen trunks, which is in accordance with the substrate preferences of wood-inhabiting fungi in general (Sippola and Renvall 1999; Sippola et al. 2005; Lindhe et al. 2004, **IV**). Moreover, most species growing on dead standing trees, such as *Inonotus radiatus* and *Stereum rugosum* can also grow on downed dead wood and were also common on dead standing trees in this data (**V**). Decay stage is an important substrate factor for most aphyllophoroid species and many species favour or depend on certain stages of decay (Niemelä et al. 1995; Renvall 1995; Lindblad 1998; Nordén et al. 2013). Most of the wood-inhabiting aphyllophoroid species favour the intermediately decayed dead wood (Kruys et al. 1999; Heilmann-Clausen et al. 2005; Jönsson et al. 2008; Junninen and Komonen 2011), but on alder most of the records derived from recently dead or initially decayed dead wood. However, a few common species with preference for hard wood can affect this result significantly, since they can dominate the record based data.

The relative frequency distributions of total fungal records among dead wood variables differed from the distribution of the surveyed dead wood units both in the decay stage and in dead wood type. However, the magnitude of differences between fungal records and surveyed dead wood units were not large. The largest difference was observed on fallen trunks that clearly hosted more fungi than what was the availability of these trunks (**V**). It should be noted that these results were based on the number of records, so it does not reveal the preferences of individual species. A few numerous species can affect this result remarkably.

3.5 Improvements on fungal databases, monitoring and storage of fungal information for improving knowledge and conservation of poorly known macrofungi

In the review, we observed that there are several serious shortcomings in regard to fungal monitoring, and a rapid and comprehensive improvement is required to reach a better understanding of the distribution, population trends and habitat requirements of fungal species (**VI**) that would better serve the conservation of fungi.

Opportunistic fungal foraying is highly unstructured and the results depend on the skills or interest of the mycologist, the time spent and the fungal season. However, foraying is often the best way to record rarely sporulating species that may be missed using more structured sampling methods (Mueller et al. 2004). While it is easy to standardize for changes in foray activity over time, it is a challenge to standardize for changes in the quality or focus of forays over time or between mycologists (Heilmann-Clausen and Læssøe 2012).

More structured data on fungal records can be derived from professional field studies, but little research has been carried out to optimize sampling designs (O’Dell et al. 2004; Keizer and Arnolds 1990; Halme and Kotiaho 2012). The practices of field methodologies and sampling procedures vary considerably between studies. If the field methodology is well-defined and adequate, studies of changes over space or environmental gradients have the potential to produce high-quality structured data (**VI**) that is suitable to document changes in fungal sporulation over time (Arnolds 1988; Senn-Irlet et al. 2007; Arnolds and Veerkamp 2011).

The scientific relevance of samplings based on sporocarps has been repeatedly questioned as the vegetative mycelium cannot be observed with these methods (Allmér et al. 2006), which results in incomplete data on fungal assemblages (Geml et al. 2009). Alternative techniques based on the isolation of fungi present in environmental samples, and molecular tools have been developed recently (Allmér et al. 2006; Lindahl and Boberg 2008; Porter et al. 2008). Molecular methods have a high potential when applied in a specific conservation context and give remarkable benefits to fungal monitoring (Parfitt et al. 2005). However, these methods are not without problems either. One serious constraint is the lack of comprehensive reference sequence libraries, which may inhibit effective species identification. However, the progress in methodological and data analysis techniques has been rapid and reference libraries are likely to be developed quickly (e.g. Huson et al. 2007; Quince et al. 2009, 2011; Schloss et al. 2009).

In addition, molecular techniques are developing rapidly and will likely offer new tools to fungal monitoring (**VI**). For example, high throughput sequencing methods are not yet widely used in monitoring programmes yet their potential is enormous, and fungal population trends in the near future can probably be followed in a meaningful way by using standardized sampling methods based on environmental samples. Nonetheless, monitoring based on sporocarps is still needed and will probably remain useful in the future for several reasons (**VI**). Firstly, sporocarps can use citizen science in data collection (Bonney et al. 2009) and for very rare species the search for sporocarps might be the only cost-effective way to obtain records. Secondly, the emergence of sporocarps may provide more information about the reproductive success than the presence of mycelia. Finally, existing monitoring data on sporocarps has been collected for decades and this data provides the baseline for fungal monitoring (e.g. Arnolds and Jansen 1992; Gange et al. 2011). The molecular data grows quickly but it will nevertheless take long before its temporal coverage exceeds what is currently available in sporocarp data.

In addition to the field sampling methods, the storage and analyses of existing samples requires more attention. Specimens deposited in fungaria, which provide collections of samples of taxonomic value, are typically biased towards rare or otherwise notable species or difficult species complexes. Thus, the detection of population trends is difficult based on fungarium specimens (**VI**). However, the advantage of fungarium collections is that they provide unambiguous proof that a species occurred in a specific site at a given date. Further, they allow the species identity to be rechecked when more taxonomic and molecular knowledge becomes available.

In the review, we observed that the information related to sampling details in research projects is rarely stored in a standardized way, and in more unstructured foraying surveys the input is often not recorded at all. It is likely that the value of fungal recording can be increased considerably if the survey input is recorded in a standardized way. Survey data should include details on time spent searching, the type of sampling conducted and targets for the survey i.e. an index of survey input (**VI**). Current GPS systems and techniques offer a practical way to record survey input and enable, for example, the tracking of survey routes and the calculation of the surveyed area. All collected information should be stored in electronical global databases with special entries regarding fungi (**VI**). These databases should be in connection with the Global Biodiversity Information Facility, the most extensive metadatabase currently available (Telenius 2011).

In general, the review pointed out several new aspects to fungal monitoring schemes: there are needs for standardization of information collected during field work, determination of survey input, storage of data, development of a global and fungal focused database, utilization of molecular techniques and more effective use of data collected by amateur mycologists (**VI**).

4. CONCLUDING REMARKS

Although our knowledge on dead-wood-associated species has developed significantly during the last decades, there are still major unexplored issues that may also have an influence on how the diversity of these assemblages is best maintained. My results on occurrence patterns imply high importance and ecological significance of substrate quality and diversity on dead-wood-associated fungi. The substrate patterns of different fungal groups vary, and in many cases their substrates were not directly reflected to the dead wood that was available (**IV**). It is not only large-diameter and intermediate or advanced decayed dead wood that are important for dead wood-associated fungi; smaller-diameter and slightly decayed dead wood are also significant (**IV**). For example, the smallest fraction of CWD seems to be important for corticioids (**IV**). Furthermore, the diversity of the host trees directly affects both fungal occurrence and specialized species (**IV**, **V**). My analyses were based on fungal records and may also reveal the ecological role and the differences between wood decaying fungi in a wider perspective in regard to the decomposition process and carbon cycling in forest ecosystems.

Measures in assessment of forest naturalness are based on the same dead wood related variables as the substrate characteristics of the fungi. The state of forest naturalness affects the amount and characteristics of CWD and, thus, also modifies the assemblages of wood-inhabiting fungi (e.g. Junninen et al. 2006). Variations and changes in the naturalness affect the type of dead wood that is available. It is essential to recognize the most reliable methods for naturalness assessment, and to develop consistent methods to assess it (**III**). Dead wood is widely recognized as a key element in forest naturalness. Despite this, simple methods to use CWD as an indicator are lacking or are used inconsistently. My results (**III**) show that there is still an obvious need for further studies that relate the indicators based on dead wood to real levels of naturalness and to the occurrence of saproxylic species. It is also a future challenge to define reference levels or thresholds for such indicators that are scaled relative to site productivity and forest habitat types.

Reliable and extensively performed species surveys provide essential baseline data for conservation work. Field work methods (collected information) and storage of the data should receive more attention in order to take full advantage of several fungal sampling methods and to promote their compatibility and comparability (**VI**). It is essential to standardize the ways that data are collected in research projects. For example, there are gaps in the recording of negative species records i.e. unoccupied substrates or habitats (**IV**, **VI**). This information is crucial since only with species occurrence data is it possible to connect resource availability to species occurrence and to identify the true preference patterns of wood-associated fungi.

In conclusion, my results suggest that the diversity of dead wood is essential when planning conservation measures for dead wood associated fungi. In particular, uncommon hosts may also contribute significantly to fungal diversity. Assessment of forest naturalness can be performed with several methods, but the most promising methods may vary depending on the purpose of the study and the forest type or region where the assessment is done. Finally, the collection of data is not enough. It must be stored in an open access database with adequate information of all aspects of survey input. This would then allow population trends to be monitored and area or habitat related information utilized for conservation efforts.

REFERENCES

Abarenkov K., Nilsson R.H., Larsson K., Alexander I.J., Eberhardt U., Erland S., Hoiland K., Kjoller R., Larsson E., Pennanen T., Sen R., Taylor A.F.S., Tedersoo L., Ursing B.M., Vralstad T., Liimatainen K., Peintner U., Kõljalg U. (2010). The UNITE database for molecular identification of fungi e recent updates and future perspectives. New Phytologist 186: 281–285. http://dx.doi.org/10.1111/j.1469-8137.2009.03160.x

Abrego N., Salcedo I. (2013). Variety of woody debris as the factor influencing wood-inhabiting fungal richness and assemblages: is it a question of quantity or quality? Forest Ecology and Management 291: 377–385. http://dx.doi.org/10.1016/j.foreco.2012.11.025

Ahti T., Hämet-Ahti L., Jalas J. (1968). Vegetation zones and their sections in northwestern Europe. Annales Botanici Fennici 5: 169–211.

Aksenov D., Dobrynin D., Dubinin M., Egorov A., Isaev A., Karpachevskiy M., Laestadius L., Potapov P., Purekhovskiy A., Turubanova S., Yaroshenko A. (2002). Atlas of Russia’s Intact Forest Landscapes.

Allmér J., Vasiliauskas R., Ihrmark K., Stenlid J., Dahlberg A. (2006). Wood-inhabiting fungal communities in woody debris of Norway spruce (*Picea abies* (L.) Karst.), as reflected by sporocarps, mycelial isolations and T-RFLP identification. FEMS Microbiology Ecology 55: 57–67. http://dx.doi.org/10.1111/j.1574-6941.2005.00010.x

Arnolds E. (1988). The changing macromycete flora in the. Netherlands. Transactions of the British Mycological Society 90: 391–406.

Arnolds E., Jansen E. (1992). New evidence for changes in the macromycete flora of the Netherlands. Nova Hedwigia 55: 325–351.

Arnolds E., Veerkamp M.T. (2011). Paddestoelenmeetnet. http://nem.paddestoelenkartering.nl [Cited 30 Apr 2016]

Benson D.A., Karsch-Mizrachi I., Lipman D.J., Ostell J., Sayers E.W. (2011). GenBank. Nucleic Acids Research 39: D32-D37. http://dx.doi.org/10.1093/nar/gkq1079

Bernicchia A., Gorjón S.P. (2010). Corticiaceae s. l. Fungi Europaei, Vol. 12, Edizioni Candusso, Alassio.

Bergroth O. (1894). Anteckningar om vegetationen i gränstrakterna mellan Åland och Åbo-området. Acta Societatis pro Fauna et Flora Fennica 11(3): 1–78.

http://hdl.handle.net/10138/15949

Boddy L., Heilmann-Clausen J. (2008). Basidiomycete community development in temperate angiosperm wood. In: Boddy L., Frankland J.C. van West P. (eds.) Ecology of saprotrofic Basidiomycetes. Academic Press, London. p. 211–237.

Bonney R., Cooper C.B., Dickinson J., Kelling S., Phillips T., Rosenberg K.V., Shirk J. (2009). Citizen science: a developing tool for expanding science knowledge and scientific literacy. BioScience 59: 977–984. http://dx.doi.org/10.1525/bio.2009.59.11.9

Borges P.A.V., Gabriel R., Arroz A.M., Costa A., Cunha R.T., Silva L., Mendonça E., Martins A.M.F., Reis F., Cardoso P. (2010). The Azorean Biodiversity Portal: An Internet database for regional biodiversity outreach. Systematics and Biodiversity 8: 423–434. http://dx.doi.org/10.1080/14772000.2010.514306

Biodiversity Information Standards (2016). http://www.tdwg.org/ [Cited 22 Apr 2016]

Brūmelis G., Jonsson B.G., Kuuluvainen T., Kouki J., Shorohova E. (2011). Forest naturalness in northern Europe: perspectives on processes, structures and species diversity. Silva Fennica 45: 807–821. http://dx.doi.org/10.14214/sf.446

Bryant D., Nielsen D., Tangley L. (1997). The last frontier forest. Ecosystems & Economies on the edge. World Resources Institute. Washington D.C. 42 p.

