Eesti Maaülikool
Estonian University of Life Sciences

SYSTEMATICS AND ECOLOGY OF SELECTED TAXA OF WOOD-DECAYING BASIDIOMYCETES

PUITULAGUNDAVATE KANDSEENTE VALITUD TAKSONITE SÜSTEMAATIKA JA ÖKOLOOGIA

INDREK SELL

A thesis
for applying for the degree of Doctor of Philosophy
in Mycology

Väitekiri
filosoofiadoktori kraadi taotlemiseks mükoloogia erialal

Tartu 2012

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LIST OF ORIGINAL PUBLICATIONS

The present thesis is a summary of the following papers; in the text the references to these papers are given in Roman numerals. The papers are reproduced by kind permission of the publishers of the following journals: Agronomy Research (I), Mycotaxon (II), Mycological Progress (III), Annales Botanici Fennici (IV), Folia Cryptogamica Estonica (V).

I **Sell, I.** 2006. Size and shape of basidiospores in the *Phellinus igniarius* group. Agronomy Research 4: 359–362.

II **Sell, I.** 2008. Taxonomy of the species in the *Phellinus igniarius* group. Mycotaxon 104: 337–347.

III **Sell, I.**, Kotiranta, H., Miettinen, O., Põldmaa, K. 2012. Analysis of molecular characters confirms that *Botryodontia millavensis* and *Oxyporus philadelphi* are conspecific. Mycological Progress: submitted manuscript.

IV **Sell, I.**, Kotiranta, H., Kaart, T. 2011. Habitat requirements of *Peniophora junipericola* (Basidiomycota, Russulales). Annales Botanici Fennici 48: 232–236.

V **Sell, I.**, Kotiranta, H. 2011. Diversity and distribution of aphyllophoroid fungi growing on Common Juniper (*Juniperus communis* L.) in Estonia. Folia Cryptogamica Estonica 48: 73–84.

The corresponding Roman numerals are used to refer to those articles throughout the thesis. The contribution of the author to the papers is as follows:

Paper	Idea and study design	Sampling	Data analysis	Manuscript preparation
I	**IS**	**IS**	**IS**	**IS**
II	EP, **IS,** KP	**IS**	**IS**	**IS,** KP, EP
III	**IS**, OM, HK, KP	**IS**, HK, OM	**IS**, HK, OM, KP	**IS**, HK, OM, KP
IV	**IS**, HK	**IS**, HK	**IS**, TK, HK	**IS**, HK, TK
V	**IS**, HK	**IS**, HK	**IS**, HK	**IS**, HK

TK – Tanel Kaart, HK – Heikki Kotiranta, OM – Otto Miettinen, EP – Erast Parmasto, KP – Kadri Põldmaa, IS – Indrek Sell

1. INTRODUCTION

During a long period, the main groups of aphyllophoroid macrofungi: polypores and corticioids were treated under the collective family names Corticiaceae and Polyporaceae (Hjortstam *et al.* 1987, Ryvarden 1991). These represent wood-inhabiting basidiomycetes, some of which participate in mycorrhizal associations (Tedersoo *et al.* 2010). There are 212 species of polypores known to grow in Estonia (Parmasto 2004, Sell 2010), and more than 230 species in Finland (Niemelä 2005, Niemelä *et al*. 2012). The number of known species of corticioids in Finland is 425 (Kotiranta *et al.* 2009, Kunttu *et al.* 2011) and the estimated number in Estonia is nearly 350.

Numerous groups of polypores and corticioids have been subject to taxonomic rearrangements within the last decades. However, taxonomic affiliation of many species has remained obscure. Earlier studies in fungal taxonomy were mostly based on analyses of morphological characters. Morphological characters of different species can sometimes overlap and do not always offer a reliable basis for distinguishing the species. The development of new methods, like analysis of molecular characters, can give useful means for more precise identifications. Today, mostly morphological and molecular characters in combination are used for species delimitation (Lee 2004). Nevertheless, several traditional taxa have not been studied using molecular methods. In addition, ecological studies can give additional information about the species.

Nowadays the delimitation of fungal taxa implies studies of molecular phylogeny. Corticoid and polyporoid basidiomycetes have been treated as belonging to the families Corticiaceae and Polyporaceae (Hjortstam *et al.* 1987, Ryvarden 1991). New studies have shown that their origin is polyphyletic (Larsson *et al.* 2004). Molecular phylogenetic analyses have shown that most of the polypores belong to the order Polyporales (Hibbett *et al.* 2007), corticoid fungi are distributed among all major clades within Agaricomycetes (Binder *et al.* 2005, Larsson 2007). The species in the genus *Peniophora*, for a long time considered to belong to Corticiaceae, form a separate family Peniophoraceae which belongs to the order Russulales (Larsson, Larsson 2003, Miller *et al.* 2006).

The species in the genus *Phellinus* (Hymenochaetales, Hymenochaetaceae) are distributed worldwide (Bondarzew 1953, Domanski 1972, Gilbertson, Ryvarden 1987). The *Phellinus* species occur on a number of tree species. *Phellinus igniarius* s.l. is regarded as one of the most important wood-rotting fungi on many deciduous trees (Niemelä 1975, Niemelä, Kotiranta 1982, Erkkilä, Niemelä 1986, Järve 2006, Larsson *et al.* 2006). Systematics of this group is difficult because of high interspecific variability. Spore size is a character widely used in the taxonomy of fungi when distinguishing closely related species. Probably, it is possible to distinguish the species within the *P. igniarius* complex based on this character. Most species of the *P. igniarius* group are highly host-specific, and it is possible that a few new species can be delineated on different hosts. The hypothesis that the collections from ash (*Fraxinus* spp.), maple (*Acer* spp.) ond oak (*Quercus* spp.) represent new undescribed taxa, as supposed by Parmasto (2004), should be verified on the basis of morphological and molecular criteria.

Similar unclear taxonomical situations also exist in other genera, *e.g.* in *Oxyporus* (Polyporales, Meripilaceae) and *Botryodontia* (Polyporales, Phanerochaetaceae). Donk (1966, 1967) states that the two species – *Poria millavensis* Bourdot & Galzin (=*Botryodontia millavensis* (Bourdot & Galzin) Duhem & H. Michel) and *Chaetoporus philadelphi* Parm. (=*Oxyporus philadelphi* (Parmasto) Ryvarden) may be close to each other. Their morphological similarity was shown 40 years later by Michel *et al.* (2006). Likewise, *Hyphodontia* has been mentioned as a probable genus for the species (Parmasto 2009). In Estonia, the main hosts of *Oxyporus philadelphi*, are the Common Juniper (*Juniperus communis*) and the Sweet Mock-orange (*Philadelphus coronarius*). These two vascular plant species are not closely related, differing also in their ecology. Probably, more than one species on different hosts occur in Estonia. To test the heteropecificity of the specimens on different hosts, analysis of molecular characters is necessary.

In addition to the above-mentioned problems in systematics, the ecology of some aphyllophoroid fungi is still uncertain. *Peniophora junipericola* (Russulales, Peniophoraceae) is a pathogenic fungus of junipers in Scandinavia and in the Baltic States. However, little is known about the habitat preferences of this species. In this thesis, the diversity and distribution of the above-mentioned species, as well as other polyporoid and corticioid basidiomycetes growing on juniper, has been addressed.

2. REVIEW OF THE LITERATURE

This thesis deals with the taxonomical groups of wood-decaying basidiomycetes in which certain species are problematic in their taxonomy or ecology.

2.1. *Phellinus igniarius* group

Phellinus igniarius s.l. (Basidiomycota, Hymenochaetales) (Fig. 1), one of the most important wood-rotting fungus of many deciduous trees, was described by Fries (1821) with two species: *Polyporus igniarius* (synonyms: *Boletus igniarius*, *Fomes igniarius*, *Phellinus igniarius*) growing on willow (*Salix* spp.) and ash (*Fraxinus* spp.), and *Polyporus nigricans* (*Fomes nigricans*, *Boletus nigricans*) growing on birch (*Betula* spp.). Several forms of *Phellinus igniarius* (as *Fomes igniarius*) were distinguished by Bondarzew (1912); these are qualified as independent species at present: forma *alni* is *Phellinus alni*, f. *betulae* is probably *P. nigricans* (or *P. cinereus*), f. *tremulae* is *P. tremulae*, f. *pruni* is *P. tuberculosus* and f. *quercus* is *Fomiti-*

Fig 1. *Phellinus igniarius* s.l. (Estonia, Ida-Viru Co., Illuka Comm. Puhatu Nature Reserve, 14 May 2006, TAAM 191398). Photo by I. Sell.

poria robusta. Currently, there are 11 species in the *Phellinus igniarius* complex in Europe: *Phellinus alni* (Bondartsev) Parmasto, *P. cinereus* (Niemelä) M. Fischer, *P. igniarius* (L.:Fr.) Quél., *P. laevigatus* (Fr.:Fr.) Bourdot & Galzin, *P. lundellii* Niemelä, *P. neolundellii* Zmitr., Malysheva et Spirin, *P. nigricans* (Fr.:Fr.) P. Karst, *P. populicola* Niemelä, *P. rhamni* (Bondartseva) H. Jahn, *P. tremulae* (Bondartsev) Bondartsev & Borisov, and *P. tuberculosus* (Baumg.) Niemelä (Tomšovsky *et al.* 2010).

In earlier times, morphological characters and pairing tests have been used to delimit the species in the *P. igniarius* group (Niemelä 1972, 1974, 1975, 1977, Parmasto 1976, 2007, Fischer 1987, 1995, Ficher, Binder 1995, Lamrood, Góes-Neto 2006, Dai, Yang 2008). However, morphological differences are usually small and not always dependable for species delimitation. In molecular analyses of *Phellinus* s.l., nuclear internal transcribed spacer (ITS), mitochondrial small subunit (SSU) of ribosomal DNA and large subunit (LSU) have been used (Niemelä *et al.* 2001, Wagner, Fischer 2001, 2002, Nam *et al.* 2002, Wagner, Ryvarden 2002, Jeong *et al.* 2005, Decock *et al.* 2007). However, large subunit has mainly been used to differentiate genera, rather than species.

2.2. *Botryodontia millavensis* and *Oxyporus philadelphi*

Botryodontia millavensis (Bourdot & Galzin) Duhem & H. Michel (Basidiomycota, Phanerochaetaceae), according to Michel *et al.* (2006) found on *Juniperus communis*, *Pinus sylvestris*, *Lavandula* and *Rosa* in France, was described as *Poria mucida* subsp. *millavensis* Bourdot and Galzin 87 years ago (Bourdot, Galzin 1925). Overholts (1939) raised this subspecies to species rank – *Poria millavensis* (Bourdot & Galzin) Overholts. Almost fifteen years later, the species was placed in a different genus and renamed *Xylodon millavensis* (Bourdot & Galzin) Bondartsev (Bondarzew 1953). The same author reports the presence of this fungus in France, Germany and in the USA growing on *Pinus* and *Juniperus*.

In 1951, Erast Parmasto found a resupinate polypore from Puhtulaid Islet (Lääne County, West Estonia). This fungus, with white basidiocarps and low pores, was discovered on the bark of an old *Philadelphus coronarius* bush. In the following years, he found the species growing on *P. coronarius*, *J. communis* and *Picea abies* in the above-mentioned locality as well as in the Matsalu Nature Reserve in West Estonia. Within a period of

eight years after the first record of the species, E. Parmasto had no success in identifying these collections. Finally, his discovery was described as a new species, *Chaetoporus philadelphi* (Parmasto 1959).

The widely used name of the species under consideration is *Oxyporus philadelphi* (Parmasto) Ryvarden (Meripilaceae, Basidiomycota) (Fig. 2). In Estonia, it mainly grows on *Juniperus communis* and *Philadelphus coronarius*. The fungus has also been found growing on *Picea abies*, *Fraxinus excelsior* and *Lonicera* sp. in Estonia. As *J. communis* and *P. coronarius* are distant according to their phylogeny, the author's opinion is that it is possible that *O. philadelphi* contains more than one species. *O. philadelphi* is reported from *Taxus baccata* (specimen in fungal collection of the Estonian University of Life Sciences) and on *Populus* or on *Betula* in the Czech Republic, and from *Picea abies* in Slovakia (Vampola 1991). On very rare occasions, the fungus has been sited in semi-deserts and mountain-steppes in Turkmenistan, on *Juniperus turcomanica*, and *Hymenocrater bungei* (Parmasto 1984, 2009). Moreover, *O. philadelphi* has been mentioned growing on *Philadelphus tenuifolius* in Primorsky Krai in Russian Far East (Parmasto 1984, 2009).

Fig. 2. *Oxyporus philadelphi* (Estonia, Hiiu Co., Käina Comm., Käina Bay-Kassari Landscape Reserve, Kassari, 27 Sept 2007, TAAM 196182). Photo by I. Sell.

The possible closeness of *O. philadelphi* and *B. millavensis* had been indicated already earlier (Donk 1966, 1967). Michel *et al.* (2006) compared in detail specimens of *B. millavensis* from France, studied the isotype of *O. philadelphi* collected from Estonia, and an exicat-specimen from Estonia (Mycotheca Estonica II, No. 37, 1959). The authors found that all these specimens represent one species. However, their study was based only on morphological characters. In order to verify these results, molecular analyses of these and other available specimens are needed.

2.3. *Peniophora junipericola*

Peniophora junipericola J. Erikss. (Basidiomycota, Russulales) (Fig. 3), one of the most important wood rotting fungi on junipers in the Baltic countries and Scandinavia was described more than 60 years ago by Eriksson (1950). Its close relative is *Peniophora piceae* (Pers.). J. Erikss. which mostly grows on *Abies* spp. (Andreasen, Hallenberg 2009). The favourite habitats for *P. junipericola* are located near shores, especially in sunny, periodically warm localities where it grows on dead, but still attached branches or dead trunks of juniper. According to Eriksson *et al.*

Fig. 3. *Peniophora junipericola* (Estonia, Hiiu Co., Käina Comm., Käina Bay-Kassari Landscape Reserve, Kassari, 27 Sept 2007, Kta 21988 & Sell). Photo by I. Sell.

(1978) it grows on *Juniperus communis* in Sweden, France and Estonia. Moreover, a few other juniper species (*Juniperus excelsa, J. oxycedrus, J. semiglobatus, J. virginiana*) have been mentioned in Spain, Macedonia, Ukraine (the Crimea), Kazakhstan, North-West Caucasus, and Louisiana in the United States (García-Manjón, Moreno 1981, Gilbertson, Blackwell 1985, Mukhamedshin 1992, Parmasto, Parmasto 1992, Boidin 1994, Karadelev 1995).

Several studies of the genus *Peniophora* have focused on the taxonomy of the species (Boidin, Pomeys 1961, Hallenberg 1984, 1986, 1987, 1988, 1991, Hallenberg, Larsson 1991, 1992, Hallenberg *et al.* 1996, 2010). Eriksson (1950) reports that all the localities of *P. junipericola* are situated close to water (sea-shores, lakes etc.) but materials available at present do not fully support that view. According to Parmasto and Parmasto (1992), the distribution pattern of *P. junipericola* is reminiscent of that of a typically xerothermic species.

3. AIMS OF THE STUDY

The present series of studies was designed to ascertain some aspects of the taxonomy and ecology of selected taxa of wood-decaying basidiomycetes (**Papers I, II, III, IV, V**).

The hypotheses addressed were:

– *Phellinus igniarius* s.l. specimens growing on oak (*Quercus* spp.), ash (*Fraxinus* spp.) and maple (*Acer* spp.) represent one or more undescribed taxa;
– *Oxyporus philadelphi* and *Botryodontia millavensis* are a single species which belongs to the genus *Hyphodontia*.

The main aims of the study were the following:

– to find out possible differences in the size and shape of the basidiospores of species in the *Phellinus igniarius* group (**Papers I, II**);
– to ascertain (based on the analysis of morphological and molecular characters) whether the *Phellinus igniarius* s.l. specimens collected from oak (*Quercus* spp.), ash (*Fraxinus* spp.) and maple (*Acer* spp.) represent new undescribed taxa (**Paper II**);
– to elucidate (on the basis of analysis of molecular characters) if *Oxyporus philadelphi* (Parmasto) Ryvarden and *Botryodontia millavensis* (Bourdot & Galzin) Duhem & H. Michel are conspecific as suggested by their similar morphology, and to determine the taxonomic status of the species (**Paper III**);
– to test (based on the analysis of molecular characters) if *Oxyporus philadelphi* comprises more than one species growing on different hosts in Estonia (**Paper III**);
– to evaluate habitat requirements of *Peniophora junipericola* J. Erikss. in Northern Europe (**Paper IV**);
– to review the diversity and distribution of aphyllophoroid fungi growing on Common Juniper (*Juniperus communis*) in Estonia (**Paper V**).

4. MATERIALS AND METHODS

The study is based on fungal material collected by the author or received from various fungal collections. The specimens collected by the author are deposited at the fungarium of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences (TAAM). Data of studied specimens deposited at TAAM were added to the PlutoF database (Abarenkov *et al.* 2010) and can be found at the eBiodiversity webpage [http://elurikkus.ut.ee/]. In addition, study material has been obtained on loan from the following herbaria: Botanical Museum of Helsinki University, Finland (H), Centre for Biodiversity, University of Turku, Finland (TUR), University of Gothenburg, Sweden (GB), Museum of Evolution, Uppsala University, Sweden (UPS), Swedish Museum of Natural History, Stockholm, Sweden (S), Botanical Museum of Oslo, Norway (O), Natural History Museum of Paris, France (PC) and the reference herbarium of Heikki Kotiranta, Helsinki, Finland (HK). In addition, strains from Fungal Biodiversity Centre, Institute of Royal Netherlands Academy of Art and Sciences (CBS) were used. DNA extractions, polymerase chain reaction (PCR) and purification of the products were performed at the joint laboratory of molecular analyses of the Centre of Excellence of Frontiers in Biodiversity Research (FIBIR) and the Chair of Mycology of the Department of Botany, Institute of Ecology and Earth Sciences, University of Tartu.

Nomenclature used in this study follows the Index Fungorum [http://www.indexfungorum.org]. Specimens of *Phellinus igniarius* s.l. collected from ash (*Fraxinus* spp.), maple (*Acer* spp.) and oak (*Quercus* spp.) are tentatively named as 'Phellinus fraxini', 'Phellinus aceris' and 'Phellinus quercus'.

4.1. Analysis of morphological characters

For analysis of micromorphological characters, 3% aquaeous potassium hydroxide (KOH) was used. Morphology was studied using Nikon Labophot-2 microscope (**Papers I, II**). The program Global Lab Image was used for micromorphological measurements.

For **Papers I** and **II**, 30 spores were measured from every specimen. To characterize the specimen, mean spore length and width (calculated from 30 measured spores) were used (Parmasto, Parmasto 1987). For **Paper II**, 15 setae were measured from every specimen. Parallel versus interwoven hyphal arrangement in the dissepiments was estimated for each specimen. The number of pores per millimetre was counted on ten separate parts of the hymenophore of each basidiocarp of the species of the *Phellinus igniarius* group by means of a dissecting microscope, and later on, the average was calculated. In the basidiocarps several morphological characters were studied: character of the upper surface (presence of crevices, colour, width of the zones and presence of the marginal zone), shape of the margin (triangular, narrowly- or widely-roundish), thickness measured at mid-length, thickness of context, and the presence of the core.

For the phenetic analysis of all morphological characters, the program NTSYSpc 2.2 was used (**Paper II**). Manhattan distance measuring and complete clustering methods were used. The other distance measuring and clustering methods applied (Eucleides, UPGMA) did not give clearer results and respective data is not presented.

4.2. Fungal isolates

Pure cultures of *Phellinus* spp. were obtained (**Paper II**) by inoculating small parts of basidiocarps' inner tissue onto agar medium in 9 cm diam Petri dishes. 1.5% malt extract agar (MEA) with the addition of streptomycine (100 µg/ml) and tetracycline (1.25 µg/ml) was used. After the incubation of about two weeks at 24 °C in darkness, the cultures were transferred to agar slants in test tubes. All pure cultures made by the author are preserved at the fungal culture collection of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences (TFC).

For molecular analysis, the isolates were transferred to MEA plates, which had been covered with sterile cellophane membrane. After incubation about ten days at 24 °C in darkness, the hyphal mass from the edge of colonies was removed from the membrane and stored in Eppendorf tubes at –18 °C until extracting the DNA.

4.3. Molecular techniques

DNA was extracted from pure cultures of *Phellinus igniarius* s.l. species (**Paper II**) or from dried basidiocarps of *Oxyporus philadelphi* and the closely related species (**Paper III**) by using the High Pure PCR Template Preparation Kit (Roche Applied Science, Mannheim, Germany). The internal transcribed spacer (ITS) of the nuclear ribosomal DNA was amplified using polymerase chain reaction (PCR), on Techne Genius (Techne Inc.), using puReTaq™ Ready-To-Go™ PCR Beads (Amersham Biosciences, Uppsala) and the primers ITS1F and ITS4 (White *et al.* 1990, Gardes, Bruns 1993). Amplified fragments were purified using Exo-SAP (GE Healthcare, Freiburg, Germany) treatment and sequenced at the MWG-Biotech AG (Ebersberg, Germany) or Macrogen Inc (Seoul, Korea). The sequences were edited and assembled using the Sequencher 4.7 (Gene Codes, Ann Arbour). All sequences obtained during this study were uploaded to the National Center for Biotechnology Information (NCBI) database. Additional sequences, included in the analyses, were retrieved from the same database. Sequences were aligned automatically with the program MAFFT, followed by manual adjustment in the program GENEDOC 2.6.0.3.

4.4. Phylogenetic analyses

Phylogenetical analyses were carried out using the program PAUP* 4.0b10 (Swofford 2002, **Paper II**) or MEGA 5.05 (Tamura *et al.* 2011, **Paper III**). Maximum Parsimony (MP) analysis (**Paper II**) were conducted using 1000 heuristic searches with random taxon addition sequences, TBR (tree-bisection reconnection) branch swapping, Maxtrees set to 10 000, the restriction to save 100 trees in each replicate applied, followed by additional swapping of the resulting trees. The confidence of branching was assessed using bootstrap-resampling: 1000 replicates, each with 10 random taxon addition sequences and MulTrees off. All characters were treated as unordered, equally weighted, treating gaps as missing data. *Phellinus robustus*, *P. punctatus* and *P. bicuspidatus* were used as the outgroup when studying the phylogeny of *P. igniarius* s.l. (**Paper II**). Maximum Likelihood (ML) analysis (**Paper III**) were conducted with 1000 bootstrap replicates, using General Time Reversible (GTR) model. *Oxyporus corticola* was used as outgroup when studying *O. philadelphi* and the closely related species (**Paper III**).

4.5. Ecological studies

In order to determine the habitat preferences of *Peniophora junipericola*, a total of 399 specimens were studied (**Paper IV**). Studied collections represent almost the complete set of collections of *Peniophora junipericola* in Estonia (268), Finland (35) and Sweden (87), with the inclusion of nine samples from Latvia. In all cases, the substrate was *Juniperus communis*.

In **Papers IV** and **V**, the substrate diameter of each specimen was measured with the calliper gauge to the nearest 1 mm. The decay stage was estimated using a five-point scale described by Renvall (1995). When the substrate of the herbarium specimen was not a twig (only bark was preserved), the decay stage was not estimated.

In order to measure pH, modification of the potentiometric method 943.02 (originally utilised for measuring pH of flour, AOAC 1990) was used (**Paper IV**). Since only 103 specimens were large enough (at least 5 grams per specimen is required), it was not possible to measure the pH of all specimens. The steps of the procedure were as follows: 1) a twig sample was milled to less than 1 mm particle size using Cyclotec™ Tecator; 2) the particles were mixed with distilled water, and the pH of the solution was measured with a Sentron pH-meter. The measurements were carried out in the Plant Biochemistry Laboratory of the Estonian University of Life Sciences.

In **Paper IV**, the locality data (given on the label of each specimen in the fungariums) were taken into account. The distance of a locality from the sea was evaluated using a map and assigned to one of the following classes: 1) 0–2 km, 2) 2–20 km, 3) 21–40 km, 4) 41–60 km, 5) 61 km or more.

In order to analyze how the amount of precipitation influences the distribution of *Peniophora junipericola*, precipitation data (courtesy of the Estonian Meteorological and Hydrological Institute, the Swedish Meteorological and Hydrological Institute, the Latvian Environment, Geology and Meteorology Agency, and the Finnish Meteorological Institute) from the nearest meteorological station located at the same distance from the seashore, were used (**Paper IV**). As the distribution of annual precipitation is uneven and the formation period of basidiocarps is not exactly known, the average yearly precipitation was calculated from a longer period, *e.g.*

in Estonia 1961–2007, Finland 1961–2007, Latvia 1966–2007, Sweden 1961–1990 (because all the Swedish specimens were collected between 1961 and 1990).

In **Paper V**, the forest types were classified according to the Estonian forest site type groups (Paal 1997, Lõhmus 2004). However, eutrophic alvar forests were divided into two groups: eutrophic alvar forests and eutrophic alvar juniper shrublands. Likewise, oligotrophic boreal heath forests were divided into two groups: oligotrophic boreal heath forests and oligotrophic boreal heath juniper shrublands. The collections and observations originate from the following forest type groups:

1) eutrophic alvar forests;
2) eutrophic alvar juniper shrublands;
3) oligotrophic boreal heath forests;
4) oligotrophic boreal heath juniper shrublands;
5) oligo-mesotrophic boreal forests;
6) mesotrophic boreal forests;
7) eutrophic boreo-nemoral forests;
8) eutrophic paludified forests;
9) oligotrophic paludified forests.

4.6. Statistical analyses

For statistical analyses, the program SAS 9.1 was used.

In Paper I, *Tukey*-test was used to compare species by their mean spore length, width and Q (quotation between spore length and width).
In Paper IV, Spearman rank correlation analysis was used to study the associations between variables. Additionally, principal component analysis (PCA) of the selected variables was carried out.

5. RESULTS

5.1. Taxonomical studies

5.1.1. *Phellinus igniarius* complex

Morphological characters

On the basis of spore size, three species – 'P. querqus', *P. tremulae* and *P. laevigatus* can be distinguished in the *P. igniarius* complex; the remaining species formed groups when representing graphically mean values and standard deviations of spore size (Fig. 4). *P. nigricans* and *P. cinereus* are characterized by the largest spores in the group: mean length 6.6 µm (n=12 specimens, 30 spores measured from each specimen) and 6.5 µm (n=10), mean width 5.9 µm (n=12) and 5.8 µm (n=10), respectively. The mean spore size of *P. nigricans* is considerably larger than that of others, except for *P. cinereus* (**Papers I, II**). Likewise, 'P. quercus' differs somewhat according to this character (mean length 6.2 × width 5.5 µm, n=10) but there is no statistically significant difference between *P. alni* and 'P. querqus' ($p>0.05$). *Phellinus alni* (5.9 × 5.1 µm, n=15), *P. igniarius* s.str. (5.9 × 5.1 µm, n=13), 'P. aceris' (5.8 × 5.0 µm, n=15) and 'P. fraxini' (5.8 × 5.0 µm, n=9) form one group; *P. populicola* (5.6 × 4.8 µm, n=12), *P. tuberculosus* (5.6 × 4.5 µm, n=10) and *P. lundellii* (5.5 × 4.6 µm, n=11) another, both of which are characterized by overlapping spore sizes of the constituting species. The species having the smallest spores in the group, *P. tremulae* (5.0 × 4.1 µm, n=10) and *P. laevigatus* (4.6 × 3.8 µm, n=12) can both be distinguished by their spore size. The mean spore length, as well as the width of *P. laevigatus* differs statistically from the other species in the *P. igniarius* group in all cases.

Setal size offers a clear distinction of *P. tremulae* and *P. tuberculosus* by having larger setae than other species (mean length 18.2 and 17.0 µm, mean width 7.4 and 6.7 µm, respectively). In all the other species the mean values of this feature were found to coincide. Hyphal arrangement in the dissepiments enables division of the species into two groups. Three species, *P. tuberculosus*, *P. tremulae* and *P. laevigatus* have a parallel arrangement of hyphae in the dissepiments, while in the other species the hyphae are interwoven.

Basidiocarps of *P. laevigatus* have more pores per millimetre (7.2 on average) than the other species (4.2–5.1); this measure therefore offers a good means of distinguishing *P. laevigatus* from the other species.

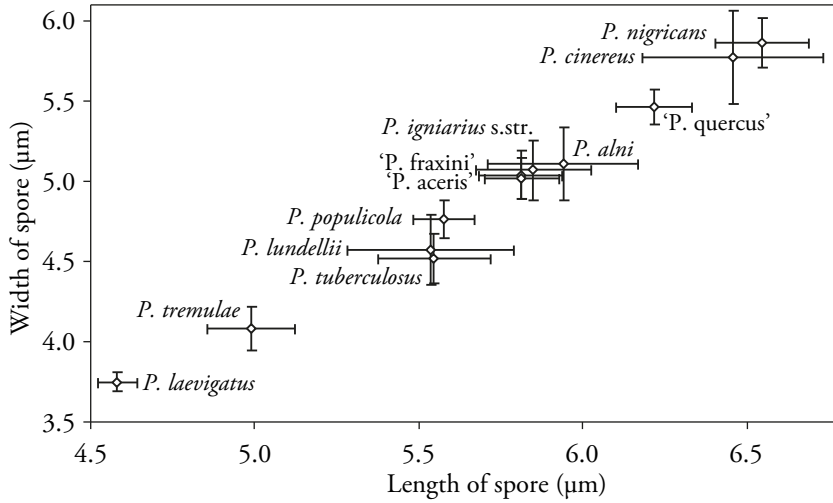

Fig. 4. Mean spore length and width (± standard deviation) among the species in the *Phellinus igniarius* group.

In the phenetic analysis of all the morphological characters, no one-species clusters were observed except that of *P. laevigatus*. Four specimens of 'P. quercus' form a cluster distinct from all the other specimens studied, but other four specimens of the same taxon are scattered in the dendrogram in the clusters together with *P. alni* and *P. cinereus*. In the *P. nigricans* cluster, a few specimens of *P. igniarius* s.str. are included, and in the *P. tremulae* cluster several *P. tuberculosus* specimens. 'P. aceris' and 'P. fraxini' are intermixed with several other species in many clusters of the dendrogram.

