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Microfungus communities of rotting wood in the boreal mixed-wood region of northern Alberta, Canada

by

Trevor C. Lumley ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

Department of Biological Sciences

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Date: 4 Oct, 1999.

This entire work, from conception to completion, is dedicated to Sherry, for being a helping hand whenever I stumbled.

I also dedicate it to the memory of my grandfather, who passed away after this research began. I hope the fish are bitin'.

Abstract

Fallen logs provide habitat for forest dwelling animals and a rooting medium for many plant species, but the microfungi associated with rotting wood, especially during the late stages, are poorly known. The purpose of this research was to identify the communities of microfungi associated with rotting wood and to evaluate the effects of log and site variables on these communities. Logs of trembling aspen and white spruce at various stages of decomposition were sampled from undisturbed and 1-, 14-, and 28-year-old post-fire and post-harvest sites in northern Alberta. Wood samples were plated directly onto each of six different media from which fungal species were identified and enumerated. Approximately 10 000 isolates were obtained, representing 289 species of filamentous microfungi including 30 zygomycetes, 44 ascomycetes, and 215 fungi imperfecti. A list of species recovered is provided, with annotations supporting their identification, as well as pertinent ecological information, including known habitat and enzymatic capabilities.

A large number of ascomycete species was isolated, including taxa that are poorly-known (e.g. Microascaceae) or unknown from wood (e.g. *Gymnoascus* spp.). Members of the genus *Pseudogymnoascus* (Myxotrichaceae: Onygenales) were isolated with unexpected frequency, including several rare and one species newly described as part of this research. Wood decomposition microfungus communities displayed evidence of succession concurrent with the breakdown of logs and changes in overall log morphology. Undisturbed site logs showed a transition in microfungus communities that was correlated to stage of decomposition. Mean number of species per sample was highest for undisturbed sites (4.6) and lowest in the most recently disturbed sites (2.0 – 2.2) with an increase over time following disturbance. In general, species diversity (Shannon) showed no significant trend, but the greatest diversity was found in undisturbed sites. Cluster analysis of microfungus communities from logs showed distinct spruce and aspen groupings, demonstrating a significant influence of log species on microfungus communities. Ordination of log microfungus communities confirmed the influence of log species, but also showed an influence of stage of decomposition, log

moisture, and site variables, including precipitation, temperature, type of disturbance, and time since disturbance.

Acknowledgments

The greatest and most significant accomplishments in our lives are impossible without the help of others. Unfortunately, we are rarely afforded the opportunity to acknowledge the support of those people. Thus it gives me a great deal of satisfaction to offer my heart-felt thanks to all those who contributed to the completion of this work. First and foremost, I owe a debt of gratitude to my family. To Sherry, my wife, friend, confidante, psychiatrist, lab technician, secretary, fan, and mother of my son. Her patience and support were in seemingly endless supply, even when I am sure I deserved neither. To Jared, my son, for providing the purest kind of inspiration.

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Many others have helped with technical aspects of this research, as field or lab technicians, or as editors, and to Sean Abbott, George Braybrook (SEM), Trevor April, Jim Wickware, and Markus Thormann, in particular, I offer my thanks. I also owe a debt of gratitude to the gang at the University of Alberta Microfungus Collection and Herbarium (Lynne Sigler, Arlene Flis, Sean and Linda Abbott) for patiently dealing with my cultures, and many times going out of their way to help me.

Finally, I wish to acknowledge the financial support from Sustainable Forest Management Network, Biodiversity Grants Program (Alberta Department of Environmental Protection, Fish and Wildlife Trust Fund and the University of Alberta, Department of Biological Sciences), and Canadian Circumpolar Institute.

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Chapter 1. Introduction and literature review

Rotting logs are an important element of the boreal forest in that they represent a significant carbon source, but they also provide a habitat for animals (Olszewski, 1968) and plants (Harvey et al., 1979; Kropp, 1982; McGee and Birmingham, 1997). Our understanding of the fungi associated with rotting wood comes mainly from research on basidiomycetes from the early stages of decomposition (Boddy et al.,1987; Boddy and Rayner, 1984; Martin and Gilbertson, 1978; Rayner and Boddy, 1988; Shigo, 1972). Although information is sparse, non-basidiomycetous fungi also appear to be significant components of wood decomposition communities. Ascomycetes and fungi imperfecti cause soft-rot, producing a damp, spongy wood, and zygomycetes have been reported in rotting wood (Good and Nelson, 1962; Chapela, 1989; Crane et al., 1996) and may be dominant during the latter stages (Crawford et al., 1990). However, the species involved in late stage communities (community composition) and how their numbers change as decomposition proceeds (succession), are virtually unknown.