Dahlberg A., Mueller G.M. (2011). Applying IUCN red-listing criteria for assessing and reporting on the conservation status of fungal species. Fungal Ecology 4: 147–162. http://dx.doi.org/10.1016/j.funeco.2010.11.001

Dahlberg A., Stokland J. (2004). Vedlevande arters krav på substrat – en sammanställning och analys av 3600 arter. Rapport 7/2004, Skogsstyrelsen, Jönköping.

Djupström L. B., Perhans K., Weslien J., Schroeder M. L., Gustafsson L., Wikberg S. (2010). Co-variation of lichens, bryophytes, saproxylic beetles and dead wood in Swedish boreal forests. Systematics and Biodiversity 8: 247–256. http://dx.doi.org/10.1080/14772001003786022

Djupström L. B., Weslien J., Schroeder M. L. (2008). Dead wood and saproxylic beetles in set-aside and non set-aside forests in a boreal region. Forest Ecology and Management 255: 3340–3350. http://dx.doi.org/10.1016/j.foreco.2008.02.015

Eklund O. (1931). Über die Ursachen der regionalen Verteilung der Schärenflora Südwest-Finnlands. Eine Kausalitätsanalyse mit besonderer Berücksichtigung der Pflanzenwelt in den Kirchspielen Korpo und Houtskär. Acta Botanica Fennica 8: 1–133.

Enrong Y., Xihua W., Jianjun H. (2006). Concept and classification of coarse woody debris in forest ecosystems. Frontiers of Biology in China 1: 76–84. http://dx.doi.org/10.1007/s11515-005-0019-y

Esseen P.-A., Ehnström B., Sjöberg K., Ericson L. (1997). Boreal forests. Ecological Bulletins 46: 16–47. http://www.jstor.org/stable/20113207

European Environment Agency (2014). Developing a forest naturalness indicator for Europe. EEA Technical report No 13/2014. 60 pp. http://dx.doi.org/10.2800/20177

Fukasawa Y., Osono T., Takeda H (2009). Effects of attack of saprobic fungi on twig litter decomposition by endophytic fungi. Ecological Research 24: 1067. http://dx.doi.org/10.1007/s11284-009-0582-9

Fukasawa Y., Osono T., Takeda H. (2011). Wood decomposing abilities of diverse lignicolous fungi on nondecayed and decayed beech wood. Mycologia 103: 474–482. http://dx.doi.org/10.3852/10-246

Gange A.C., Gange E.G., Mohammed A.B., Boddy L. (2011). Host shifts in fungi caused by climate change? Fungal Ecology 4: 184–190. http://dx.doi.org/10.1016/j.funeco.2010.09.004

Gao T., Nielsen A.B, Hedblom M. (2015). Reviewing the strength of evidence of biodiversity indicators for forest ecosystems in Europe. Ecological Indicators 57: 420–434. http://dx.doi.org/10.1016/j.ecolind.2015.05.028

Geml J., Laursen G.A., Timling I., McFarland J.M., Booth M.G., Lennon N., Nusbaum C., Taylor D.L. (2009). Molecular phylogenetic biodiversity assessment of arctic and boreal ectomycorrhizal Lactarius Pers. (Russulales; Basidiomycota) in Alaska, based on soil and sporocarp DNA. Molecular Ecology 18: 2213–2227. http://dx.doi.org/10.1111/j.1365-294X.2009.04192.x

Grove S.J. (2002). Saproxylic insect ecology and the sustainable management of Forests. Annual Review of Ecology and Systematics 33: 1–23. http://dx.doi.org/10.1146/annurev.ecolsys.33.010802.150507

Groven R., Rolstad J., Storaunet K.O., Rolstad E. (2002). Using forest stand reconstructions to assess the role of structural continuity for late-successional species. Forest Ecology and Management 164: 39–55. http://dx.doi.org/10.1016/S0378-1127(01)00611-9

GTK (2015). Maankamara – the web map application of precise elevation data hillshading, superficial deposits and bedrock maps and aerial photographs. The Geological Survey of Finland. http://en.gtk.fi/informationservices/map_services/index.html [Cited 10 Apr 2016]

Hakala T.K., Maijala P., Konn J., Hatakka A. (2004). Evaluation of novel wood-rotting polypores and corticoid fungi for the decay and biopulping of Norway spruce (*Picea abies*) wood. Enzyme and Microbial Technology 34: 255–263. http://dx.doi.org/10.1016/j.enzmictec.2003.10.014

Halme P., Kotiaho J.S. (2012). The importance of timing and number of surveys in fungal biodiversity research. Biodiversity and Conservation 21: 205–219. http://dx.doi.org/10.1007/s10531-011-0176-z

Halme P., Allen K.A., Auniņš A., Bradshaw R.H.W., Brūmelis G., Čada V., Clear J.L, Eriksson A.-M., Hannon G., Hyvärinen E., Ikauniece S., Iršėnaitė R., Jonsson B.G., Junninen K., Kareksela S., Komonen A., Kotiaho J.S., Kouki J., Kuuluvainen T., Mazziotta A., Mönkkönen M., Nyholm K., Oldén A., Shorohova E., Strange N., Toivanen T., Vanha-Majamaa I., Wallenius T., Ylisirniö A.-L., Zin E. (2013). Challenges of ecological restoration: lessons from forests in northern Europe. Biological Conservation 167: 248–256. http://dx.doi.org/110.1016/j.biocon.2013.08.029

Halme P., Kotiaho J.S., Ylisirniö A.-L., Hottola J., Junninen K., Kouki J., Lindgren M., Mönkkönen M., Penttilä R., Renvall P., Siitonen S., Similä M. (2009). Perennial polypores as indicators of annual and red-listed polypores. Ecological Indicators 9: 256–266. http://dx.doi.org/10.1016/j.ecolind.2008.04.005

Heilmann-Clausen J. (2001). A gradient analysis of communities of macrofungi and slime moulds on decaying beech logs. Mycological Research 105: 575–596. http://dx.doi.org/10.1017/S0953756201003665

Heilmann-Clausen J., Christensen M. (2004). Does size matter? On the importance of various dead wood fractions for fungal diversity in Danish beech forests. Forest Ecology and Management 201: 105–117. http://dx.doi.org/10.1016/j.foreco.2004.07.010

Heilmann-Clausen J., Læssøe T. (2012). On species richness estimates, climate change and host shifts in wood-inhabiting fungi. Fungal Ecology 5: 641–646.
http://dx.doi.org/10.1016/j.funeco.2011.10.003

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. http://dx.doi.org/10.1007/s10531-004-4284-x

Heilmann-Clausen J., Vesterholt J. (2008). Conservation: selection criteria and approaches. In: Boddy L., Frankland J.C., van West P. (eds.) Ecology of Saprotrophic Basidiomycetes. Elsevier, Amsterdam. p. 325–347.

Hibbett D.S., Bauer R., Binder M., Giachini A.J., Hosaka K., Justo A., Larsson E., Larsson K.H., Lawrey J.D., Miettinen O., Nagy L.G., Nilsson R.H., Thorn R.G. (2014).

Agaricomycetes. In: McLaughlin D.J., Spatafora J.W. (eds.) The Mycota, A comprehensive treatise on fungi as experimental systems for basic and applied research. Vol. VII. Systematics and Evolution: 373–429. 2nd Edition. Springer-Verlag, Berlin Heidelberg.

Hinneri S. (1972). An ecological monograph on eutrofic deciduous woods in the archipelago of Finland. Turun yliopiston julkaisuja. Sarja A, II Biologica-Geographica-Geologica 50. 131 p.

Hjortstam K., Ryvarden L. (2009). A checklist of names in *Hyphodontia* sensu stricto – sensu lato and *Schizopora* with new combinations in *Lagarobasidium, Lyomyces, Kneiffiella, Schizopora* and *Xylodon*. Synopsis Fungorum 26: 33–55.

Høiland K., Bendiksen, E. (1997). Biodiversity of wood-inhabiting fungi in a boreal coniferous forest in Sor-Trondelag County, Central Norway. Nordic Journal of Botany 16: 643–659. http://dx.doi.org/10.1111/j.1756-1051.1996.tb00283.x

Hokkanen M., Aapala K., Alanen A. (2005). Ennallistamisen ja luonnonhoidon seurantasuunnitelma. Metsähallituksen luonnonsuojelujulkaisuja B 76: 1–85. [In Finnish with English summary] https://julkaisut.metsa.fi/assets/pdf/lp/Bsarja/b76.pdf

Holland S.M. (2003). Analytic Rarefaction 1.3. UGA Stratigraphy Lab, The University of Georgia. http://strata.uga.edu/software/anRareReadme.html

Hoppe B., Purahong W., Wubet T., Kahl T., Bauhus J., Arnstadt T., Hofrichter M., Buscot F., Krüger D. (2016). Linking molecular deadwood-inhabiting fungal diversity and community dynamics to ecosystem functions and processes in Central European forests. Fungal Diversity 77: 367–379. http://dx.doi.org/10.1007/s13225-015-0341-x

Hottola J., Siitonen J. (2008). Significance of woodland key habitats for polypore diversity and red-listed species in boreal forests. Biodiversity and Conservation 17: 2559–2577. http://dx.doi.org/10.1007/s10531-008-9317-4

Huson D.H., Auch A.F., Qi J., Schuster S.C. (2007). MEGAN analysis of metagenomic data. Genome Research 17: 377–386. http://dx.doi.org/10.1101/gr.5969107

Hyvönen R., Ågren G.I. (2001). Decomposer invasion rate, decomposer growth rate, and substrate chemical quality: how they influence soil organic matter turnover. Canadian Journal of Forest Research 31: 1594–1601. http://dx.doi.org/10.1139/x01-097

Ikauniece S., Brūmelis G., Kondratovičs T. (2012). Naturalness of *Quercus robur* stands in Latvia, estimated by structure, species, and processes. Estonian Journal of Ecology 61: 64–81.
http://dx.doi.org/10.3176/eco.2012.1.07

Ingerpuu N., Vellak K., Kukk T. & Pärtel M. (2001). Bryophyte and vascular plant species richness in boreo-nemoral moist forests and mires. Biodiversity and Conservation 10: 2153–2166.
http://dx.doi.org/10.1023/A:1013141609742

Janisch J.E., Harmon M.E. (2002). Successional changes in live and dead wood carbon stores: implications for net ecosystem productivity. Tree Physiology 22(2–3): 77–89.
http://dx.doi.org/10.1093/treephys/22.2-3.77

Jetz W., McPherson J.M., Guralnick R.P. (2012). Integrating biodiversity distribution knowledge: toward a global map of life. Trends in Ecology and Evolution 27: 151–159.
http://dx.doi.org/10.1016/j.tree.2011.09.007

Jones M.D., Forn I., Gadelha C., Egan M.J., Bass D., Massana R., Richards T.A. (2011). Discovery of novel intermediate forms redefines the fungal tree of life. Nature 474: 200–203.
http://dx.doi.org/10.1038/nature09984

Jonsson B., Jonsell M. (1999). Exploring potential biodiversity indicators in boreal forests. Biodiversity and Conservation 8: 1417–1433.
http://dx.doi.org/10.1023/A:1008900309571

Jonsson B.G., Kruys N. (eds.) (2001). Ecology of woody debris in boreal forests. Ecological Bulletins 49. 283 p.
http://www.jstor.org/stable/i20113259

Jonsson B.G., Kruys N., Ranius T. (2005). Ecology of species living on dead wood – Lessons for dead wood management. Silva Fennica 39: 289–309.
http://dx.doi.org/10.14214/sf.390

Jönsson M.T., Edman M., Jonsson B.G. (2008). Colonization and extinction patterns of wood-decaying fungi in a boreal old-growth *Picea abies* forest. Journal of Ecology 96: 1065–1075.
http://dx.doi.org/10.1111/j.1365-2745.2008.01411.x

Junninen K., Komonen A. (2011). Conservation ecology of boreal polypores: A review. Biological Conservation 144: 11–20.
http://dx.doi.org/10.1016/j.biocon.2010.07.010

Junninen K., Kouki J. (2006). Are woodland key habitats in Finland hotspots for polypores (Basidiomycota)? Scandinavian Journal of Forest Research 21: 32–40.
http://dx.doi.org/10.1080/02827580500530009

Junninen K., Penttilä R., Martikainen P. (2007). Fallen retention aspen trees on clear-cuts can be important habitats for red-listed polypores: a case study in Finland. Biodiversity and Conservation 16: 475–490.
http://dx.doi.org/10.1007/s10531-005-6227-6