Molecular characters

Ingroup constituted DNA sequences of 35 strains of *P. igniarius* s.l. The data matrix of rDNA ITS regions contained 733 characters of which 248 were parsimony-informative. Phylogenetic analysis resulted in 4 083 800 most parsimonious trees of 447 steps.

In the strict consensus tree, 10 monophyletic groups were distinguished, nine of which represent *P. igniarius* s.l. species (Fig. 5). Sequences of *P. alni* are part of a well-supported clade, which also includes the subclades of *P. igniarius* s.str.–*P. populicola*, *P. cinereus*–*P. nigricans*, and *P. lundellii*. All the included *P. igniarius* s.l. specimens growing on *Acer*, *Fraxinus* and *Quercus* form one clade with seven strains of *P. alni* (on *Alnus* spp. or *Betula* spp.) obtained from the Genebank. However, this moderately

supported clade remains mostly unresolved. The only subclade, comprising a specimen growing on *Fraxinus* and another on *Quercus*, is weakly supported in bootstrap analysis.

The clade involving *P. igniarius* s.str. and *P. populicola* is strongly supported. While support for *P. igniarius* s.str. subclade is weak, the subclade of *P. populicola* has received strong support. *P. nigricans* and *P. cinereus* together form a well-supported clade, while strains of *P. nigricans* form moderately and strains of *P. cinereus* a weakly supported subclade. The clade of *P. lundellii* has also strong support. The other species of the *P. igniarius* complex form clades, which correspond to the species *P. tremulae*, *P. tuberculosus*, and *P. laevigatus*.

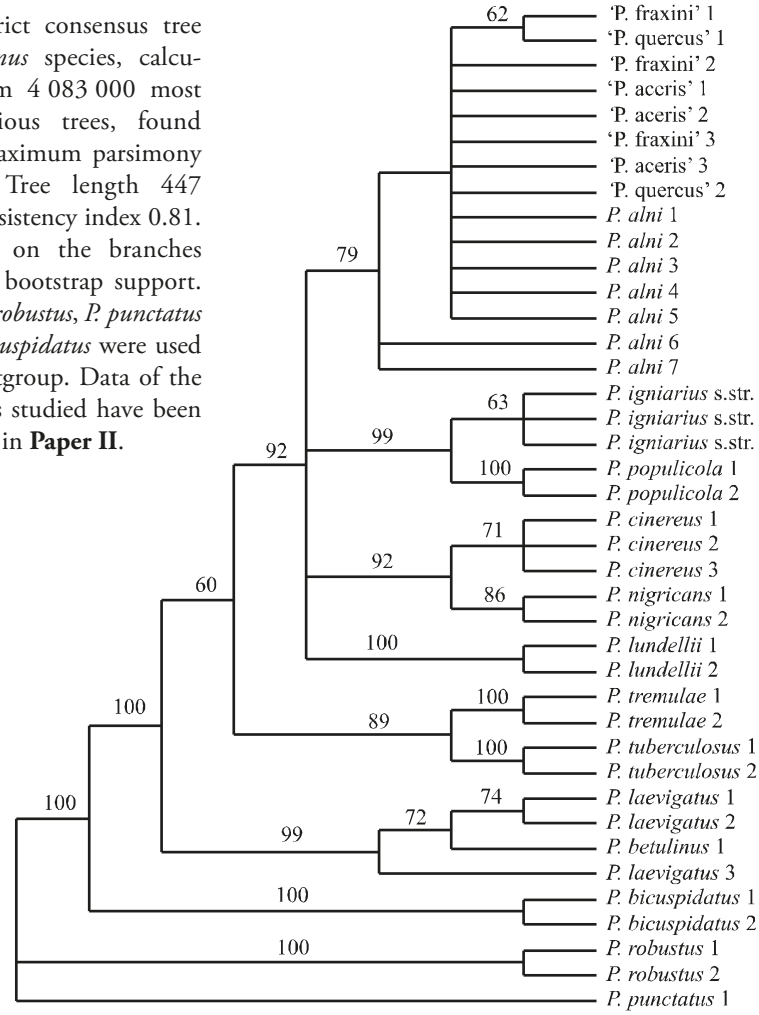

Fig. 5. Strict consensus tree of *Phellinus* species, calculated from 4 083 000 most parsimonious trees, found by the maximum parsimony analysis. Tree length 447 steps, consistency index 0.81. Numbers on the branches show the bootstrap support. *Phellinus robustus*, *P. punctatus* and *P. bicuspidatus* were used as the outgroup. Data of the specimens studied have been presented in **Paper II**.

5.1.2. *Botryodontia millavensis* and *Oxyporus philadelphi*

The dataset of rDNA ITS sequences contains 16 sequences of *Oxyporus philadelphi* and *Botryodontia millavensis* from Estonia, France, Norway and Turkmenistan. All sequences of *O. philadelphi*, *B. millavensis*, *B. cirrata* and unnamed fungi from the GeneBank form a strongly supported clade (Fig. 6). In this clade, a well-supported subclade consists of 16 specimens of *O. philadelphi*, collected from different substrates, and of two specimens of *B. millavensis*. Their ITS sequences are almost identical, supporting the conspecificity of the specimens deposited under these two names. Our analysis also confirms the close relationship between *B. millavensis* and *B. cirrata* s.l., the type species of *Botryodontia*. Closest relatives of *B. millavensis* and *B. cirrata* are found within the *Oxyporus* clade of the Hymenochaetales, where *O. corticola* is their closest kin.

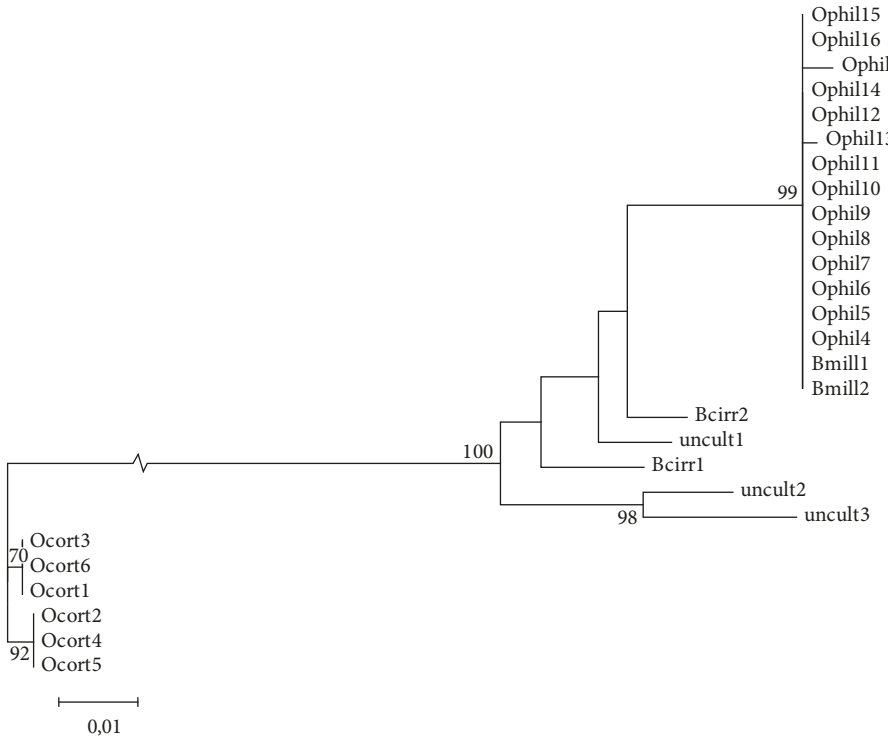

Fig. 6. Phylogenetic tree inferred from the Maximum Likelihood (ML) analysis of ITS rDNA sequences of *Oxyporus philadelphi* and closely related species. Numbers on the branches are the bootstrap values. The bar indicates the number of expected substitutions per position. The tree is rooted with *Oxyporus corticola*. Data of the specimens studied have been presented in **Paper III**.

The two *B. cirrata* specimens from Madagascar and Brunei appear to represent separate species (ITS similarity 93%). Additional, somewhat deviating GeneBank sequences indicate that several unnamed species are present in this clade.

5.2. Ecological studies

5.2.1. *Peniophora junipericola*

Diameter of the substrate twigs varies from 0.3 cm to 4.0 cm (mean ±SD=1.08±0.46 cm, n=381) (**Paper IV**). The percentage of twigs with a diameter of ≤0.5 cm is 8.4% and branches with a diameter ≥1.5 cm formes 12.6%.

The twigs (n=341) belong to decay classes 1–4 (percentages being 70.1%, 21.1%, 7.9% and 0.9%, respectively), and the occurrence of very rotten twigs (5th class) were not recorded.

Peniophora junipericola favours strongly acidic (pH_{KCl}≤ 3.5, 52.4% of the twigs [n=103]) or acidic (pH_{KCl}=3.6–4.5, 45.6% of the twigs) juniper twigs. However, it apparently can sometimes grow on moderately acidic twigs (pH_{KCl}=4.6–5.5, 1.9% of the twigs).

About two thirds (65.7%) of all the localities are situated ≤2 km from the sea; 22.5%, 6.8% and 4.5% are 2–20 km, 21–40 km and 41–60 km from the sea, respectively. There are only two localities (both in Estonia) >61 km from the sea.

Mean (±SD) annual precipitation at the *P. junipericola* localities is 599.5 ±69.0 mm (range=396.3–807.5 mm). Almost half of the habitats (49.5%) have an annual precipitation between 551 and 650 mm; at one locality the annual precipitation exceed 800 mm and at one it was less than 400 mm.

A statistically significant positive correlation between precipitation at the locality and the distance of the locality from the sea exist ($r=0.55$, $p<0.001$). Correlations between the diameter and the decay degree of twigs ($r=-0.10$, $p=0.07$), and between the decay degree of twigs and their pH ($r=0.16$, $p=0.10$) are not significant.

The first and second principal components of the PCA (PC1 and PC2, respectively) describe 64.3% of the total variation in twig diameter, decay degree, precipitation and distance from the sea. The PC1, characterising the habitat, is positively correlated with precipitation and distance from the sea, and almost not correlated with the decay degree and twig diameter. The PC2, characterising the substrate, is positively correlated with decay degree, and negatively correlated with twig diameter, but almost not correlated with precipitation and the distance from the sea.

In the second PCA, where additionally acidity of the 102 specimens are considered, the relationships between principal components and initial variables used also in the first PCA remained the same. The additional variable acidity is positively correlated with PC2 and not correlated with PC1.

5.2.2. Diversity of aphyllophoroid fungi on *Juniperus communis*

Altogether 1026 collections and observations were obtained in this study (**Paper V**). 104 species of polypores and corticioid basidiomycetes grow on the Common Juniper in Estonia. 56 of the species (53.8%) were discovered growing on the juniper only once, and 12 species (11.5%) were discovered twice.

74 rare species (1–3 specimens or observations per species) make up 71.1% of all the species and 9.8% of all the observations, whereas 15 common species (over 10 observations) form 81.9% and the remainder (4–10 observations) 8.3%, respectively. The six most common species (*Peniophora junipericola*, *Amylostereum laevigatum*, *Hyphodontia juniperi*, *H. alutaria*, *Basidioradulum crustosum*, and *H. arguta*) account for 61.9% of all the observations. The total list of aphyllophoroid fungi growing on *Juniperus communis* in Estonia is presented in **Paper V**.

6. DISCUSSION

6.1. *Phellinus igniarius* group

To date, species delimitation within the *Phellinus igniarius* group has been problematic. In order to resolve the species in that complex, additional knowledge on species systematics, morphology, ecology, genetics, and evolution is needed. For identification of the species under question, several methods have been used.

In addition to nine presently known species belonging to the *P. igniarius* group, hypothetical new taxa collected from oak, ash and maple have been studied in this thesis, using the analysis of morphological as well as molecular characters. From the hyphal arrangement in the dissepiments, two groups can be distinguished in the *P. igniarius* complex: most of the species have interwoven hyphae in the dissepiments. However, the three species, *P. tuberculosus*, *P. tremulae* and *P. laevigatus* have a parallel hyphal arrangement in the dissepiments. Based on this character, it is only possible to separate species into two groups in the *P. igniarius* complex but not to distinguish species. In addition to the hyphal arrangement in the dissepiments, other micromorphological characters of *P. igniarius* s.l. species (spore and setal dimensions) have been analyzed. According to the setal dimensions, *P. tremulae* and *P. tuberculosus* can certainly be distinguished from others. However, it is not possible to differentiate the other species based on this character because their setal size (rest of the species) is overlapping.

With respect to micromorphological characters, spore size gave better results for distinguishing species in the *P. igniarius* complex. Comparison of spore size indicated that the two species – *P. tremulae* and *P. laevigatus* – could be identified by that character. The remaining species form three groups: *P. nigricans* and *P. cinereus* formed one, *P. igniarius* s. str, *P. alni*, *P. igniarius* s.l. taxa on oak, ash and maple the second, *P. populicola*, *P. lundellii* and *P. tuberculosus* formed the third group. When using macromorphological characters, the number of pores per millimetre offers a clear distinction of *P. laevigatus.* According to this character the average number of pores per millimetre is higher here than in other species.

Before this study, it was supposed that *P. igniarius* s.l. specimens growing on the three species of the above-mentioned deciduous trees might be new, up to the present time undescribed species as supposed by Parmasto (2004). It has also been supposed that the same species may belong to *P. cinereus* (Parmasto 1993). According to spore dimensions, *P. igniarius* s.l. specimens growing on ash and maple are close to *P. igniarius* s.str. as well as to *P. alni*. However, the average spore size of the taxa growing on oak is higher than that of *P. igniarius* s.str. and *P. alni*, and is lower than that of *P. cinereus* and *P. nigricans* but there was no statistically significant difference of spore size between *P. igniarius* s.l. growing on oak and *P. alni*. The analysis of molecular characters shows that the *Phellinus igniarius* s.l. taxa growing on oak, ash and maple belong to *P. alni*. Pieri and Rivoire (2000) maintain that differentiation of *P. igniarius* s.str. and *P. alni* by their morphological characters is not possible. This has been confirmed by the present study. All the same, molecular characters present a clear distinction between the above-mentioned two species.

A more complicated problem in the *P. igniarius* group is presented by the differentiation between *P. nigricans* and *P. cinereus*. The differentiation of these two species is difficult because of the closeness of their morphological characters. Niemelä (1975) states that the spores of *P. nigricans* have a somewhat thicker wall than those of *P. cinereus*. Yet, measuring the spore wall is complicated even when one posesses a good microscope. *P. nigricans* differs from the others by its basidiocarp upper surface characters: the surface is mostly narrowly-zoned, rimosed and always with a narrow margin-zone, black or dark-grey in colour. However, these morphological characters can be very variable.

In some cases, the species' host-preference can serve as an aid in differentiating the species in the *P. igniarius* group. According to Parmasto (1985), ecological criteria are the most useful in the *Hymenochaetaceae*, owing to the obvious specialization of most of the species. Tomšovsky (2010) regards these criteria as critical in species delimitation because most species are restricted to a few closely related genera. Material collected from Estonia and neighbouring countries confirms that *P. nigricans*, *P. cinereus*, *P. lundellii* and *P. laevigatus* grow mostly on species of *Betula*; *P. igniarius* s.str. grows on the members of the genus *Salix*; *P. populicola* and *P. tremulae* on *Populus*; *P. tuberculosus* on stone fruit trees (e.g. *Prunus insititia*, *Prunus domestica*, *Cerasus vulgaris*). *Phellinus alni* differs from the others by its wide host range: it grows on *Alnus*, *Betula*, *Corylus*, *Malus*, *Padus*

avium, *Sorbus* and as an outcome of the present study, it is known to occur also on *Acer*, *Fraxinus* and *Quercus*. Tomšovsky (2010) has mentioned that *P. alni* may also occur on *Aesculus* and *Juglans*. Also in Estonia, *P. alni* grows on *Aesculus hippocastanum* and *Juglans cinerea*.

6.2. *Botryodontia millavensis* and *Oxyporus philadelphi*

Based on phylogenetic analysis, specimens of *O. philadelphi* from Estonia and Turkmenistan, and specimens of *B. millavensis* from France and Norway are conspecific. As *B. millavensis* had been described earlier, the epithet '*millavensis*' should be preserved. Molecular analysis carried out in the present study has shown that the species does not belong to the genus *Hyphodontia* as suggested by Parmasto (2009), but to the *Oxyporus* clade defined by Larsson *et al.* (2006). The species is closely related to the type species of the genus *Botryodontia* (*B. cirrata*), and therefore the name *Botryodontia millavensis* should be used for this taxon for now. *Oxyporus corticola* is also closely related to *B. cirrata* and *B. millavensis*, but relationships with other members of *Oxyporus* remain unknown. Before a thorough investigation of the *Botryodontia-Oxyporus-Rigidoporus* complex has been carried out, the author considers it wise not to make any new combinations.

Before the present study, the author considered the possibility that more than one species might occur on different hosts in Estonia. Particularly, *Juniperus* communis and *Philadelphus coronarius* are distant from each other phylogenetically. The results of the analysis of morphological characters did not detect a significant difference between the specimens of *O. philadelphi* collected from various hosts. Also the analysis of molecular characters indicated that the specimens collected from *Juniperus communis*, *J. turcomanica*, *Philadelphus coronarius*, *Picea abies*, *Fraxinus excelsior* and *Lonicera* sp. belong to the same species.

The species is evidently rare in Northern Europe. Parmasto (1984, 2009) suggested that this is a relict species. However, one of the reasons of fragmentary distribution (Estonia, France, Norway, Turkmenistan and Russia) can be poor sampling: the author has found many new localities in Western Estonia, *e.g.* in Hiiumaa (Dagö) and Vormsi (Ormsö) Islands, during the fieldwork in recent years and it is possible that some localities exist also in Southern Finland and Sweden. *Botryodontia mil-*

lavensis appears to be a coastal species in Northern Europe: all localities in Estonia are situated less than five kilometers from the seashore (Parmasto 2009). *Peniophora junipericola* has a similar distribution pattern (**Paper IV**). Study of climate characteristics in *B. millavensis* habitats might shed light on the factors behind such a distribution. It is possible that soil parameters or precipitation are important in determining the distribution.

6.3. *Peniophora junipericola* and other fungi on *Juniperus communis*

The results of the present study show that *Peniophora junipericola* can grow on thin as well as on thick juniper twigs, or even on stems, with the minimum diameter 0.3 cm (mean diameter 1.08 cm). *P. pini*, which also infects mostly dead branches, grows on pine twigs (*Pinus sylvestris*), which are 1–2 cm in diameter (Eriksson *et al.* 1978). Jahn (1971) indicates that *P. pini* can grow on thin twigs, 0.3 cm in diameter, which is in line with the author's records for *P. junipericola*.

Eriksson (1950) mentioned that juniper branches are very tough and resistant, but those infected by *P. junipericola* are fragile. The results of the present study show that *P. junipericola* grows also on hard, newly dead twigs even with needles still attached, as well as on highly decayed twigs. The basidiocarp formation on newly dead, almost fresh branches indicates that *P. junipericola* is a parasite, which can also grow as a saprobe. Sometimes it was accompanied by *Peniophora pithya* which, however, does not infect living bushes and whose fruitbodies emerge on stems, but not twigs. *Amylostereum laevigatum*, which is one of the most common decayers on junipers in the Baltic States and Scandinavia, attacks also living bushes, and basidiocarp formation on thin twigs is rare.

In the study area (Estonia, Finland, Sweden, Latvia) of *P. junipericola,* the fungus grows mainly at the seaside. The western islands of Estonia, where *P. junipericola* is especially common, are characterized by warm and dry summers, mild autumns and (compared to Central-, East- and South-Estonia) fairly mild winters (Parmasto, Parmasto 1992, Tammets, Jaagus 2007). For example, on the small Vilsandi (Felsland) Island, where *P. junipericola* is common, the average amount of precipitation is 568 mm per year. In some earlier studies (Eriksson 1950, Eriksson *et al.* 1978)

P. junipericola has been reported to occur close to waterbodies. Now this preference has been corroborated: two-thirds of *P. junipericola* habitats are situated ≤2 km of the sea. Occasionally, it can also grow inland (11.8% localities situated more than 20 km from the sea).

It has not been ascertained why *P. junipericola* does not exist inland in Finland. Its distribution in Finland is limited to the hemiboreal subzone (Kotiranta *et al.* 2009). Winter minimal temperatures may restrict its distribution northwards. There is neither lack of suitable substrate nor shores of the large lakes. It would be interesting to see whether global warming will bring the distribution limit of the fungus further to the north in the future.

6.4. Future prospects

Results of the present study revealed conspecificity of *Oxyporus philadelphi* and *Botryodontia millavensis*. However, the taxonomic placement of the species needs furhter investigation. In order to solve this problem, the first step is to delimit the genera *Oxyporus*, *Rigidoporus* and *Botryodontia* based on the analyses of molecular characters as well as on morphology. It remains unclear what is the reason of fragmentary distribution of the species: the ecology of *B. millavensis* needs further studies.

According to the present study, *Peniophora junipericola* has been found on *Juniperus communis* more than 300 times in Estonia. By contrast, there are only a few records of *Heterobasidion annosum* growing on juniper in Estonia. During recent years, Estonian forest pathologists have been receiving more and more reports of infected junipers in Western Estonia. In most cases no fungal basidiocarps have been observed on dead junipers. It is possible that the role of *H. annosum* as a pathogen on junipers in Estonia is more important because the species forms basidiocarps infrequently, thus finding basidiocarps of *H. annosum* is complicated. However, the possible pathogen can be *H. annosum*. In order to test the possible causes of juniper infections in Western Estonia, especially on islands, isolating fungi to pure culture, a study of cultural characteristics and analysis of molecular characters should be conducted.

7. CONCLUSIONS

The dissertation provides information about the systematics and ecology of selected taxa of wood-decaying basidiomycetes.

The main results of the present study are as follows:

– There are clear differences in spore size of the species in the *Phellinus igniarius* complex. The spores of *P. nigricans* are statistically significantly larger than those of the other species in this group, except for *P. cinereus*. The spores of *P. laevigatus* are considerably smaller than those of all the other species in the group. The spore size is obviously a good characteristic for distinguishing species, but even if the differences are statistically significant, they do not always enable us to identify specimens. (**Papers I, II**).

– The analysis of molecular characters showed that specimens of *P. igniarius* s.l. growing on ash (*Fraxinus* spp.), maple (*Acer* spp.) and oak (*Quercus* spp.) belong neither to *P. cinereus* nor represent new species as supposed in some previous studies (Parmasto 1993, 2004). The results of the present study based on the analyses of morphological and molecular characters showed that the specimens growing on ash, oak and maple belong to *P. alni*. (**Paper II**).

– *Oxyporus philadelphi* and *Botryodontia millavensis* do not represent two different species. The analysis of molecular characters shows that the specimens of *O. philadelphi* and *B. millavensis* represent the same species. The species is closely related to the type species (*B. cirrata*) of the genus *Botryodontia*, and therefore the name *Botryodontia millavensis* should currently be used for this taxon. (**Paper III**).

– Despite the fact that *Juniperus communis* and *Philadelphus coronarius* are phylogenetically distant, only *O. philadelphi* grows on different hosts in Estonia. According to the analysis of molecular characters, the specimens growing on *J. communis*, *P. coronarius*, *Picea abies*, *Fraxinus excelsior*, *Lonicera* sp. and *J. turcomanica* belong to the same species. (**Paper III**).

– *Peniophora junipericola,* one of the most important wood-rotting fungi on junipers, can grow on thin as well as on thick juniper twigs, or even on stems, with a diameter of 0.3–4.0 cm. The fungus grows on hard, as well as on much decayed twigs. In the study area (Estonia, Finland, Sweden and Latvia), *P. junipericola* occurs near the coast: two thirds of the habitats are situated less than 2 km from the sea. However, it can sometimes grow inland. *P. junipericola* favours strongly acidic or acidic juniper twigs. Nevertheless, it can also grow on moderately acidic twigs, apparently. The annual precipitation at the locality is connected with the distance of the locality from the seaside. (**Paper IV**).

– There are 104 species of polyporoid and corticioid basidiomycetes recorded growing on the Common Juniper in Estonia. 56 of them have been found only once. The most frequent species is *Peniophora junipericola*, followed by *Amylostereum laevigatum*, *Hyphodontia juniperi*, *H. alutaria*, *Basidioradulum crustosum* and *H. arguta* in their frequency. *Atheloderma mirabile* and *Sistotrema heteronemum* are rare species which have been found in Estonia, growing exclusively on junipers. Two of the species, *O. philadelphi* and *Lindtneria trachyspora*, have been recorded in threatened categories of the Estonian Red List; the former is also protected by law in Estonia. (**Paper V**).

REFERENCES

Abarenkov, K., Tedersoo, L., Nilsson, R. H., Vellak, K., Saar, I., Veldre, V., Parmasto, E., Prous, M., Aan, A., Ots, M., Kurina, O., Ostonen, I., Jõgeva, J., Halapuu, S., Põldmaa, K., Toots, M., Truu, J., Larsson, K.-H., Kõljalg, U. 2010. PlutoF – a Web Based Workbench for Ecological and Taxonomic Reasearch, with an Online Implementation for Fungal ITS sequences. Evolutionary Bioinformatics 6: 189–196.

Andreasen, M., Hallenberg, N. 2009. A taxonomic survey of the Peniophoraceae. Synopsis Fungorum 26: 56–119.

AOAC. 1990. AOAC, pH of flour. Procedure 943–02. In: Official Methods of Analysis. Association of Official Analytical Chemists. DC, Washington.

Binder, M., Hibbett, D. S., Larsson, K.-H., Langer, E., Langer, G. 2005. The phylogenetic distribution of resupinate forms across the major clades of mushroom-forming fungi (Homobasidiomycetes). Systematics and Biodiversity 3: 113–157.

Boidin, J. 1994. Les Péniophoraceae des parties tempérées et froides de l' hémisphère nord (Basidiomycotina). Bulletin Mensuel de la Société Linnéenne de Lyon 63: 317–334. [In French].

Boidin, J., Pomeys, M. 1961. Hétérobasidiomycètes saprophytes et homobasidiomycètes résupinés. IX. De l'utilisation des critères d'interfertilité et de polarité pour la reconnaissance objective des limites spécifiques et des affinities. Bulletin de la Société Mycologique de France 77: 237–261. [In French].

[Bondarzew, A. S]. Бондарцев, А. С. 1912. Грибы собранные на стволах лесных пород в Брянском опытном лесничеетве. Труды по лесному опытному делу в России 37: 1–56. Zusammenfassung: Pilze, gesammelt auf Stämmen verschiedener Baumgattungen in der Forstversuchs Oberförsterei Bryansk. Trudy po lesnomu opytnomu delu v Rossii 37: 1–56. [In Russian, summary in German].

[Bondarzew, A. S.] Бондарцев, А. С. 1953. Трутовые грибы европейской части СССР и Кавказа. Академия Наук СССР, Москва-Ленинград. 1103 стр. Pore fungi of European USSR and Caucasus. Akademiya Nauk USSR, Moskva-Leningrad. 1103 p. [In Russian].

Bourdot, H., Galzin, A. 1925. Hyménomycetes de France. Bulletin de la Société Mycologique de France 41: 98–255. [In French].

Dai, Y.-C., Yang, F. 2008. A new species of *Phellinus* (Basidiomycota, Hymenochaetales) from western China. Mycotaxon 104: 103–106.

Decock, C., Figueroa, S. H., Robledo, G., Castillo, G. 2007. *Fomitiporia punctata* (Basidiomycota, Hymenochaetales) and its presumed taxonomic synonyms in America: taxonomy and phylogeny of some species from tropical/subtropical areas. Mycologia 99: 733–752.

Domanski, S. 1972. Fungi. Polyporaceae I, Mucronoporaceae I. Revised translated edition, Warsaw, 235 pp.

Donk, M. A. 1966. Notes on European Polypores – I. Persoonia 4: 337–343.

Donk, M. A. 1967. Notes on European Polypores – II. Notes on Poria. Persoonia 5: 47–130.

Eriksson, J. 1950. *Peniophora* Cke sect. Coloratae Bourd. & Galz. Taxonomical study with special reference to the Swedish species. Symbolae Botanicae Upsaliensis 10: 1–76.

Eriksson, J., Hjortstam, K., Ryvarden, L. 1978. The Corticiaceae of North-Europe 5. *Mycoaciella* to *Phanerochaete*. Fungiflora, Oslo: 889–1047.

Erkkilä, R., Niemelä, T. 1986. Polypores in the parks and forests of the City of Helsinki. Karstenia 26: 1–40.

Fischer, M. 1987. Biosystematische Untersuchungen an den Porlingsgattungen *Phellinus* Quél. und *Inonotus* Karst. J. Cramer, Berlin-Stuttgart. 133 S. [In German].

Fischer, M. 1995. *Phellinus igniarius* and its closest relatives in Europe. Mycological Research 99: 735–744.

Fischer, M, Binder, M. 1995. *Phellinus* species on *Betula*. Mating tests, RFLP analyses and enzymatically amplified rDNA, and relations to *Phellinus alni*. Karstenia 35: 67–84.

Fries, E. M. 1821. Systema Mycologicum. E. Mayritius, Gryphiswaldie. 520 p. [In Latin].

García-Manjón, J. L., Moreno, G. 1981. Estudos sobre Aphyllophorales. I. Frutificaciones sobre *Juniperus*. Anales del Jardín Botánico de Madrid 37: 407–416. [In Spanish].

Gardes, M., Bruns, T. D. 1993. ITS primers with enhanced specifity for basidiomycetes – application to the identification of mycorrhizae and rusts. Molecular Ecology 2: 113–118.

Gilbertson, R. L., Blackwell, M. 1985. Notes on wood-rotting fungi on junipers in the Gulf Coast Region. Mycotaxon 24: 325–348.

Gilbertson, R. L., Ryvarden, L. 1987. North American polypores. 2. *Megasporoporia – Wrightoporia*. pp. 437–885. Fungiflora, Oslo.

Hallenberg, N. 1984. Compatibility between species of Corticiaceae s.l. (Basidiomycetes) from Europe and North America. Mycotaxon 21: 335–388.