Community composition and succession

Over the course of decomposition, physical and chemical characteristics of wood change. First, water accumulates from incipient to advanced stages of decomposition, and 5- to 10-fold increases are not uncommon (Jurgensen et al., 1984; Larsen et al., 1978). Second, levels of available nutrients, especially nitrogen, change as wood decomposes (Fyles et al., 1990; Grier, 1978). The C:N ratio of newly-fallen wood can be as high as 2000:1 (Levi and Cowling, 1969), levels at which only certain basidiomycetes can degrade cellulose. Nitrogen accumulates as decomposition proceeds and nitrogen availability may be an important factor in the transition of wood decomposition communities (Dix and Webster, 1995). Finally, temperature and moisture have been shown to be important factors in the formation of microfungus communities in leaf litter (Kuter, 1986; Widden, 1984), but a similar effect on wood communities has not been investigated. In addition to community changes driven by chemical and environmental changes in the logs, species interactions are probably a significant impetus. Antagonistic interactions can be direct, including overgrowth and parasitism, or indirect, such as antibiosis or competition for space (Dix and Webster, 1995).

Unlike seral succession, substrate succession leads, not to a stable climax community, but to complete mineralization of a substrate (defined here as a nutritional resource, such as cellulose or keratin) or a substratum (the immediate environment of the fungal mycelium, e.g., dung, wood, etc.). This type of succession is common among saprobic fungi, including those communities associated with plant debris (Gams, 1992). Nikolayevskaya and Chastookhin (1945) reported a triphasic colonization process, or "succession" for fungi in spruce wood. The first phase was a pioneer colonization phase, and several genera of dematiaceous hyphomycetes. The second phase involved the "wood destroyers", fungi that acidified the wood and promoted the colonization by acid tolerant fungi imperfecti. The third phase, or "red rot" phase, was characterized by a rise in pH and subsequent colonization by a larger suite of fungi imperfecti.

More recent research on various log species and on wooden stakes has broadened our understanding of community development. The first fungi to appear are soil fungi,

mainly species of *Aureobasidium, Cladosporium, Mortierella, Mucor, Penicillium*, and *Trichoderma*, which colonize non-lignified cell walls (Dix and Webster, 1995; Rayner, 1977). Basidiomycetes and soft rot fungi probably colonize next, degrading lignin and cellulose, followed by what Clubbe (1980) and Butcher (1968) refer to as secondary molds, fungi that show a diversity of enzymatic capabilities. These "sugar fungi" lack ligninases and cellulases and probably benefit from cellulolysis residuals (Hudson, 1968). They occur, to some extent, at all successionary stages (Gams, 1992) and accelerate the decomposition process (Hulme and Shields, 1975).

Ecological analysis

The application of ecological techniques in mycology has been problematic and, according to Thomas and Shattock (1986), these techniques have not been sufficiently challenged. First, there is no real consensus on the validity of sampling techniques or degree of effort required to establish a representative cross-section of a community. The presence of fruiting structures gives little indication of the diversity of species present as mycelium and, consequently, isolation is the only method that accurately reflects the true composition of communities. The weakness of most isolation studies is that dilution plating preferentially selects prolifically-sporulating species, and direct plating causes plates to be overrun by these species. Crawford et al (1990), for example, used dilution plating for isolation from late stage Douglas fir logs and recovered 36 species of microfungi, 18 of which were species of *Penicillium*, giving a skewed impression of late stage communities.

Second, there is no clear definition of what an individual is and what a population comprises. This limits the types of analyses that can be performed to those that utilize presence-absence data or importance values based on frequency of isolation, number of isolates, or counting visible fruiting bodies for macrofungal species (Singh, 1976; Wacha and Tiffany, 1979; Wicklow and Whittingham, 1974). In most cases, abundance estimates are prone to overestimation of abundance for prolifically-sporulating species, and underestimation in non- or poorly-sporulating species. In the case of macrofungi, abundance estimates are affected by seasonality and ephemerality of fruiting bodies and, as previously mentioned, fail to accurately reflect mycelial communities. Consequently, diversity indices, which rely on abundance values, have proven difficult to interpret. Although species richness can be estimated so that samples or sites can be compared, the inconsistency in abundance estimates from one study to the next limits comparison among studies. Diversity indices can, however, be used to compare communities within studies, especially with respect to effects of certain environmental parameters (e.g., Bissett and Parkinson, 1979).