Junninen K., Similä M., Kouki J., Kotiranta H. (2006). Assemblages of wood-inhabiting fungi along the gradients of succession and naturalness in boreal pine-dominated forests in Fennoscandia. Ecography 29: 75–83.
http://dx.doi.org/10.1111/j.2005.0906-7590.04358.x

Juntunen M.-L. (ed.) (2014). Forest biodiversity and health. In: Peltola A. (ed.) Statistical yearbook of forestry 2014. Finnish Forest Research Institute, Tampere. p. 79–104. [In Finnish with English summary]
http://www.metla.fi/metinfo/tilasto/julkaisut/vsk/2013/vsk13_02.pdf

Juutilainen K. (2016). Ecology, environmental requirements and conservation of corticioid fungi occupying small diameter dead wood. Jyväskylä Studies in Biological and Environmental Science 313: 1–55.
https://jyx.jyu.fi/dspace/bitstream/handle/123456789/49112/978-951-39-6574-7_vaitos01042016.pdf?sequence=1

Juutilainen K., Halme P., Kotiranta H., Mönkkönen M. (2011). Size matters in studies of dead wood and wood-inhabiting fungi. Fungal Ecology 4: 342–349.
http://dx.doi.org/10.1016/j.funeco.2011.05.004

Juutilainen K., Mönkkönen M., Kotiranta H., Halme P. (2014). The effects of forest management on wood-inhabiting fungi occupying dead wood of different diameter fractions. Forest Ecology and Management 313: 283–291.
http://dx.doi.org/10.1016/j.foreco.2013.1

Kaila A., Ihalainen A. (eds.) (2014). Forest resources. In: Peltola A. (ed.) Statistical yearbook of forestry 2014. Finnish Forest Research Institute, Tampere. p. 33–78. [in Finnish with English summary]
http://www.metla.fi/metinfo/tilasto/julkaisut/vsk/2013/vsk13_01.pdf

Kakkuri J. (1987). Character of the Fennoscandian land uplift in the 20th century. Geological Survey of Finland, Special Paper 2: 15–20.

Kangas A., Aakala T., Alanen H., Haavisto M., Heikkilä J., Kaila A., Kankaanpää S., Kämäri H., Leino O., Mäkinen A., Nurmela E., Oksa S., Saari A., Tikkanen S.-M., Wathén M. (2004). Lahopuuinventoinnin menetelmien vertailu Nuuksion ulkoilualueilla. Metsätieteen aikakauskirja 1/2004: 43–51.
www.metla.fi/aikakauskirja/full/ff04/ff041043.pdf

Karjalainen L., Kuuluvainen T. (2002). Amount and diversity of coarse woody debris within a boreal forest landscape dominated by Pinus sylvestris in Vienansalo wilderness, eastern Fennoscandia. Silva Fennica 36: 147–167.

http://dx.doi.org/10.14214/sf.555

Karström M. (1992). Steget före – en presentation. Svensk Botanisk Tidskrift 86: 103–14. [In Swedish with English summary]

Keizer P.J., Arnolds E.J.M. (1990). Mycocoenology of marshy forests and scrubs. I. Host range of wood-decomposing Aphyllophorales and Heterobasidiomycetes. In: Oldeman R.A.A., Schmidt P., Arnolds E.J.M. (eds.) Forest components. Wageningen Agricultural University papers 90-6, Wageningen. p. 77–92.
http://library.wur.nl/WebQuery/wurpubs/fulltext/282842

Knudsen H., Vesterholt J. (eds.) (2008). Funga Nordica. Agaricoid, boletoid and cyphelloid genera. Nordsvamp, Copenhagen. 965 p.

Komonen A., Niemi M.E., Junninen K. (2008). Lakeside riparian forests support diversity of wood fungi in managed boreal forests. Canadian Journal of Forest Research 38: 2650–2659.
http://dx.doi.org/10.1139/X08-105

Korvenpää T., von Numers M., Hinneri S. (2003). A mesoscale analysis of floristic patterns in the SW Finnish Archipelago. Journal of Biogeography 30: 1019–1031.

Koskinen J. (2011). The distribution of coniferous and deciduous trees in southwest Finnish archipelago. Master's thesis, University of Turku, Department of Geography and Geology. 155 p. [In Finnish with English summary]

Kotiranta H., Junninen K., Saarenoksa R., Kinnunen J., Kytövuori I. (2010). Aphyllophorales & Heterobasidiomycetes. In: Rassi P., Hyvärinen E., Juslén A., Mannerkoski I. (eds.) The 2010 Red List of Finnish Species. Ministry of the Environment and Finnish Environment Institute, Helsinki. p. 249–263.

Kotiranta H., Larsson K.-H. (2013). *Sistotrema luteoviride* sp. nov. (Cantharellales, Basidiomycota) from Finland. Acta Mycologica 48: 219–222.
http://dx.doi.org/10.5586/am.2013.023

Kotiranta H., Niemelä T. (1996). Threatened polypores in Finland. Finnish Environment Institute, Helsinki. 184 p.

Kotiranta H., Saarenoksa R., Kytövuori I. (2009). Aphyllophoroid fungi of Finland. A check-list with ecology, distribution, and threat categories. Norrlinia 19: 1–223.

Kotiranta H., Shiryaev A. (2013). Notes on Aphyllophoroid fungi (Basidiomycota) in Kevo, collected in 2009. Kevo Notes 14: 1–22.

Kouki J., Löfman S., Martikainen P., Rouvinen S., Uotila A. (2001). Forest fragmentation in Fennoscandia: linking habitat requirements of woodassociated threatened species to landscape and habitat changes. Scandinavian Journal of Forest Research Supplement 3: 27–37.

http://dx.doi.org/10.1080/028275801300090564

Kruys N., Fries C., Jonsson B.G., Lämås T., Ståhl G. (1999). Wood-inhabiting cryptogams on dead Norway spruce (*Picea abies*) trees in managed Swedish boreal forests. Canadian Journal of Forest Research 29: 178–186.
http://dx.doi.org/10.1139/x98-191

Küffer N., Gillet F., Senn-Irlet B., Aragno M., Job D. (2008). Ecological determinants of fungal diversity on dead wood in European forests. Fungal Diversity 30: 83–95.
www.fungaldiversity.org/fdp/sfdp/30_7.pdf

Küffer N., Senn-Irlet B. (2000). Diversity and ecology of corticioid basidiomycetes in green alder stands in Switzerland. Nova Hedwigia 71: 131–143.

Küffer N., Senn-Irlet B. (2005). Influence of forest management on the species richness and composition of wood-inhabiting basidiomycetes in Swiss forests. Biodiversity and Conservation 14: 2419–2435.
http://dx.doi.org/10.1007/s10531-004-0151-z

Kunttu P., Kulju M., Kekki T., Pennanen J., Savola K., Helo T., Kotiranta H. (2016a). Extensions of known geographic distribution of aphyllophoroid fungi (Basidiomycota) in Finland. Mycosphere 7: 333–357.
http://dx.doi.org/10.5943/mycosphere/7/3/7

Kunttu P., Kulju M., Kotiranta H. (2012). New national and regional biological records for Finland 2. Contributions to the Finnish aphyllophoroid funga (Basidiomycota). Memoranda Societas pro Fauna et Flora Fennica 88: 61–66.
http://ojs.tsv.fi/index.php/msff/article/view/7818

Kunttu P., Kulju M., Kotiranta H. (2016b). *Athelia singularis* and *Leptosporomyces mundus* (Basidiomycota) new to Finland. Mycobiota 6: 29–37.
http://dx.doi.org/10.12664/mycobiota.2016.06.03

Kunttu P., Kulju M., Pennanen J., Kotiranta H., Halme P. (2011). Additions to the Finnish aphyllophoroid fungi. Folia Cryptogamica Estonica 48: 25–30.
www.ut.ee/ial5/fce/fce48pdf/fce48_kunttu.pdf

Kunttu P., Pennanen J., Kotiranta H. (2015). Checklist of aphyllophoroid fungi (Basidiomycota) of Ekenäs Archipelago National Park. Biodiversity Journal 6: 497–504.
www.biodiversityjournal.com/pdf/6(2)_497-504.pdf

Kuuluvainen T. (1994). Gap disturbance, ground microtopography, and the regeneration dynamics of boreal coniferous forests in Finland: a review. Annales Zoologici Fennici 31: 35–51.
www.sekj.org/PDF/anzf31/anz31-035-051.pdf

Kuuluvainen T. (2002). Disturbance dynamics in boreal forests: defining the ecological basis of restoration and management of biodiversity. Silva Fennica 36: 5–11. http://dx.doi.org/10.14214/sf.547

Kuuluvainen T. (2009). Forest management and biodiversity conservation based on natural ecosystem dynamics in Northern Europe: the complexity challenge. Ambio 38: 309–315. http://dx.doi.org/10.1579/08-A-490.1

Kuuluvainen T. and Aakala T. (2011). Natural forest dynamics in boreal Fennoscandia: a review and classification. Silva Fennica 45: 823–841. http://dx.doi.org/10.14214/sf.73

Kuusipalo J. (1996). Suomen metsätyypit. Kirjayhtymä Oy, Rauma. 144 p.

Lachat T., Wermelinger B., Gossner M.M., Bussler H., Isacsson G., Müller J. (2012). Saproxylic beetles as indicator species for dead-wood amount and temperature in European beech forests. Ecological Indicators 23: 323–331. http://dx.doi.org/10.1016/j.ecolind.2012.04.013

Laine J., Vasander H. (1998). Suotyypit. Kirjayhtymä, Hämeenlinna. 80 p.

Lassauce A., Paillet Y., Jactel H., Bouget C. (2011). Deadwood as a surrogate for forest biodiversity: Meta-analysis of correlations between deadwood volume and species richness of saproxylic organisms. Ecological Indicators 11: 1027–1039. http://dx.doi.org/10.1016/j.ecolind.2011.02.004

Lagana A., Angiolini C., Loppi S., Salerni E., Perini C., Barluzzi C., De Dominicis V. (2002). Periodicity, fluctuations and successions of macrofungi in fir forests (*Abies alba* Miller) in Tuscany, Italy. Forest Ecology and Management 169: 187–202. http://dx.doi.org/10.1016/S0378-1127(01)00672-7

Lee P., Aksenov D., Laestadius L., Nogueron R., Smith W. (2006). Canada's large intact forest landscapes. Global Forest Watch Canada.

Leikola M. (1969). On the termination of diameter growth of Scots pine in old age in northernmost Finnish Lapland. Silva Fennica 3: 50–61. [In Finnish with English summary]

Lindahl B., Boberg J. (2008). Distribution and function of litter basidiomycetes in coniferous forests. In: Boddy L., Frankland J.C., van West P. (eds.) Ecology of saprotrophic Basidiomycetes. Elsevier, Amsterdam. p. 183–196.

Lindblad I. (1998). Wood-inhabiting fungi on fallen logs of Norway spruce: relations to forest management and substrate quality. Nordic Journal of Botany 18: 243–255. http://dx.doi.org/10.1111/j.1756-1051.1998.tb01877.x

Lindhe A., Asenblad N., Toresson H.-G. (2004). Cut logs and high stumps of spruce, birch, aspen and oak – 9 years of saproxylic fungi succession. Biological Conservation 119: 443–454.
http://dx.doi.org/10.1016/j.biocon.2004.01.005

Linder P., Elfving B., Zackrisson O. (1997). Stand structure and successional trends in virgin boreal forest reserves in Sweden. Forest Ecology and Management 98: 17–33.
http://dx.doi.org/10.1016/S0378-1127(97)00076-5

Lindgren L. (2000). Island pastures. Metsähallitus and Edita, Helsinki. 203 p.

Lindgren L., Stjernberg T. (1986). Skärgårdshavets nationalpark. Nordenskiöld-samfundet i Finland and WSOY, Porvoo. 143 p.

Lindgren M. (2001). Polypore (Basidiomycetes) species richness and community structure in natural boreal forests of NW Russian Karelia and adjacent areas in Finland. Acta Botanica Fennica 170: 1–41.