Hallenberg, N. 1986. On speciation and species delimitation in *Peniophora cinerea*-group (Corticiaceae, Basidiomycetes). Windahlia 16: 73–80.

Hallenberg, N. 1987. On speciation in Corticiaceae (Basidiomycetes). Windahlia 17: 19–25.

Hallenberg, N. 1988. Species delimitation in Corticiaceae (Basidiomycetes). Mycotaxon 31: 445–465.

Hallenberg, N. 1991. Pairing tests with species of Aphyllophorales (Basidiomycetes) from two phytogeographically isolated areas. Mycotaxon 42: 355–386.

Hallenberg, N., Larsson, E. 1991. Differences in cultural characters and electrophoretic patterns among sibling species in four different species complexes (Corticiaceae, Basidiomycetes). Mycologia 83: 131–141.

Hallenberg, N., Larsson, E. 1992. Mating biology in *Peniophora cinerea* (Basidiomycetes). Canadian Journal of Botany 70: 1758–1764.

Hallenberg, N., Larsson, E., Mahlapuu, M. 1996. Phylogenetic studies in *Peniophora*. Mycological Research 100: 179–187.

Hallenberg, N., Yurchenko, E., Ghobad-Nejhad, M. 2010. *Peniophora pseudonuda* is a synonym of *P. laeta*. Mycotaxon 112: 153–162.

Hibbett, S., Binder, M., Bischoff, J., Blackwell, M., Cannon, P., Eriksson, O., Huhndorf, S., James, T., Kirk, P., Lücking, R., Lumbsch, H., Lutzoni, F., Matheny, P., Mclaughlin, D., Powell, M., Redhead, S., Schoch, C., Spatafora, J., Stalpers, J., Vilgalys, R., Aime, C., Aptroot, A., Bauer, R., Begerow, D., Benny, G., Castlebury, L., Crous, P., Dai, Y.-C., Gams, W., Geiser, D., Griffith, G, Gueidan, C., Hawksworth, D., Hestmark, G., Hosaka, K., Humber, R., Hyde, K., Ironside, J., Kõljalg, U., Kurtzman, C., Larsson, K.-H., Lichtwardt, R, Longcore, J., Miądlikowska, J., Miller, A., Moncalvo, J.-M., Mozley-Stanridge, S., Oberwinkler, F, Parmasto, E., Reeb, V., Rogers, J., Roux, C., Ryvarden, L., Sampaio, J., Shübler, A., Sugiyama, J., Thorn, R., Tibell, L., Untereiner, W., Walker, C., Wang, Z., Weir, A., Weiss, M., White, M., Winka, K., Yao, Y.-J., Zhang, N. 2007. A higher-level phylogenetic classification of the Fungi. Mycological Research 111: 509–547.

Hjortstam, K., Larsson, K.-H., Ryvarden, L. 1987. The Corticiaceae of North Europe 1. Introduction and keys. Fungiflora, Oslo. 59 p.

Jahn, H. 1971. Steroide Pilze in Europa (Stereaceae Pil. emend. Parm. u.a., *Hymenochaete*) mit besonderer Berücksichtigung ihres Vorkommens in Bundesrepublik Deutchland. Westfälische Pilzbriefe 8: 69–176. [In German].

Jeong, W. J., Lim, Y. W, Lee, J. S., Jung, H. S. 2005. Phylogeny of *Phellinus* and Related Genera Inferred from Combined Data of ITS and Mitochondrial SSU rDNA Sequences. Journal of Microbiology and Biotechnology 15: 1028–1038.

Järve, S. 2006. Puuseened pargi- ja ilupuudel. [Tree fungi on park and ornamental plants]. Maalehe Raamat, Tallinn. 127 p. [In Estonian].

Karadelev, M. 1995. Lignicolous Aphyllophorales (Basidiomycetes) on Greek Juniper (*Juniperus excelsa*) in the republic of Macedonia. Mycotaxon 56: 467–472.

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

Kunttu, P., Kulju, M., Pennanen, J., Kotiranta, H., Halme, P. 2011. Additions to the Finnish aphyllophoroid fungi. Folia Cryptogamica Estonica 48: 25–30.

Lamrood, P., Góes-Neto, A. 2006. Taxonomic studies on Indian *Phellinus* s.l. species: parsimony analysis using morphological characters. Mycotaxon 95: 117–131.

Larsson, E., Larsson, K.-H. 2003. Phylogenetic relationships of russuloid basidiomycetes with emphasis on aphyllophoralean taxa. Mycologia 95: 1037–1065.

Larsson, K.-H.. 2007. Re-thinking the classification of corticoid fungi. Mycological Research 111: 1040–1063.

Larsson, K.-H., Larsson, E., Kóljalg, U. 2004. High phylogenetic diversity among corticoid homobasidiomycetes. Mycological Research 108: 983–1002.

Larsson, K.-H., Parmasto, E., Fischer, M., Langer, E., Nakasone, K., Redhead, S. 2006. Hymenochaetales: a molecular phylogeny for the hymenochaetoid clade. Mycologia 98: 926–936.

Lee, M. 2004. Molecular and morphological datasets have similar number of relevant phylogenetic characters. Taxon 53: 1019–1022.

Lõhmus, E. 2004. Eesti metsakasvukohatüübid [Estonian forest site-types]. EPMÜ Metsanduslik Uurimisinstituut, Eesti Loodusfoto. Tartu. 80 p. [In Estonian].

Michel, H., Duhem, B., Trichies, G. 2006. Nouveau regard sur *Poria millavensis*. Bulletin de la Société Mycologique de France 121: 29–46. [In French].

Miller, S. L., Larsson, E., Larsson, K.-H., Verbeken, A., Nuytinck, J. 2006. Perspectives in the new Russulales. Mycologia 98: 960–970.

[Mukhamedshin, R. K.] Мухамедшин, Р. К. 1992. Кортициоидные грибы (Corticiaceae s. lato) Северо Западного Кавказа. Микология и фитопатология 26: 104–109. Corticiaceae s. lato in the North-West Caucasus. Mikologiya i fitopatologiya 26: 104–109. [In Russian].

Nam, B. H., Kim, G. J., Park, H. S., Lee, S. J., Lee, J. D. 2002. Molecular Detection of *Phellinus linteus* and *P. baumii* by PCR Specific Primer. Mycobiology 30: 197–201.

Niemelä, T. 1972. On Fennoscandian Polypores. II. *Phellinus laevigatus* (Fr.) Bourd. & Galz. and *P. lundellii* Niemelä, n. sp. Annales Botanici Fennici 9: 41–59.

Niemelä, T. 1974. On Fennoscandian Polypores. III. *Phellinus tremulae* (Bond.) Bond. & Borisov. Annales Botanici Fennici 11: 202–215.

Niemelä, T. 1975. On Fennoscandian Polypores. IV. *Phellinus igniarius*, *P. nigricans* and *P. populicola*, n. sp. Annales Botanici Fennici 12: 93–122.

Niemelä, T. 1977. On Fennoscandian Polypores 5. *Phellinus pomaceus*. Karstenia 17: 77–86.

Niemelä, T. 1986. Growing old: twenty years of morphological changes in a polypore. Windahlia 16: 27–33.

Niemelä, T. 2005. Käävät, puiden sienet [Polypores, lignicolous fungi]. Norrlinia 13: 1–320. [In Finnish, Summary in English].

Niemelä, T., Kotiranta, H. 1982. Polypore survey of Finland 2. The genus *Phellinus*. Karstenia 22: 27–42.

Niemelä, T., Miettinen, O., Manninen, O. 2012. *Aurantiporus priscus* (Basidiomycota), a new polypore from old fallen conifer trees. Annales Botanici Fennici 49: 201–205.

Niemelä, T., Wagner, T., Fischer, M., Dai, Y.-C. 2001. *Phellopilus* gen. nov. and its affinities within *Phellinus* s. lato and *Inonotus* s. lato (Basidiomycetes). Annales Botanici Fennici 38: 51–62.

Overholts, L. O. 1939. New or little known species of *Poria*. Proceedings of the Pennsylvania Academy of Science 13: 121–125.

Paal, J. 1997. Eesti taimkatte kasvukohatüüpide klassifikatsioon. [Classification of Estonian vegetation site types]. TÜ Botaanika ja Ökoloogia Instituut. 297 p. [In Estonian].

Parmasto, E. 1959. De speciebus et formis novis Polyporacearum in RSS Estonica inventis [New species and forms of polypores found in Estonian USSR]. Notulae Systematicae e Sectione Cryptogamica Instituti Botanici Nomine V. L. Komarovii Academiae Scientarum URSS 12: 237–239. [In Russian and Latin].

Parmasto, E. 1976. Studies of Yakutian fungi. II. Eesti NSV Teaduste Akadeemia toimetised. Bioloogia 25: 316–321.

[Parmasto, E. H.] Пармасто, Э. Х. 1984. *Oxyporus philadelphi* – пример распространения древнего реликта. In: VII Конференция по споровым растениям Средней Ази и Казахстана. Тезисы докладов. Алма-Ата, с. 49. *Oxyporus philadelphi* – an example of distribution of old relics. In: VII Conference on spore plants of Middle Asia and Kazakhstan Abstracts, p. 49 [In Russian].

Parmasto, E. 1985. The species concept in Hymenochaetaceae (Fungi, Hymenomycetes). Proceedings Indian Academy of Sciences (Plant Sciences) 94: 369–380.

Parmasto, E. 1993. Distribution maps of Estonian fungi. 1. Hymenochaetaceae. Institute of Zoology and Botany, Estonian Academy of Sciences. Tartu.

Parmasto, E. 2004. Distribution maps of Estonian fungi. 3. Pore fungi. Institute of Zoology and Botany, Estonian Agricultural University, Tartu.

Parmasto, E. 2007. *Phellinus laevigatus* s.l. (Hymenochaetales): a ring species. Folia Cryptogamica Estonica 43: 39–49.

Parmasto, E. 2009. Kadakatarjak, Puhtu kummalisim torikseen. Lugu ühe seene üheksast nimest ja kummalisest levilast. [*Botryodontia millavensis*, a polypore with a living type specimen on Puhtu Island]. Estonia Maritima 8: 97–105. [In Estonian, Summary in English].

Parmasto, E., Parmasto, I. 1987. Variation of basidiospores in the Hymenomycetes and its significance to their taxonomy. J. Cramer, Berlin & Stuttgart. 168 p.

Parmasto, E., Parmasto, I. 1992. *Peniophora junipericola* (Aphyllophorales, Corticiaceae): distribution and spore variability. Karstenia 32: 13–16.

Pieri, M., Rivoire, B. 2000. Le genre *Phellinus*. Quelques espèces rares ou critiques récoltées en France (avec une clé des espèces du genre *Phellinus* s.l. signalées en Europe occidentale). Bulletin de la Société Mycologique de France 116: 305–331. [In French].

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

Ryvarden, L. 1991. Genera of polypores. Nomenclature and taxonomy. Synopsis fungorum 5: 1–363.

Sell, I. 2010. Liibuva roostetoriku esmasleid Eestist [First record of *Pycnoporellus alboluteus* from Estonia]. Eesti Loodus [Estonian Nature] 10: 40–40. [In Estonian].

Swofford, D. L. 2002. PAUP*. Phylogenetic analyses using parsimony (* and other methods), 4b10. Sinauer Associates, Sunderland.

Tammets, T., Jaagus, J. 2007. Äärmuslikult kuivade ja sajuste päevade esinemissageduse territoriaalne jaotus Eestis perioodil 1957–2006 [Spatial pattern of frequency of extreme dry and wet days in Estonia during the period 1957–2006]. Publicationes Instituti Geografici Universitatis Tartuensis 102: 109–116. [In Estonian, Summary in English].

Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M., Kumar, S. 2011. MEGA 5: Molecular Evolutionary Genetics Analysis using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony Methods. Molecular Biology and Evolution 28: 2731–2739.

Tedersoo, L., May, T. V., Smith, M. E. 2010. Ectomycorrhizal lifestyle in fungi: global diversity, distribution and evolution of phylogenetic lineages. Mycorrhiza 20: 217–263.

Tomšovsky, M., Vampola, P., Sedlak, P., Byrtusova, Z, Jankovsky, L. 2010. Delimitation of central and northern European species of the *Phellinus igniarius* group (Basidiomycota, Hymenochaetales) based on analysis of ITS and translation elongation factor 1 alpha DNA sequences. Mycological Progress 9: 431–445.

Vampola, P. 1991. *Oxyporus philadelphi* – Ostropórka síťkovitá, nový choroš středoevropské mykoflóry [*Oxyporus philadelphi*, a new polypore of the Centraleuropean mycoflora]. Česká Mykologie 45: 150–154. [In Czech, Summary in English].

Wagner, T., Fischer, M. 2001. Natural groups and a revised system for the European poroid Hymenochaetales (Basidiomycota) supported by nLSU rDNA sequence data. Mycological Research 105: 773–782.

Wagner, T., Fischer, M. 2002. Proceedings towards a natural classification of the worldwide taxa *Phellinus* s.l. and *Inonotus* s.l., and phylogenetic relationships of allied genera. Mycologia 94: 998–1016.

Wagner, T., Ryvarden, L. 2002. Phylogeny and taxonomy of the genus *Phylloporia* (Hymenochaetales). Mycological Progress 1: 105–116.

White, T. J., Bruns, T., Lee, S., Taylor, J. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis, M. A., Sninsky, J. J., White, T. J. (eds). PCR protocols: A guide to Methods and Applications Academic Press, San Diego, 315–322.

SUMMARY IN ESTONIAN

PUITULAGUNDAVATE KANDSEENTE VALITUD TAKSONITE SÜSTEMAATIKA JA ÖKOLOOGIA

Viimasel paaril aastakümnel läbi viidud uurimused näitavad, et puitulagundavate kandseente taksonoomias on veel palju olulisi lahendamata küsimusi. Nii on molekulaarseid tunnuseid analüüsides kindlaks tehtud, et pikka aega mittelehikseente (Aphyllophorales) kahte peamisse, koorikuliste (Corticiaceae) ja torikuliste (Polyporaceae) sugukonda kuuluvate taksonite päritolu ei ole monofüleetiline ning neid leidub mitmes süstemaatilises rühmas. Torik- ja koorikseened on enamjaolt saprotroofse eluviisiga puitulagundavad seened, mõned neist ka mükoriisaseened.

Varasemates taksonoomilistes uurimustes keskenduti eeskätt seente morfoloogiliste tunnuste analüüsile. Viimasel paaril aastakümnel on üha enam rakendatud molekulaarsete tunnuste analüüsi. Liikide piiritlemisel on oluline vaadelda nii morfoloogilisi kui ka molekulaarseid tunnuseid. Lisaks mainitud tunnustele võivad kasulikku infot anda ka teadmised liikide ökoloogiast. Käesolevas väitekirjas keskendutakse puitulagundavate kandseente valitud taksonitele, mille taksonoomia või ökoloogia vajab veel täiendavat uurimist.

Tuletaelikut ehk ebatuletaela (*Phellinus igniarius* s.l.) kui üht kõige tavalisemat lehtpuudel esinevat tüve valget südamemädanikku põhjustavat seent tunti paarsada aastat tagasi kahe liigina. Nüüdseks on selles omavahel lähedaste liikide rühmas teada 11 liiki (Tomšovsky *et al.* 2010), millest Eestis esineb üheksa: lepataelik (*Phellinus alni*), hall taelik (*P. cinereus*), tuletaelik (*P. igniarius* s.str.), sile taelik (*P. laevigatus*), Lundelli taelik (*P. lundellii*), must taelik (*P. nigricans*), haava-tuletaelik (*P. populicola*), haavataelik (*P. tremulae*) ja ploomitaelik (*P. tuberculosus*) (Parmasto 2004). Loetletud liigid on valdavalt peremeespuu-spetsiifilised ning nende viljakehade morfoloogiliste tunnuste erinevused on väikesed ja ebaselged.

Sarnaseid ebaselgeid olukordi liikide taksonoomias tuleb ette veel teisteski seenerühmades. Varasemas kirjanduses on mainitud, et kadakatarjak (*Oxyporus philadelphi*) ja seni veel eestikeelse nimeta seeneliik *Botryodontia millavensis* võiksid olla teineteisele lähedased. Aastakümneid hiljem uuriti põhjalikult nende kahe liigi mikromorfoloogilisi tunnuseid ning jõuti

järeldusele, et uuritud tunnuste järgi on mõlemad liigid identsed. Kuivõrd aga käsitleti üksnes morfoloogilisi tunnuseid ning molekulaarsete tunnuste kohta vajalik info seni puudus, vajas see edasist uurimist. Seeläbi oleks võimalik jõuda selgusele, kas tegemist on ühe või kahe liigiga, ning kui selgub, et liike on üks, siis millisesse seeneperekonda see kuulub. Eestis esineb kadakatarjak (*O. philadelphi*) peamiselt harilikul kadakal ja ebajasmiinil ning mõnedel teistel puu- ja põõsaliikidel. Arvestades asjaolu, et kadakas ja ebajasmiin on fülogeneetiliselt teineteisest kauged soontaimeliigid, tuleb kontrollida, kas kummalgi peremeestaimel kasvab eri kadakatarjaku liik.

Peale mainitud probleemide puitulagundavate kandseente taksonoomias on seniajani jäänud ebaselgeks mõnede liikide ökoloogia. Kadakakirmik (*Peniophora junipericola*) on üks tavalisemaid kadakaid kahjustavaid patogeene nii Skandinaavias kui Baltimaades. Enamus kadakakirmikualaseid uurimusi on keskendunud selle seeneliigi taksonoomiale, kuid tema ökoloogiast pole kuigi palju teada. Ei ole ka teada, kas Eestis kadakatel esinevatest mittelehikseentest ongi kõige tavalisem liik tõepoolest kadakakirmik (*P. junipericola*). Seni pole ilmunud ka ülevaadet Eestis harilikul kadakal esinevate mittelehikseente liigilisest koosseisust.

Doktoritöö peamised hüpoteesid on järgmised:

– tammel (*Quercus* spp.), saarel (*Fraxinus* spp.) ja vahtral (*Acer* spp.) kasvavad tuletaeliku (*Phellinus igniarius* s.l.) rühma esindajad on uued, teadusele seni kirjeldamata liigid;
– kadakatarjak (*Oxyporus philadelphi*) ja liik *Botryodontia millavensis* ei ole mitte kaks erinevat seeneliiki, vaid tegu on ühe liigiga, mis kuulub näsanahkiste (*Hyphodontia* spp.) perekonda.

Lähtudes eeltoodust on käesoleva töö eesmärgid järgmised:

– teada saada võimalikud erisused tuletaeliku (*Phellinus igniarius* s.l.) rühma liikide eoste suuruses ja kujus (**Artiklid I, II**);
– teha kindlaks, kas tammel (*Quercus* spp.), saarel (*Fraxinus* spp.) ja vahtral (*Acer* spp.) kasvavad tuletaelikud (*P. igniarius* s.l.) on uued, teadusele seni kirjeldamata liigid (**Artikkel II**);
– selgitada välja, kas kadakatarjaku (*Oxyporus philadelphi*) ja seeneliigi *Botryodontia millavensis* näol on tegemist ühe liigiga, ning kui jah, siis millisesse seeneperekonda käsitletav liik kuulub (**Artikkel III**);

– teha kindlaks, kas eri peremeespuudel (eelkõige harilikul kadakal ja ebajasmiinil) esineva kadakatarjaku (*Oxyporus philadelphi*) liike on rohkem kui üks (**Artikkel III**);
– selgitada välja, millised on kadakakirmiku (*Peniophora junipericola*) elupaiganõuded Põhja-Euroopas (**Artikkel IV**);
– anda ülevaade Eestis harilikul kadakal (*Juniperus communis*) esinevate mittelehikseente liigilisest koosseisust (**Artikkel V**).

Käesolevas töös uuritud seente herbaareksemplarid on kogutud autori poolt või saadud järgnevatest seeneherbaariumitest: Eesti Maaülikooli Põllumajandus- ja keskkonnainstituudi seente herbaarium (TAAM), Helsingi Ülikooli Botaanikamuuseum, Soome (H), Turu Ülikooli Bioloogilise Mitmekesisuse Keskus, Soome (TUR), Götebori Ülikooli herbaarium, Rootsi (GB), Uppsala Ülikooli Evolutsioonimuuseum, Rootsi (UPS), Rootsi Loodusloomuuseum, Stockholm, Rootsi (S), Oslo Botaanikamuuseum, Norra (O), Pariisi Loodusloomuuseum, Prantsusmaa (PC), Heikki Kotiranta isiklik seenekogu, Helsingi, Soome (HK). Kõik autori poolt kogutud ja uuritud seened on säilitatud Eesti Maaülikooli seenekollektsioonis (TAAM). Autori poolt käesoleva töö tarbeks valmistatud seente eluskultuurid on talletatud Eesti Maaülikooli seente kultuurkollektsioonis (TFC). Taksonite nimede osas on lähtutud rahvusvahelise andmebaasi Index Fungorum andmetest [http://www.indexfungorum.org]. Hüpoteetilised uued, saarel, vahtral ja tammel kasvavad tuletaeliku rühma liigid on nimetatud vastavalt 'Phellinus fraxini', 'P. aceris' ja 'P. quercus'.

Mikromorfoloogiliste analüüside tarbeks kasutati 3%-list kaaliumhüdroksiidi (KOH) lahust ja mikroskoopi Nikon Labophot-2 (**Artiklid I, II**). Mikromorfoloogiliste tunnuste mõõtmisel oli abiks mikroskoobiga ühenduses olev arvutiprogramm Global Lab Image. Morfoloogiliste tunnuste feneetiline analüüs viidi läbi arvutiprogrammis NTSYSpc 2.2 (**Artikkel II**). DNA eraldati seente eluskultuuridest (**Artikkel II**) või viljakehadest (**Artikkel III**). DNA eraldamisel kasutati Roche lahustekomplekti High Pure PCR Template Preparation Kit. Polümeraasi ahelreaktsiooni (PCR, mille tulemusel amplifitseeritakse antud DNA-järjestus) läbiviimiseks kasutati komplekti puReTaq™ Ready-To-Go™ PCR Beads. Uuritud seente ribosomaalse DNA sisemise transkribeeritud vahejärjestuse (ITS) amplifitseerimiseks kasutatud praimerid olid ITS1F ja ITS4 (White *et al.* 1990, Gardes, Bruns 1993). Sekveneerimise tulemusel saadud ITS-järjestuste kummagi ahela kromatogrammid ühendati ning saa-

dud järjestust korrigeeriti arvutiprogrammis Sequencher 4.7. Järjestuse automaatne joondamine teostati arvutiprogrammis MAFFT ning seejärel viimistleti saadud maatriksit käsitsi programmis GENEDOC 2.6.0.3. Fülogeneetiliste analüüside läbiviimiseks kasutati programme PAUP 4.0b10 (Swofford 2002) (**Artikkel II**) ja MEGA 5.05 (**Artikkel III**). Molekulaarsete tunnuste analüüs viidi läbi Tartu Ülikooli Ökoloogia ja Maateaduste Instituudi botaanika osakonna mükoloogia õppetooli ning Bioloogilise mitmekesisuse tippkeskuse (FIBIR) ühendlaboris.

Liikide ökoloogia uurimisel kasutati seente substraadiks olevate okste läbimõõdu teadasaamiseks nihikkaliibrit (**Artikkel IV**). Puuokste lagunemisastme hindamisel kasutati Renvalli (1995) poolt välja töötatud 5-astmelist skaalat. Seene substraadiks olevate kadakaokste keskkonna happelisuse (pH) teadasaamiseks kasutati veidi muudetud potetsiomeetrilist meetodit 943.02 (algselt kasutati seda jahu happesuse teadasaamiseks), vastav analüüs viidi läbi Eesti Maaülikooli taimebiokeemia laboris. Leiukoha kaugus merest arvutati kaardi järgi, võttes aluseks vahemaa linnulennult. Saamaks teada, kuidas mõjutab sademete hulk seente levikut, kasutati seene leiukoha iseloomustamiseks aasta sademetehulga summa pikaajalist keskmist näitajat (näiteks Eestis aastaid 1961–2007). Andmed saadi Eesti Meteoroloogia ja Hüdroloogia Instituudist, Rootsi Meteoroloogia ja Hüdroloogia Instituudist, Läti Keskkonna-, Geoloogia- ja Meteoroloogiaagentuurist või Soome Meteoroloogiainstituudist.

Liikide kasvukohtade iseloomustamisel jaotati kasvukohad metsa-tüübirühmadesse, aluseks Paali (1997) ja Lõhmuse (2004) klassifikatsioon (**Artikkel V**). Statistiline analüüs viidi läbi arvutiprogrammiga SAS 9.1.

Käesoleva doktoritöö tulemused on järgmised:

– Tuletaeliku rühmas on eri liikide vahel mõningaid selgeid erinevusi eoste keskmises suuruses. Musta taeliku (*Phellinus nigricans*) eosed on suuremad kui ülejäänud liikidel. See on ka statistiliselt oluline erinevus musta taeliku ja kõigi teiste tuletaeliku rühma liikide vahel, välja arvatud musta ja halli taeliku (*P. cinereus*) vahel. Sileda taeliku (*P. laevigatus*) eosed on statistiliselt väiksemad kui kõigil ülejäänud liikidel selles rühmas. Eoste keskmise suuruse ja selle varieeruvuse järgi on teistest tuletaeliku rühma liikidest võimalik eristada ka haavataelikut (*P. tremulae*). Saarel ja vahtral kasvavad tuletaeliku rühma taksonid on eoste suuruse poolest ligidased lepataelikule (*P. alni*) ja tuletaelikule

(*P. igniarius* s.str.). Tammel kasvava tuletaeliku rühma kuuluva taksoni eoste keskmine suurus ei ole statistiliselt erinev lepataeliku eoste suurusest. Eoste suurus näib olevat hea tunnus eristamaks mõningaid tuletaeliku rühma liike üksteisest, ent isegi juhul, kui erinevused on eri liikide vahel statistiliselt olulised, ei ole alati võimalik ainult nende tunnuste alusel liike määrata. (**Artiklid I, II**).

– Molekulaarsete tunnuste analüüsi tulemusel selgus, et saarel (*Fraxinus* spp.), vahtral (*Acer* spp.) ja tammel (*Quercus* spp.) esinevad tuletaelikud ei kuulu halli taeliku alla ega ole ka uued teadusele seni kirjeldamata liigid, nagu on oletanud Parmasto (1993, 2004). Käesolevas töös läbi viidud morfoloogiliste ja molekulaarsete tunnuste analüüsid näitasid, et saarel, vahtral ja tammel kasvavad perekonna taelik eksemplarid kuuluvad liiki lepataelik (*P. alni*). (**Artikkel II**).

– *Oxyporus philadelphi* ja *Botryodontia millavensis* ei ole mitte kaks erinevat liiki, vaid tegu on ühe liigiga, mida on teadusele kirjeldatud uue liigina kahel korral. Molekulaarsete tunnuste analüüs näitas, et nende DNA-järjestused on identsed. Kuivõrd kahest liigist kirjeldati esimesena *B. millavensis*, on selle liigi õigeks epiteediks *millavensis*. Vastavalt molekulaarsete tunnuste analüüsile on aga mõlema liigi uuritud eksemplaridele sarnane ka *Botryodontia* perekonna tüüpliik, *B. cirrata*. Seega on kadakatarjaku korrektseks ladinakeelseks nimeks *Botryodontia millavensis*. (**Artikkel III**).

– Vaatamata asjaolule, et harilik kadakas (*Juniperus communis*) ja harilik ebajasmiin (*Philadelphus coronarius*) on fülogeneetiliselt teineteisest kauged taimeliigid, ei ole erinevatel peremeestaimedel kasvava kadakatarjaku (*Oxyporus philadelphi*) puhul tegu eri seeneliikidega. Vastavalt molekulaarsete tunnuste analüüsile kuuluvad ühte liiki nii harilikul kadakal, harilikul ebajasmiinil, harilikul kuusel, harilikul saarel kui ka kuslapuul ja turkmeenia kadakal kasvavad eksemplarid. (**Artikkel III**).

– Kadakakirmik (*Peniophora junipericola*) kui üks olulisemaid kadakal esinevaid puitulagundavaid seeni kasvab nii peentel kui ka jämedatel, nii kõvadel kui ka kõdunenud kadakaokstel. Uurimisalal (Eesti, Soome, Rootsi ja Läti) kasvab kadakakirmik enamasti ranniku ligidal: kaks kolmandikku leiukohtadest paiknevad merest maksimaalselt kahe kilomeetri kaugusel. Sellele vaatamata võib seent leida ka

sisemaalt. Substraadina eelistab kadakakirmik tugevalt happelisi või happelisi kadakaoksi, harvem võib teda leida ka nõrgalt happelistelt kadakaokstelt. Aastane sademetehulk kadakakirmiku leiukohas on seotud leiukoha kaugusega merest. (**Artikkel IV**).

– Eestis on harilikult kadakalt leitud kokku 104 liiki mittelehikseeni, neist 56 esinemist harilikul kadakal on täheldatud vaid korra. Kõige sagedasem kadakatel kasvav liik on kadakakirmik (*Peniophora junipericola*), sellele järgnevad *Amylostereum laevigatum* ja mitmed näsanahkised: *Hyphodontia juniperi*, *H. alutaria*, *Basidioradulum crustosum* ja *H. arguta*. Haruldasematest liikidest esinevad kadakal näiteks *Atheloderma mirabile* ja sistotreemi perekonda kuuluv liik *Sistotrema heteronemum*, mõlema esinemist on Eestis täheldatud vaid ühel korral. Kaks liiki, kadakatarjak (*Oxyporus philadelphi*) ja ogaeoseline ebapoorik (*Lindtneria trachyspora*) kuuluvad ka siinse Punase Nimestiku ohukategooriatesse, lisaks öeldule on kadakatarjak Eestis looduskaitse all. (**Artikkel V**).

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I

PUBLICATIONS

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Size and shape of basidiospores in the *Phellinus igniarius* group

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Abstract. *Phellinus igniarius* group, one of the most important wood-rotting fungi of many deciduous trees, was described as two species *(P. igniarius, P. nigricans)* more than a hundred years ago. Nowadays, in this group there are known 11 macromorphologically similar species, nine out of which occur in Estonia *(P. alni, P. cinereus, P. igniarius* s. str.*, P. laevigatus, P. lundellii, P. nigricans, P. populicola, P. tremulae, P. tuberculosus).* These species, difficult to distinguish morphologically, are genetically different.