Disturbance

Disturbance generally decreases species diversity, by increasing dominance of few species, and increases the number of ruderal species (Odum, 1985). Post-disturbance communities of animals (Attiwill, 1994), plants (Ahlgren, 1960; Outcalt and White, 1981), and bacteria (Grier, 1975) have all demonstrated effects of disturbance. Although there has been some research on the effect of disturbance on soil fungi (Bradbury, 1998;

Bradbury et al., 1998; Egger, 1986; Widden and Parkinson, 1975), the effect of disturbance on wood decomposition fungus communities has not been investigated.

Thesis objectives

The purpose of this study was to identify and contrast the communities of microfungi associated with decomposing logs of trembling aspen and white spruce at different stages of decomposition and from undisturbed, post-fire, and post-harvest sites. My hypothesis was that rotting wood is much richer in species of ascomycetes, fungi imperfecti, and zygomycetes than previous studies indicate, and that careful isolation using a broad range of media and long incubation time would reflect this. Additionally, I hypothesized that some species would be more common from a certain decomposition stage (or stages) or log species, thus contributing to significant community differences for different log classes (log species and stage of decomposition). The annotated list in Chapter 2 provides basic information on the habitats of these fungi and some clues to their identification in pure culture. Geographic ranges have been expanded for numerous species, and for some species, wood is newly-reported as a substratum.

Chapter 3 is a taxonomic revision of the genus *Pseudogymnoascus*, including description of a new species and justification for new combinations based on the synonymization of *Gymnostellatospora* with *Pseudogymnoascus*. This revision was prompted by observations made possible only after isolation, from wood, of several species previously known from only one or two isolates.

The primary hypothesis tested in chapter 4, and the pivotal principle on which the rest of the research was based, is that morphologically distinct decomposition stages display unique assemblages of microfungi. Secondary hypotheses were that these communities are influenced by log variables (species, diameter, moisture), climatic variables (mean daily temperature, mean annual precipitation, and degree-days greater than 5 °C), and site variables (type of disturbance and time since disturbance). Assessing the importance of environmental variables in determining community composition is critical for understanding the dynamics of these communities.

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Chapter 2. Annotated list of filamentous microfungi from rotting wood*

Introduction

Decomposing logs constitute a significant proportion of biomass in the boreal forest and are also sites of significant non-symbiotic nitrogen fixation (Jurgensen et al., 1992), thus contributing usable nitrogen to forest soil. Understanding the microbiology of rotting wood may lead to a better understanding of the contribution of rotten wood to nutrient reservoirs as wood is humified and nutrients are released (Abbott and Crossley, 1982). However, our knowledge of wood decomposition microbiology comes almost exclusively from studies of basidiomycetes (Niemelä et al., 1995), especially during the early stages of decomposition (Frankland et al., 1982; Martin and Gilbertson, 1978; Rayner and Todd, 1979). There is evidence that wood decomposition fungus communities increase in complexity as wood decomposes, and include other groups of fungi. Ascomycetes, fungi imperfecti, and zygomycetes have all been observed in rotting wood (Chapela, 1989; Crane et al., 1996), and ultimately contribute to the mycoflora of soil as wood becomes humified. The species involved in these communities and how their numbers change as decomposition proceeds are unknown.

Several reports exist of microfungi from rotting wood. Crawford et al. (1990) investigated the filamentous microfungi of decomposing Douglas fir (*Pseudotsuga menziesii* (Mirb) Franco) logs and observed 33 species (excluding basidiomycetes and yeasts), including 18 species of *Penicillium*, and one zygomycete species (*Mortierella ramanniana*). Crane et al. (1996) reported a number of common microfungus species from standing aspen (*Populus tremuloides* Michx.), including a number of *Phialophora* and coelomycete species, but no zygomycete or *Penicillium* species. Butcher (1968) isolated four zygomycetes, two ascomycetes, and 22 species of fungi imperfecti, the most common of which was *Trichoderma viride*.