Lindner D.L., Burdsall Jr. H.H., Stanosz G.R. (2006). Species diversity of polyporoid and corticioid fungi in northern hardwood forests with differing management histories. Mycologia 98: 195–217.
http://dx.doi.org/10.3852/mycologia.98.2.195

Liu Y., He J., Shi G., An L., Öpik M., Feng H. (2011). Diverse communities of arbuscular mycorrhizal fungi inhabit sites with very high altitude in Tibet Plateau. FEMS Microbiology Ecology 78: 355–365.
http://dx.doi.org/10.1111/j.1574-6941.2011.01163.x

Lõhmus A. (2011). Aspen-inhabiting Aphyllophoroid fungi in a managed forest landscape in Estonia. Scandinavian Journal of Forest Research 26: 212–220.
http://dx.doi.org/10.1080/02827581.2011.558850

Lonsdale D., Pautasso M., Holdenrieder O. (2008). Wood-decaying fungi in the forest: conservation needs and management options. European Journal of Forest Research 127: 1–22.
http://dx.doi.org/10.5735/086.051.0501

Machado A. 2014. An index of naturalness. Journal of Nature Conservation 12: 95–110.
http://dx.doi.org/10.1016/j.jnc.2003.12.002

Magnusson M., Olsson J., Hedenås H. (2014). Red-listed wood-inhabiting fungi in natural and managed forest landscapes adjacent to the timberline in central Sweden. Scandinavian Journal of Forest Research 29: 455–465.
http://dx.doi.org/10.1080/02827581.2014.919353

Mäkinen A. (1978). Tervalepän kasvupaikoista ja ekologiasta Suomessa. Dendrologian Seuran Tiedotuksia 9(1): 6–17.

Markkanen A., Halme P. (2012). Polypore communities in broadleaved boreal forests. Silva Fennica 46: 317–331.
http://dx.doi.org/10.14214/sf.43

Martikainen P., Siitonen J., Punttila P., Kaila L., Rauh J. (2000). Species richness of Coleoptera in mature managed and old-growth boreal forests in southern Finland. Biological Conservation 94: 199–209.
http://dx.doi.org/10.1016/S0006-3207(99)00175-5

McCullough H.A. (1948). Plant succession on fallen logs in a virgin spruce-fir forest. Journal of Ecology 29: 508–513.

McDonald J.H. (2014). Handbook of Biological Statistics. (3rd ed.). Sparky House Publishing, Baltimore, Maryland. http://www.biostathandbook.com/

Miettinen O. (2012). Orvakkalajistoselvitys Veräjämäen, Patolan ja Talin alueilla 2011. Helsingin kaupungin ympäristökeskuksen julkaisuja 6/2012: 1–28.
www.hel.fi/static/ymk/julkaisut/julkaisu-06-12.pdf

Miettinen O., Larsson K.-H. (2010). *Sidera*, a new genus in Hymenochaetales with poroid and hydnoid species. Mycological Progress 10: 131–141.
http://dx.doi.org/10.1007/s11557-010-0682-5

Miettinen O., Larsson E., Sjökvist E., Larsson K.-H. (2012a): Comprehensive taxon sampling reveals unaccounted diversity and morphological plasticity in a group of dimitic polypores (Basidiomycota, Polyporales). Cladistics 28: 251–270.
http://dx.doi.org/10.1111/j.10960031.2011.00380.x

Miettinen O., Spirin, V., Niemelä T. (2012b). Notes on the genus *Aporpium* (Auriculariales, Basidiomycota), with a new species for temperate Europe. Annales Botanici Fennici 49: 359–368.
http://dx.doi.org/10.5735/085.049.0607

Molina R., Horton T.R., Trappe J.M., Marcot B.G. (2011). Addressing uncertainty: how to conserve and manage rare or little-known fungi. Fungal Ecology 4: 134–146.
http://dx.doi.org/10.1016/j.funeco.2010.06.003

Mönkkönen M., Ylisirniö A.-L., Hämäläinen T. (2008). Ecological efficiency of voluntary conservation of boreal-forest biodiversity. Conservation Biology 23: 339–347.
http://dx.doi.org/10.1111/j.1523-1739.2008.01082.x

Mueller G.M., Schmit J.P., Huhndorf S.M., Ryvarden L., O’Dell T.E., Lodge J.E., Leacock P.R., Mata M., Umaña L., Wu Q., Czederpiltz D.L. (2004). Recommended protocols for sampling macrofungi. In: Mueller G.M., Bills G.F., Foster M.S. (eds.) Biodiversity of fungi: inventory and monitoring methods. Elsevier Academic Press, San Diego. p. 168–172.

Müller J., Bütler R. (2010). A review of habitat thresholds for dead wood: a baseline for management recommendations in European forests. European Journal of Forest Research 129: 981–992.
http://dx.doi.org/10.1007/s10342-010-0400-5

Nilsson H., Hallenberg N. (2003). Phylogeny of the *Hypochnicium punctulatum* complex as inferred from ITS sequence data. Mycologia 95: 54–60.
http://www.mycologia.org/content/95/1/54.full

Nilsson S.G., Arup U., Baranowski R., Ekman S. (1995). Tree-dependent lichens and beetles as indicators in conservation forests. Conservation Biology 9: 1208–1215.

Nilsson S.G., Hedin J., Niklasson M. (2001). Biodiversity and its assessment in boreal and nemoral forests. Scandinavian Journal of Forest Research Supplement 3: 10–26.
http://dx.doi.org/110.1080/028275801300090546

Niemelä T. (2005). Polypores, lignicolous fungi. Norrlinia 13: 1–319. [In Finnish with English summary]

Niemelä T. (2012). Guide to the polypores of Finland. Botanical Bulletins of the University of Helsinki 194: 1–118. [In Finnish, keys in English]

Niemelä T., Kotiranta H. (1983). Polypore survey of Finland 3. The genera *Coltricia, Inonotopsis, Inonotus* and *Onnia*. Karstenia 23: 15–25.

Niemelä T., Renvall P., Penttilä R. (1995). Interactions of fungi at late stages of wood decomposition. Annales Botanici Fennici 32: 141–152.

Niemelä T., Wallenius T., Kotiranta H. (2002). The kelo tree, a vanishing substrate of specified wood-inhabiting fungi. Polish Botanical Journal 47: 91–101.
http://bomax.botany.pl/pubs/data/article_pdf?id=763

Nitare J. (2000). Indicator species for assesing the nature conservation value of woodland sites – a flora of selected cryptogams. Skogstyrelsens förlag, Karlshamn. [In Swedish with English summary]

Nordén B, Ryberg M., Götmark F., Olausson B. (2004). Relative importance of coarse and fine woody debris for the diversity of wood-inhabiting fungi in temperate broadleaf forests. Biological Conservation 117: 1–10.
http://dx.doi.org/10.1016/S0006-3207(03)00235-0

Nordén J., Penttilä R., Siitonen J., Tomppo E., Ovaskainen O. (2013). Specialist species of wood-inhabiting fungi struggle while generalists thrive in fragmented boreal forests. Journal of Ecology 101: 701–712.
http://dx.doi.org/10.1111/1365-2745.12085

Noss R.F. (1999). Assessing and monitoring forest biodiversity: a suggested framework and indicators. Forest Ecology Management 115: 135–146. http://dx.doi.org/10.1016/S0378-1127(98)00394-6

von Numers M. (1995). Distribution, numbers and ecological gradients of birds breeding on small islands in the Archipelago Sea, SW Finland. Acta Zoologica Fennica 197: 1–127.

von Numers M., Korvenpää T. (2007). 20th century vegetation changes in an island archipelago, SW Finland. Ecography 30: 789–800. http://dx.doi.org/10.1111/j.2007.0906-7590.05053.x

O'Dell T.E., Lodge J.E., Mueller G.M. (2004). Approaches to sampling macrofungi. In: Mueller G.M., Bills G.F., Foster M.S. (eds.) Biodiversity of fungi: inventory and monitoring methods. Elsevier Academic Press, San Diego. p. 163–168.

Ohlson M., Söderström L., Hörnberg G., Zackrisson O. (1997). Habitat qualities versus long-term continuity as determinants of biodiversity in boreal old-growth swamp forests. Biological Conservation 81: 221–231. http://dx.doi.org/10.1016/S0006-3207(97)00001-3

Økland B., Bakke A., Hågvar S., Kvamme T. (1996). What factors influence the diversity of saproxylic beetles? A multiscaled study from a spruce forest in southern Norway. Biodiversity and Conservation 5: 75–100. http://dx.doi.org/10.1007/BF00056293

Okland B., Rydgren K., Okland R.H., Storaunet K.O., Rolstad J. (2003). Variation in environmental conditions, understorey species number, abundance and composition among natural and managed Picea abies forest stands. Forest Ecology and Management 177: 17–37. http://dx.doi.org/10.1016/S0378-1127(02)00331-6

Olsoni B. (1939). Botaniskt från Ab Kimito – Dragsfjärd – Hitis 1936–38. Memoranda Societas Fauna et Flora Fennica 15: 92–94.

Öpik M., Vanatoa A., Vanatoa E., Moora M., Davison J., Kalwij J.M., Reier Ü., Zobel M. (2010). The online database MaarjAM reveals global and ecosystemic distribution patterns in arbuscular Mycorrhizal fungi (Glomeromycota). New Phytologist 188: 223–241. http://dx.doi.org/10.1111/j.1469-8137.2010.03334.x

Östlund L., Zackrisson O., Axelsson A.L. (1997). The history and transformation of a Scandinavian boreal forest landscape since the 19th century. Canadian Journal of Forest Researh 27: 1198–1206. http://dx.doi.org/10.1139/x97-070

Paltto H., Nordén B., Götmark F., Franc N. (2006). At which spatial and temporal scales does landscape context affect local density of Red Data Book and indicator species? Biological Conservation 133: 442–454. http://dx.doi.org/10.1016/j.biocon.2006.07.006

Parfitt D., Hynes J., Rogers H.J., Boddy L. (2005). New PCR assay detects rare tooth fungi in wood where traditional approaches fail. Mycological Research 109: 1187–1194. http://dx.doi.org/10.1017/S095375620500359X

Pasanen H., Junninen K., Kouki J. (2014). Restoring dead wood in forests diversifies wood decaying fungal assemblages but does not quickly benefit red-listed species. Forest Ecology and Management 312: 92–100. http://dx.doi.org/10.1016/j.foreco.2013.10.018

Penttilä R., Kotiranta H. (1996). Short-term effects of prescribed burning on wood-rotting fungi. Silva Fennica 30: 399–419. https://helda.helsinki.fi/handle/1975/8501

Penttilä R., Lindgren M., Miettinen O., Rita H., Hanski I. (2006). Consequences of forest fragmentation for polyporous fungi at two spatial scales. Oikos 114: 225–240. http://dx.doi.org/10.1111/j.2006.0030-1299.14349.x

Penttilä R., Siitonen J., Kuusinen M. (2004). Polypore diversity in managed and old-growth boreal Picea abies forests in southern Finland. Biological Conservation 117: 271–283. http://dx.doi.org/10.1016/j.biocon.2003.12.007

Pippola E., Kotiranta H. (2008). The genus *Tremella* (Basidiomycota, Tremellales) in Finland. Annales Botanici Fennici 45: 401–434. www.sekj.org/PDF/anbf45/anbf45-401.pdf

Porter T.M., Skillman J.E., Moncalvo J.M. (2008). Fruiting body and soil rDNA sampling detects complementary assemblage of Agaricomycotina (Basidiomycota, Fungi) in a hemlock-dominated forest plot in southern Ontario. Molecular Ecology 17: 3037–3050. http://dx.doi.org/10.1111/j.1365-294X.2008.03813.x

Pouska V., Lepša J., Svobodac M., Lepšovád A. (2011). How do log characteristics influence the occurrence of wood fungi in a mountain spruce forest? Fungal Ecology 4: 201–209. http://dx.doi.org/10.1016/j.funeco.2010.11.004

Pressey R.L., Humphries C.J., Margules C.R., Vane-Wright R.I., Williams P.H. (1993). Beyond opportunism: key principles for systematic reserve selection. Trends in Ecology and Evolution 8: 124–128. http://dx.doi.org/10.1016/0169-5347(93)90023-I

Punttila P., Ihalainen A. (2006). Luonnontilaisen kaltaiset metsä suojelu- ja ei-suojelluilla alueilla. In: Horne P., Koskela T., Kuusinen M., Otsamo A., Syrjänen K. (eds.) Metson jäljillä. Etelä-Suomen metsien monimuotoisuusohjelman tutkimusraportti. Maa- ja metsätalousministeriö, ympäristöministeriö, Metsäntutkimuslaitos ja Suomen ympäristökeskus. p. 19–20.