The aim of the study is to find possible differences in the size and shape of basidiospores of the species of the *Phellinus igniarius* group. There are some clear differences in the spore size of the species, but even being statistically significant, they do not enable us to identify the specimens in all cases.

Key words: basidiospores, *Phellinus igniarius*

INTRODUCTION

There are still some taxonomical problems in delimiting species in the *P. igniarius* group. Originally, there were only two species in this group: *Polyporus igniarius* (synonyms: *Boletus igniarius, Fomes igniarius, Phellinus igniarius)* growing on Salix and Fraxinus trees, and *Polyporus nigricans (Fomes nigricans, Boletus nigricans)* growing on Betula (Fries, 1821). It was asserted that the same species may have different varieties depending on the host tree, for example, *Cerasus, Ribes, Prunus, Salix* or *Populus* (Purton, 1821). On drupes *Fomes igniarius* var. *minor* was known which has small and perpendicular basidiocarps (Fries, 1821). Nowadays this fungus is *P. tuberculosus,* clearly separated from the other species by its microscopical and cultural characteristics as well as *P. tremulae* and *P. populicola* (Niemelä, 1974; Niemelä, 1975; Niemelä, 1977). Sometimes these species are difficult to distinguish morphologically; nevertheless, they are different genetically (Fischer, 1987; Fischer, 1995; Fischer & Binder, 1995).

More than a hundred years ago *P. igniarius* was regarded as two species; now it comprises at least 11 species, nine of which have been found in Estonia (Parmasto, 2004). In the *P. igniarius* group, differences between the species are small, but reliable if properly measured (Niemelä, 1972). The aim of the study is to find possible differences in the size and shape of basidiospores of the species of the *P. igniarius* group.

MATERIALS AND METHODS

The following species were studied: *P. alni* (Bondartsev) Parmasto, *P. cinereus* (Niemelä) M. Fischer, *P. igniarius* (L.: Fr.) Quél., *P. laevigatus* (Fr.: Fr.) Bourdot & Galzin, *P. lundellii* Niemelä, *P. nigricans* (Fr.: Fr.) P. Karst., *P. populicola* Niemelä, *P. tremulae* (Bondartsev) Bondartsev & Borisov in Bond., *P. tuberculosus* (Baumg.) Niemelä.

This study is based on the collections of the mycological herbarium of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences (TAA(M)). Most of the specimens were collected in Estonia; several European collections were also studied. A section was made of each basidiocarp. When possible, spores were measured from spore prints, collected on black paper. Basidiocarp sections or spore prints were soaked in 3% potassium hydroxide (KOH) solution, covered with coverslip and then studied under a Nikon Labophot-2 microscope. The enlargement was 600x. Ninety-four (94) specimens from nine species were studied. Thirty (30) spores of each specimen were measured, which is a sufficient number (Parmasto & Parmasto, 1987). The total number of spores measured was 2820.

Spore variation within one individual is the character of this particular individual and it may be used toe characterize only this specimen, not that of the entire species (Raitviir, 1972; Parmasto & Parmasto, 1987). The mean values of spore length, width and Q (quotient of spore length and width) of these data were calculated in the case of every specimen measured. Statistical program SAS was used to perform the *Tukey*-test to compare species by their mean spore length, width and quotient.

RESULTS AND DISCUSSION

It is easy to distinguish *P. nigricans* from the other species of the *P. igniarius* complex by its spore size: the mean spore size of *P. nigricans* is statistically remarkably larger than that of others, except *P. cinereus* (Table 1, Fig. 1).

P. cinereus differs statistically from *P. laevigatus, P. tremulae* and *P. tuberculosus* by its larger spore size and smaller Q value, from *P. populicola* by its larger spore size, from *P. lundellii* by its greater spore width and smaller Q value, (Table 1). The spores of *P. cinereus* are larger than the other species in this group, except *P. nigricans* (Fig. 1).

The mean spore size of *P. alni* differs statistically from *P. laevigatus* and *P. tremulae* by its larger size; from *P. lundellii* and *P. tuberculosus* by its greater width and smaller quotation, and from *P. populicola* by its greater width (Table 1). Differentiation between *P. alni* and *P. igniarius* is difficult and often not possible (Fischer, 1995), but it has been found that *P. alni* is well distinguishable from both *P. igniarius* and *P. nigricans* by its basidiocarp characters (Parmasto, 1976; Parmasto, 1988). Also, *P. alni* is well distinguishable from *P. nigricans* by its spore size (Table 1, Fig. 1). The spores of *P. igniarius* are smaller than the spores of *P. nigricans* and larger than the spores of *P. tremulae* and *P. laevigatus* (Table 1, Fig. 1). The spores of *P. populicola* are smaller than those of *P. igniarius* and *P. nigricans*, and are rather close to those of *P. lundellii* (Fig. 1; see also Niemelä, 1975). There is significant statistical difference between spore size of *P. populicola* and *P. nigricans* as well as *P. cinereus* and *P. laevigatus* (Table 1).

Table 1. Differences of mean spore size in *P. igniarius* complex (*Tukey*-test, $P < 0.05$, $N = 94$). A–significant difference of mean spore length of species, B–significant difference of mean spore width of species, C–significant difference of the mean spore quotient.

	P. laevigatus	P. tremulae	P. lundellii	P. tuberculosus	P. populicola	P. igniarius	P. alni	P. cinereus	P. nigricans
P. nigricans	ABC	ABC	ABC	ABC	AB	AB	AB		
P. cinereus	ABC	ABC	BC	ABC	AB				
P. alni	ABC	ABC	BC	BC	B				
P. igniarius	ABC	ABC							
P. populicola	ABC								
P. tuberculosus	AB								
P. lundellii	AB	A							
P. tremulae	AB								
P. laevigatus									

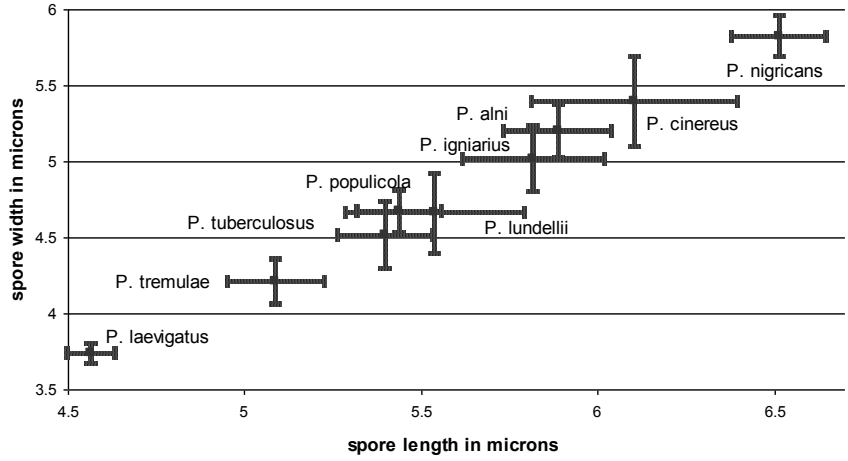

Fig. 1. The mean spore length, width and their standard deviations of *P. igniarius* complex.It is reliable to separate *P. tuberculosus* from *P. cinereus* and *P. nigricans* by its statistically smaller mean spore size, by smaller width and larger Q value from *P. alni* and from *P. laevigatus* by larger size (Table 1, Fig. 1).

The spores of *P. tremulae* are smaller than other species in the *P. igniarius* group, except *P. laevigatus* (Fig. 1). The mean spore size of *P. tremulae* differs statistically from *P. nigricans, P. cinereus, P. alni* and *P. igniarius* (Table 1).

The mean spore size of *P. lundellii* differs statistically from *P. tremulae* and *P. laevigatus* by its length; from *P. cinereus, P. alni* and *P. laevigatus* by its width; from *P. cinereus* and *P. alni* by its quotient and from *P. nigricans* by its size (Table 1).

In comparison with the measures of spores in *P. igniarius* group, it is revealed that the mean spore length and width of *P. laevigatus* differ statistically from the other species in the *P. igniarius* group in all cases, and by the proportions of its spore measurements in five cases out of nine (Table 1, Fig. 1). The spores of *P. laevigatus* are smaller and somewhat cylindrical.

CONCLUSIONS

There are some clear differences in the spore size of the species in the *P. igniarius* complex. The spores of *P. nigricans* are statistically larger than the other species in this group, except *P. cinereus.* The spores of *P. laevigatus* are statistically smaller than all other species in this group. Characters used in species delimitation in the *P. igniarius* group are numerous: morphology and anatomy of basidiocarps, host, habitat and culture characteristics. The spore size seems to be a good characteristic for distinguishing the separate species, but even if the differences are statistically significant, they do not enable us to identify the specimens in all cases.

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REFERENCES

Fischer, M. 1987. *Biosystematische Untersuchungen an den Porlingsgattungen Phellinus Quél.und Inonotus Karst.* J. Cramer, Berlin & Stuttgart, 133 pp.

Fischer, M. 1995. Phellinus igniarius and its closest relatives in Europe. *Mycol. Res.* **99**(6), 735–744.

Fischer, M. & Binder, M. 1995. Phellinus species on Betula. Mating tests, RFLP analysis ofenzymatically amplified rDNA, and relations to Phellinus alni. *Karstenia* **35**, 67–84.

Fries, E. M. 1821. *Systema Mycologicum.* E. Mayritius, Gryphiswaldiae, 520 pp.

Niemelä, T. 1972. On Fennoscandian Polypores.II. Phellinus laevigatus (Fr.) Bourd. & Galz.and P. lundellii Niemelä, n.sp. *Ann. Bot. Fennici* **9**, 41–59.

Niemelä, T. 1974. On Fennoscandian Polypores. III. Phellinus tremulae (Bond.) Bond. &Borisov. *Ann. Bot. Fennici* **11**, 202–215.

Niemelä, T. 1975. On Fennoscandian Polypores. IV. Phellinus igniarius, P. nigricans and P.populicola, n. sp. *Ann. Bot. Fennici* **12**, 93–122.

Niemelä, T. 1977. On Fennoscandian Polypores 5. Phellinus pomaceus. *Karstenia* **17**, 77–86.

Parmasto, E. 1976. Studies on Yakutian fungi. II. *Eesti NSV Teaduste Akadeemia toimetised.Bioloogia* **25**(4), 316–321.

Parmasto, E. & Parmasto, I. 1987. *Variation of basidiospores in the Hymenomycetes and itssignificance to their taxonomy.* J. Cramer, Berlin & Stuttgart, 168 pp.

Parmasto, E. 1988. What is Ochroporus ossatus (Hymenochaetaceae)? *Mycotaxon* **32**, 219–222.

Parmasto, E. 2004. *Distribution maps of Estonian fungi. 3. Pore fungi.* Institute of Zoology andBotany, Estonian Agricultural University, Tartu.

Purton, T. 1821. *An appendix to the Midland flora.* III. 1. T. Purton, London.

Raitviir, A. 1972. Statistical methods and species delimitation in the genus Otidea. *Persoonia* **6**(4), 415–423.

II

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Taxonomy of the species in the *Phellinus igniarius* group

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Abstract — Differences between the species of the *Phellinus igniarius* complex are characterized using morphological and molecular analysis. The study focuses on the possibly new taxa collected from ashes (*Fraxinus*), maples (*Acer*) and oaks (*Quercus*). It is shown that the species growing on ashes and maples belong to *Phellinus alni*. The situation regarding *Phellinus* found on oaks is unclear: that material belongs to *Phellinus alni* genetically but differs somewhat in its micromorphology.

Key words — wood-rotting polypores, *Hymenochaetaceae*, morphology, rDNA ITS

Introduction

Twelve species of *Phellinus igniarius* group are known in Europe, nine of which occur in Estonia (*Phellinus alni* (Bondartsev) Parmasto, *P. cinereus* (Niemelä) M. Fisch., *P. igniarius* (L.: Fr.) Quél., *P. laevigatus* (P. Karst.) Bourdot & Galzin, *P. lundellii* Niemelä, *P. nigricans* (Fr.: Fr.) P. Karst., *P. populicola* Niemelä, *P. tremulae* (Bondartsev) Bondartsev & P.N. Borisov, *P. tuberculosus* (Baumg.) Niemelä).

The *P. igniarius* group, one of the most important wood-rotting fungi of many deciduous trees, was described by Fries (1821) with two species: *Polyporus igniarius* (synonyms: *Boletus igniarius*, *Fomes igniarius*, *Phellinus igniarius*) growing on *Salix* and *Fraxinus* trees, and *Polyporus nigricans* (*Fomes nigricans*, *Boletus nigricans*) growing on *Betula*. Several forms of *Phellinus igniarius* (as *Fomes igniarius*) were distinguished by Bondartsev (1912); today these are recognized as independent species: forma *alni* is *Phellinus alni*, f. *betulae* is probably *Phellinus cinereus*, f. *tremulae* is *Phellinus tremulae*, f. *pruni* is *Phellinus tuberculosus* and f. *quercus* is *Fomitiporia robusta* (Larsson et al. 2007). For delimiting species in the *P. igniarius* group, morphological, as well as molecular characters have been used (Niemelä 1972, 1974, 1975, 1977, 2005, Parmasto 1976, 2007, Fischer 1987, 1995, Wagner & Fischer 2001, Sell 2006).

However, morphological differences are small and not dependable for species delimitation.

Most species of this group are highly host-specific, and it is possible that some more, new species may be found on different hosts. The aim of the present study is to give an overview about the taxonomy of the species in the *P. igniarius* group. Particularly, the paper attempts to clarify whether the collections from ashes (*Fraxinus*), maples (*Acer*) and oaks (*Quercus*) belong to known species or represent undescribed new taxa.

Materials and methods

The study is based on specimens and strains preserved at the mycological herbarium (TAA) and culture collection (TFC) of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences, Tartu, Estonia. Also one strain from the CBS fungal collections and 29 sequences from the European Molecular Biology Laboratory (EMBL) genebank were used (Table 1). In addition to the nine species mentioned above, specimens of *Phellinus igniarius* s.l. collected from ash, maple and oak, were also studied: they are tentatively named as 'P. fraxini', 'P. aceris' and 'P. quercus'.

Ten to twelve basidiocarps from each known and putative species were studied morphologically. Most of these were collected in Estonia. Thirty spores and 15 setae from each specimen were measured in 3% aqueous KOH using a Nikon Labophot-2 microscope. Parallel versus interwoven hyphal arrangement in the dissepiments was estimated for each specimen. The number of pores per millimetre was counted on each basidiocarp from ten different places with the help of a dissecting microscope, and the average was calculated. In the basidiocarps several morphological characters were studied: character of the upper surface (presence of crevices, colour, width of the zones and marginal zone), shape of the margin (acute, narrowly- or widely-roundish), thickness measured in the middle of the length (radius from the base to the edge), thickness of the context and the presence of the core. For phenetic analyses different distance measuring methods (Manhattan, Eucleides) and clustering methods (Complete, UPGMA) in the program NTSYSpc vers. 2 were used.

rDNA was isolated from cultures using High Pure PCR Template Preparation Kit. PCR reactions were made using puReTaqTM Ready-To-GoIM PCR Beads (Amersham Biosciences, Uppsala). PCR products were purified using ExoSAP solution and sequenced at the MWG-Biotech AG (Ebersberg, Germany). The primers used to amplify the ITS region were ITS1F and ITS4 (White et al. 1990). The sequences were edited and assembled using the Sequencher 4.7 (Gene Codes, Ann Arbour) and aligned automatically with the program MAFFT, followed by adjustment with the program GENEDOC 2.6.0.3. All DNA-sequences of strains from the collection TFC studied were sent to EMBL GenBank. Phylogenetic analyses were made using the program PAUP 4.0b10 (Swofford 2002). Bootstrapping was performed using 10 000 replicates. This was followed by additional swapping of the trees. Applying maximum parsimony algorithm, *Fomitiporia robusta*, *Fomitiporia punctata* and *Phellinus bicuspidatus* were used as an outgroup. Krall et al. (2007) botanical nomenclature was used as the source of the host names when characterizing the specialization of *P. igniarius* s.l. species.

Table 1. Specimens of *Phellinus* used in the analysis of molecular data with their voucher numbers in TFC collection and GenBank

Sample	Species	TFC number	GenBank number
'P. fraxini' 1	*Phellinus alni (Fraxinus)*	2005-16	AM 931245
'P. quercus' 1	*Phellinus alni* (*Quercus)*	2006-01	AM 931250
'P. fraxini' 2	*Phellinus alni (Fraxinus)*	2000-05	AM 931242
'P. aceris' 1	*Phellinus alni (Acer)*	2005-40	AM 931243
'P. aceris' 2	*Phellinus alni (Acer)*	2005-123	AM 931244
'P. fraxini' 3	*Phellinus alni (Fraxinus)*	2005-33	AM 931246
'P. aceris' 3	*Phellinus alni (Acer)*	2005-38	AM 931249
'P. quercus' 2	*Phellinus alni (Quercus)*	2006-02	AM 931251
P. alni 1	*Phellinus alni*		AY 340035
P. alni 2	*Phellinus alni*		AY 340036
P. alni 3	*Phellinus alni*		AY 340040
P. alni 4	*Phellinus alni*		AY 340041
P. alni 5	*Phellinus alni*		AY 340042
P. alni 6	*Phellinus alni*		AY 340037
P. alni 7	*Phellinus alni*		AY 340038
P. igniarius s.str. 1	*Phellinus igniarius* s.str.	2005-34	AM 931247
P. igniarius s.str. 2	*Phellinus igniarius* s.str.		AF 515574
P. igniarius s.str. 3	*Phellinus igniarius* s.str.		AY 340069
P. populicola 1	*Phellinus populicola*	81-48	AM 931252
P. populicola 2	*Phellinus populicola*		AY 558638
P. cinereus 1	*Phellinus cinereus*	2005-37	AM 931248
P. cinereus 2	*Phellinus cinereus*		AY 340043
P. cinereus 3	*Phellinus cinereus*		AY 340047
P. nigricans 1	*Phellinus nigricans*		AF 200239
P. nigricans 2	*Phellinus nigricans*		AY 558631
P. lundellii 1	*Phellinus lundellii*		AY 340058
P. lundellii 2	*Phellinus lundellii*		AY 340060
P. tremulae 1	*Phellinus tremulae*		AY 340064
P. tremulae 2	*Phellinus tremulae*		AY 340066
P. tuberculosus 1	*Phellinus tuberculosus*		AY 529699
P. tuberculosus 2	*Phellinus tuberculosus*		AY 529700
P. laevigatus 1	*Phellinus laevigatus*		AY 340054
P. laevigatus 2	*Phellinus laevigatus*		AY 340055
P. betulinus 1	*Phellinus betulinus* ssp. *orienticus*		AY 558626
P. laevigatus 3	*Phellinus laevigatus*		AY 340056
P. bicuspidatus 1	*Phellinus bicuspidatus*		AY 189699
P. bicuspidatus 2	*Phellinus bicuspidatus*		AY 558610
F. robusta 1	*Fomitiporia robusta*		AY 340007
F. robusta 2	*Fomitiporia robusta*		AY 340018
F. punctata 1	*Fomitiporia punctata*		AY 558640

Results

Morphological characters

On the basis of spore size three species and three groups can be recognized in the *P. igniarius* complex. Spores of *P. nigricans* and *P. cinereus* are characterized by the largest spores (mean length 6.55 and 6.46 µm, mean width 5.86 and 5.77 µm, respectively) in the group (Fig. 1). Likewise, 'P. quercus' can be distinguished from all other species according to this character (mean length 6.22 × width 5.46 µm). *P. alni* (5.94 × 5.11 µm), *P. igniarius* s.str. (5.85 × 5.07 µm), 'P. aceris' (5.81 × 5.04 µm) and 'P. fraxini' (5.81 × 5.02 µm) formed one group; *P. populicola* (5.58 × 4.76 µm), *P. tuberculosus* (5.55 × 4.52 µm) and *P. lundellii* (5.54 × 4.57 µm) another, both of which are characterized by overlapping spore sizes of the constituting species. The species having the smallest spores in the group, *P. tremulae* (4.99 × 4.08 µm) and *P. laevigatus* (4.58 × 3.75 µm) can both be distinguished according to their spore size.

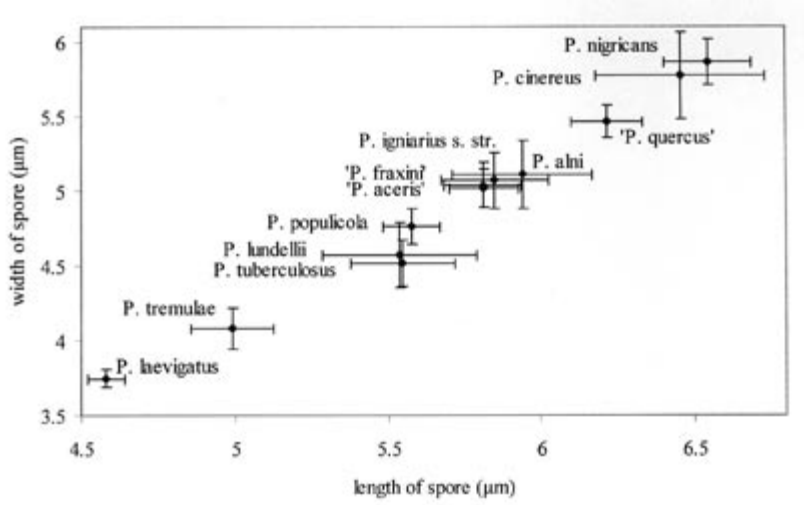

Fig. 1. Mean spore length, width and standard deviation among the species in the *Phellinus igniarius* group.

Setal size offers clear distinction of *P. tremulae* and *P. tuberculosus* by having larger setae than other species (mean length 18.22 and 16.97 µm, mean width 7.35 and 6.74 µm, respectively) (Fig. 2). In all other species the mean values of this feature were found to overlap. Hyphal arrangement in the dissepiments enables the species to divide into two groups. Three species, *P. tuberculosus*, *P. tremulae* and *P. laevigatus* have parallel arrangement of hyphae in the dissepiments, while in the other species the hyphae are interwoven.

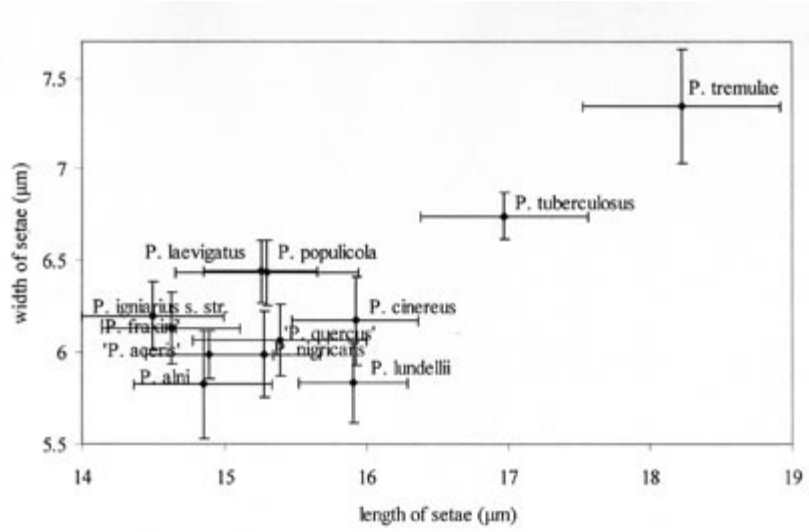

Fig. 2. Mean setal length, width and standard deviation among the species in the *Phellinus igniarius* complex.

Basidiocarps of *P. laevigatus* have more pores per millimetre (7.2 in average) than the other species (4.2–5.1) (Fig. 3). The number of pores per millimetre offers a good opportunity for distinguishing *P. laevigatus* from the other species.

Relative importance of rimose upper surface of the basidiocarps was highest in *P. nigricans*. Rimose upper surface characterizes also the basidiocarps of 'P. aceris', 'P. fraxini' and *P. populicola*. Crevices on the upper surface of the basidiocarps of *P. lundellii* and *P. tuberculosus* are usually absent.

Percentage of the basidiocarps with widely zoned (zones 0.7 cm or more on average) upper surface is highest in *P. populicola* and 'P. fraxini', half of the basidiocarps of 'P. quercus' and 'P. aceris' are also wide-zoned. In the other species, most of the basidiocarps are narrowly zoned (average width less than 0.7 cm). Basidiocarps of *P. nigricans* are mostly narrowly zoned, and all of *P. tremulae* are narrow-zoned.

Higher percentage of basidiocarps with mostly wide (0.7 cm or more) marginal zone was observed in 'P. aceris', 'P. quercus' and 'P. fraxini', but also in *P. tuberculosus* and *P. alni*. Most of the basidiocarps of *P. populicola* and *P. lundellii* have narrow (less than 0.7 cm) marginal zone. All basidiocarps of *P. nigricans* have a narrow marginal zone.

All basidiocarps of *P. nigricans* studied are characterized by black or dark grey upper surface. Few of the basidiocarps of *P. cinereus* and *P. tuberculosus*

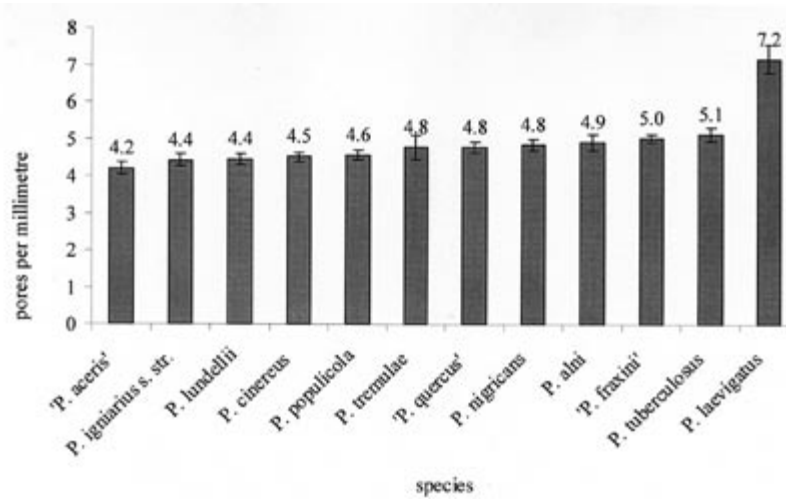

Fig. 3. Average number of pores per millimetre with standard deviation among the species in the *Phellinus igniarius* group.

are black or dark grey. The percentage of basidiocarps with grey upper surface is higher in *P. tuberculosus*. The percentage of basidiocarps with brownish grey upper surface is higher in *P. cinereus*, and also in 'P. quercus', 'P. fraxini' and 'P. aceris'. Half of the basidiocarps of *P. lundellii* have brown upper surface, this colour being present also in the basidiocarps of *P. cinereus* and 'P. quercus', and seldom in 'P. aceris', *P. tuberculosus*, *P. populicola* and *P. igniarius* s.str.

Most of the basidiocarps of *P. nigricans*, *P. lundellii* and *P. tremulae* have acute margins, some have roundish margins, and there are no basidiocarps with widely-rounded margins in these species. In the rest of the species, there are basidiocarps with acute as well as roundish or widely-roundish margins. The percentage of basidiocarps with roundish margins is higher in *P. populicola* and *P. alni*. Widely roundish margins are usual in basidiocarps of *P. alni* and 'P. aceris'.

'P. aceris' has the thickest context compared with the thickness of the basidiocarp; also *P. alni* and 'P. fraxini' have also comparatively thick context. *P. nigricans* and *P. tremulae* have thin context with a relative thickness of one-half or less compared to the other species.

All basidiocarps of *P. alni* and 'P. aceris' and most basidiocarps of *P. populicola*, 'P. quercus' and 'P. fraxini' have a core in the base of the basidiome. The core is rare in *P. cinereus* and *P. igniarius* s.str. and absent in all basidiocarps of *P. nigricans*, *P. tuberculosus*, *P. lundellii*, *P. populicola* and *P. laevigatus*.

In the phenetic analysis of all morphological characters using the program NTSYSpc, Manhattan distance measuring and complete clustering, no one-species clusters were observed except that of *P. laevigatus*. Four specimens of *P. quercus* form a cluster distinct from all other specimens studied, but four other specimens of the same taxon are scattered in the dendrogram in the clusters together with *P. alni* and *P. cinereus*. In the *P. nigricans* cluster some *P. igniarius* s.str. specimens are included, and in the *P. tremulae* cluster several *P. tuberculosus* specimens. 'P. aceris' and 'P. fraxini' are intermixed with several other species in many clusters of the dendrogram. The other measuring and clustering methods (Eucleides, UPGMA) did not give more clear results.

Molecular characters

Ingroup constituted DNA-sequences of 35 strains of the *P. igniarius* s.l. specimens. Ribosomal DNA ITS region data matrix contained 733 characters of which 248 were parsimony-informative. Phylogenetic analysis resulted in 4 083 800 most parsimonious trees of 447 steps. In the strict consensus tree, nine monophyletic groups distinguished, 10 of which represent *P. igniarius* group species (Fig. 4). All the species of the *P. igniarius* complex form one clade, which has a very strong support (100 % in bootstrap analysis).

The *P. alni* clade is part of a larger well supported clade (92 %) that also includes the clades of *P. igniarius* s.str.–*P. populicola*, *P. cinereus*–*P. nigricans*, and *P. lundellii*. All the *P. igniarius* s.l. specimens studied molecularly growing on *Acer*, *Fraxinus* and *Quercus* form one clade with seven *P. alni* (on *Alnus* or *Betula*) strains obtained from EMBL genebank. However, this moderately supported clade (79 % in bootstrap analysis) remains mostly unresolved. The only subclade, comprising a specimen growing on *Fraxinus* and another on *Quercus*, is weakly supported in bootstrap analysis (62 %).