The purpose of this study was to conduct a comprehensive survey of microfungi from rotting wood of trembling aspen and white spruce at all stages of decomposition and from various sites, including post-fire and post-harvest sites. I hypothesized that decaying wood is much richer in fungal taxa than previous studies indicate, and the use of different media, longer incubation time, and sampling from all stages of decomposition would yield a species number that reflects this.

Materials and Methods

Eight log classes, defined on the basis of species and decay stage, were studied, including five decay stages in white spruce and three in aspen. Decay stages of white spruce (*Picea glauca* (Moench) Voss) follow Sollins (1982):1, bark and all branches intact; 2, fine branches lost and bark loosening; 3, most bark and branches gone; 4, bark and branches gone and wood softened; and 5, wood crumbly, usually moss-covered, and sunken into the humus. Stage 1 trembling aspen (*Populus tremuloides* Michx.) had bark and branches

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* A version of this chapter has been submitted for publication. Lumley, T. C., S. P. Abbott, and R. S. Currah. 1999. Microscopic ascomycetes isolated from rotting wood in the boreal forest. *Mycotaxon*.

intact, stage 2 had no branches and occasionally some bark, and stage 3 was moss covered, stringy, and sunken into the humus.

Sampling

Sites were located in the southern boreal mixed-wood of Alberta (Table 1) as follows: one undisturbed site at Elk Island (UEI) (site 1 in Fig. 1); four sites near Mariana Lake (sites included as "a"), including one undisturbed (UML), and three post-fire (F83, F91, and F93); five near Slave Lake (sites 4-8), including one post-fire (F61) and four post-harvest (H61, H62, H82, and H83); one post-fire near Little Buffalo (F82, site 9); one post-harvest near Calling Lake (H91, site 2); and one post-harvest near the Lawrence Lake Recreation area (H93, site 3).

At undisturbed sites, six sections per log were taken from each of the eight different log classes. Five white spruce logs, one from each of five decomposition classes, and three aspen logs, one from each of the three decomposition classes, were sampled. Stages 1, 2, and 3 spruce, and stages 1 and 2 aspen logs were sampled by cutting, using an ethanol-sterilized bow-saw, 5 to 10 cm thick sections ("cookies") at 1 m intervals along the length of the log, beginning at approximately 1 m from the base of the tree. Cookies were bagged and transported to the laboratory and put immediately in cold storage. Wood was processed within 48 hours after collection. From cookies, ten samples were taken along a vertical transect at 10 equidistant points. The first sample was taken from the top of each section and included bark, if present. The last sample was taken from the part of the section closest to the ground. Wood from late stage logs was collected by taking the first sample from the top of the log, and then excavating a hole through the centre of the log, and taking 2-3 cm^3 samples at nine equidistant points, with the last sample coming from the bottom of the log. Wood from fire and harvest sites was similarly sampled, but only three sections from each log and only five samples from each section were collected to accommodate a larger number of sites. In addition, the number of logs per site varied with availability of each log type. Harvest sites, for example, contained no early stage spruce logs.

Isolation

Wood from cookies was extracted by shaving off a thin layer of wood using an ethanol-sterilized chisel, and digging out a 1 cm^3 sample from the underlying wood. All wood samples were surface sterilized by brief flame exposure, broken up using a sterile scalpel, and plated, 5-10 pieces per plate, onto each of six media: malt extract agar (MEA, 1.5 % Difco malt extract, 1.5 % Difco agar, w:v), tapwater agar (1.5 % agar w:v in water), cornmeal agar (Difco), MEA with benomyl (4 ppm), MEA with rose bengal (50 ppm), and Mycobiotic agar (Difco). Tetracycline (0.01 %) was added, after autoclaving, to all media to inhibit the growth of bacteria.

Identification and culture maintenance

Primary isolation plates were assessed for fungal growth after four weeks and again every 8-12 weeks for 18-24 months, depending on the condition of the plates.