Pyke G.H., Ehrlich P.R. (2010). Biological collections and ecological/environmental research: a review, some observations and a look to the future. Biological Reviews 85: 247–266.
http://dx.doi.org/10.1111/j.1469-185X.2009.00098.x

Quince C., Lanzen A., Curtis T.P., Davenport R.J., Hall N., Head I.M., Read L.F., Sloan W.T. (2009). Accurate determination of microbial diversity from 454 pyrosequencing data. Nature Methods 6: 639–641.
http://dx.doi.org/10.1038/nmeth.1361

Quince C., Lanzen A., Davenport R., Turnbaugh P. (2011). Removing noise from pyrosequenced amplicons. BMC Bioinformatics 12: 38.
http://dx.doi.org/10.1186/1471-2105-12-38

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.
http://dx.doi.org/110.1016/j.funeco.2011.05.005

Rajala T., Tuomivirta T., Pennanen T., Mäkipää R. (2015). Habitat models of wood-inhabiting fungi along a decay gradient of Norway spruce logs. Fungal Ecology 18: 48–55.
http://dx.doi.org/10.1016/j.funeco.2015.08.007

Rassi P., Alanen A., Kanerva T., Mannerkoski I. (eds.) (2001). The 2000 Red List of Finnish Species. Ministry of the Environment and Finnish Environment Institute, Helsinki. 432 p. [In Finnish with English summary]

Rassi P., Hyvärinen E., Juslén A., Mannerkoski I. (eds.) (2010). The 2010 Red List of Finnish Species. Ministry of the Environment and Finnish Environment Institute, Helsinki. 685 p.
http://www.environment.fi/redlist

Raunio A., Schulman A., Kontula T. (eds.) (2008). Assessment of threatened habitat types in Finland. Part 2: Habitat type descriptions. The Finnish Environment 8/2008. 572 p. [In Finnish with English summary]
http://hdl.handle.net/10138/37932

Renvall P. (1995). Community structure and dynamics of wood-rotting Basidiomycetes on decomposing conifer trunks in northern Finland. Karstenia 35: 1–51.

Rhodes J.R., Tyre A.J., Jonzen N., McAlpine C.A., Possingham H.P. (2006). Optimizing presence-absence surveys for detecting population trends. Journal of Wildlife Management 70: 8–18.
http://dx.doi.org/10.2193/0022-541X(2006)70[8:OPSFDP]2.0.CO

Rondeux J., Sanchez C. (2010). Review of indicators and field methods for monitoring biodiversity within national forest inventories. Core variable: Deadwood. Environmental Monitoring and Assessment 164: 617–630. http://dx.doi.org/10.1007/s10661-009-0917-6

Rouvinen S., Kouki J. (2008). The natural northern European boreal forests: unifying the concepts, terminologies, and their application. Silva Fennica 42: 135–146. http://dx.doi.org/10.14214/sf.270

Rouvinen S., Kuuluvainen T., Karjalainen L. (2002). Coarse woody debris in old *Pinus sylvestris* dominated forests along a geographic and human impact gradient in boreal Fennoscandia. Canadian Journal of Forest Research 32: 2184–2200. http://dx.doi.org/10.1139/X02-144

Rydin H., Diekmann M., Hallingbäck T. (1997). Biological characteristics, habitat associations, and distribution of macrofungi in Sweden. Conservation Biology 11: 628–640. http://dx.doi.org/10.1046/j.1523-1739.1997.96437.x

Safonov M.A. (2006). Wood-inhabiting aphyllophoroid fungi of the Southern Preurals (Russia). Mycena 6: 57–66. http://www.mycena.org/Vol.6/Mycena6_57-66.pdf

Safonov M.A. (2014). Wood-destroying Basidiomycetes, found on the elder woods in the South Urals (Orenburg Oblast, Russia). European Researcher 83: 9–2. http://dx.doi.org/10.13187/er.2014.83.1671

Savola K. (2015). Helsingin metsien kääpäselvityksen täydennys. Helsingin kaupungin ympäristökeskuksen julkaisuja 1/2015: 1–61. www.hel.fi/static/ymk/julkaisut/julkaisu-01-15.pdf

Savola K., Kolehmainen K. (2015). Pääkaupunkiseudun Viherkehän suojelualueiden käävät. Metsähallituksen luonnonsuojelujulkaisuja A 220: 1–65. https://julkaisut.metsa.fi/assets/pdf/lp/Asarja/a220.pdf

Schigel D.S. (2007). Polypores of Åland Islands – species inventory report. University of Helsinki, Botanical Museum. 83 p.

Schloss P.D., Westcott S.L., Ryabin T., Hall J.R., Hartmann M., Hollister E.B., Lesniewski R.A., Oakley B.B., Parks D.H., Robinson C.J., Sahl J.W., Stres B., Thallinger G.G., Van Horn D.J., Weber C.F. (2009). Introducing mothur: open-source, platform-independent, community-supported software for describing and comparing microbial communities. Applied and Environmental Microbiology 75: 7537–7541. http://dx.doi.org/110.1128/AEM.01541-09

Senn-Irlet B., Heilmann-Clausen J., Genney D., Dahlberg A. (2007). Guidance for the conservation of fungi. The Directorate of Culture and Cultural and Natural Heritage, European Council, Strasbourg. 39 p. [Cited 21 Apr 2016] http://www.wsl.ch/eccf/Guidance_Fungi.pdf

Shiryaev A. (2008). New and interesting clavarioid fungi from the hemiboreal zone of Finland. Karstenia 48: 29–32.

Shiver B.D., Borders B.E. (1996). Sampling techniques for forest resource inventory. John Wiley & Sons, New York. 356 p.

Siitonen J. (2001). Forest management, coarse woody debris and saproxylic organisms: Fennoscandian boreal forests as an example. Ecological Bulletins 49: 11–41. http://www.jstor.org/stable/20113262

Siitonen J., Martikainen P., Punttila P., Rauh J. (2000). Coarse woody debris and stand characteristics in mature managed and old-growth boreal mesic forest in southern Finland. Forest Ecology and Management 128: 211–225. http://dx.doi.org/10.1016/S0378-1127(99)00148-6

Siitonen J., Penttilä R., Ihalainen A. (2012). METSO-ohjelman uusien pysyvien ja määräaikaisten suojelualueiden ekologinen laatu Uudenmaan alueella. Metsätieteen aikakauskirja 4/2012: 259–283. http://www.metla.fi/aikakauskirja/full/ff12/ff124259.pdf

Siitonen J., Penttilä R., Kotiranta H. (2001). Coarse woody debris, polyporous fungi and saproxylic insects in an old-growth spruce forest in Vodlozero National Park, Russian Karelia. Ecological Bulletins: 231–242. http://www.jstor.org/stable/20113279

Siitonen J., Saaristo L. (2000). Habitat requirements and conservation of *Pytho kolwensis*, a beetle species of old-growth boreal forest. Biological Conservation 94: 211–220. http://dx.doi.org/10.1016/S0006-3207(99)00174-3

Siitonen P., Lehtinen A., Siitonen M. (2005). Effects of forest edges on the distribution, abundance, and regional persistence of wood-rotting fungi. Conservation Biology 19: 250–260. http://dx.doi.org/10.1111/j.1523-1739.2005.00232.x

Similä M., Kouki J., Martikainen P. (2003). Saproxylic beetles in managed and seminatural Scots pine forests: quality of dead wood matters. Forest Ecology and Management 174: 365–381. http://dx.doi.org/10.1016/S0378-1127(02)00061-0

Similä M., Kouki J., Mönkkönen M., Sippola A.-L., Huhta E. (2006). Co-variation and indicators, of species diversity: Can richness of forest-dwelling species be predicted in northern boreal forests? Ecological Indicators 6: 686–700. http://dx.doi.org/10.1016/j.ecolind.2005.08.028

Simojoki T. (1975). Varsinais-Suomen saaristometsät. Varsinais-Suomen maakuntaliitto, Maakuntapoliittisia julkaisuja 4, Turku. 103 p.

Singer R. (1944). Notes on taxonomy and nomenclature of the polypores. Mycologia 36: 65–69.

Sippola A.-L., Mönkkönen M., Renvall P. (2005). Polypore diversity in the herb-rich woodland key habitats of Koli National park in eastern Finland. Biological Conservation 126: 260–269.
http://dx.doi.org/j.biocon.2005.06.002

Sippola A-L., Renvall P. (1999). Wood-decomposing fungi and seed-tree cutting: A 40-year perspective. Forest Ecology and Management 115: 183–201.
http://dx.doi.org/10.1016/S0378-1127(98)00398-3

Sippola A.-L., Siitonen J., Kallio R. (1998). The amount and quality of coarse woody debris in natural and managed coniferous forests near the timberline in Finnish Lapland. Scandinavian Journal of Forest Research 13: 204–214.
http://dx.doi.org/10.1080/02827589809382978

Sirén G. (1961). Skogsgränstallen som indikator för klimatfluktuationerna i norra Fennoscandien under historisk tid. Metsäntutkimuslaitoksen tiedonantoja 54: 1–66.

Skult H. (1956). Skogsbotaniska studier i Skärgårdshavet med speciell hänsyn till förhållandena i Korpo skär. Acta Botanica Fennica 57: 1–244 [In Swedish with English summary]

Spirin V., Miettinen O., Pennanen J., Kotiranta H., Niemelä T. (2013a): *Antrodia hyalina*, a new polypore from Russia, and *A. leucaena*, new to Europe. Mycological Progress 12: 53–61.
http://dx.doi.org/10.1007/s11557-012-0815-0

Spirin V., Vlasák J., Niemelä T., Miettinen O. 2013b. What is *Antrodia* sensu stricto? Mycologia 105: 1555–1576.
http://dx.doi.org/10.3852/13-039

Soberón J., Llorente J. (1993). The use of species accumulation functions for the prediction of species richness. Conservation Biology 7: 480–488.
http://dx.doi.org/10.1046/j.1523-1739.1993.07030480.x

Stjernberg T., Lindgren L., Cygnel M. (1974). Naturinventering inom glesbygden i Dragsfjärd. Dragsfjärds kommun, Helsingfors. 207 p. + 44 maps.

Stokland J.N. (2001). The coarse woody debris profile: an archive of recent forest history and an important biodiversity indicator. Ecological Bulletins 49: 71–83.
http://www.jstor.org/stable/20113265

Stokland J.N., Larsson K.-H. (2011). Legacies from natural forest dynamics: Different effects of forest management on wood-inhabiting fungi in pine and spruce forests. Forest Ecology and Management 26: 1707–1721. http://dx.doi.org/10.1016/j.foreco.2011.01.003

Stokland, J., Sippola, A.-L. 2004. Monitoring protocol for wood-inhabiting fungi in the Alberta Biodiversity Monitoring Program. Alberta Biodiversity Monitoring Program, 58 pp. http://www.barbau.ca/content/monitoring-protocols-wood-inhabiting-fungi-alberta-biodiversity-monitoring-program-alberta-b

Stokland J. N., Tomter S. M., Söderberg U. (2004). Development of dead wood indicators for biodiversity monitoring: experiences from Scandinavia. EFI Proceedings 51: 207–226. http://www.efi.int/files/attachments/publications/proc51_net.pdf

Stokland J.N., Siitonen J., Jonsson B.G. (2012). Biodiversity in dead wood. Cambridge University Press, Cambridge. 509 p.

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: 515–523. http://dx.doi.org/10.1017/S0953756201004154

Strid Å. (1975). Wood-inhabiting fungi of alder forests in north-central Scandinavia 1. Aphylloporales (Basidiomycetes). Taxonomy, ecology and distribution. Wahlenbergia 1: 1–237.

Sverdrup-Thygeson A., Lindenmayer D.B. (2003). Ecological continuity and assumed indicator fungi in boreal forest: the importance of the landscape matrix. Forest Ecology and Management 174: 353–363. http://dx.doi.org/10.1016/S0378-1127(02)00043-9

Tarasov M.E., Birdsey R.A. (2001). Decay rate and potential storage of coarse woody debris in the Leningrad Region. Ecological Bulletins 49: 137–147. http://www.jstor.org/stable/20113271

Tenovuo R. (1955). Männyn esiintyminen saaristossa Gullkronanselän alueella. Maantieteellinen tutkimus. Laudatur-työ. Turun yliopisto.