The clade uniting *P. igniarius* s.str. and *P. populicola* is strongly supported (99 %). While support for *P. igniarius* s.str. subclade is weak (63 %), the subclade of *P. populicola* received strong support (100 %). *P. nigricans* and *P. cinereus* together form a well supported (92 %) clade, while strains of *P. nigricans* form moderately and strains of *P. cinereus* weakly supported subclade (86 % and 71 % respectively). The clade of *P. lundellii* has also strong support (100 %). The other species of the *P. igniarius* complex form clades which correspond to the species *P. tremulae*, *P. tuberculosus*, and *P. laevigatus*.

Discussion

The results of the present study show that spore measurements of *P. igniarius* s.l. growing on *Quercus*, *P. tremulae* and *P. laevigatus* differ from the other species in the *P. igniarius* complex. The rest of the species form three groups. Spore size seems to be a good character for distinguishing separate species, but even if

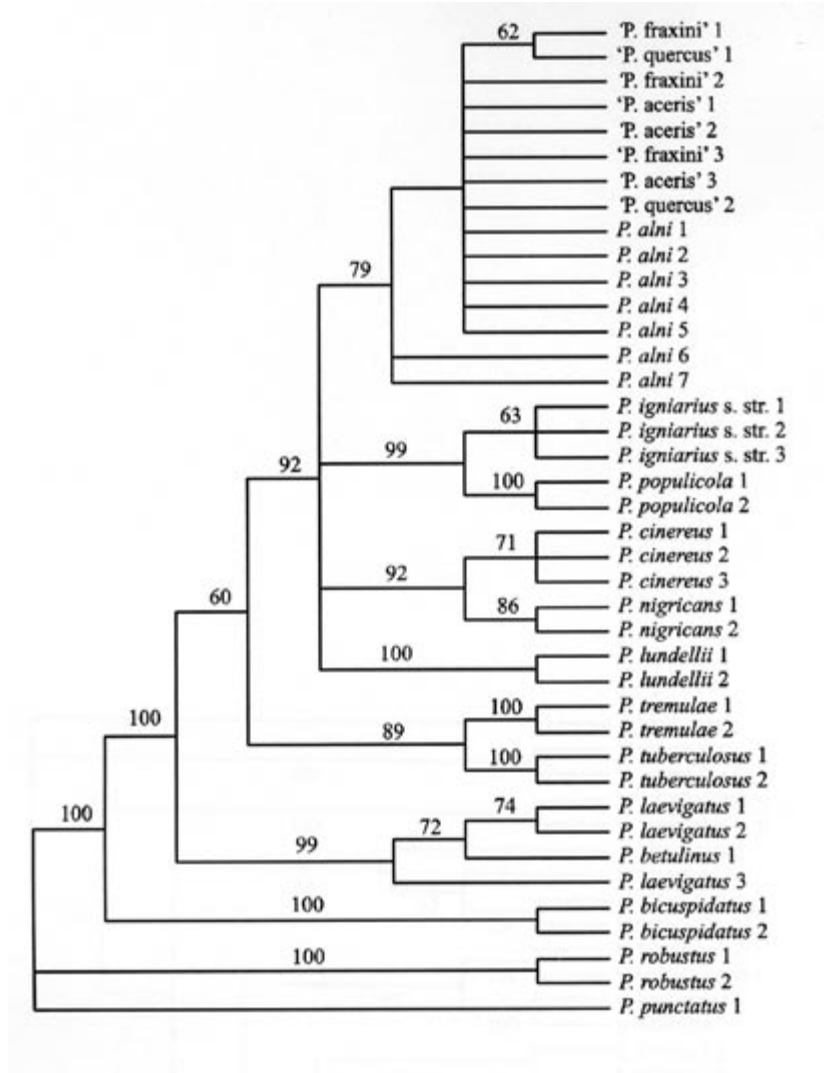

Fig. 4. Strict consensus tree of *Phellinus* species, calculated from 4 083 800 most parsimonious trees, found in the maximum parsimony analysis. Tree length 447 steps, consistency index 0.81. Numbers on the branches show the bootstrap support. Data of the specimens studied are indicated in Table 1.

the differences are statistically significant, they do not enable us to identify the specimens in all cases as proposed by Sell (2006). Setae are useful at specific level throughout the family of *Hymenochaetaceae* (Niemelä 1972). Measurements of hymenial setae distinguished both *P. tremulae* and *P. tuberculosus* from the

rest of the species in which size of setae was found to be largely overlapping. According to the density of pores per millimetre on the hymenophore, *P. laevigatus* differs from all the other species in the *P. igniarius* group exhibiting largest number of pores per millimetre. While the core is found in most of the examined specimens of *P. alni*, it is absent in all studied basidiocarps of *P. nigricans*, *P. tuberculosus*, *P. lundellii*, *P. tremulae* and *P. laevigatus*.

Both morphological and molecular characters are important for species delimitation (Lee 2004). Although studies of morphological characters need less time and are simpler, these characters are variable. *P. nigricans* usually differs from the other species in its basidiocarp characters: upper surface is rimose, black or dark-grey coloured with narrow marginal and other zones. On the other hand, it is difficult or almost impossible to distinguish *P. cinereus* and *P. nigricans* using morphological characters. Molecular data offers clear separation as demonstrated also by Wagner & Fischer (2001).

Most of the phenetic clustering methods applied to the studied morphological characters did not separate the putative species, except the taxa growing on *Quercus* spp. Phenetic clustering methods (Manhattan, Eucleides) are almost useless in the study of morphological characters, and only statistical spore measurement data gave some useful information for distinguishing species.

The analysis of molecular characters indicated that the specimens of *P. igniarius* s.l. growing on *Acer*, *Fraxinus* and *Quercus* neither belong to *P. cinereus* nor represent new species as supposed in some previous studies (Parmasto 1993, 2004). The results of the present study with the use of molecular characters showed that the specimens growing on *Acer*, *Fraxinus* and *Quercus* are very closely related to *P. alni* (growing on *Alnus* spp.). However, the clade received only moderate support (79 %) to be unambiguously considered as containing just one species.

Taxonomic status of the specimens found on *Quercus* is unclear. According to the molecular data, these belong to *P. alni*, but morphological data (spore size and basidiocarp characters) are remarkably different. In the present research ITS rDNA region was studied, the region most widely used as a species-level molecular marker in fungi. Fischer & Binder (1995) used the mating tests for studying *Phellinus* species on *Betula*. Using the mating tests may be laborious; however, it may help to clear up the taxonomic position of the specimens growing on *Quercus*. Isoenzymatic analyses can also be of help to solve some taxonomical problems in the above-mentioned complex.

In general, the species in the *P. igniarius* group are narrowly specialized according to hosts: *P. nigricans*, *P. cinereus*, *P. lundellii* and *P. laevigatus* are mostly species of *Betula*; *P. igniarius* s.str. grows on the members of the genus *Salix*; *P. populicola* and *P. tremulae* on *Populus*; *P. tuberculosus* on drupes (*Prunus insititia, Prunus domestica, Cerasus vulgaris*). *P. alni* differs from the

others by its wide host range: it grows on *Alnus*, *Betula, Corylus*, *Malus*, *Padus avium*, *Sorbus*, and as a result of the present study, also on *Acer* and *Fraxinus*. Probably, *P. igniarius* s.l. growing on *Fagus* and *Carpinus* in Central and East Europe also belongs to *P. alni*.

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Literature cited

Bondartsev AS. 1912. Griby sobrannye na stvolakh lesnykh porod v Bryanskom opytnom lesnichestve. Trudy Lesn. Opytn. Delu Rossii 37: 1–56

Fischer M. 1987. Biosystematische Untersuchungen an den Porlingsgattungen *Phellinus* Quél. und *Inonotus* Karst. Biblioth. Mycol. 107: 1–33

Fischer M. 1995. *Phellinus igniarius* and its closest relatives in Europe. Mycol. Res. 99: 735–744

Fischer M, Binder M. 1995. *Phellinus* species on *Betula*. Mating tests, RFLP analyses of enzymatically amplified rDNA, and relations to *Phellinus alni*. Karstenia 35: 67–84

Fries EM. 1821. Systema mycologicum. E. Mayritius, Gryphiswaldiae. 520 p.

Krall H, Kukk T, Kull T, Kuusk V, Leht M, Oja T, Reier Ü, Sepp S, Zingel H, Tuulik T. 2007. Identification guide of Estonian Plants. Institute of Agricultural and Environmental Sciences, Estonian University of Life Sciences, Tartu. 447 p. (in Estonian).

Larsson KH, Parmasto E, Fischer M, Langer E, Nakasone K, Redhead S. 2007. *Hymenochaetales*: a molecular phylogeny for the hymenochaetoid clade. Mycologia 98: 926–936

Lee M. 2004. Molecular and morphological datasets have similar numbers of relevant phylogenetic characters. Taxon 53: 1019–1022

Niemelä T. 1972. On Fennoscandian polypores. II. *Phellinus laevigatus* (Fr.) Bourd. & Galz. and *P. lundellii* Niemelä, n. sp. Ann. Bot. Fennici 9: 41–59

Niemelä T. 1974. On Fennoscandian polypores. III. *Phellinus tremulae* (Bond.) Bond. & Borisov. Ann. Bot. Fennici 11: 202–215

Niemelä T. 1975. On Fennoscandian polypores. IV. *Phellinus igniarius*, *P. nigricans* and *P. populicola*, n. sp. Ann. Bot. Fennici 12: 93–122

Niemelä T. 1977. On Fennoscandian polypores 5. *Phellinus pomaceus*. Karstenia 17: 77–86

Niemelä T. 2005. Polypores, lignicolous fungi. Norrlinia 13: 1–320 (in Finnish, with English summary).

Parmasto E. 1976. Studies of Yakutian fungi. II. Proc. Estonian Acad. Sci. Biol. 25: 316–321

Parmasto E. 1993. Distribution maps of Estonian fungi. I. *Hymenochaetaceae*. Institute of Zoology and Botany of the Estonian Academy of Sciences, Tartu.

Parmasto E. 2004. Distribution maps of Estonian fungi. III. Pore fungi. Institute of Zoology and Botany of the Estonian Agricultural University, Tartu.

Parmasto E. 2007. *Phellinus laevigatus* s.l. (*Hymenochaetales*): a ring species. Folia Cryptog. Estonica 43: 39–49

Sell I. 2006. Size and shape of basidiospores in the *Phellinus igniarius* group. Agronomy Research 4: 359–362

Swofford DL. 2002. PAUP*. Phylogenetic analyses using parsimony (* and other methods), 4b10. Sinauer Associates, Sunderland.

Wagner T, Fischer M. 2001. Natural groups and a revised system for the European poroid *Hymenochaetales* (*Basidiomycota*) supported by nLSU rDNA sequence data. Mycol. Res. 105: 773–782

White TJ, Bruns T, Lee S, Taylor J. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand DH, Sninsky JJ, White TJ (eds), PCR protocols: A guide to Methods and Applications, Academic Press, San Diego, pp. 315–322.

III

Molecular analysis confirms that *Botryodontia millavensis* and *Oxyporus philadelphi* are conspecific

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Abstract. The aim of the present study is to elucidate if *Oxyporus philadelphi* (Parmasto) Ryvarden and *Botryodontia millavensis* (Bourdot & Galzin) Duhem & H. Michel are conspecific as suggested by their similar morphology.

O. philadelphi and *B. millavensis* do not represent two different species. The analysis of molecular characters shows that the specimens of *O. philadelphi* and *B. millavensis* represent the same species. The species is closely related to the type species (*B. cirrata*) of the genus Botryodontia, and therefore the name Botryodontia millavensis should currently be used for this taxon. Despite the fact that Juniperus communis and Philadelphus coronarius are phylogenetically distant, only *O. philadelphi* grows on different hosts in Estonia. According to the analysis of molecular characters, the specimens growing on *J. communis*, *P. coronarius, Picea abies, Fraxinus excelsior, Lonicera* sp. and *J. turcomanica* belong to the same species.

Key words: *Botryodontia*, polypore, rDNA ITS, wood-rotting fungi

Introduction

A resupinate white-rot polypore with thin, white or slightly yellowish basidiocarps and large pores, found growing on junipers and pines, was described as *Poria mucida* subsp. *millavensis* by Bourdot & Galzin (1925). Overholts (1939) raised this subspecies to the species rank – *Poria millavensis* (Bourdot & Galzin) Overholts. Almost fifteen years later, the species was placed in a different genus and renamed *Xylodon millavensis* (Bourdot & Galzin) Bondartsev (Bondartsev 1953). The latter author described its occurrence on *Pinus* and *Juniperus* in France, Germany and the USA. Michel et al. (2006) found it growing on *Juniperus communis*, *Pinus sylvestris*, *Lavandula* sp. and *Rosa* sp. in France and transferred the species to *Botryodontia* (Basidiomycota, Phanerochaetaceae) *as B. millavensis* (Bourdot & Galzin) Duhem & H. Michel.

In 1951, Erast Parmasto found a similar resupinate polypore from Puhtulaid Islet in Western Estonia. This fungus, with white basidiocarps and low pores, was

discovered on the bark of an old *Philadelphus coronarius* bush. In the following years, he found the species growing on *P. coronarius*, *J. communis* and *Picea abies* in the above-mentioned locality as well as in the Matsalu Nature Reserve in West Estonia. Within a period of eight years after the first record of the species, E. Parmasto had no success in identifying these collections. Finally, his discovery was described as a new species, *Chaetoporus philadelphi* (Parmasto 1959). The species was transferred to the genus *Oxyporus* (Meripilaceae, Basidiomycota) by Ryvarden (1972), and since then *O. philadelphi* (Parmasto) Ryvarden has been widely used. Lately Parmasto (2009) mentioned that the species could also belong to *Hyphodontia.*

In Estonia, *O. philadelphi* mainly grows on *J. communis* and *P. coronarius*, also on *Picea abies*, *Fraxinus excelsior* and *Lonicera* sp. It has been collected also on *Taxus baccata* (specimen in TAAM) and *P. abies* in Slovakia, on *Populus* sp. and *Betula* sp. in the Czech Republic (Vampola 1991). It is rare in semi-deserts and mountain-steppes in Turkmenistan, growing on *Juniperus turcomanica* and *Hymenocrater bungei* (Parmasto 1984, 2009). Moreover, it has been found on *Philadelphus tenuifolius* in Primorsky Krai in Russian Far East (Parmasto 1984, 2009).

Donk (1966, 1967) states that the two species – *Poria millavensis* and *Chaetoporus philadelphi* may be close to each other. The morphological similarity of *B. millavensis* and *O. philadephi* was shown 40 years later by Michel et al. (2006). In order to verify these assumptions, molecular analyses of specimens identified as belonging to these two species are needed. The main hosts of *O. philadelphi* in Estonia, *J. communis* and *P. coronarius*, are not closely related, differing also in their ecology. This fact led us to suspect that more than one species grows on these as well as the other diverse hosts.

The aim of the present study is to elucidate if *O. philadelphi* (Parmasto) Ryvarden and *B. millavensis* (Bourdot & Galzin) Duhem & H. Michel are conspecific as suggested by their similar morphology, and clarify the taxonomic status of the species. The paper attempts to ascertain if *O. philadelphi* involves more than one species growing on different hosts in Estonia. For this purpose ITS rDNA sequences and morphological data from numerous specimens of selected species of *Botryodontia* and *Oxyporus* was obtained and analysed.

Material and methods

The study is based on material received from the fungal collection of the Institute of Agricultural and Environmental Sciences of the Estonian University of Life Sciences (TAAM), Botanical Museum of Oslo University, Norway (O), Botanical Museum of the University of Helsinki (H), Natural History Museum of Paris, France (PC) and reference collection of Heikki Kotiranta (HK). Thirty spores per specimen were measured, and all measurements were made in Cotton

Blue (CB). The other mounting media used were Melzer´s reagent (IKI) and 5% potassium hydroxide (KOH). To characterize the specimen, mean spore length and width (calculated from 30 measured spores) were used (Parmasto & Parmasto 1987).

DNA was extracted from dried basidiocarps of *O. philadelphi* and closely related species by using High Pure PCR Template Preparation Kit (Roche Applied Science, Mannheim, Germany). The nuclear ribosomal DNA ITS regions were amplified by using puReTaq™ Ready-To-Go™ PCR Beads (Amersham Biosciences, Uppsala) and the primers ITS1 and ITS4 (White *et al.* 1990). Amplified fragments were purified using ExoSAP solution and sequenced at Macrogen Inc. (Seoul, Korea). The sequences were edited and assembled using Sequencher 4.7 (Gene Codes, Ann Arbour) and aligned automatically with the program MAFFT, followed by manual adjustment in the program GENEDOC 2.6.0.3. All new sequences were deposited at the European Molecular Biology Laboratory (EMBL) under the accession numbers given in Table 1. DNA extractions, PCR (polymerase chain reaction) and purification of the products were performed at the joint laboratory of molecular analyses of the Centre of Excellence of Frontiers in Biodiversity Research (FIBIR) and the Chair of Mycology of the Department of Botany, Institute of Ecology and Earth Sciences, University of Tartu.

Phylogenetic analyses were run using the program MEGA 5.05 (Tamura et al. 2011). Maximum likelihood tree were conducted with 1000 replicates, using General Time Reversible (GTR) model.

Results

Phylogeny

Our dataset of rDNA ITS sequences contains 16 sequences of *Oxyporus philadelphi* and *Botryodontia millavensis* from Estonia, France, Norway and Turkmenistan. All sequences of *O. philadelphi*, *B. millavensis*, *B. cirrata* and unnamed fungi from the GeneBank form a strongly supported clade (Fig. 2). In this clade, a well-supported subclade consists of 16 specimens of *O. philadelphi*, collected from different substrates, and of two specimens of *B. millavensis*. Their ITS sequences are almost identical, supporting the conspecificity of the specimens deposited under these two names. Our analysis also confirms the close relationship between *B. millavensis* and *B. cirrata* s.l., the type species of *Botryodontia*. Closest relatives of *B. millavensis* and *B. cirrata* are found within the *Oxyporus* clade of the Hymenochaetales, where *O. corticola* is their closest kin.

The two *B. cirrata* specimens, from Madagascar and Brunei, appear to represent separate species (ITS similarity 93%). Additional somewhat deviating

sequences from the International Nucleotide Sequence Database indicate that several unnamed species are presented in this clade.

Morphology

Botryodontia and similar species in other genera

There are no clear explanation why *B. cirrata* and *B. millavensis* have been placed in several genera by different authors (Parmasto 1959, Hjortstam & Ryvarden 1986, Hjortstam 1987, Wu 1990). The genus *Botryodontia* shares characteristics, at least, of the genera *Candelabrochaete*, *Kneiffiella* (species without clamps) and *Oxyporus*. The species have simple septa and often possess some kind of cystidia. *Botryodontia* has small, oblong basidia that collapse quickly after the sporulation.

Candelabrochaete Boidin is characterized above all by pseudocystidia (e.g. Dueñas et al. 2008), which are formed of barrel-shaped, thin- to thick-walled cells, wide, often double-walled hyphae and relatively small, subcylindrical, constricted basidia, often with linear repetition. The pseudocystidia are somewhat similar to the hyphae in aculeal apices of, but wider and not encrusted. The basidia are different, in being subcylindrical rather than oblong.

The basidia in clampless species of *Kneiffiella*, *K. efibulata* (J. Erikss. & Hjortstam) Jülich & Stalpers, *K. subglobosa* (S.H. Wu) Hjortstam and *K. tetraspora* (S.S. Rattan) Hjortstam & Ryvarden are more or less subcylindrical, constricted and the cystidia are tubular, thick-walled. The branching in *Botryodontia* and *Kneiffiella* is very similar: hyphae are narrowing just at the branching point, giving the hyphae a very characteristic appearance. This is seen also in *Hyphodontia* s. l.

Oxyporus corticola has the same kind of branching system as *B. cirrata* and *B. millavensis*. Also its basidia are very similar, short and oblong, with very short sterigmata and quickly collapse after the sporulation. Also the gloeocystidia are similar, but the small, apically encrusted cystidia and larger spores make it easy to distinguish from *B. millavensis*.

Botryodontia cirrata (Hjortstam & Ryvarden) Hjortstam, Mycotaxon 28:20, 1987. Fig. 3.

Basionym: *Candelabrochaete cirrata* Hjortstam & Ryvarden, Mycotaxon 25:545, 1986.

Synonyms: *Botryodontia denticulata* Hjortstam, Mycotaxon 28:20, 1987, *Hyphodontia formosana* S.H. Wu & Burds., Acta Bot. Fenn. 142:91, 1990.

The following description is based on the holotype, since other material we studied deviates somewhat from the type.

Fruitbody resupinate, relatively thin or very thin, soft, in young parts porose-reticulate, in old parts often with small, delicate, apically penicillate aculei, margin not differentiated, thinning out. A good macroscopic description is given by Hjortstam and Ryvarden (1986, 2002).

Hyphal system monomitic, hyphae simple septate, CB–, IKI–, KOH–. Subiculum almost lacking, but in type specimen a few hyphal strands, consisting of relatively thick-walled hyphae, 6–9 µm in diam. Tramal hyphae sub parallel, thin- to slightly thick-walled, (2.5–)3–4 µm wide, in apical apices, cells 10–15 µm long, thin-walled, 2.5–3 µm wide. Subhymenial hyphae thin-walled, 2.5–3 µm wide. Gloeocystidia few (only one seen in the type), cylindrical, thin-walled, 38 × 7 µm. Basidia short, oblong, very seldom basally prolonged, sometimes covered with resinous matter, fading soon after sporulation, 11–14 × (5–)5.5–6.5 µm, with four short, up to 2 µm long sterigmata. Spores ellipsoid to broadly ellipsoid, 5.6–7(–8) × 4–5.2(–5.5) µm, L=6.4 µm, W=4.6 µm, Q=1.3–1.6, Q*=1.4, thin-walled, CB(+), IKI–.

We studied also some other specimens (*Spooner* B113 from Brunei, *Wu* 880819-24, 880819-27 from Taiwan) mentioned by Hjortstam and Ryvarden (2002) and one from Madagascar (*Duhem*, PC 0084172).

All these specimens are macroscopically very much alike: basidiocarps are thin, pale cream coloured, strongly porose-reticulate, mostly with small, delicate, apically penicillate aculei; margin not differentiated, thinning out.

These specimens have similar hyphal system as the isotype of *B. cirrata*, but the specimens from Taiwan, have very numerous gloeocystidia, (24–)30–46 × (6–)8–11 µm, unlike the type or the specimens from Brunei or Madagascar.

Wu (1990) described *Hyphodontia formosana* S.H. Wu & Burds. and Hjortstam (1997) considered it to be conspecific with *B. cirrata* and made the combination *Botryodontia formosana* (Sheng H. Wu & Burds.) Hjortstam. He was also in the opinion that *B. denticulata* Hjortstam is very similar to *B. formosana*, and later he (in Hjortstam & Ryvarden 2002) synonymized these names. The two specimens of *H. formosana* which we studied have similar encrusted hyphal tips as *B. denticulata* (Hjortstam 1987:21) in the drawing. We did not study *B. denticulata*.

The material we studied gives the impression that *B. cirrata* is morphologically relatively uniform: the size of the spores varies somewhat as well as the number of gloeocystidia. The basidiocarps are more or less similar like the hyphal structure and basidia in all specimens seen by us. Sequence comparison,

however, gives an impression, that there is more than one taxon involved. It must be kept in mind, that we could not sequence the types of *B. cirrata, B. denticulata* or *H. formosana*.

Specimens examined: Argentina. Missiones, Iguazu Nat. Park, Cataratas de Iguatsu, on deciduous leaves, 1–5.3.1983, *Ryvarden 19572* (O, holotype of *Candelabrochaete cirrata*). Brunei. Temburon Distr., Sungai Belalong, near Field Centre, on fallen leaves, 13.3.1992 *Spooner B113* (K(M)28077). Madagaskar. Near Andasibe, on *Lantana camara,* 22.2.2000, *Duhem* (PC 0084172). Taiwan. Hsinchu. Chienchic Hsiang, Neiwan, on twig of angiosperm, 19.8.1988 *Wu 88019-24* (H), and same place, date and substrate, *Wu 88019-27* (H, isotype of *Hyphodontia formosana*).

Botryodontia millavensis (Bourdot & Galzin) Duhem & Michel, Figs. 4, 5

Basionym: *Poria mucida* ssp. *millavensis* Bourdot & Galzin, Bull. Soc. Mycol. Fr. 40: 238, 1925.

Synonym: *Chaetoporus philadelphi* Parm., Not. System. Sect. Crypt. Inst. Bot. Acad. Sci. URSS 12: 237, 1959.

Fruitbody resupinate, relatively thin, soft, with shallow, often incomplete, irpicoid or labyrinth form to angular pores, 1–2(–3)/mm, dissepiments dentate, when fresh white, later cream coloured to pale buff. Subiculum thin, white, porose reticulate on pore bottoms, margin white, not differentiated, thinning out.

Hyphal system monomitic, hyphae simple septate, faintly CB+, IKI– (in lectotype golden brownish), KOH–. Subicular hyphae with slightly thickened walls, running in all directions, tangled looking, 2–3.5(–4) µm in diam., branching at right angles, narrowing at the branching point. Hyphae in dissepiment edge thin-walled, apically roundish, 3–5 µm wide. Subhymenial hyphae thin-walled, 3–5 µm in diam., sometimes almost conical cells, 10 × 6 µm, give rise to two or three basidia. Often large crystals in subhymenium. Cystidioles basally simple septate, sometimes numerous, sometimes very few, thin-walled, conical or bottle-shaped, narrowing to the roundish apex, often covered with resinous matter (appearing rough) (17–)20–35 × (4–)5.5–7(–8) µm, projecting up to 15 µm above the basidia. Gloeocystidia basally simple septate, always´ present, clavate or sinuous, thin-walled, contents pale yellowish in Melzer´s reagent and KOH, blue in CB, (15–)20–35(–40) × (6–)8–10 µm, sometimes projecting slightly over the basidia. Basidia oblong, thin-walled, basally simple septate, 10–15(–18) × 5–7 µm, with four, needle-like, up to 3 µm long sterigmata. Spores broadly ellipsoid to subglobose, ab. 5 × 4 µm (Table 2), thin-walled, CB– (or very faintly CB+), KOH–, IKI–.

Specimens examined: Estonia. Hiiu County, Käina comm., Kassari Landscape Res., Kassari, *Juniperus*-alvar, corticated *Juniperus communis*, decay 2, diam. 1 cm, 27.9.2007, *Kotiranta 21986 & Sell* (HK). Lääne County, Hanila Distr., Puhtu Peninsula near Virtsu, *Philadelphus coronarius*, on dead twig, 7.10.1951, *E. Parmasto* (TAAM 000014, isotype of *Chaetoporus philadelphi*); the same place, on bark of *Philadelphus coronarius*, 18.10.2009, *Sell* (TAAM 196898); Virtsu, corticated dead *J. communis*, 15.10.2004 Kotiranta 21219 (HK); Lihula comm., Matsalu Nat. Park, Viita, *P. abies*, on fallen twig in wooded meadow, 5.9.2006, *Sell* (TAAM 191462); Vormsi comm., Vormsi island, Borrby, corticated *J. communis* branch, decay 3, diam. 1 cm, 11.8.2008, *Sell & Kotiranta* (TAAM 196555). France. Aveyron, *J. communis*, 27.10.2004 *Trichies* (PC 0084171), Causse Noir, Aveyron, *J. communis*, 2.5.1914, *Bourdot 29508* (PC 0084686, lectotype of *Poria millavensis*). Norway. Finnmark, Tunes/Sandfjorden, coniferous driftwood (*Picea*), 21.8.2002, *Ryvarden 44981* (O).

Oxyporus corticola (Fr.) Ryvarden, Persoonia 7: 19, 1972, Fig. 6

Basionym: *Polyporus corticola* Fr., Syst. Mycol. 1: 385, 1821.

Basidiocarp resupinate, relatively thick (up to 3 mm), very seldom with small, narrow pilei, which are covered with rough, agglutinated hairs, pale creamish or pale ochre – pale brownish, tough but not especially hard, pores angular to almost roundish, (1–)2–4(–5) per mm, dissepiments lacerate or fimbriate, pore surface rough when dry, margin whitish or pale cream coloured, abrupt, often fimbriate.

Hyphal system monomitic, hyphae simple septate, faintly CB+, in subiculum thick- to relatively thick-walled (walls up to 2 µm), (2–)3–5.5(–6) µm, running in all directions, branches at right angles and narrowing just at the branching point. Hyphae in wood cracks much wider, 10–15 µm in diam. Tramal hyphae fairly thin-walled, sub parallel, partly intertwined in upper trama, 2–3.5(–4) µm, in dissepiments edge thin-walled, 2.5–3 µm in diam., sometimes covered with crystalline caps. Subhymenium consists of a few hyphal layers only, hyphae thin-walled, 2–3 µm wide. Small, oblong, normally thin-walled, apically encrusted cystidia abundant, (11–)13–18(–20) × (5–)5.5–7(–7.5) µm, gloeocystidia thin-walled, cylindrical or tubular, (20–)23–40(–45) × (5.5–)7–10.5 µm, contents faintly CB+, sometimes slightly projecting over the basidia, especially close to the pore bottoms. Basidia oblong, seldom somewhat stalked, quickly fading after the sporulation, (10–)12–16 × 6–7 µm, with four needle-like, up to 3 µm long sterigmata. Spores often glued in tetrads, oblong ellipsoid, widest close to the base, ab. 5.5–6.6 × 3.6–4.3 µm (see Table 2), with a very small apiculus, thin-walled, very faintly CB+, inamyloid, indextrinoid.

Specimens examined: Finland. Etelä-Häme: Padasjoki, Vesijako Strict Nat. Reserve, *Picea abies* dominated old-growth forest, very large, decorticated

Populus tremula, 21.9.1980, *Kotiranta 2616 & Koski* (HK); same place, large decorticated *Populus tremula*, 9.8.1981, *Kotiranta 2884* (HK); Ruovesi, Keinumäki E, Musturi Nat. Reserve, *Picea abies* dominated old-growth forest, corticated *Populus tremula*, 14.6.1989, *Kotiranta 7404 & Mannerkoski* (HK). Pohjois-Häme: Saarijärvi, Pyhä-Häkki Nat. Park, *Picea abies* dominated old-growth forest, corticated *Populus tremula*, 5.8.1980, *Kotiranta 2065* (HK). Kuusamo: Posio, Korouoma Nat. Res., *Populus tremula*, fallen thick branch in moist brookside forest, 31.8.2001 Niemelä 7068 & Kinnunen (H). Perä-Pohjanmaa: Rovaniemi comm., Tervola, Pisavaara Strict Nat. Res., *Picea abies* dominated old-growth forest, corticated *Picea abies*, together with *Fomitopsis pinicola*, *Leptoporus mollis* and *Trichaptum laricinum*, 30.7.1979, *Kotiranta 1306 & Niemelä* (HK). Inarin Lappi: Inari, Nellim S, Haapakuru, luxuriant mixed forest with *Populus tremula, Alnus incana* and *Betula* spp., large strongly decayed *Populus tremula* branch on the ground, 26.8.1990, *Kotiranta 8500* (HK).

Discussion

Based on the phylogenetic analysis, specimens of *O. philadelphi* from Estonia and Turkmenistan, and specimens of *B. millavensis* from France and Norway are conspecific. Our results reveal that these represent one widely, although sporadically distributed species in western Eurasia. As *B. millavensis* had beed described earlier, the epithet '*millavensis*' should be preserved. Blast searches revealing sequence similarity values and our molecular analysis showed that the species does not belong to the genus *Hyphodontia* as suggested by Parmasto (2009), but to the *Oxyporus* clade defined by Larsson et al. (2006). The species is closely related to the type species of the genus *Botryodontia (B. cirrata)*, and therefore the name *Botryodontia millavensis* should be used for this taxon for now.

Oxyporus corticola is also closely related to *B. cirrata* and *B. millavensis,* and it might belong to the genus *Botryodontia* as well. Before a thorough investigation of the *Botryodontia/Oxyporus/Rigidoporus*-complex has been carried out, we consider it wise not to make any new combinations.

Before the present study, we have considered a possibility that there can be more than one species occurring on different hosts in Estonia. Particularly, *J. communis* and *P. coronarius* are phylogenetically distant. The results of the analysis of morphological characters did not detect a significant difference between the specimens of *O. philadelphi* collected from various hosts. Also the analysis of molecular characters has indicated that the specimens collected from *Juniperus communis*, *J. turcomanica*, *Philadelphus coronarius*, *Picea abies*, *Fraxinus excelsior* and *Lonicera* sp. belong to the same species.

Botryodontia millavensis is evidently a rare species in North Europe. Parmasto (1984, 2009) has suggested that it is a relict species. However, one of the

reasons of such kind of distribution (Estonia, France, Norway, Turkmenistan and Russia) can be poor sampling: we have found many new localities from western Estonia, *e.g.* in Hiiumaa (Dagö) and Vormsi (Ormsö) Islands, during the fieldworks in recent years and it is possible that the species occurs also in South Finland and Sweden. *Botryodontia millavensis* appears to be a coastal species in North Europe: all localities in Estonia are situated less than 5 kilometers from the seashore (Parmasto 2009). *Peniophora junipericola* has a similar distribution pattern (Sell et al. 2011). Study of climate characteristics in *B. millavensis* habitats might shed light on the factors behind such a distribution. It is possible that soil parameters or precipitation are important in determining its distribution.

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References

[Bondartsev, A. S.] Бондарцев, А. С. 1953. Трутовые грибы европейской части СССР и Кавказа. Академия Наук СССР, Москва-Ленинград. 1103 стр. Pore fungi of European USSR and Caucasus. Akademiya Nauk USSR, Moskva-Leningrad. 1103 p. [In Russian].

Bourdot, H., Galzin, A. 1925. Hyménomycetes de France. Bulletin de la Société Mycologique de France 41: 98–255. [In French].

Donk, M. A. 1966. Notes on European Polypores – I. Persoonia 4: 337–343.

Donk, M. A. 1967. Notes on European Polypores – II. Notes on Poria. Persoonia 5: 47–130.

Dueñas, M., Telleria, M. T., Melo, I., Rodíguez-Armas, J. L., Beltrán, E. 2008. A new species of Candelabrochaete (Polyporales, Basidiomycota). Mycotaxon 103: 299–305. Hjortstam, K. 1987. Studies in tropical Corticiaceae (Basidiomycetes) VII. Specimens from East Africa, collected by L. Ryvarden. Mycotaxon 28: 19–37.

Hjortstam, K. 1998. A checklist to genera and species of corticioid fungi (Basidiomycotina, Aphyllophorales). Windahlia 23: 1–54.

Hjortstam, K., Ryvarden, L. 1986. Some new and noteworthy fungi (Aphyllophorales, Basidiomycetes) from Iguazu, Argentina. Mycotaxon 25: 539–567.

Hjortstam, K., Ryvarden, L. 2002. Studies in tropical corticioid fungi (Basidiomycotina, Aphyllophorales) Alutaceodontia, Botryodontia, Hyphodontia s.s. and Kneiffiella. Synopsis Fungorum 15: 7–17.

Larsson, K.H., Parmasto, E., Fischer, M., Langer, E., Nakasone, K.K., Redhead,

S.A. 2006. Hymenochaetales: a molecular phylogeny for the hymenochaetoid clade. Mycologia 98: 926–936.
Michel, H., Duhem, B., Trichies, G. 2006. Nouveau regard sur Poria millavensis. Bulletin de la Société Mycologique de France 121: 29–46. [In French].
Overholts, L. O. 1939. New or little known species of Poria. Proceedings of the Pennsylvania Academy of Science 13: 121–125.
Parmasto, E. 1959. De speciebus et formis novis Polyporacearum in RSS Estonica inventis [New species and forms of polypores found in Estonian USSR]. Notulae Systematicae e Sectione Cryptogamica Instituti Botanici Nomine V. L. Komarovii Academiae Scientarum URSS 12: 237–239. [In Russian and Latin].
[Parmasto, E. H.] Пармасто, Э. Х. 1984. Oxyporus philadelphi – пример распространения древнего реликта. In: VII Конференция по споровым растениям Средней Ази и Казахстана. Тезисы докладов. Алма-Ата, с. 49. Oxyporus philadelphi – an example of distribution of old relics. In: VII Conference on spore plants of Middle Asia and Kazakhstan Abstracts, p. 49 [In Russian].
Parmasto, E. 2009. Kadakatarjak, Puhtu kummalisim torikseen. Lugu ühe seene üheksast nimest ja kummalisest levilast. [Botryodontia millavensis, a polypore with a living type specimen on Puhtu Island]. Estonia Maritima 8: 97–105. [In Estonian, Summary in English].
Parmasto, E., Parmasto, I. 1987. Variation of basidiospores in the Hymenomycetes and its significance to their taxonomy. J. Cramer, Berlin & Stuttgart. 168 p.
Sell, I., Kotiranta, H., Kaart, T. 2011. Habitat requirements of Peniophora junipericola (Basidiomycota, Russulales). Annales Botanici Fennici 48: 232–236.
Tamura, K., Peterson, D., Peterson, N., Stecher, G., Nei, M., Kumar, S. 2011. MEGA 5: Molecular Evolutionary Genetics Analysis using Maximum Likelihood, Evolutionary Distance, and Maximum Parsimony Methods. Molecular Biology and Evolution 28: 2731–2739.
White, T. J., Bruns, T., Lee, S., Taylor, J. 1990. Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis, M. A., Sninsky, J. J., White, T. J. (eds). PCR protocols: A guide to Methods and Applications Academic Press, San Diego, 315–322.
Wu, S. H. 1990. The Corticiaceae (Basidiomycetes) subfamilies Phlebioideae, Phanerochatoideae and Hyphodermoideae in Taiwan. Acta Botanici Fennici 142: 1–123.

Table 1. Data of specimens used in the analysis of molecular characters with their numbers of herbarium specimens and other data.

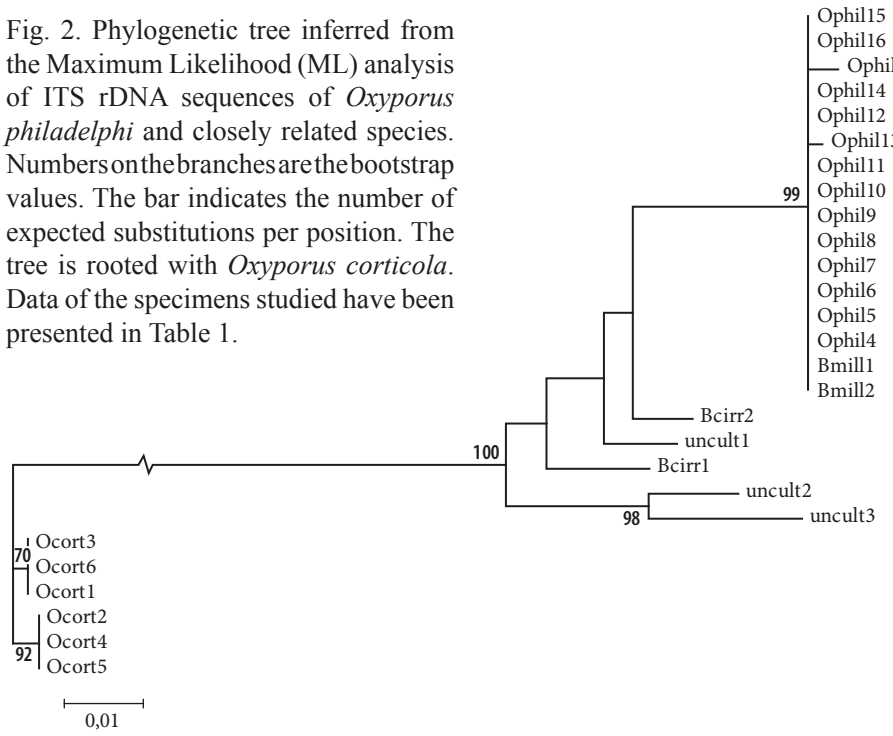
ID	Taxon	Herbarium specimen	Origin	Host-tree	GenBank nr.
Ophil1	*Oxyporus philadelphi*	TAAM 055448	Turkmenistan	*Juniperus turcomanica*	
Ophil4	*Oxyporus philadelphi*	TAAM 101759	Estonia	*Picea abies*	
Ophil5	*Oxyporus philadelphi*	TAAM 125642	Estonia	*Lonicera* sp.	
Ophil6	*Oxyporus philadelphi*	TAAM 135131	Estonia	*Fraxinus excelsior*	
Ophil7	*Oxyporus philadelphi*	TAAM 191462	Estonia	*Picea abies*	
Ophil8	*Oxyporus philadelphi*	TAAM 196406	Estonia	*Philadelphus coronarius*	
Ophil9	*Oxyporus philadelphi*	TAAM 196888	Estonia	*Philadelphus coronarius*	
Ophil10	*Oxyporus philadelphi*	TAAM 196889	Estonia	*Philadelphus coronarius*	
Ophil11	*Oxyporus philadelphi*	TAAM 196898	Estonia	*Philadelphus coronarius*	
Ophil12	*Oxyporus philadelphi*	TAAM 196182	Estonia	*Juniperus communis*	
Ophil13	*Oxyporus philadelphi*	TAAM 196555	Estonia	*Juniperus communis*	
Ophil14	*Oxyporus philadelphi*	TAAM 196570	Estonia	*Juniperus communis*	
Ophil15	*Oxyporus philadelphi*	TAAM 196577	Estonia	*Juniperus communis*	
Ophil16	*Oxyporus philadelphi*	Kotiranta 21219	Estonia	*Juniperus communis*	
Bmill1	*Botryodontia millavensis*	PC 0084171	France	*Juniperus communis*	
Bmill2	*Botryodontia millavensis*	O 44981	Norway	coniferous tree	
Bcirr1	*Botryodontia cirrata*	PC 0084172	Madagaskar	*Lantana camara*	
Bcirr2	*Botryodontia cirrata*	O 28077	Brunei	fallen leaves	
uncult1	uncultured fungus				GQ921826
uncult2	uncultured fungus				GU053920
uncult3	uncultured fungus				GU053923
Ocort1	*Oxyporus corticola*				FJ903327
Ocort2	*Oxyporus corticola*				EF011124
Ocort3	*Oxyporus corticola*				DQ873641
Ocort4	*Oxyporus corticola*				EF011123
Ocort5	*Oxyporus corticola*				EF011122
Ocort6	*Oxyporus corticola*	Niemelä 7068 (H)			

Table 2. Spore dimensions of the studied specimens. Bold-face values are composite statistics for species. *L* = average of spore length, *W* = average of spore width, *Q'* = length/width ratio of individual spores, *Q* = *L*/*W*, and *n* = number of spores measured. The extreme value of the whole range is given in parentheses; 90% range excluding 5% extreme values from both ends of variation is given without parentheses; in case the values are identical, parentheses are omitted.

	L	L*	W	W*	Q	Q*
B. cirrata						
Ryvarden 19572 (holotype of *B. cirrata*)	**5.6–7**(–8)	6.4	**4-5.2**(–5.5)	4.6	1.3–1.6	1.4
Spooner B113	**4.6–5.4**(–6)	5	(3.1–)**3.3–3.8**(–4.8)	3.5	1.2–1.7	1.4
Duhem 22.2.2000	**5.1–6.4**(–7)	5.7	(3.7–)**4–4.6**(–4.8)	4.2	1.2–1.6	1.4
Wu 880819-24	(4.8–)**6.2**(–6.5)	5.3	(3.6–)**3.8–4.4**	4	1.2–1.5	1.3
Wu 880819-27 (isotype of *H. formosana*)	(4.4–)**5-6.7**	5.5	(3.5–)**3.9–4.7**	4.2	1.1–1.5	1.3
B. millavensis						
Bourdot 2958 (lectotype of *Poria millavensis*)	**4.6–5.2**	4.9	**3.8–4.5**(–4.7)	4.1	1–1.3	1.2
Parmasto TAAM 000014 (isotype of *Chaetoporus philadelphi*)	**4.6–5.3**(–5.6)	5	(3.6–)**3.8–4.2**	4	1.1–1.4	1.3
Trichies PC 0084171	**4–4.8**	4.4	(3.3–)**3.5–4.2**(–4.4)	3.8	1–1.3	1.1
Kotiranta 21986 & Sell	**4.5–5.2**(–5.5)	4.8	(3.5–)**3.7–4.2**	3.9	1.1–1.3	1.2
Sell TAAM 191462	**5–6**	5.4	**4.2–5**	4.6	1.1–1.3	1.2
Sell TAAM 196898	(4.6–)**4.8–6**(–7)	5.3	(3.8–)**4–5**(–5.6)	4.5	1.1–1.3	1.2
Sell & Kotiranta TAAM 196555	**4.6–5.4**(–5.7)	5	**3.6–4.2**	3.9	1.1–1.5	1.3
Ryvarden 44981	(4.4–)**4.6–5**	4.8	(3.6–)**3.6–4.4**(–4.8)	4.2	1–1.3	1.2
O. corticola						
Kotiranta 2884	**6–7.2**(–8)	6.6	**4-4.6**(–4.9)	4.3	1.3–1.9	1.5
Kotiranta 7404	**5.8–7.3**(–7.6)	6.4	(3.6–)**3.8–4.2**	4	1.3–1.0	1.6
Kotiranta 2065	**5–6**(–6.3)	5.5	(3–)**3.4–4.1**	3.7	1.2–1.9	1.5
Kotiranta 1306	**5–6**(–6.3)	5.6	(3–)**3.4–4**	3.6	1.4–1.8	1.5
Kotiranta 8500	**5.5–6.8**(–8)	6.2	**3.5–4.1**	3.7	1.4–2.1	1.7

Fig. 1. *Botryodontia millavensis* (Estonia, Hiiu Co., Käina Comm., Käina Bay-Kassari Landscape Reserve, Kassari, 27 Sept 2007, TAAM 196182). Photo by I. Sell.

Fig. 2. Phylogenetic tree inferred from the Maximum Likelihood (ML) analysis of ITS rDNA sequences of *Oxyporus philadelphi* and closely related species. Numbers on the branches are the bootstrap values. The bar indicates the number of expected substitutions per position. The tree is rooted with *Oxyporus corticola*. Data of the specimens studied have been presented in Table 1.



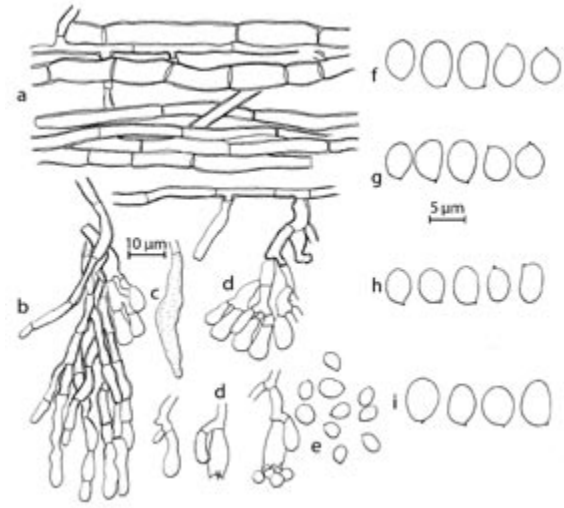


Fig. 3. *Botryodontia cirrata* (a–d: from holotype of *Candelabrochaete cirrata*, g: from isotype of *Hyphodontia formosana*, h: from *Spooner B113*, i: from *Duhem PC 0084172*).
a: Hyphal strand. b: Dissepiment edge with basidioles.
c: A gloeocystidium. d: Basidioles and basidia. e–i: Spores.

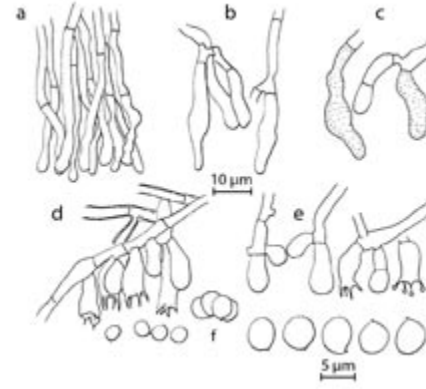


Fig. 4. *Botryodontia millavensis* (lectotype of *Poria millavensis*).
a: Dissepiment edge. b: Cystidioles. c: Gloeocystidia.
d: Hymenium e: Basidioles and basidia. f: Spores.

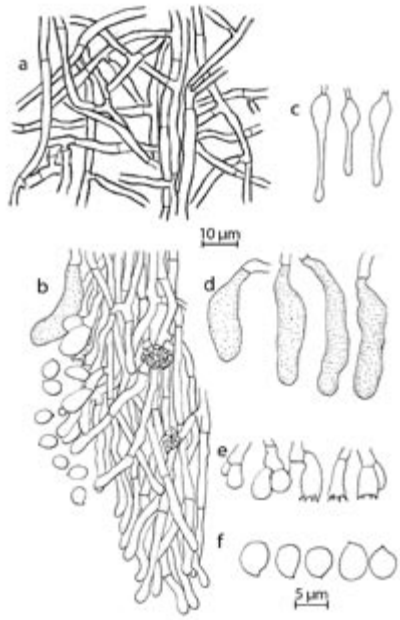


Fig. 5. *Botryodontia millavensis* (isotype of *Chaetoporus philadelphi*).
a: Subiculum. b: Dissepiment edge with a gloeocystidium and basidioles.
c: Cystidioles. d: Gloeocystidia. e: Basidioles and basidia. f: Spores.

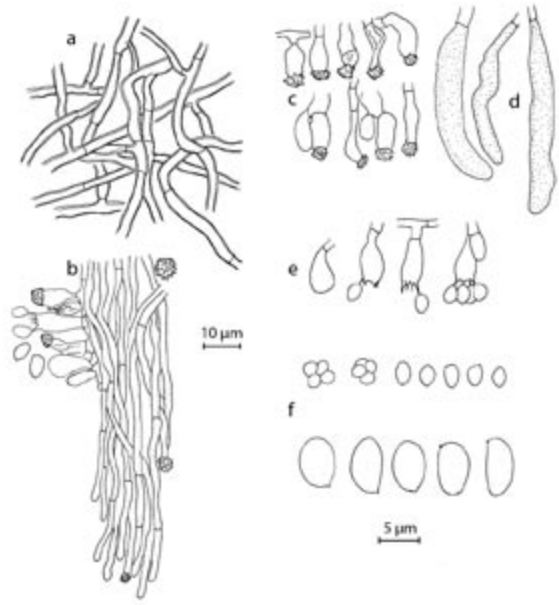


Fig. 6. *Oxyporus corticola* (*Kotiranta 2884*).
a: Subiculum. b: Dissepiment edge with cystidia and basidia.
c: Apically encrusted cystidia. d: Gloeocystidia. e: Basidia. f: Spores.

IV

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Habitat requirements of *Peniophora junipericola* (Basidiomycota, Russulales)

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Peniophora junipericola is a decayer on dead junipers (*Juniperus communis*). It is locally-common near the shores of the Baltic Sea. The aim of the present study was to characterise its habitat requirements by measuring the diameter of the substrate, as well as the stage of decay and the pH values of the infested twigs. Precipitation at the localities where *P. junipericola* is present was also taken into account. The results of the study show that the fungus can grow on thin and thick juniper branches as well as on hard, newly dead ones and on twigs more or less decayed. Most of its habitats are situated close to the sea.

Introduction

Peniophora junipericola (Fig. 1), a wood-rotting fungi on junipers common in the Baltic states and Scandinavia (*see* Fig. 2), was described more than 60 years ago (Eriksson 1950). Its favourite habitats are located near shores, especially in sunny, periodically warm localities where it grows on dead, but still attached branches or dead trunks of junipers. According to Eriksson *et al*. (1978), it grows on *Juniperus communis* in Sweden, France and Estonia. However, it has also been reported from other juniper species (*Juniperus excelsa, J. oxycedrus, J. semiglobatus, J. virginiana*) in Spain, Macedonia, Ukraine (Crimean peninsula), Kazakhstan, North-West Caucasus, and Louisiana in the United States (García-Manjón & Moreno 1981, Gilbertson & Blackwell 1985, Mukhamedsin 1992, Parmasto & Parmasto 1992, Boidin 1994, Karadelev 1995).

Studies of the genus *Peniophora* have to date been focused on the taxonomy and reproductive compatibility (Boidin & Pomeys 1961, Hallenberg 1984, 1986, 1987, 1988, 1991, Hallenberg & Larsson 1991, 1992, Hallenberg *et al*. 1996), hence, the habitat preferences of *P. junipericola* remain poorly known. Eriksson (1950) mentioned that all its localities are situated close to water (sea, lakes, etc.). According to Parmasto and Parmasto (1992) the distribution pattern very much resembles that of xerothermic species.

The aim of the present study was to characterise habitat requirements of *P. junipericola* by measuring the diameter of the substrate, as well as the stage of decay and the pH values of the infested twigs. Precipitation at the localities

Fig. 1. *Peniophora junipericola in situ* (*Estonia, Hiiu Co., Käina Comm., Kassari, 27 Sep. 2007, Kotiranta 21988 & Sell*). Photo Indrek Sell.

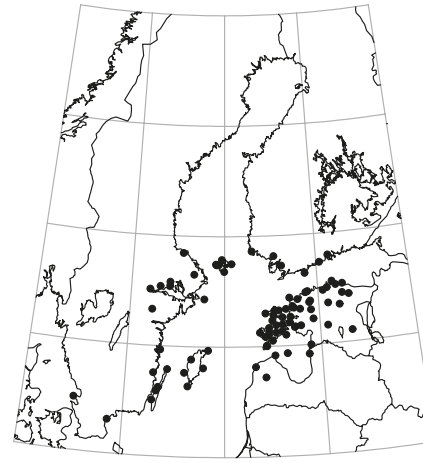

Fig. 2. The distribution of *Peniophora junipericola* in Estonia, Finland, Sweden and Latvia.

where *P. junipericola* is present was also taken into account. Also the life style of the fungus (parasite/saprobe) is discussed, and how the distance from the sea influences the frequency of infested junipers.

Material and methods

The material we studied is preserved in the herbaria TAAM, H, TUR, UPS, S, and GB or in the reference herbarium of Heikki Kotiranta (HK). The 399 specimens studied constitute almost the complete body of collections of *Peniophora junipericola* in Estonia (268), Finland (35) and Sweden (87), also entailing samples from Latvia (9). In all cases, the substrate was *Juniperus communis*.

The substrate diameter of each specimen was measured with the galliper gauge to the nearest 1 mm. The decay stage was estimated using a five-point scale described by Renvall (1995), but modified by us, since Renvall's method is for trunks, not for twigs. The degree of decay was estimated with a fingernail, since a knife is too robust for small twigs. When the substrate of the herbarium specimen was not a twig, but bark, the decay stage was not measured.

In order to measure pH, a modification of the the potentiometric method 943.02 (originally utilised for measuring pH of flour, AOAC 1990) was used. Since only 103 specimens were large enough (at least 5 grams per specimen is required) we were not able to measure the pH of all specimens. The steps of the procedure were as follows: (1) a twig sample was milled to less than 1 mm particle size using a Cyclotec™ Tecator; (2) the particles were mixed with distilled water, and the pH of the solution was measured with a Sentron pH-meter. The measurements were carried out in the Plant Biochemistry Laboratory of the Estonian University of Life Sciences in Tartu.

In addition to the data mentioned above, the locality data given on the label of each specimen were taken into account. The distance of a locality from the sea was evaluated using a map and a ruler and assigned to one of the following classes: (1) 0–2 km, (2) 2–20 km, (3) 21–40 km, (4) 41–60 km, and (5) 61 km or more.

In order to analyze how the amount of precipitation influences the distribution of *P. junipericola*, precipitation data (courtesy of the Estonian Meteorological and Hydrological Institute, the Swedish Meteorological and Hydrological Institute, the Latvian Environment, Geology and Meteorology Agency, and the Finnish Meteorological Institute) from the nearest meteorological station located at the same distance from the seashore, were used. In case there were several meteorological stations near the locality, the average values of two to three stations were used. As the distribution of annual precipitation

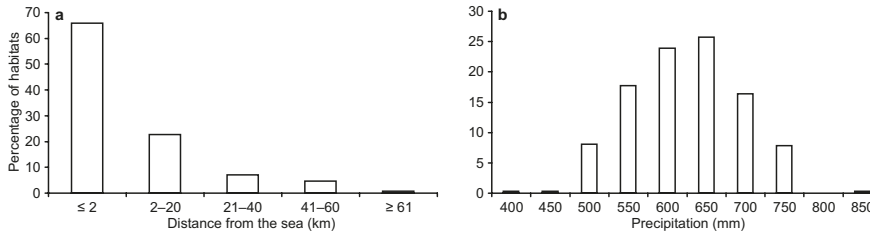

Fig. 3. The habitats of *Peniophora junipericola*. — **a**: Distance of the localities from the sea; — **b**: Localities partitioned by amount of precipitation.

is uneven and the forming period of basidiocarps is not exactly known, the average yearly precipitation was calculated from a longer period, e.g., in Estonia 1961–2007, Finland 1961–2007, Latvia 1966–2007, Sweden 1961–1990 (because all Swedish specimens were collected between 1961 and 1990).

A Spearman rank correlation analysis was used to study associations between variables. Additionally, the principal component analysis (PCA) on the selected variables was performed. Calculations were performed using SAS ver. 9.1.

Results

Diameters of the substrate twigs varied from 0.3 cm to 4.0 cm (mean ± SD = 1.08 ± 0.46 cm, n = 381). The percentage of twigs with a diameter of ≤ 0.5 cm was 8.4% and branches with a diameter ≥ 1.5 cm was 12.6%.

The twigs (n = 341) belonged to decay classes 1–4 (percentages being 70.1%, 21.1%, 7.9% and 0.9%, respectively), and no occurrences of very rotten twigs (5th class) were recorded.

Peniophora junipericola favours strongly acidic (pH_{KCl} ≤ 3.5, 52.4% of the twigs [n = 103]) or acidic (pH_{KCl} = 3.6–4.5, 45.6% of the twigs) juniper twigs. However, it apparently can also grow on moderately acidic twigs (pH_{KCl} = 4.6–5.5, 1.9% of the twigs).

About two thirds (65.7%) of all the localities were situated ≤ 2 km from the sea (Fig. 3a); 22.5%, 6.8% and 4.5% were 2–20 km, 21–40 km and 41–60 km from the sea, respectively. There were only two localities (both in Estonia) > 61 km from the sea.

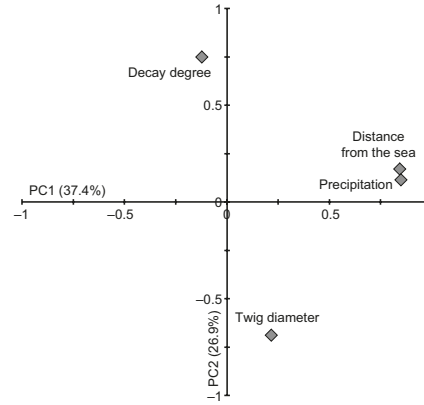

Fig. 4. Principal component analyses for twig diameter, decay degree, precipitation and distance from the sea (n = 331).

Mean (± SD) annual precipitation at the *P. junipericola* localities was 599.5 ± 69.0 mm (range = 396.3–807.5 mm). Almost half of the habitats (49.5%) had the annual precipitation between 551 and 650 mm; at one locality the annual precipitation exceeded 800 mm and at one it was less than 400 mm (Fig. 3b).

We found statistically significant, positive correlation between precipitation at the locality and the distance of the locality from the sea (Spearman r = 0.55, p < 0.001). Correlations between the diameter and the decay degree of twigs (Spearman r = –0.10, p = 0.07), and between the decay degree of twigs and their pH (Spearman r = 0.16, p = 0.10) were not significant.

The first and second principal components of the PCA (Fig. 4) explained 64.3% of the total vari-

ation in twig diameter, decay degree, precipitation and distance from the sea. PC1, characterising the habitat, was positively correlated with precipitation and distance from the sea, and almost not correlated with the decay degree and twig diameter. PC2, characterising the substrate, was positively correlated with decay degree and negatively correlated with twig diameter, but almost not correlated with precipitation and distance from the sea.

In the second PCA, where additionally acidity of the 103 specimens was considered, the relationships between principal components and initial variables used also in the first PCA remained the same. Acidity was positively correlated with PC2 and not correlated with PC1.