Telenius A. (2011). Biodiversity information goes public: GBIF at your service. Nordic Journal of Botany 29: 378–381. http://dx.doi.org/10.1111/j.1756-1051.2011.01167.x

Thompson I.D. (2006). Monitoring of biodiversity indicators in boreal forests: A need for improved focus. Environmental Monitoring and Assessment 121: 263–273. http://dx.doi.org/10.1007/s10661-005-9119-z

Tikkanen O.-P., Martikainen P., Hyvärinen E., Junninen K., Kouki J. (2006). Red-listed boreal forest species of Finland: associations with forest structure, tree species, and decaying wood. Annales Zoologici Fennici 43: 373–383. www.sekj.org/PDF/anzf43/anzf43-373.pdf

Tonteri T., Siitonen J. (2001). Lahopuu talousmetsissä 9.valtakunnan metsien tulosten mukaan – vertailu luonnonmetsiin. In: Siitonen J. (eds.) Monimuotoinen metsä. Metsäluonnon monimuotoisuuden tutkimusohjelman loppuraportti. Metsäntutkimuslaitoksen tiedonantoja 812: 57–72.

Uotila A., Kouki J., Kontkanen H., Pulkkinen P. (2002). Assessing the naturalness of boreal forests in eastern Fennoscandia. Forest Ecology and Management 161: 257–277. http://dx.doi.org/10.1016/S0378-1127(01)00496-0

van der Linde S., Holden E., Parkin P.I., Alexander I.J., Anderson I.C. (2012). Now you see it, now you don't: the challenge of detecting, monitoring and conserving ectomycorrhizal fungi. Fungal Ecology 5: 633–640. http://dx.doi.org/10.1016/j.funeco.2012.04.002

Van Wagner C.E. (1968). The line intersect method in forest fuel sampling. Forest Science 14: 20–26.

Vauras J. (2000). Macrofungi of the Southwestern Archipelago National Park. Metsähallituksen luonnonsuojelujulkaisuja A 112: 1–91. [In Finnish with English summary] https://julkaisut.metsa.fi/assets/pdf/lp/Asarja/a112.pdf

Wallenius T., Niskanen L., Virtanen T., Hottola J., Brūmelis G., Angervuori A., Julkunen J., Pihlström M. (2010). Loss of habitats, naturalness and species diversity in Eurasian forest landscapes. Ecological Indicators 10: 1093–1101. http://dx.doi.org/10.1016/j.ecolind.2010.03.006

Whitlock M.C. (2011). Data archiving in ecology and evolution: best practices. Trends in Ecology and Evolution 26: 61–65. http://dx.doi.org/10.1016/j.tree.2010.11.006

Winter S. (2012). Forest naturalness assessment as a component of biodiversity monitoring and conservation management. Forestry 85: 293–304. http://dx.doi.org/10.1093/forestry/cps004

Winter S., Fischer H.S., Fischer A. (2010). Relative quantitative reference approach for naturalness assessments of forests. Forest Ecology and Management 259: 1624–1632. http://dx.doi.org/10.1016/j.foreco.2010.01.040

Ylisirniö A.-L., Penttilä R., Berglund H., Hallikainen V., Isaeva L., Kauhanen H., Koivula M., Mikkola K. (2012). Dead wood and polypore diversity in natural post-fire succession forests and managed stands – Lessons for biodiversity management in boreal forests. Forest Ecology and Management 268: 16–27. http://dx.doi.org/10.1016/j.foreco.2012.08.018

Ylläsjärvi I., Berglund H., Kuuluvainen T. (2011). Relationships between wood-inhabiting fungal species richness and habitat variables in old-growth forest stands in the Pallas-Yllästunturi National Park, northern boreal Finland. Silva Fennica 45: 995–1013. http://dx.doi.org/10.14214/sf.83

Yurchenko E.O. (2006). Natural substrata for corticioid fungi. Acta Mycologica 41: 113–124. http://dx.doi.org/10.5586/am.2006.015

APPENDIX 1. Recorded fungal species and their abundance (number of dead wood units) according to host trees.

Nomenclature is mainly according to Kotiranta et al. (2009) and Hjortstam and Ryvarden (2009), but the names of some species are according to following literature: Singer (1944), Nilsson and Hallenberg (2003), Bernicchia and Gorjón (2010), Miettinen and Larsson (2011), Miettinen et al. (2012b), Niemelä (2012), and Spirin et al. (2013b).

	Alnus glutinosa	*Pinus sylvestris*	*Betula* spp.	*Picea abies*	*Populus tremula*	Other trees[1]	Total
Alutaceodontia alutacea (Fr.) Hjortstam & Ryvarden	-	4	-	4	-	-	8
Amphinema byssoides (Pers. : Fr.) J. Erikss.	6	16	20	14	2	2	60
Amylocorticiellum subillaqueatum (Litsch.) Spirin & Zmitr.	1	2	-	2	-	-	5
Amyloporia xantha (Fr. : Fr.) Bondartsev & Singer	-	52	1	-	-	-	53
Amylostereum areolatum (Chaillet ex Fr.) Boidin	-	-	-	1	-	-	1
Amylostereum chailletii (Pers. : Fr.) Boidin	-	-	-	1	-	-	1
Amyloxenasma grisellum (Bourdot) Hjortstam & Ryvarden	1	-	-	-	-	-	1
Anomoporia kamtschatica (Parmasto) Bondartseva	-	-	-	1	-	-	1
Antrodia macra (Sommerf.) Niemelä	-	-	-	-	-	1	1
Antrodia mappa (Overh. & J. Lowe) Miettinen & Vlasák	-	1	-	-	-	-	1
Antrodia ramentacea (Berk. & Broome) Donk	-	8	-	-	-	-	8
Antrodia serialis (Fr.: Fr.) Donk	-	7	-	62	-	-	69
Antrodia sinuosa (Fr.: Fr.) P. Karst.	-	28	-	3	-	-	31
Antrodiella faginea Vampola & Pouzar	4	-	2	-	3	5	14
Antrodiella ichnusana (Bernicchia, Renvall & Arras	1	-	-	-	-	1	2
Antrodiella pallescens (Pilát) Niemelä & Miettinen	3	-	14	-	-	-	17
Antrodiella serpula (P. Karst.) Spirin & Niemelä	69	-	-	-	1	9	79
Aphanobasidium pseudotsugae (Burt) Boid. & Gilles	2	99	-	2	-	-	103
Aporpium canescens (P. Krast.) Bondartsev & Singer	-	-	6	-	-	-	6
Asterostroma laxum Bres.	-	2	1	1	-	-	4
Athelia acrospora Jülich	-	1	-	-	-	-	1
Athelia arachnoidea (Berk.) Jülich	-	1	-	1	-	1	3
Athelia decipiens (Höhn. & Litsch.) J. Erikss.	-	5	1	-	-	-	6

Athelia epiphylla Pers. : Fr. coll.	51	2	16	1	-	8	78
Athelia neuhoffii (Bres.) Donk	-	1	-	-	-	-	1
Athelopsis lembospora (Bourdot) Oberw.	1	-	-	-	-	-	1
Athelopsis subinconspicua (Litsch.) Jülich	-	-	-	1	-	-	1
Basidiodendron caesiocinereum (Höhn. & Litsch.) Luck-Allen	-	2	1	1	-	1	5
Basidioradulum radula (Fr.) Nobles	13	1	41	-	7	29	91
Bjerkandera adusta (Willd. : Fr.) P. Karst.	-	-	9	2	-	-	11
Boidinia furfuracea (Bres.) Stalpers & Hjortstam	-	1	1	3	-	-	5
Botryobasidium aureum Parmasto stat. conid.	1	-	-	-	-	-	1
Botryobasidium botryosum (Bres.) J. Erikss.)	5	31	8	10	-	1	55
Botryobasidium candicans J. Erikss.	53	-	10	1	-	1	65
Botryobasidium conspersum J. Erikss.	10	2	12	-	2	1	27
Botryobasidium isabellinum (Fr.) D.P. Rogers	3	-	3	1	1	1	9
Botryobasidium laeve (J. Erikss.) Parmasto	11	1	1	1	-	-	14
Botryobasidium obtusisporum J. Erikss.	-	10	5	1	-	-	16
Botryobasidium subcoronatum (Höhn. & Litsch.) Donk	130	83	50	14	2	6	285
Brevicellicium exile (H.S. Jacks.) K.H. Larsson & Hjortstam	1	-	-	-	-	-	1
Brevicellicium olivascens (Bres.) K.H. Larsson & Hjortstam	1	-	3	-	-	-	4
Bulbillomyces farinosus (Bres.) Jülich	1	-	-	-	-	-	1
Byssomerulius corium (Fr.) Parmasto	-	-	-	-	3	-	3
Ceraceomyces eludens K.H. Larsson	-	14	-	2	-	-	16
Ceraceomyces microsporus K.H. Larsson	3	8	-	2	-	-	13
Ceraceomyces serpens (Tode: Fr.) Ginns	1	-	-	-	2	2	5
Ceraceomyces tessulatus (Cooke) Jülich	-	-	2	-	-	-	2
Ceraceomyces violascens (Fr. : Fr.) Jülich	-	-	1	-	-	-	1
Ceratobasidium cornigerum (Bourdot) D.P. Rogers	-	-	-	1	-	-	1
Ceriporia excelsa (S. Lundell) Parmasto	-	-	3	-	-	-	3
Ceriporia reticulata (H. Hoffm. : Fr.) Domanski	19	-	1	-	4	4	28
Ceriporia viridans (Berk. & Broome) Donk	1	-	1	-	4	2	8
Ceriporiopsis aneirina (Sommerf.) Domanski	1	-	-	-	-	-	1
Cerrena unicolor (Bull. : Fr.) Murrill	-	-	16	-	1	-	17

Chaetoderma luna (Romell ex Rogers & Jacks.) Parmasto	-	6	-	-	-	-	6
Chondrostereum purpureum (Pers. : Fr.) Pouzar	23	-	6	-	14	2	45
Cinereomyces lindbladii (Berk.) Jülich	-	9	-	1	-	-	10
Climacocystis borealis (Fr.) Kotl. & Pouzar	-	-	-	1	-	-	1
Colacogloea peniophorae (Bourdot & Galzin) Oberw. & Bandoni	5	2	-	-	-	1	8
Conferticium ochraceum (Fr. : Fr.) Hallenb.	-	-	-	2	-	-	2
Coniophora arida (Fr.) P. Karst.	4	24	-	6	3	1	38
Coniophora fusispora (Cooke & Ellis) Sacc.	1	-	-	-	-	-	1
Coniophora olivacea (Pers. : Fr.) P. Karst.	-	-	-	6	-	-	6
Coniophora puteana (Schumach. : Fr.) P. Karst.	3	4	2	-	-	-	9
Corticiaceae sp. nova	2	-	-	-	-	-	2
Corticium boreoroseum Boidin & Lanquetin	-	1	1	-	-	-	2
Corticium roseum Pers.: Fr.	-	-	-	-	4	2	6
Cristinia helvetica (Pers.) Parmasto	15	1	3	-	-	2	21
Crustoderma corneum (Bourd. & Galz.) Nakasone	-	1	-	-	-	-	1
Cylindrobasidium evolvens (Fr. : Fr.) Jülich	1	-	3	1	-	2	7
Cytidia salicina (Fr.) Burt	-	-	-	-	-	2	2
Dacryobolus karstenii (Bres.) Oberw. ex Parmasto	-	3	-	-	-	-	3
Dacryobolus sudans (Fr.) Fr.	-	3	-	-	-	-	3
Daedalea quercina L. : Fr.	-	-	-	-	-	1	1
Daedaleopsis confragosa (Bolton : Fr.) J. Schröt.	2	-	2	-	-	7	11
Datronia mollis (Sommerf.) Donk	1	-	2	-	8	3	14
Dendrothele amygdalispora Hjortstam	-	-	-	-	-	1	1
Dichomitus campestris (Quél.) Domański & Orlicz	-	-	-	-	-	1	1
Exidiopsis calcea (Pers. : Fr.) K. Wells	-	4	-	33	-	-	37
Fibroporia norrlandica (Berglund & Ryvarden) Niemelä	-	1	-	-	-	-	1
Fibroporia vaillantii (DC. : Fr.) Parmasto	-	-	-	1	-	-	1
Fomes fomentarius (L. : Fr.) Fr.	15	-	302	-	-	1	318
Fomitopsis pinicola (Sw. : Fr.) P. Karst.	4	74	15	62	1	3	159
Galzinia incrustans Parmasto	1	-	-	-	-	1	2
Ganoderma applanatum (Pers.) Pat.	2	-	14	-	10	3	29