Discussion

The results show that *P. junipericola* can grow on thin as well as on thick juniper twigs, or even on stems, with the minimum diameter 0.3 cm (mean = 1.08 cm). *Peniophora pini*, which also infects mostly dead branches, grows on pine twigs (*Pinus sylvestris*) which are 1–2 cm in diameter (Eriksson *et al*. 1978). Jahn (1971) indicated that *P. pini* can grow on thin twigs, with the thickness 0.3 cm which is in line with our findings for *P. junipericola*.

Eriksson (1950) mentioned that juniper branches are very tough and resistant, but those infected by *P. junipericola* are easily broken. The results of our study show that *P. junipericola* grows both on hard, newly dead twigs even with needles still attached, as well as on highly decayed twigs. The basidiocarp formation on newly dead, almost fresh branches, indicates that *P. junipericola* is a parasite, which can continue its growth as a saprobe. Sometimes it was accompanied by *Peniophora pithya* which, however, does not infect living bushes and whose fruitbodies emerge on stems, not twigs. *Amylostereum laevigatum*, which is one of the most common decayers of junipers in the study area, attaches also to living bushes, and the basidiocarp formation on thin twigs is rare.

In the study area, *P. junipericola* grows near the sea coast. As compared with the other areas of the country, the western islands of Estonia, where *P. junipericola* is especially common, are characterized by warm and dry summers, mild autumns and fairly mild winters (Parmasto & Parmasto 1992, Tammets & Jaagus 2007). In some earlier studies (Eriksson 1950, Eriksson *et al*. 1978) *P. junipericola* was reported to occur close to waterbodies. We can now confirm that preference; two thirds of the *P. junipericola* habitats are situated ≤ 2 km from the sea.

As evidenced by PCA, precipitation and distance from the sea had the similar loadings on PC1 (Fig. 4). The decay degree, pH and twig diameter had the highest loadings on PC2, whereby the loadings of twig diameter were opposite to those of decay degree and acidity.

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References

AOAC 1990: AOAC, pH of flour. Procedure 943-02. — In: *Official Methods of Analysis*, Association of Official Analytical Chemists, Washington, DC.

Boidin, J. 1994: Les Peniophoraceae des parties tempérées et froides de l'hémisphère nord (Basidiomycotina). — *Bull. Mens. Soc. Linn. Lyon* 63: 317–334.

Boidin, J. & Pomeys, M. 1961: Hétérobasidiomycètes saprophytes et homobasidiomycètes résupinés. IX. De l' utilisation des critères d'interfertilité et de polarité pour la reconnaissance objective des limites spécifiques et des affinities. — *Bull. Soc. Myc. France* 77: 237–261.

Eriksson, J. 1950: *Peniophora* Cke sect. Coloratae Bourd. & Galz. Taxonomical study with special reference to the Swedish species. — *Symb. Bot. Upsalienses* 10: 1–76.

Eriksson, J., Hjortstam, K. & Ryvarden, L. 1978: *The Corticiaceae of North Europe* 5: *Mycoaciella* to *Phanerochaete*. — Fungiflora, Oslo.

García-Manjón, J. L. & Moreno, G. 1981: Estudos sobre Aphyllophorales. I. Frutificaciones sobre *Juniperus*. — *Ann. Jar. Bot. Madrid* 37: 407–416.

Gilbertson, R. L. & Blackwell, M. 1985: Notes on wood-rotting fungi on junipers in the Gulf Coast Region. — *Mycotaxon* 24: 325–348.

Hallenberg, N. 1984: Compatibility between species of Corticiaceae s. l. (*Basidiomycetes*) from Europe and North

America. — *Mycotaxon* 21: 335–388.
Hallenberg, N. 1986: On speciation and species delimitation in *Peniophora cinerea*-group (Corticiaceae, Basidiomycetes). — *Windahlia* 16: 73–80.
Hallenberg, N. 1987: On speciation in Corticiaceae (Basidiomycetes). — *Windahlia* 17: 19–25.
Hallenberg, N. 1988: Species delimitation in Corticiaceae (Basidiomycetes). — *Mycotaxon* 31: 445–465.
Hallenberg, N. 1991: Pairing tests with species of Aphyllophorales (Basidiomycetes) from two phytogeographically isolated areas. — *Mycotaxon* 42: 355–386.
Hallenberg, N. & Larsson, E. 1991: Differences in cultural characters and electrophoretic patterns among sibling species in four different species complexes (Corticiaceae, Basidiomycetes). — *Mycologia* 83: 131–141.
Hallenberg, N. & Larsson, E. 1992: Mating biology in *Peniophora cinerea* (*Basidiomycetes*). — *Can. J. Bot.* 70: 1758–1764.
Hallenberg, N., Larsson, E. & Mahlapuu, M. 1996: Phylogenetic studies in *Peniophora*. — *Mycol. Res.* 100: 179–187.
Jahn, H. 1971. Steroide Pilze in Europa (*Stereaceae* Pil. emend. Parm. u.a., *Hymenochaete*) mit besonderer Berücksihtigung ihres workommens in der Bundesrepublik Deutschland. — *Westf. Pilzbr.* 8: 69–176.
Karadelev, M. 1995: Lignicolous Aphyllophorales (Basidiomycetes) on Greek Juniper (*Juniperus excelsa*) in the republic of Macedonia. — *Mycotaxon* 56: 467–472.
Mukhamedsin, R. K. [Мухамедшин, Р. К.] 1992: [Corticiaceae *s. lato* in the North-West Caucasus]. — *Mikol. Fitop.* 26: 104–109. [In Russian].
Parmasto, E. & Parmasto, I. 1992: *Peniophora junipericola* (Aphyllophorales, Corticiaceae): distribution and spore variability. — *Karstenia* 32: 13–16.
Renvall, P. 1995: Community structure and dynamics of wood-rotting Basidiomycetes on decomposing conifer trunks in northern Finland. — *Karstenia* 35: 1–51.
Tammets, T. & Jaagus, J. 2007: Spatial pattern of frequency of extreme dry and wet days in Estonia during the period 1957–2006. — *Publ. Inst. Geogr. Univ. Tartuensis* 102: 109–116. [In Estonian with English Summary].

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Diversity and distribution of aphyllophoroid fungi growing on Common Juniper (*Juniperus communis* L.) in Estonia

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Abstract: In the study we present a checklist of aphyllophoroid fungi growing on *Juniperus communis* in Estonia with the data of ecology, phenology and distribution. The paper summarizes results of study on 1026 specimens from fungus collections, and authors' observations. There are 104 species of aphyllophoroid fungi recorded growing on junipers in Estonia, 56 of them have only been found once. The most frequent species can be claimed to be *Peniophora junipericola*, followed in its frequency by *Amylostereum laevigatum*, *Hyphodontia juniperi*, *Hyphodontia alutaria*, *Basidioradulum crustosum* and *Hyphodontia arguta*. *Atheloderma mirabile* and *Sistotrema heteronemum* can be considered among rare species, which have only been found once in Estonia (also they are growing on juniper). Two species are listed in threat categories of the Estonian Red List: *Oxyporus philadelphi* and *Lindtneria trachyspora*. The former one is also protected by law in Estonia.

Kokkuvõte: Harilikul kadakal (*Juniperus communis* L.) kasvavate mittelehikseente mitmekesisus ja levik Eestis

Esitatakse Eestis harilikul kadakal (*Juniperus communis*) kasvavate mittelehikseente nimestik koos ökoloogiliste, fenoloogiliste ja levikuliste andmetega. Kirjutises on kokku võetud 1026 herbaareksemplari uurimise tulemused ja vaatlused. Eestist on kadakatelt leitud kokku 104 liiki mittelehikseeni, neist 56 esinemist harilikul kadakal on meil täheldatud vaid korra. Kõige sagedasem kadakatel kasvav liik on kadakakirmik (*Peniophora junipericola*), sellele järgnevad *Amylostereum laevigatum*, *Hyphodontia juniperi*, *Hyphodontia alutaria*, *Basidioradulum crustosum* ja *Hyphodontia arguta*. Haruldasematest liikidest esinevad kadakal näiteks *Atheloderma mirabile* ja sistotreemi perekonda kuuluv liik *Sistotrema heteronemum*, mõlema esinemist on Eestis täheldatud vaid ühel korral. Kaks liiki, kadakatarjak (*Oxyporus philadelphi*) ja ogaeoseline ebapoorik (*Lindtneria trachyspora*), kuuluvad ka siinse Punase Nimestiku ohukategooriatesse, lisaks öeldule on kadakatarjak meil looduskaitse all.

INTRODUCTION

Juniperus communis is in Estonia (and in the other Baltic States) the only natural representative of the family *Cupressaceae*. *Juniperus communis* has the largest distribution of all the juniper species: it is the only one found in both the Eastern and Western Hemispheres (Adams, 2008). Almost 40 years ago, the area of juniper stands in Estonia was approximately 100,000 hectares, most of them were situating in Saaremaa Island (Kaar, 1965). However, this number may be overvalued and nowadays the situation has changed: some of the areas are forests now. According to recent data, this area is about 10,000 hectares (Kukk & Sammul, 2006).

The present article deals with two important life forms of aphyllophoroid macrofungi, including polypores and corticioids. 211 species of polypores are known to grow in Estonia (Parmasto, 2004). The number is slightly higher in Finland, viz. 230 species (Niemelä, 2005). The number of corticioids in Finland is 422 (Kotiranta et al., 2009), while in Estonia it is slightly below 350. Most of the collections have been gathered from Norway Spruce (*Picea abies*) or from European Aspen (*Populus tremula*). Only some studies (Parmasto & Parmasto, 1992; Sell et al., 2011) focus particularly on aphyllophoroid fungi growing on juniper in Estonia; these deal with *Peniophora junipericola*. However, any up-to-date checklist of aphyllophoroid fungi growing on *Juniperus communis* in Estonia has not been published. The aim of the present study is to give an overview on the diversity and distribution of aphyllophoroid fungi growing on *Juniperus communis* in Estonia.

MATERIALS AND METHODS

The study is based on specimens preserved at the fungal collection of the Institute of Ag-

ricultural and Environmental Sciences of the Estonian University of Life Sciences (TAAM) and on the reference fungal collection of Heikki Kotiranta (H. K.). The conventional methods for the mycological field work and light microscopy were used. The decay stage of the juniper twigs was estimated using a Renvall's (1995) five-point scale modified by Sell et al. (2011). Forest types were classified according to the Estonian forest site type grops (Paal, 1997; Lõhmus, 2004). However, eutrophic alvar forests were divided into two groups: eutrophic alvar forests and eutrophic alvar juniper shrublands. Also oligotrophic boreal heath forests were divided into two groups: oligotrophic boreal heath forests and oligotrophic boreal heath juniper shrublands. The collections and observations originate from the following forest type groups:

eutrophic alvar forests;
eutrophic alvar juniper shrublands;
oligotrophic boreal heath forests;
oligotrophic boreal heath juniper shrublands;
oligo-mesotrophic boreal forests;
mesotrophic boreal forests;
eutrophic boreo-nemoral forests;
eutrophic paludified forests;
oligotrophic paludified forests.

The taxa in the species list are arranged in alphabetic order. Nomenclature follows the Index Fungorum (4 May 2011). The following data is given on each species: Latin name, data on the ecology, phenology, distribution and references to the specimens available in the fungal collections of TAAM or H. K. (reference fungal collection of Heikki Kotiranta).

RESULTS

Altogether 1026 collections and observations were obtained in the study. 104 species were detected from Estonia; of them 56 species (53.8%) were found only once growing on juniper, and 12 species (11.5%) were discovered twice.

74 rare species (1–3 specimens or observations per species) make up 71.1% of all the species and 9.8% of all the observations, whereas 15 common species (over 10 observations) form 81.9% and the rest of the species (4–10 observations) 8.3%, respectively. The six common species include 61.9% of all observations.

LIST OF SPECIES

Amphinema byssoides (Pers.) J. Erikss.
46 records from *Juniperus communis*.
Basidiocarps seen from July to November; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath forests, *Oligo-mesotrophic boreal forest*s, mesotrophic boreal forests; in Hiiu, Järva, Lääne, Lääne-Viru, Põlva, Pärnu, Saare, Tartu, Võru Counties.
Substrate diametre: 0.2–4.5 cm (average 2.1 cm, N=39).
Decay stages: 1 (66.7%), 2 (25.6%), 3 (5.1%), 4 (2.6%), N=39.

Amylocorticellum cremeoisabellinum (Litsch.) Spirin & Zmitr.
Single record from *Juniperus communis*.
Basidiocarps seen in October; in Lääne-Viru County.
Voucher specimen studied: TAAM 009643.

Amylocorticellum molle (Fr.) Spirin & Zmitr.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar juniper shrubland; in Hiiu County.
Substrate diametre: 6.0 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimen studied: HK 21916.

Amylostereum laevigatum (Fr.) Boidin
110 records from *Juniperus communis*.
Basidiocarps seen from May to November; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath forests, oligo-mesotrophic boreal forests and mesotrophic boreal forests; in Harju, Hiiu, Järva, Lääne, Lääne-Viru, Põlva, Pärnu, Rapla, Saare, Tartu, Valga, Viljandi, Võru Counties.
Substrate diametre: 0.3–6.0 cm (average 3.0 cm, N=29).
Decay stages: 1 (64.5%), 2 (25.8%), 3 (6.5%), 4 (3.2%).

Athelia epiphylla Pers.
Single record from *Juniperus communis*.
Basidiocarps seen in November; in oligotrophic boreal heath forest; in Lääne-Viru County.
Substrate diametre: 0.1 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21516.

Athelia pyriformis (M.P. Christ.) Jülich
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar juniper shrubland; in Hiiu County.

Substrate diametre: 3.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21914.

Atheloderma mirabile Parmasto
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar forest; in Rapla County.
Voucher specimen studied: TAAM 196155.

Athelopsis glaucina (Bourdot & Galzin) Oberw. ex Parmasto
Single record from *Juniperus communis*.
Basidiocarps seen in October; in eutrophic alvar juniper shrubland; in Saare County.
Substrate diametre: 2.0 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimen studied: HK 21128.

Basidiodendron pini (H.S. Jacks. & G.W. Martin) Luck-Allen
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar forest; in Lääne County.
Substrate diametre: 1.5 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimens studied: HK 21721.

Basidiodendron radians (Rick) P. Roberts
2 records from *Juniperus communis*.
Basidiocarps seen in November; in oligotrophic boreal heath forests; in Lääne-Viru County.
Substrate diametre: 2.0–3.0 cm (average 2.5 cm, N=2).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=2.
Voucher specimens studied: HK 21512, HK 21526.

Basidiodendron rimosum (H.S. Jacks. & G.W. Martin) Luck-Allen
2 records from *Juniperus communis*.
Basidiocarps seen from October to November; in eutrophic alvar juniper shrublands; in Harju and Lääne Counties.
Substrate diametre: 1.5–2.5 cm (average 2.0 cm, N=2).
Decay stages: 1 (0%), 2 (50.0%), 3 (0%), 4 (50.0%), N=2.
Voucher specimens studied: HK 21205, TAAM 196086.

Basidioradulum crustosum (Pers.) Zmitr., Malysheva & Hjortstam
54 records from *Juniperus communis*.
Basidiocarps seen from July to November, once in May; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath forests, oligo-mesotrophic boreal forests and mesotrophic boreal forests; in Harju, Hiiu, Lääne, Lääne-Viru, Rapla, Saare, Võru Counties.
Substrate diametre: 0.3–7.0 cm (average 1.8 cm, N=46).
Decay stages: 1 (63.6%), 2 (27.3%), 3 (4.5%), 4 (4.5%), N=44.

Bjerkandera adusta (Willd.) P. Karst.
3 records from *Juniperus communis*.
Basidiocarps seen in October; in eutrophic alvar juniper shrublands; in Lääne County.
Substrate diametre: 6.0 cm (N=1).
Voucher specimens studied: TAAM 006957, TAAM 158351, TAAM 196581.

Botryobasidium candicans J. Erikss.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in Rapla County.
Voucher specimen studied: TAAM 153639.

Bortyobasidium subcoronatum (Höhn. & Litsch.) Donk
Single record from *Juniperus communis*.
Basidiocarps seen in September; in Järva County.
Voucher specimen studied: TAAM 164641.

Botryobasidium vagum (Berk. & M.A. Curtis) D.P. Rogers
6 records from *Juniperus communis*.
Basidiocarps seen from August to September; in mesotrophic boreal forests; in Lääne, Saare, Tartu and Valga Counties.
Substrate diametre: 1.4–1.5 cm (average 1.5 cm, N=2).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=1.
Voucher specimens studied: TAAM 152705, TAAM 153705, TAAM 167224, TAAM 167362, TAAM 167364, TAAM 167837.

Brevicellicium olivascens (Bres.) K.H. Larss. & Hjortstam
9 records from *Juniperus communis*.
Basidiocarps seen from July to October; in eutrophic alvar juniper shrublands and oligotrophic boreal heath forests; in Harju, Hiiu, Lääne-Viru and Saare Counties.
Substrate diametre: 0.5–4.0 cm (average 2.2 cm, N=7).

Decay stages: 1 (14.3%), 2 (14.3%), 3 (71.4%), 4 (9.1%), N=7.
Voucher specimens studied: TAAM 052942, TAAM 105833, TAAM 196080 (HK 21478), TAAM 196090 (HK 21491), TAAM 196094 (HK 21497), HK 21498, HK 21512, HK 21943.

Cabalodontia cretacea (Romell ex Bourdot & Galzin) Piątek
Single record from *Juniperus communis*.
Basidiocarps seen in September; in oligotrophic boreal heath forest; in Saare County.
Voucher specimen studied: TAAM 174226.

Ceraceomyces serpens (Tode) Ginns
2 records from *Juniperus communis*.
Basidiocarps seen in October to November; in oligo-mesotrophic boreal forest; in Järva and Põlva Counties.
Substrate diametre: 2.5 cm (N=1).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=1.
Voucher specimens studied: TAAM 164923, TAAM 201110.

Ceraceomyces eludens K.H. Larss.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in Harju County.
Voucher specimen studied: TAAM 153733.

Ceratobasidium cornigerum (Bourdot) D.P. Rogers
Single record from *Juniperus communis*.
Basidiocarps seen in September; in oligotrophic boreal heath forest; in Pärnu County.
Substrate diametre: 3.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21657.

Ceriporiopsis mucida (Pers.) Gilb. & Ryvarden
2 records from *Juniperus communis*.
Basidiocarps seen in May and November; in eutrophic alvar forests; in Saare and Rapla Counties.
Voucher specimens studied: TAAM 003391, TAAM 101366.

Coniophora arida (Fr.) P. Karst.
12 records from *Juniperus communis*.
Basidiocarps seen from August to October; in eutrophic alvar juniper shrublands, oligotrophic boreal heath forests, mesotrophic boreal forests and eutrophic paludifying forests; in Hiiu, Lääne, Saare Counties.
Substrate diametre: 2.0–7.0 cm (average 3.4 cm, N=11).
Decay stages: 1 (36.4%), 2 (27.3%), 3 (27.3%), 4 (9.1%), N=11.

Coniophora olivacea (Fr.) P. Karst.
2 records from *Juniperus communis*.
Basidiocarps seen in September; in mesotrophic boreal forests; in Hiiu County.
Substrate diametre: 2.5–4.0 cm (average 3.3 cm, N=2).
Decay stages: 1 (0%), 2 (50.0%), 3 (50.0%), 4 (0%), N=2.
Voucher specimens studied: HK 21928, HK 21929.

Coniophora puteana (Schumach.) P. Karst.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar juniper shrubland; in Hiiu County.
Substrate diametre: 3.0 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimen studied: HK 21902.

Conohypha albocremea (Höhn. & Litsch.) Jülich
Single record from *Juniperus communis*.
Basidiocarps seen in September; in Rapla County.
Voucher specimen studied: TAAM 153648.

Corticium confine Bourdot & Galzin
5 records from *Juniperus communis*.
Basidiocarps seen from September to October; in mesotrophic boreal forests and oligotrophic boreal heath forests; in Lääne and Saare Counties.
Substrate diametre: 1.5–4.0 cm (average 2.5 cm, N=5).
Decay stages: 1 (0%), 2 (60%), 3 (40%), 4 (0%), N=5.
Voucher specimens studied: HK 21061, HK 21069, HK 21958, HK 21972.

Cristinia helvetica (Pers.) Parm.
Single record from *Juniperus communis*.
Basidiocarps seen in August; in Saare County.
Voucher specimen studied: TAAM 167937.

Globulicium hyemale (Laurila) Hjortstam
Single record from *Juniperus communis*.
Basidiocarps seen in August; Valga County.
Voucher specimen studied: TAAM 167838.

Gloeocystidiellum porosum (Berk. & M.A. Curtis) Donk
Single record from *Juniperus communis*.

Basidiocarps seen in October; in mesotrophic boreal forest; in Tartu County.
Voucher specimen studied: TAAM 007111.

Gloiothele citrina (Pers.) Ginns & G.W. Freeman
28 records from *Juniperus communis*.
Basidiocarps seen from August to November; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath forests, oligo-mesotrophic boreal forests, mesotrophic boreal forests, eutrophic paludifying forests; in Hiiu, Põlva, Saare Counties.
Substrate diametre: 1.0–9.0 cm (average 3.6 cm, N=24).
Decay stages: 1 (52.0%), 2 (24.0%), 3 (16.0%), 4 (8.0%), N=25.

Heterobasidium annosum (Fr.) Bref.
7 records from *Juniperus communis*.
Basidiocarps seen from September to November; in oligo-mesotrophic boreal forests and eutrophic alvar forests; in Põlva, Saare and Võru Counties.
Voucher specimens studied: TAAM 101913, TAAM 180295, TAAM 201134, TAAM 201142, TAAM 201143, TAAM 201144.

Hydnocristella himantia (Schwein.) R.H. Petersen
Single record from *Juniperus communis*.
Basidiocarps seen in October; in Tartu County.
Voucher specimen studied: TAAM 118202.

Hyphoderma argillaceum (Bres.) Donk
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar forest; in Rapla County.
Voucher specimen studied: TAAM 153651.

Hyphodontia alutaria (Burt.) J. Erikss.
57 records from *Juniperus communis*.
Basidiocarps seen from September to November, also in July; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath forests, mesotrophic boreal forests and once in oligotrophic bog forests; in Harju, Hiiu, Lääne, Saare Counties.
Substrate diametre: 0.5–6.0 cm (average 2.2 cm, N=55).
Decay stages: 1 (54.5%), 2 (38.2%), 3 (7.3%), 4 (0%), N=55.

Hyphodontia arguta (Fr.) J. Erikss.
53 records from *Juniperus communis*.
Basidiocarps seen from July to November; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath juniper shrublands, mesotrophic boreal forests and eutrophic boreo-nemoral forests; in Harju, Hiiu, Lääne, Lääne-Viru, Rapla, Saare Counties.
Substrate diametre: 0.5–7.0 cm (average 2.2 cm, N=48).
Decay stages: 1 (53.8%), 2 (32.7%), 3 (13.5%), 4 (0%), N=52.

Hyphodontia aspera (Fr.) J. Erikss.
3 records from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar forests; in Hiiu County.
Substrate diametre: 5.0–7.0 cm (average 6.0 cm, N=3).
Decay stages: 1 (66.7%), 2 (33.3%), 3 (0%), 4 (0%), N=3.
Voucher specimens studied: TAAM 196194, TAAM 196195, TAAM 196199.

Hyphodontia borealis Kotir. & Saaren.
2 records from *Juniperus communis*.
Basidiocarps seen in November; in oligotrophic boreal heath forest and oligo-mesotrophic boreal forest; in Lääne-Viru and Põlva Counties.
Substrate diametre: 0.5–2.0 cm (average 1.3 cm, N=2).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=2.
Voucher specimens studied: HK 21522, TAAM 201120.

Hyphodontia breviseta (P. Karst.) J. Erikss.
4 records from *Juniperus communis*.
Basidiocarps seen from September to October; in mesotrophic boreal forests and oligo-mesotrophic boreal forests; in Harju, Hiiu, Järva and Saare Counties.
Substrate diametre: 1.5–3.5 cm (average 2.5 cm, N=2).
Decay stages: 1 (50.0%), 2 (50.0%), 3 (0%), 4 (0%), N=2.
Voucher specimens studied: TAAM 164643, TAAM 164808, HK 21085, HK 21953.

Hyphodontia cineracea (Bourdot & Galzin) J. Erikss. & Hjortstam
3 records from *Juniperus communis*.
Basidiocarps seen from September to October; in eutrophic alvar juniper shrublands; in Järva and Saare Counties.
Substrate diametre: 2.0 cm (N=1).
Decay stages: 1 (0%), 2 (50.0%), 3 (50.0%), 4 (0%), N=2.
Voucher specimens studied: TAAM 164608, TAAM 164742, HK 21161.

Hyphodontia erastii Kotir. & Saaren.
8 records from *Juniperus communis*.
Basidiocarps seen in November; in eutrophic alvar juniper shrublands and oligotrophic boreal heath forests; in Harju and Lääne-Viru Counties.
Substrate diametre: 0.3–2.0 cm (average 0.7 cm, N=8).
Decay stages: 1 (75.0%), 2 (25.0%), 3 (0%), 4 (0%), N=8.
Voucher specimens studied: TAAM 196085 (HK 21486), TAAM 196091 (HK 21492), TAAM 196093 (HK 21493), HK 21496, HK 21499, HK 21503, HK 21521, HK 21523.

Hyphodontia halonata J. Erikss. & Hjortstam
Single record from *Juniperus communis*.
Basidiocarps seen in September; in oligotrophic boreal heath forest; in Hiiu County
Substrate diametre: 3.5 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21959.

Hyphodontia hastata (Litsch.) & J. Erikss.
2 records from *Juniperus communis*.
Basidiocarps seen from September to November; in oligotrophic boreal heath forests; in Hiiu and Põlva Counties.
Substrate diametre: 3.5 cm (N=1).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=1.
Voucher specimens studied: HK 21952, TAAM 069658.

Hyphodontia juniperi (Bourdot & Galzin) J. Erikss. & Hjortstam
59 records from *Juniperus communis*.
Basidiocarps seen from August to November; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath forests and mesotrophic boreal forests; in Harju, Hiiu, Lääne, Lääne-Viru, Saare Counties.
Substrate diametre: 0.5–6.0 cm (average 2.3 cm, N=52).
Decay stages: 1 (53.8%), 2 (32.7%), 3 (13.5%), 4 (0%), N=52.

Hyphodontia pallidula (Bres.) J. Erikss.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in mesotrophic boreal forest; in Hiiu County.
Substrate diametre: 4.0 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimen studied: HK 22014.

Hyphodontia sambuci (Pers.) J. Erikss.
30 records from *Juniperus communis*.
Basidiocarps seen from September to November, also collected in May; in eutrophic alvar forests and eutrophic alvar juniper shrublands; in Harju, Hiiu, Lääne, Saare, Tartu Counties.
Substrate diametre: 0.2–6.0 cm (average 1.8 cm, N=29).
Decay stages: 1 (50.0%), 2 (39.3%), 3 (10.7%), 4 (0%), N=28.

Hyphodontia subalutacea (P. Karst.) J. Erikss.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in Rapla County.
Voucher specimen studied: TAAM 153642.

Hypochniciellum ovoideum (Jülich) Hjortstam & Ryvarden
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar juniper shrubland; in Hiiu County.
Substrate diametre: 0.5 cm (N=1).
Decay stage: 4 (N=1).
Voucher specimen studied: HK 21994.

Hypochnicium eichleri (Bres. ex Sacc. & P. Syd) J. Erikss. & Ryvarden
Single record from *Juniperus communis*.
Basidiocarps seen in November; in oligo-mesotrophic boreal forest; in Põlva County
Substrate diametre: 3.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: TAAM 201131.

Hypochnicium lundellii (Bourdot) J. Erikss.
Single record from *Juniperus communis*.
Basidiocarps seen in October; in mesotrophic boreal forest; in Saare County.
Substrate diametre: 0.4 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21091.

Intextomyces contiguus (P. Karst.) Erikss. & Ryvarden
Single record from *Juniperus communis*.
Basidiocarps seen in July; in Lääne County.
Voucher specimen studied: TAAM 152396.

Leptosporomyces galzinii (Bourdot) Jülich
7 records from *Juniperus communis*.
Basidiocarps seen from September to November; in mesotrophic boreal forests, oligotrophic boreal heath forests, eutrophic alvar forests and oligo-mesotrophic boreal forests; in Hiiu, Lääne, Lääne-Viru, Põlva and Saare Counties.

Substrate diametre: 0.5–3.0 cm (average 1.4 cm, N=5).
Decay stages: 1 (75.0%), 2 (25.0%), 3 (0%), 4 (0%), N=4.
Voucher specimens studied: TAAM 167363, TAAM 167371, TAAM 167387, TAAM 196530, TAAM 201103, HK 21520, HK 21965.

Leucogyrophana romellii Ginns
Single record from *Juniperus communis*
Basidiocarps seen in November; in eutrophic alvar juniper shrubland; in Harju County.
Substrate diametre: 2.0 cm (N=1).
Decay stage: 2 (N=1).
Voucher specimen studied: HK 21509.

Litschauerella clematitis (Bourdot & Galzin) J. Erikss. & Ryvarden
5 records from *Juniperus communis*.
Basidiocarps seen from July to November; in eutrophic alvar juniper shrublands, oligotrophic boreal heath juniper shrublands and mesotrophic boreal forests; in Harju, Lääne and Saare Counties.
Substrate diametre: 1.0–2.0 cm (average 1.4 cm, N=4).
Decay stages: 1 (0%), 2 (100%), 3 (0%), 4 (0%), N=4.
Voucher specimens studied: TAAM 166475, HK 21105, HK 21117, HK 21209, HK 21500.

Melzericium udicola (Bourdot) Hauerslev
Single record from *Juniperus communis*.
Basidiocarps seen in May; in Harju County.
Voucher specimen studied: TAAM 153897.

Metulodontia nivea (P. Karst.) Parmasto
Single record from *Juniperus communis*.
Basidiocarps seen in October; in mesotrophic boreal forest; in Lääne-Viru County.
Voucher specimen studied: TAAM 04996.