Ganoderma lucidum (M.A. Curtis : Fr.) P. Karst.	3	-	4	1	-	-	8
Gelatoporia subvermispora (Pilát) Niemelä	-	-	3	-	-	-	3
Globulicium hiemale (Laurila) Hjortstam	-	1	-	2	-	-	3
Gloeocystidiellum porosum (Berk. & M.A. Curtis) Donk	-	-	1	-	4	-	5
Gloeophyllum sepiarium (Wulfen : Fr.) P. Karst.	-	9	-	31	1	-	41
Gloeoporus dichrous (Fr. : Fr.) Bres.	-	-	25	-	1	-	26
Gloeoporus pannocinctus (Romell) J. Erikss.	-	-	3	-	-	-	3
Hapalopilus rutilans (Pers. : Fr.) P. Karst.	3	-	13	1	1	19	37
Hastodontia halonata (J. Eriksson & Hjortstam) Hjortstam & Ryvarden	-	1	-	-	-	-	1
Hastodontia hastata (Litsch.) Hjortstam & Ryvarden	-	19	3	4	-	-	26
Helicogloea lagerheimii Pat.	-	-	-	-	-	2	2
Henningsomyces candidus (Pers. : Fr.) Kuntze	-	-	3	-	-	-	3
Heterobasidion annosum (Fr.) Bref.	-	1	-	-	-	-	1
Heterobasidion parviporum Niemelä & Korhonen	-	-	-	13	-	-	13
Hymenochaete cinnamomea (Fr.) Bres.	-	-	-	-	-	10	10
Hymenochaete fuliginosa (Pers.) Bres.	-	1	-	-	-	-	1
Hymenochaete tabacina (Fr.) Lév.)	1	-	3	-	2	10	16
Hyphoderma argillaceum (Bres.) Donk	1	1	7	6	-	1	16
Hyphoderma definitum (H.S. Jacks.) Donk	-	1	-	-	-	-	1
Hyphoderma medioburiense (Burt) Donk	-	-	2	-	-	-	2
Hyphoderma obtusiforme J. Erikss. & Å. Strid	2	-	-	1	-	-	3
Hyphoderma obtusum J. Erikss.	-	1	-	-	1	-	2
Hyphoderma occidentale (D.P. Rogers) Boidin & Gilles	-	-	-	-	-	1	1
Hyphoderma roseocremeum (Bres.) Donk	28	4	7	3	11	16	69
Hyphoderma setigerum (Fr.) Donk	18	-	22	-	2	5	47
Hyphodontia "*globisporum*"	-	1	-	-	-	-	1
Hyphodontia "*langeri*"	-	20	-	1	1	-	22
Hyphodontia alutaria (Burt) J. Erikss.	23	3	2	4	-	3	35
Hyphodontia arguta (Fr.) J. Erikss.	8	-	1	1	-	1	11
Hyphodontia pallidula (Bres.) J. Erikss.	10	5	1	11	1	1	29
Hyphodontia sp. (species nova)	-	1	-	1	-	-	2

Hypochnicium albostramineum (Bres.) Hallenb.	-	2	2	-	-	-	4
Hypochnicium bombycinum (Sommerf. & Fr.) J. Erikss.	1	-	1	-	-	-	2
Hypochnicium cremicolor (Bres.) H. Nilsson & Hallenb.	1	-	1	-	-	-	2
Hypochnicium erikssonii Hallenb. & Hjortstam	7	-	-	-	-	-	7
Hypochnicium geogenium (Bres.) J. Erikss.	1	-	1	1	-	-	3
Hypochnicium lundellii (Bourdot) J. Erikss.	-	-	-	2	-	-	2
Hypochnicium multiforme (Berk. & Broome) Hjorstam	-	1	-	-	-	-	1
Hypochnicium punctulatum (Cooke) J. Erikss.	-	2	-	-	-	-	2
Hypochnicium subrigescens Boidin	-	-	-	1	-	-	1
Hypochnicium cf. *wakefieldiae*	1	-	-	-	-	-	1
Inonotus obliquus (Pers. : Fr.) Pilát	1	-	203	-	-	-	204
Inonotus radiatus (Sowerby : Fr.) P. Karst.	879	-	9	-	4	61	953
Inonotus rheades (Pers.) Bondartsev & Singer	-	-	-	-	10	-	10
Irpex cf. *lacteus* (Fr. : Fr.) Fr.	-	-	-	-	1	-	1
Irpex oreophilus (Lindsey & Gilb.) Niemelä	-	-	-	-	1	-	1
Irpicodon pendulus (Alb. & Schwein. : Fr.) Pouzar	-	1	-	-	-	-	1
Ischnoderma benzoinum (Wahlenb. : Fr.) P. Karst.	-	31	-	5	-	-	36
Jaapia ochroleuca (Bres.) Nannf. & J. Erikss.	1	-	-	-	-	-	1
Kavinia alboviridis (Morgan) Gilb. & Budington	1	1	1	-	-	-	3
Kneiffiella abieticola (Bourdot & Galzin) Jülich & Stalpers	-	10	-	-	-	-	10
Kneiffiella barba-jovis (Bull.: Fr.) J. Erikss.	-	-	6	-	1	-	7
Kneiffiella subalutacea (P. Karst.) Jül. & Stalpers	5	10	2	5	1	-	23
Lagarobasidium detriticum (Bourdot & Galzin) Jül.	-	-	-	-	-	1	1
Laxitextum bicolor (Pers. : Fr.) Lentz	-	-	8	-	2	1	11
Lenzites betulinus (L. : Fr.) Fr.	-	-	2	-	-	-	2
Leptosporomyces galzinii (Bourdot) Jülich	12	54	7	1	3	1	78
Leucogyrophana mollusca (Fr.) Pouzar	-	2	1	2	-	-	5
Leucogyrophana pinastri (Fr.) Ginns & Weresub	-	1	-	-	-	-	1
Leucogyrophana romellii (Fr.) Ginns	-	2	2	-	-	-	4
Leucogyrophana sororia (Burt) Ginns	-	1	-	3	-	-	4
Lindtneria chordulata (D.P. Rogers) Hjortstam	-	-	-	-	3	-	3

Luellia recondita (H.S. Jacks.) K.H. Larsson & Hjortstam	-	1	-	1	-	-	2
Lyomyces sambuci (Pers.: Fr.) P. Karst.	-	-	-	-	2	-	2
Megalocystidium leucoxanthum (Bres.) Jül.	-	-	-	-	1	2	3
Meruliopsis taxicola (Pers.: Fr.) Bondartsev	-	60	-	1	-	-	61
Metulodontia nivea (P. Karst.) Parmasto	-	-	-	-	1	3	4
Mycoacia fuscoatra (Fr. : Fr.) Donk	-	-	-	-	-	2	2
Oligoporus rennyi (Berk. & Broome) Donk	-	3	-	2	-	-	5
Oligoporus sericeomollis (Romell) Bondartsev	-	5	-	-	-	-	5
Oliveonia fibrillosa (Burt) Donk	-	-	1	-	5	1	7
Peniophora cinerea (Pers. : Fr.) Cooke	1	-	-	-	1	1	3
Peniophora incarnata (Pers. : Fr.) P. Karst.	2	-	3	-	8	7	20
Peniophora limitata (Chaillet ex Fr.) Cooke	-	-	-	-	-	1	1
Peniophora nuda (Fr.) Bres.	-	-	-	-	3	-	3
Peniophora pithya (Pers.) J. Erikss.	-	9	-	9	-	-	18
Peniophora polygonia (Pers. : Fr.) Bourdot & Galzin	-	-	-	-	17	-	17
Peniophora violaceolivida (Sommerf.) Massee	-	-	-	-	2	3	5
Peniophorella echinocystis (J. Erikss. & Strid) K.H. Larss.	2	-	1	-	1	1	5
Peniophorella guttulifera (P. Karst.) K.H. Larss.	-	-	3	-	-	1	4
Peniophorella pallida (Bres.) K.H. Larss.	1	3	-	2	-	-	6
Peniophorella praetermissa (P. Karst.) K.H. Larss.	21	19	13	6	4	5	68
Peniophorella pubera (Fr.) P. Karst.	134	15	54	4	1	11	219
Peniophorella tsugae (Burt) K.H. Larss.	1	-	-	-	-	-	1
Phaeolus schweinitzii (Fr.) Pat.	-	10	-	-	-	-	10
Phanerochaete laevis (Pers. : Fr.) J. Erikss. & Ryvarden	1	-	6	1	3	-	11
Phanerochaete magnoliae (Berk. & M.A. Curtis) Burdsall	2	-	-	-	-	-	2
Phanerochaete sanguinea (Fr.) Pouzar	2	78	13	6	-	1	100
Phanerochaete sordida (P. Karst.) J. Erikss. & Ryvarden	19	1	5	2	1	6	34
Phanerochaete tuberculata (P. Karst.) Parmasto	4	-	-	-	-	1	5
Phanerochaete velutina (DC. : Fr.) P. Karst.	12	1	10	1	3	10	37
Phellinus alni (Bondartsev) Parmasto	3	-	-	-	-	5	8
Phellinus chrysoloma (Fr.) Donk	-	-	-	1	-	-	1

Phellinus cinereus (Niemelä) M. Fisch.	-	-	51	-	-	-	51
Phellinus conchatus (Pers. : Fr.) Quél.	-	-	-	-	-	47	47
Phellinus ferrugineofuscus (P. Karst.) Bourdot	-	-	-	1	-	-	1
Phellinus igniarius s. str. (L. : Fr.) Quél.	-	-	-	-	-	8	8
Phellinus laevigatus (P. Karst.) Bourdot & Galzin	-	-	55	-	-	-	55
Phellinus lundellii Niemelä	-	-	7	-	-	-	7
Phellinus nigrolimitatus (Romell) Bourdot & Galzin	-	2	-	-	-	-	2
Phellinus pini (Brot. : Fr.) A. Ames	-	50	-	-	-	-	50
Phellinus populicola Niemelä	-	-	-	-	9	-	9
Phellinus punctatus (P. Karst.) Pilát	-	-	-	-	-	46	46
Phellinus tremulae (Bondartsev) Bondartsev & Borisov	-	-	-	-	114	-	114
Phlebia albida H. Post	-	-	-	-	2	-	2
Phlebia cremeoalutacea (Parmasto) K.H. Larss. & Hjortstam	-	2	1	-	-	-	3
Phlebia radiata Fr.	3	-	5	-	1	18	27
Phlebia rufa (Pers. : Fr.) M.P. Christ.	-	-	1	-	-	-	1
Phlebia segregata (Bourdot & Galzin) Parmasto	-	1	-	-	-	-	1
Phlebia subochracea (Bres.) J. Erikss. & Ryvarden	8	-	-	-	-	-	8
Phlebia tremellosa (Schrad. : Fr.) Nakasone	2	1	8	-	1	-	12
Phlebia uda (Fr.) Nakasone	1	-	1	-	-	-	2
Phlebiella christiansenii (Parmasto) K.H. Larsson & Hjortstam	-	1	-	-	-	-	1
Phlebiella sulphurea (Pers. : Fr.) Ginns & Lefebvre	4	44	10	12	4	1	75
Phlebiella tulasnelloidea (Höhn. & Litsch.) Ginns & Lefevbre	-	-	-	1	2	-	3
Phlebiopsis gigantea (Fr. : Fr.) Jülich)	-	12	-	-	-	-	12
Physisporinus vitreus (Pers. : Fr.) P. Karst.	1	-	-	-	-	-	1
Piloderma byssinum (P. Karst.) Jülich	-	6	1	2	-	-	9
Piloderma fallax (Liberta) Stalpers	19	190	61	39	12	8	329
Piloderma sp. (species nova)	-	-	1	-	-	-	1
Piloderma sphaerosporum Jülich	-	2	-	-	-	-	2
Piptoporus betulinus (Bull. : Fr.) P. Karst.	-	-	321	-	-	-	321
Polyporus ciliatus Fr. : Fr.	-	-	10	-	-	2	12
Polyporus leptocephalus (Jacq. : Fr.) Fr.	1	-	1	-	-	-	2

Porpomyces mucidus (Pers. : Fr.) Jülich	-	-	-	4	-	-	4
Postia alni Niemelä & Vampola	4	-	-	-	2	3	9
Postia caesia (Schrad. : Fr.) P. Karst.	-	4	-	25	-	1	30
Postia floriformis (Quél. ex Bres.) Jülich	-	1	-	2	-	-	3
Postia fragilis (Fr.) Jülich	-	5	-	4	-	-	9
Postia hibernica (Berk. & Broome) Jülich	-	1	-	1	-	-	2
Postia immitis (Peck) Niemelä	1	-	-	-	-	-	1
Postia leucomallella (Murrill) Jülich	-	30	1	-	-	-	31
Postia ptychogaster (F. Ludw.) Vesterh.	-	2	-	1	-	-	3
Postia stiptica (Pers.: Fr.) Jülich	-	4	-	28	-	1	33
Postia tephroleuca (Fr.) Jülich	-	2	3	5	-	2	12
Pseudomerulius montanus (Burt) Kotir., Larss. & Kulju	-	1	-	-	-	-	1
Pseudotomentella tristis (P. Karst.) M.J. Larsen	-	-	1	-	-	-	1
Pycnoporus cinnabarinus (Jacq. : Fr.) P. Karst.	-	-	4	-	-	1	5
Radulomyces confluens (Fr. : Fr.) M.P. Christ.	12	-	9	-	3	4	28
Repetobasidium vile (Bourd. & Galz.) J. Erikss.	1	-	-	-	-	-	1
Resinicium bicolor (Alb. & Schwein. : Fr.) Parmasto	2	17	14	19	3	2	57
Resinicium furfuraceum (Bres.) Parmasto	-	6	-	-	-	1	7
Resinicium pinicola (J. Erikss.) J. Erikss. & Hjortstam	-	1	-	-	-	-	1
Rigidoporus corticola (Fr.) Pouzar	7	1	-	-	65	1	74
Rigidoporus populinus (Schumach. : Fr.) Pouzar	1	-	-	-	-	3	4
Schizopora flavipora (Berk. & M.A. Curtis ex Cooke) Ryvarden	1	-	-	-	-	-	1
Schizopora paradoxa (Schrad. : Fr.) Donk	1	-	3	-	-	3	7
Schizopora radula (Pers.: Fr.) Hallenb.	10	-	-	1	-	3	14
Scopuloides rimosa (Cooke) Jülich	20	-	-	1	8	3	32
Scytinostroma portentosum (Berk. & M.A. Curtis) Donk	19	1	-	-	1	5	26
Serpula himantioides (Fr. : Fr.) P. Karst.	-	2	-	2	-	-	4
Sidera lunata (Romell ex Bourdot & Galzin) K.H. Larsson	-	2	-	-	-	-	2
Sistotrema brinkmannii (Bres.) J. Erikss.	23	1	5	-	-	1	30
Sistotrema coroniferum (v. Höhn. & Litsch.) Donk	-	-	1	2	-	-	3
Sistotrema cf. *octosporum* (J. Schröt. ex Höhn. & Litsch.) Hallenb.	-	-	-	1	-	-	1

Sistotrema muscicola (Pers.) S. Lundell	-	-	-	-	1	1	2
Sistotrema raduloides (P. Karst.) Donk	-	-	3	-	1	-	4
Sistotrema sernanderi (Litsch.) Donk	-	-	7	-	-	-	7
Sistotremastrum niveocremeum (Höhn. & Litsch.) J. Erikss.	2	-	-	-	2	-	4
Sistotremastrum suecicum Litsch. ex J. Erikss.	1	43	-	-	-	-	44
Skeletocutis amorpha (Fr.) Kotl. & Pouzar	-	35	-	-	-	-	35
Skeletocutis biguttulata (Romell) Niemelä	-	10	-	-	-	-	10
Skeletocutis carneogrisea A. David	-	-	-	1	-	-	1
Skeletocutis papyracea A. David	-	2	-	1	-	-	3
Skeletocutis stellae (Pilát) Jean Keller	-	1	-	-	-	-	1
Spongipellis fissilis (Berk. & M.A. Curtis) Murrill	-	-	-	-	5	-	5
Spongiporus undosus (Peck) A. David	-	-	-	1	-	-	1
Steccherinum bourdotii Saliba & A. David	1	-	-	-	-	-	1
Steccherinum fimbriatum (Pers. : Fr.) J. Erikss.	5	-	-	-	3	7	15
Steccherinum lacerum (P. Karst.) Kotir. & Saaren.	1	-	-	-	1	1	3
Steccherinum luteoalbum (P. Karst.) Vesterholt	-	13	-	-	-	-	13
Steccherinum nitidum (Pers. : Fr.) Vesterholt	-	-	-	-	1	1	2
Steccherinum ochraceum (Pers.) Gray	2	-	1	-	-	-	3
Stereum hirsutum (Willd. : Fr.) Gray	14	-	41	-	2	1	58
Stereum rugosum Pers. : Fr.	289	-	96	-	-	86	471
Stereum sanguinolentum (Alb. & Schwein. : Fr.) Fr.	-	121	-	45	-	-	166
Stereum subtomentosum Pouzar	108	-	1	-	1	1	111
Stypella dubia (Bourdot & Galzin) P. Roberts	-	-	-	-	1	-	1
Stypella livida (Bres.) comb. ined.	-	-	1	-	-	-	1
Subulicystidium longisporum (Pat.) Parmasto	3	-	7	-	3	3	16
Thanatephorus fusisporus (J. Schröt.) P. Roberts & Hauerslev	1	-	-	-	-	-	1
Thelephora ”alnii” (species nova)	1	-	-	-	-	-	1
Thelephora terrestris Ehrh. : Fr.	-	3	-	2	-	1	6
Tomentella albomarginata (Bourdot & Galzin) M.J. Larsen	1	1	1	-	-	-	3
Tomentella atramentaria Rostr.	-	-	1	-	-	-	1
Tomentella bryophila (Pers.) M.J. Larsen	-	-	2	-	-	-	2

Tomentella cinereoumbrina (Bres.) Stalpers	-	-	-	-	1	-	1
Tomentella coerulea (Bres.) Höhn. & Litsch	-	-	3	-	1	-	4
Tomentella ellisii (Sacc.) Jülich & Stalpers	5	-	-	-	-	-	5
Tomentella fibrosa (Berk. & M.A. Curtis) Kõljalg	-	-	1	-	-	-	1
Tomentella fuscocinerea (Pers.) Donk	-	-	1	-	-	-	1
Tomentella galzinii Bourdot	-	-	-	-	2	-	2
Tomentella radiosa (P. Karst.) Rick	-	4	-	-	-	-	4
Tomentella stuposa (Link) Stalpers	2	-	3	-	-	-	5
Tomentella sublilacina (Ellis & Holw.) Wakef. coll.	18	1	7	2	-	-	28
Tomentella terrestris (Berk. & Broome) M.J. Larsen	-	-	1	-	-	-	1
Tomentellopsis echinospora (Ellis) Hjortstam	2	2	1	-	1	-	6
Tomentellopsis submollis (Svrček) Hjortstam	1	-	1	-	-	-	2
Tomentellopsis zygodesmoides Ellis & Hjortstam	1	1	1	-	-	-	3
Trametes hirsuta (Wulfen : Fr.) Pilát	9	-	7	-	3	8	27
Trametes ochracea (Pers.) Gilb. & Ryvarden	2	-	17	-	25	1	45
Trametes pubescens (Schumach. : Fr.) Pilát	-	-	6	-	-	-	6
Trametes velutina (Fr.) G. Cunn.	-	-	5	-	-	-	5
Trechispora araneosa (Höhnel & Litsch.) K.H. Larss.	2	-	-	-	-	-	2
Trechispora byssinella (Bourdot) Liberta	-	1	1	-	-	-	2
Trechispora caucasica (Parm.) Liberta	1	-	-	-	-	-	1
Trechispora cohaerens (Schw.) Jülich & Stalpers	2	-	1	-	-	-	3
Trechispora confinis (Bourdot & Galzin) Liberta	41	6	8	7	3	7	72
Trechispora farinacea (Pers. : Fr.) Liberta	69	55	11	6	7	9	157
Trechispora hymenocystis (Berk. & Broome) K.H. Larsson	23	9	28	7	1	5	73
Trechispora invisitata (H.S. Jacks.) Liberta ssp. *hauerslevi* K.H. Larsson	1	-	1	-	-	-	2
Trechispora kavinioides de Vries	-	-	1	-	-	1	2
Trechispora laevis K.H. Larsson	-	4	-	1	-	-	5
Trechispora microspora (P. Karst.) Liberta	1	-	1	1	-	-	3
Trechispora minima K.H. Larsson	-	-	-	1	-	-	1
Trechispora minuta K.H. Larsson	2	-	1	-	-	-	3
Trechispora mollusca (Pers. : Fr.) Liberta	-	-	1	1	-	-	2

Trechispora nivea (Pers.) K.H. Larsson	1	-	1	-	1	-	3
Trechispora praefocata (Bourdot & Galzin) Liberta	13	2	4	-	-	-	19
Trechispora stellulata (Bourdot & Galzin) Liberta	-	1	-	-	-	-	1
Trechispora stevensonii (Berk. & Broome) K.H. Larsson	24	1	7	-	-	2	34
Trechispora subsphaerospora (Litsch.) Liberta	-	3	1	-	-	2	6
Trichaptum abietinum (Pers. : Fr.) Ryvarden	-	181	-	152	-	-	333
Trichaptum fuscoviolaceum (J.C. Schmidt : Fr.) Kreisel	-	58	-	-	-	-	58
Tubulicium vermiferum (Bourd.) Oberw. ex Jülich	-	-	-	-	-	1	1
Tubulicrinis accedens (Bourdot & Galzin) Donk	-	1	-	-	-	-	1
Tubulicrinis angustus (D.P. Rogers & Weresub) Donk	-	1	-	-	-	-	1
Tubulicrinis borealis J. Erikss.	-	-	-	1	-	-	1
Tubulicrinis calothrix (Pat.) Donk	-	2	-	1	-	-	3
Tubulicrinis glebulosus (Bres.) Donk	-	2	2	-	-	-	4
Tubulicrinis medius (Bourdot & Galzin) Oberw.	-	1	-	-	-	-	1
Tubulicrinis propinquus (Bourdot & Galzin) Donk	-	6	-	-	-	-	6
Tubulicrinis subulatus (Bourdot & Galzin) Donk	1	109	1	9	3	-	123
Tulasnella danica Hauersl.	1	-	-	-	-	-	1
Tulasnella pinicola Bres.	1	-	2	-	-	-	3
Tulasnella subglobispora Hjortstam	-	1	-	-	-	-	1
Tulasnella violea (Quél.) Bourdot & Galzin	2	-	2	-	-	2	6
Tylospora fibrillosa (Burt) Donk	2	1	-	-	-	-	3
Tyromyces chioneus (Fr.) P. Karst.	1	-	6	-	-	-	7
Vesiculomyces citrinus (Pers.) Hagström	28	25	9	16	1	1	80
Vuilleminia comedens (Nees : Fr.) Maire	1	-	-	-	-	-	1
Xylodon asperus (Fr.) Hjortstam & Ryvarden	-	-	1	1	-	-	2
Xylodon borealis (Kotir. & Saaren.) Hjortstam & Ryvarden	-	-	1	-	-	-	1
Xylodon brevisetus (P. Karst.) Hjortstam & Ryvarden	-	66	-	30	-	-	96
Xylodon crustosus (Pers.: Fr.) Chevall	1	1	-	-	1	-	3
Xylodon rimosissimus (Peck) Hjortstam & Ryvarden	22	2	3	-	3	6	36

Records that remained on genus level

Antrodia sp.	-	2	-	1	-	-	3
Athelia sp.	1	-	-	-	1	1	3
Athelopsis sp.	-	2	-	1	-	-	3
Botryobasidium sp.	5	7	3	-	-	-	15
Ceraceomyces sp.	-	1	-	1	-	-	2
Ceriporia sp.	2	-	-	-	-	1	3
Galzinia sp.	-	1	-	-	-	-	1
Hyphodontia sp.	-	4	-	2	-	-	6
Leptosporomyces sp.	-	1	-	-	-	-	1
Oligoporus sp.	-	2	-	1	-	-	3
Phanerochaete sp.	1	-	1	-	-	-	2
Phlebia sp.	-	1	-	-	-	-	1
Phlebiella sp.	1	-	-	-	-	-	1
Physisporinus sp.	1	-	-	-	-	-	1
Piloderma sp.	-	2	-	1	-	-	3
Postia sp.	-	1	-	2	-	1	4
Pseudotomentella sp.	-	-	-	1	-	-	1
Sistotrema sp.	-	-	-	-	1	-	1
Tomentella sp.	3	-	5	-	1	-	9
Tomentellopsis sp.	-	6	2	1	-	-	9
Trametes sp.	6	-	2	-	-	-	8
Trechispora sp.	5	3	1	1	1	-	11
Trichaptum sp.	-	3	-	-	-	-	3
Tubulicrinis sp.	-	-	-	1	-	-	1
Tulasnella sp.	-	-	-	1	-	-	1

[1] *Corylus avellana*, *Sorbus aucuparia, Salix caprea* + spp., *Prunus padus*, *Tilia cordata*, and *Fraxinus excelsior*