Mycolindtneria trachyspora (Bourdot & Galzin) Rauschert
4 records from *Juniperus communis*.
Basidiocarps seen from September to October; in eutrophic alvar juniper shrublands; in Lääne and Saare Counties.
Substrate diametre: 1.0–1.5 cm (average 1.3 cm, N=3).
Decay stages: 1 (66.7%), 2 (33.3%), 3 (0%), 4 (0%), N=3.
Voucher specimens studied: TAAM 180280, HK 21208, HK 21214, HK 21220.

Oxyporus philadelphi (Parmasto) Ryvarden
28 records from *Juniperus communis*.
Basidiocarps seen from July to October; in eutrophic alvar forests, eutrophic alvar juniper shrublands and oligotrophic boreal heath forests; in Harju, Hiiu, Lääne, Saare Counties.
Substrate diametre: 0.5–6.0 cm (average 2.2 cm, N=20).
Decay stages: 1 (40.0%), 2 (45.0%), 3 (10.0%), 4 (5.0%), N=20.

Peniophora junipericola J. Erikss.
302 records from *Juniperus communis*.
Collected in January, from April to November; in eutrophic alvar forests, eutrophic alvar juniper shrublands, oligotrophic boreal heath forests and mesotrophic boreal forests; in Harju, Järva, Lääne, Lääne-Viru, Pärnu, Rapla, Saare, Tartu, Viljandi Counties.
Substrate diametre: 0.2–5.0 cm (average 1.1 cm, N=291).
Decay stages: 1 (60.4%), 2 (28.7%), 3 (9.6%), 4 (1.4%).

Peniophora pithya J. Erikss.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar forest; in Hiiu County.
Substrate diametre: 3.5 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 22006.

Peniophorella pallida (Bres.) K.H. Larss.
2 records from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar juniper shrubland; in Hiiu County.
Substrate diametre: 3.0 cm (average 3.0 cm, N=2).
Decay stages: 1 (0%), 2 (50%), 3 (50%), 4 (0%), N=2.
Voucher specimens studied: HK 21903, HK 21910.

Peniophorella praetermissa (Bres.) K.H. Larss.
4 records from *Juniperus communis*.
Basidiocarps seen from August to November; in eutrophic alvar juniper shrublands; in Harju, Hiiu, Lääne and Saare Counties.
Substrate diametre: 1.5–7.0 cm (average 4.5 cm, N=3).
Decay stages: 1 (33.3%), 2 (33.3%), 3 (0%), 4 (33.3%), N=3.
Voucher specimens studied: TAAM 174077, TAAM 196089 (HK 21490), TAAM 196170.

Peniophorella pubera (Fr.) P. Karst.
3 records from *Juniperus communis*.
Basidiocarps seen from September to November; in eutrophic alvar juniper shrublands and mesotrophic boreal forests; in Harju, Pärnu and Saare Counties.
Substrate diametre: 2.0–3.0 cm (average 2.5 cm, N=2).
Decay stages: 1 (0%), 2 (50.0%), 3 (50.0%), 4 (0%), N=2.
Voucher specimens studied: TAAM 153748, HK 21067, HK 21505.

Phanerochaete sordida (P. Karst.) J. Erikss. & Ryvarden
2 records from *Juniperus communis*.
Basidiocarps seen in June and September; in oligo-mesotrophic boreal forest and eutrophic paludifying forest; in Saare and Põlva Counties.
Substrate diametre: 0.9 cm (N=1).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=1.
Voucher specimens studied: TAAM 154288, TAAM 153977.

Phlebia serialis (Fr.) Donk
Single record from *Juniperus communis*.
Basidiocarps seen in September; in Tartu County.
Voucher specimen studied: TAAM 167227.

Phylloporia ribis (Schumach.) Ryvarden
Single record from *Juniperus communis*.
Basidiocarps seen in July; in Lääne County.
Voucher specimen studied: TAAM 095657.

Piloderma byssinum (P. Karst.) Jülich
11 records from *Juniperus communis*.
Basidiocarps seen from August to November; in eutrophic alvar juniper shrublands, oligotrophic boreal heath forests and oligo-mesotrophic boreal forests; in Hiiu, Saare, Tartu and Võru Counties.
Substrate diametre: 0.5–6.5 cm (average 3.1 cm, N=7).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=7.
Voucher specimens studied: HK 21952, HK 21955, HK 21979, TAAM 166936, TAAM 167874, TAAM 169168, TAAM 201147, TAAM 201151, TAAM 201156, TAAM 201157.

Piloderma lanatum (Jülich) J. Erikss. & Hjortstam
Single record from *Juniperus communis*.
Basidiocarps seen in November; in oligo-mesotrophic boreal forest; in Põlva County
Substrate diametre: 4.5 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: TAAM 201140.

Porotheleum fimbriatum (Pers.) Fr.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar forest; in Lääne-Viru County.
Voucher specimen studied: TAAM 196122.

Postia caesia (Schrad.) P. Karst.
4 records from *Juniperus communis*.
Basidiocarps seen from August to October; in mesotrophic boreal forests; in Hiiu and Saare Counties.
Substrate diametre: 2.0–3.0 cm (average 2.3 cm, N=3).
Decay stages: 1 (0%), 2 (33.3%), 3 (33.3%), 4 (33.3%), N=3.
Voucher specimens studied: TAAM 167792, HK 21089, HK 22018.

Postia fragilis (Fr.) Jülich
Single record from *Juniperus communis*.
Basidiocarps seen in October; in eutrophic alvar juniper shrubland; in Saare County.
Substrate diametre: 4.0 cm (N=1).
Decay stage: 2 (N=1).
Voucher specimen studied: HK 21132.

Postia hibernica (Berk & Broome) Jülich
Single record from *Juniperus communis*.
Basidiocarps seen in September; in oligotrophic boreal heath forest; in Saare County.
Voucher specimen studied: TAAM 174223.

Postia sericeomollis (Romell) Jülich
3 records from *Juniperus communis*.
Basidiocarps seen from July to October; in eutrophic alvar juniper shrublands and eutrophic alvar forests; in Harju, Lääne and Saare Counties.
Substrate diametre: 6.0 cm (N=1).
Decay stages: 1 (66.7%), 2 (33.3%), 3 (0%), 4 (0%), N=3.
Voucher specimens studied: TAAM 100265, TAAM 184380, HK 21726.

Radulomyces confluens (Fr.) M.P. Christ.
17 records from *Juniperus communis*.
Basidiocarps seen from August to November; in eutrophic alvar juniper shrublands, oligo-mesotrophic boreal forests, oligotrophic boreal heath forests and mesotrophic boreal forests;

in Harju, Hiiu, Lääne, Lääne-Viru, Põlva, Saare, Tartu, Võru Counties.
Substrate diametre: 1.0–6.0 cm (average 2.4 cm, N=17).
Decay stages: 1 (71.4%), 2 (14.3%), 3 (0%), 4 (14.3%), N=14.

Resinicium bicolor (Alb. & Schwein.) Parmasto
22 records from *Juniperus communis*.
Basidiocarps seen from August to November; in eutrophic alvar juniper shrublands, oligo-mesotrophic boreal forests, oligotrophic boreal heath forests and mesotrophic boreal forests; in Harju, Hiiu, Lääne, Lääne-Viru, Põlva, Saare, Tartu, Võru Counties.
Substrate diametre: 1.0–8.0 cm (average 3.1 cm, N=15).
Decay stages: 1 (71.4%), 2 (14.3%), 3 (0%), 4 (14.3%), N=14.

Sebacina incrustans (Pers.) Tul. & C. Tul.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic boreo-nemoral forest; in Hiiu County
Substrate diametre: 2.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: TAAM 196475.

Sistotrema alboluteum (Bourdot & Galzin) Bondartsev & Singer
Single record from *Juniperus communis*.
Basidiocarps seen in November; in oligo-mesotrophic boreal forest; in Põlva County.
Substrate diametre: 4.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: TAAM 201106.

Sistotrema brinkmannii (Bres.) J. Erikss.
Single record from *Juniperus communis*.
Basidiocarps seen in October; in mesotrophic boreal forest; in Saare County.
Substrate diametre: 2.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21060.

Sistotrema efibulatum (J. Erikss.) Hjortstam
Single record from *Juniperus communis*.
Basidiocarps seen in October; in eutrophic alvar juniper shrubland; in Lääne County.
Substrate diametre: 1.5 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21204.

Sistotrema muscicola (Pers.) S. Lundell
Single record from *Juniperus communis*.
Basidiocarps seen in September; in oligotrophic boreal heath forest; in Pärnu County.
Substrate diametre: 2.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21714.

Sistotrema octosporum (J. Schröt. ex Höhn. & Litsch.) Hallenberg
Single record from *Juniperus communis*.
Basidiocarps seen in November; in oligotrophic boreal heath forest; in Lääne-Viru County.
Substrate diametre: 0.2 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21515.

Sistotremella perpusilla Hjortstam
Single record from *Juniperus communis*.
Basidiocarps seen in October; in eutrophic alvar juniper shrubland; in Saare County.
Substrate diametre: 0.7 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimen studied: HK 21106.

Steccherinum fimbriatum (Pers.) J. Erikss.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in mesotrophic boreal forest; in Hiiu County.
Substrate diametre: 4.0 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimen studied: HK 21927.

Stypella dubia (Bourdot & Galzin) P. Roberts
Single record from *Juniperus communis*.
Basidiocarps seen in October; in eutrophic alvar juniper shrubland; in Saare County.
Substrate diametre: 1.5 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21007.

Subulicium lautum (H.S. Jacks.) Hjortstam & Ryvarden
Single record from *Juniperus communis*.
Basidiocarps seen in September; in oligotrophic boreal heath forest; in Pärnu County.
Substrate diametre: 2.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21712.

Thanatephorus fusisporus (J. Schröt.) Hauerslev & P. Roberts
13 records from *Juniperus communis*.
Basidiocarps seen from August to November; in eutrophic alvar juniper shrublands and mesotrophic boreal forests; in Harju, Hiiu, Lääne, Saare Counties.
Substrate diametre: 1.0–5.0 cm (average 2.0 cm, N=12).

Decay stages: 1 (50.0%), 2 (41.7%), 3 (8.3%), 4 (0%), N=12.

Trametes hirsuta (Wulfen) Lloyd
2 records from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar juniper shrublands; in Hiiu Counties.
Substrate diametre: 8.0 cm (average 8.0 cm, N=2).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=2.
Voucher specimen studied: HK 21922.

Trechinothus smardae (Pilát) E.C. Martini & Trichies
4 records from *Juniperus communis*.
Basidiocarps seen from September to October; in eutrophic alvar juniper shrublands and mesotrophic boreal forests; in Hiiu, Lääne and Saare Counties.
Substrate diametre: 0.5–6.0 cm (average 2.5 cm, N=3).
Decay stages: 1 (50%), 2 (25%), 3 (0%), 4 (25%), N=4.
Voucher specimens studied: TAAM 196584, HK 21167, HK 21170, HK 21926.

Trechispora byssinella (Bourdot) Liberta
Single record from *Juniperus communis*.
Basidiocarps seen in November; in oligo-mesotrophic boreal forest; in Põlva County.
Substrate diametre: 5.0 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: TAAM 201100.

Trechispora cohaerens (Schwein.) Jülich & Stalpers
3 records from *Juniperus communis*.
Basidiocarps seen from September to October; in mesotrophic boreal forests and oligotrophic boreal heath forests; in Pärnu and Saare Counties.
Substrate diametre: 1.0–3.0 cm (average 1.8 cm, N=3).
Decay stages: 1 (33.3%), 2 (33.3%), 3 (33.3%), 4 (0%), N=3.
Voucher specimens studied: HK 21055, HK 21092, HK 21658.

Trechispora farinacea (Pers.) Liberta
3 records from *Juniperus communis*.
Basidiocarps seen from July to September; in Saare County.
Voucher specimens studied: TAAM 101417, TAAM 154306, 167907.

Trechispora stevensonii (Berk. & Broome) K.H. Larss.
Single record from *Juniperus communis*.
Basidiocarps seen in October; in mesotrophic boreal forest; in Saare County.
Substrate diametre: 1.5 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21066.

Trechispora tenuicola (Litsch.) K.H. Larss.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in oligotrophic boreal heath forest; in Pärnu County.
Substrate diametre: 0.3 cm (N=1).
Decay stage: 3 (N=1).
Voucher specimen studied: HK 21699.

Tubulicrinis calothrix (Pat.) Donk
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic paludifying forest; in Saare County.
Voucher specimen studied: TAAM 167392.

Tubulicrinis confusus K.H. Larss. & Hjortstam
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic alvar forest; in Rapla County.
Voucher specimen studied: TAAM 153658.

Tubulicrinis medius (Bourdot & Galzin) Oberw.
Single record from *Juniperus communis*.
Basidiocarps seen in August; in mesotrophic boreal forest; in Saare County.
Substrate diametre: 0.5 cm (N=1).
Voucher specimen studied: TAAM 174013.

Tubulicrinis sororius (Bourdot & Galzin) Oberw.
8 records from *Juniperus communis*.
Basidiocarps seen from September to October; in eutrophic alvar juniper shrublands, oligotrophic boreal heath forests and mesotrophic boreal forests; in Hiiu, Lääne, Saare Counties.
Substrate diametre: 0.8–3.5 cm (average 1.8 cm, N=8).
Decay stages: 1 (50.0%), 2 (12.5%), 3 (37.5%), N=8.
Voucher specimens studied: TAAM 152784, HK 21083b, HK 21145, HK 21168, HK 21174, HK 21178, HK 21210, HK 22022.

Tylospora asterophora (Bonord.) Donk
Single record from *Juniperus communis*.
Basidiocarps seen in November; in oligotrophic boreal heath forest; in Lääne-Viru County.
Substrate diametre: 1.0 cm (N=1).

Decay stage: 1 (N=1).
Voucher specimen studied: HK 21524.

Tyromyces chioneus (Fr.) P. Karst.
Single record from *Juniperus communis*.
Basidiocarps seen in September; in eutrophic boreo-nemoral forest; in Ida-Viru County.
Voucher specimen studied: TAAM 002252.

Vararia cremeoavellanea Pouzar
Single record from *Juniperus communis*.
Basidiocarps seen in November; in eutrophic alvar juniper shrubland; in Harju County.
Substrate diametre: 0.2 cm (N=1).
Decay stage: 1 (N=1).
Voucher specimen studied: HK 21506.

Vararia ochroleuca (Bourdot & Galzin) Donk
2 records from *Juniperus communis*.
Basidiocarps seen in October; in eutrophic alvar juniper shrublands and eutrophic alvar forests; in Rapla and Saare Counties.
Substrate diametre: 3.0 cm (N=2).
Decay stages: 1 (100%), 2 (0%), 3 (0%), 4 (0%), N=1.
Voucher specimens studied: TAAM 006963, HK 21173.

Xenasmatella vaga (Fr.) Stalpers
10 records from *Juniperus communis*.
Basidiocarps seen from August to November; in mesotrophic boreal forests, oligotrophic boreal heath forests, oligo-mesotrophic boreal forests and eutrophic paludifying forests; in Harju, Hiiu, Põlva, Pärnu, Saare and Viljandi Counties.
Substrate diametre: 0.5–4.0 cm (average 2.8 cm, N=7).
Decay stages: 1 (85.7%), 2 (14.3%), 3 (0%), 4 (0%), N=7.

Xylodon pruni (Lasch) Hjortstam & Ryvarden
2 records from *Juniperus communis*.
Basidiocarps seen from September to October; in eutrophic alvar forests; in Lääne and Rapla Counties.
Substrate diametre: 1.5 cm (N=1).
Decay stages: 1 (0%), 2 (0%), 3 (100%), 4 (0%), N=1.
Voucher specimens studied: HK 21723, TAAM 196529.

DISCUSSION

Peniophora junipericola is the most common species of aphyllophoroid fungi found on juniper in Estonia (302 records in total). Its frequent occurrence is caused by wide ecological amplitude: the fungus can grow on thin as well as thick branches; on hard, newly dead branches, and on more or less decayed twigs (Sell et al., 2011). Although *Peniophora junipericola* is also found in Estonian inland, it is very rare there and does not grow in South Estonia. In south-eastern and southern Estonia (Põlva, Valga and Võru Counties), *Amylostereum laevigatum* is the most common species growing on juniper. On average, *Peniophora junipericola* prefers thinner branch substrates (mean diametre 1.1 cm, n=291) than *Amylostereum laevigatum* (3.0 cm, n=29, respectively). *Amylostereum laevigatum* can be regarded as the most common wood-rotting fungus on junipers in Finland (authors pers. comm.). But in Estonia, it is three times less frequent than *Peniophora junipericola*.

In one case, *Phylloporia ribis* was reported growing on *Juniperus communis* in a juniper shrubland on a small islet of Kumarilaid in Matsalu Nature Reserve, Estonia. The identification of the host is doubtful, because *Phylloporia ribis* has never been found on conifers, e.g. in Finland (Niemelä, 2005; Kotiranta et al., 2009). Likewise *Ribes alpinum* is a common plant on Kumarilaid Islet, and this might be a more probable host.

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REFERENCES

Adams, R.P. 2008. *Junipers of the World: The genus Juniperus*. 2nd ed., Trafford Publishing Co., Vancouver.

Kaar, E. 1965. Kadakas – loopealsete ja paekaljude küpress. *Eesti Loodus* 2: 69–75.

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

Kukk, T., Sammul, M. 2006. *Loodusdirektiivi poollooduslikud kooslused ja nende pindala Eestis.* Sammul, M. (toim.) ELUS 84. aastaraamat. Tartu, Eesti Looduseuurijate Selts: 114–158.

Lõhmus, E. 2004. *Eesti metsakasvukohatüübid.* EPMÜ Metsanduslik Uurimisinstituut, Eesti Loodusfoto. Tartu.

Niemelä, T. 2005. Käävät, puiden sienet. *Norrlinia* 13: 1–320.

Paal, J. 1997. *Eesti taimkatte kasvukohatüüpide klassifikatsioon. Classification of Estonian vegetation site types.* TÜ Botaanika ja Ökoloogia Instituut. Tallinn.

Parmasto, E., Parmasto, I. 1992. *Peniophora junipericola* (Aphyllophorales, Corticiaceae): distribution and spore variability. *Karstenia* 32: 13–16.

Parmasto, E. 2004. *Distribution maps of Estonian fungi. 3. Pore fungi.* Institute of Zoology and Botany, Estonian Agricultural University, Tartu.

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

Sell, I., Kotiranta, H., Kaart, T. 2011. Habitat requirements of *Peniophora junipericola* (Basidiomycota, Russulales). *Annales Botanici Fennici* 48: 232–236.

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Education

2007–2012	Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, *PhD* studies in Mycology
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Professional employment

2006– ...	Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, specialist
2005–2006	Estonian University of Life Sciences, Institute of Agricultural and Environmental Sciences, laboratory assistant

Attending courses in Mycology

2009	Konnevesi Biological Station, Finland. Special course on identification of corticioid fungi.
2007	Finnish Environment Institute, Helsinki, Finland. Identification of corticioid fungi.
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Membership

2010– ...	Member of the French mycological society "Aphyllophiles"
2009–2010	Assessor of the Estonian Higher Education Quality Agency
2009– ...	Representative in Estonia of European Council for the conservation of fungi
2009– ...	Member of the Estonian Plant Protection Society
2007– ...	Member of the European Mycological Association
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Scientific Awards

2011	Scholarship of Raefond (Tartu City government and Estonian University of Life Sciences)
2010	Award of popularization of science, II prize (thanks to organizing popularization events of wood rotting fungi and publishing popular scientific papers on this field)
2009	Scholarship of the Estonian World Council, Inc.
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2011– ...	Inventory of protected fungal species of Pihla-Kaibaldi Nature Reserve in Estonia

2011– ...	Inventory of protected fungal species of Tahkuna Nature Reserve in Estonia
2011–2011	Monitoring of fungal species protected by law in Estonia
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2008–2008	Monitoring of fungal species protected by law in Estonia

Teaching experience in universities

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PK.0410	Plant pests and their control – lectures and practical sessions of plant pathology to the students of natural resources management and renewable energy resources, academic years 2007/08, 2008/09, 2009/10, 2010/11 and 2011/12
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PK.1214	Plant pests and their control – lectures and practical sessions of plant pathology to the students of farm management, academic years 2008/09 and 2010/11
PK.1203	Ornamental plant pests and their control – lectures and practical sessions of stem rot fungi to the students of ornamental horticulture, academic year 2009/10
PK.0392	Special course in ornamental plants – lectures and practical sessions of stem rot fungi to the *MSc* students of horticulture, academic year 2009/10

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BGBG 00.023	Field course of natural history – summer practics of mycology to the students of gene technology and biology, academic year 2006/07

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Dissertations supervised

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Eve Arnik, "Protected fungal species (Third Category) in Estonia and additional studies requirement in their localities", 2010

Marit Mett, "The fungi of paludifying forests and bog forests in East and South-Estonia", 2010, co-supervisor K. Kalamees

Annika Altmäe, "Rare polypores of Lahemaa National Park", 2009

Liana Lemloh, "Morphological characteristics of the species in the genus *Rigidoporus* and *Physisporinus*", 2009

Merike Merivald, "Morphological characteristics in the genus *Skeletocutis* and *Tyromyces*", 2009

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2011	Eesti Maaülikooli Raefondi Stipendium
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2009	Ülemaailmse Eesti Kesknõukogu Stipendium
2008	Eesti Maaülikooli Raefondi Stipendium
2006	I koht rahvusvahelisel üliõpilaste loodusteaduste konverentsil (“International Natural Sciences Students Conference 2006”), ettekande „Muraka looduskaitseala põlismetsade puitulagundavad seened“ (“Wood rotting fungi in primeval forests of the Muraka Nature Reserve in Estonia”) eest. Vilniuse Ülikool, Leedu
2006	Eesti Maaülikooli Raefondi Stipendium
2002	III preemia Noorte teadlaste teadustööde riiklikul konkursil teadustöö „Muna mustri ja kaalu varieeruvus kalakajakal (*Larus canus*)“ eest (juh. Kalev Rattiste)

Osalemine projektides vastutava täitjana

2011– ...	„Pihla-Kaibaldi looduskaitseala kaitstavate seeneliikide inventuur“, Keskkonnaamet
2011– ...	„Tahkuna looduskaitseala kaitstavate seeneliikide inventuur“, Keskkonnaamet
2011–2011	„Kaitsealuste seeneliikide seire“, Keskkonnaamet
2010–2010	„Täiendavate kaitsealuste seeneliikide püsielupaikade moodustamise ettepaneku koostamine“, Keskkonnaamet

2010–2010 „Kaitsealuste seeneliikide seire“, Keskkonnaamet
2009–2009 „Kaitsealuste seeneliikide seire“, Keskkonnaamet
2008–2010 „Järva ja Lääne-Viru regiooni haruldaste seente inventuur“, Riiklik looduskaitsekeskus
2008–2008 „Kaitsealuste seeneliikide seire“, Riiklik looduskaitsekeskus

Õppetöö läbiviimise kogemus kõrgkoolis

Eesti Maaülikool
PK.0410 Taimekahjustajad ja nende tõrje – fütopatoloogia osa loengud ja praktikumid loodusvarade kasutamise ja kaitse eriala statsionaarse õppevormi ja kaugõppe üliõpilastele õppeaastatel 2007/08, 2008/09, 2009/10, 2010/11 ja 2011/12
PK.0561 Mükoloogia ja Eesti seenestik – kand- ja kottseente praktikumid loodusvarade kasutamise ja kaitse ning loodusturismi erialade üliõpilastele õppeaastatel 2006/07, 2007/08, 2008/09 ja 2009/10
PK.1036 Taimekahjustajad ja nende tõrje – kand- ja kottseente osa loengud ja praktikumid aianduse ning põllumajandussaaduste tootmise ja turustamise erialade üliõpilastele õppeaastatel 2007/08 ja 2008/09
PK.1214 Taimekahjustajad ja nende tõrje – fütopatoloogia osa loengud ja praktikumid põllumajandusettevõtte majandamise eriala kaugõppe üliõpilastele õppeaastatel 2008/09 ja 2010/11
PK.1203 Ilutaimede kahjustajad ja nende tõrje – tüvemädanike osa loengud ja praktikumid iluaianduse eriala üliõpilastele õppeaastal 2009/10
PK.0392 Ilutaimede erikursus – tüvemädanike osa loengud ja praktikumid aianduse eriala magistriõppe üliõpilastele õppeaastal 2009/10

Tartu Ülikool
BGBG 00.023 Looduse tundmise praktika II – mükoloogia osa suvepraktika geenitehnoloogia ja bioloogia erialade üliõpilastele õppeaastal 2006/07

Euroakadeemia

E3B1050 Üldbioloogia (kogu ainekursus mahus 4,5 EAP) keskkonnakaitse eriala üliõpilastele õppeaastal 2010/11

Luua metsanduskool

Puude seenhaigused (kogu ainekursus mahus 32 tundi auditoorset õppetööd) arboristi eriala õpilastele õppeaastal 2011/12

Juhendamisel kaitstud lõputööd

Bakalaureusetööd Eesti Maaülikooli Metsandus- ja maaehitusinstituudis:

Katri Ahtijäinen, „Valitud kevadseente viljakehade esinemine 2011. aasta kevadel", 2011

Liilia Tamm, „Limatünniku (*Sarcosoma globosum*) viljakehade esinemine aastatel 2005–2011", 2011

Eve Arnik „III kategooria looduskaitsealused seeneliigid ja nende kaitsevajadus Eestis", 2010

Marit Mett „Ida- ja Lõuna-Eesti rabastuvate metsade ja rabametsade seenestik", 2010, kaasjuhendaja K. Kalamees

Annika Altmäe „Lahemaa rahvuspargi haruldased torikseened", 2009

Liana Lemloh „Tarjaku (*Rigidoporus*) ja lodupooriku (*Physisporinus*) seenerühmade liikide morfoloogilised tunnused ja ökoloogia", 2009

Merike Merivald „Peenpooriku (*Skeletocutis*) ja konttümaku (*Tyromyces*) seenerühmade liikide morfoloogilised tunnused ja ökoloogia", 2009

Liivika Looga „I kategooria kaitsealused seeneliigid Eestis", 2008

Kõik nimetatud 8 bakalaureusetööd on saanud kaitsmiskomisjoni poolt hindeks „A" (suurepärane) või „B" (väga hea). Lisaks on juhendamisel Annika Altmäe magistritöö Eesti Maaülikoolis teemal „Kuuse- (*Porodaedalea chrysoloma*), männi- (*P. pini*) ja lehisetaeliku (*P. laricis*) taksonoomia ja ökoloogia"

Retsenseerinud lõputöid ka Tartu Ülikoolis

LIST OF PUBLICATIONS

Publications indexed in the ISI Web of Science database:

Sell, I., Kotiranta, H., Miettinen, O., Põldmaa, K. 2012. Analysis of molecular characters confirms that *Botryodontia millavensis* and *Oxyporus philadelphi* are conspecific. Mycological Progress: submitted manuscript.

Sell, I., Kotiranta, H., Kaart, T. 2011. Habitat requirements of *Peniophora junipericola* (Basidiomycota, Russulales). Annales Botanici Fennici 48: 232–236.

Sell, I. 2008. Taxonomy of the species in the *Phellinus igniarius* group. Mycotaxon 104: 337–347.

Papers published in other peer-reviewed international journals with a registered code:

Sell, I., Kotiranta, H. 2011. Diversity and distribution of aphyllophoroid fungi growing on the Common Juniper (*Juniperus communis* L.) in Estonia. Folia Cryptogamica Estonica 48: 73–84.

Sell, I. 2006. Size and shape of basidiospores in the *Phellinus igniarius* group. Agronomy Research 4: 359–362.

Papers published in the proceedings of international conferences:

Gafforov, Y. S., Yarasheva, M. T., **Sell, I.**, Stenlid, J. 2012. Biodiversity of Uzbekistan, Central Asia: diversity of wood-inhabiting fungi in forest ecosystems. The 2nd Asia Regional Conference of the Society for Conservation Biology – Asia Section. August 7–10, 2012, Bengaluru (Bangalore), India.

Sell, I., Kotiranta, H. 2010. The ecology of *Peniophora junipericola* (Basidiomycota, Russulales). 9th International Mycological Congress IMC 9: The Biology of Fungi, Scotland, Edinburgh, August 1–6, 2010.

Sell, I. 2008. Taxonomy of the species in the *Phellinus igniarius* group. In: Abstracts: XVII Symposium of the Baltic Mycologists and Lichenologists. Estonia, Saaremaa, Mändjala, 17–21 September 2008. (ed.) Saar, I., Suija, A.. Tartu: Tartu University Publishing, 2008, 15–15.

Publications in popular scientific journals (in Estonian)

Ojango, U., **Sell, I.** 2011. Uus kährikseene leid Kõrvemaalt. Eesti Loodus [Estonian Nature] 10: 51–51.

Sell, I. 2011. Taiga-võrkpoorik Hiiumaal. Eesti Loodus [Estonian Nature] 8: 52–53.

Sell, I., Kalamees, K. 2011. Limatünnikust lakkvaabikuni. Eesti Loodus [Estonian Nature] 5: 29–31.

Sell, I. 2010. Liibuva roostetoriku esmasleid Eestist. Eesti Loodus [Estonian Nature] 10: 40–40.

Sell, I. 2010. Taelikud meie metsades. Eesti Mets [Estonian Forest] 3: 24–29.

Sell, I. 2010. Seenharuldus südalinnas. Eesti Loodus [Estonian Nature] 6: 53–53.

Sell, I. 2008. Looduse sügavuses. Eesti Loodus [Estonian Nature] 8: 28–29.

Sell, I., Kotiranta, H. 2007. Kadakatarjak Hiiumaal. Eesti Loodus [Estonian Nature] 12: 26–26.

Sell, I. 2006. Kühmtagel armastab Tartut. Eesti Loodus [Estonian Nature] 1: 51–51.

Sell, I. 2005. Puuseened haabadel. Eesti Loodus [Estonian Nature] 9: 44–45.

Sell, I. 2001. Ämblikmännid. Eesti Loodus [Estonian Nature] 5: 182–182.

Sell, I. 1999. Juulipäev Muraka rabas. Eesti Loodus [Estonian Nature] 7: 293–293.

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dots. **Alar Astover**, *PhD* **Merrit Shanskiy**

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