Plates that were overrun by mites, nematodes, or other microinvertebrates were discarded. Fungi were identified directly from primary isolation plates where possible, or were isolated into pure culture for further manipulation. To avoid confusion, a "record" from this study refers to the presence of a species in a sample, regardless of number of occurrences from one sample. Only fungi producing distinctive diagnostic colonial or micromorphological features were enumerated, even though yeasts constituted 5-10 % of isolates, basidiomycetes constituted 10-15 % of isolates, and sterile, non-basidiomycetous isolates constituted approximately 5 % of isolates. Where sporulation was slow or conidia were produced in small quantities, slide cultures were employed using the cover slip sandwich technique (Sigler, 1992). Representatives of some species have been accessioned, including live cultures, at the University of Alberta Microfungus Collection and Herbarium (UAMH) and others have been accessioned, as microscope slides, at the University of Alberta Cryptogam Herbarium (ALTA).

Results

Overall, species richness, as measured by number of species per sample, was lowest for stage 1 logs of both aspen and spruce (Fig. 2.2) and increased with stage of decomposition. Approximately 10 000 records were obtained, comprising 289 identified species, including 44 ascomycetes, 30 zygomycetes, and 215 fungi imperfecti. The most frequently isolated species were *Rhinocladiella atrovirens* (10.6 % of records), *Trichoderma viride* (10.2 %), *Mortierella ramanniana* (4.6 %), and *Oidiodendron griseum* (4.5 %). This was a reflection of the dominance of these species in the undisturbed sites, where most of the samples were taken. *Rhinocladiella atrovirens* was also among the most abundant species for most sites, with the exception of H61 and H93. Other species that dominated sites were *Gliocladium viride* (F82: 14.4 %, H62: 21.9 %, H83: 27.1 %), *Cordana pauciseptata* (F83: 11.5 %), *Aspergillus versicolor* (H82: 14.5 %), and *Phialophora americana* (H93: 15.6 %). A number of species also showed affinity to certain log classes, as demonstrated by their abundance on logs from the undisturbed sites (Figs. 2.3-2.5).

Trichoderma and *Penicillium* were the most abundant genera for all site types, and *Verticillium, Leptographium, Phialophora, Acremonium*, and *Oidiodendron* were common, but their abundance varied with site type (Fig. 2.6). Undisturbed site logs had the greatest average number of records per sample, followed by post-fire and post-harvest (Fig. 2.7).

Annotations

Annotations provide noteworthy diagnostic characters, as well as any unusual features of isolates from this study, with ascomycetes first, followed by fungi imperfecti and zygomycetes. Each annotation begins with name and citation, distinctive diagnostic morphological information, followed by isolation information from this study, isolation information from literature, including substrata and biogeography, and enzymatic capabilities, where known. Detailed descriptions are found in the reference provided for each species. To designate a taxon as a new record for Alberta, Canada, or North

America, published works (Journal papers, culture catalogues, books) were searched, but herbarium records and other unpublished works (e.g., foray lists) were not.

Ascomycetes

Arthroderma curreyi Berkeley, 1860, *Outlines of Brit. Fungology*, p. 357.

Heterothallic, cleistothecia white, sterile, appendages coiled. *Chrysosporium* anamorph. From stage 2 spruce and stage 1 aspen, UEI (UAMH 8728), and stage 1 aspen, H93. Reported from soil, often carried by birds (Pugh, 1964) or small mammals. First report for Canada and from wood. Keratinolytic (Currah, 1985). Ref.: Currah (1985).

Byssochlamys* cf. *fulvus Oliver & Smith, 1933, *J. Bot. Lond.* 72: 197.

Cleistothecia tan, ascospores hyaline, 6 x 4 µm, *Paecilomyces* anamorph abundant. From stage 3 aspen, UEI, and stage 2 spruce, F61. *Byssochlamys fulvus* has been reported mainly as a contaminant, worldwide. Ref.: Brown and Smith (1957).

Chaetomium funicola Cooke, 1873, *Grevillea* 1: 176.

Perithecia with two-tiered hairs, ascospores 5.5-6.5 x 3.5-5 µm, with one end more pointed. From stage 5 spruce and stage 1 aspen (UAMH 9370), UEI, and from stage 1 aspen, H82. Reported from timber, paper, and forest soil, worldwide (Hammill, 1970). Celluloytic, can cause soft-rot (Duncan and Eslyn, 1966). Ref.: Domsch et al. (1980).

Chaetomium globosum Kunze: Fries, 1829, *Syst. Mycol.* 3: 226.

Perithecia with undulating terminal hairs, ascospores 8.5-11 x 7-9 µm. From stage 3 aspen, UEI, and stage 2 aspen, UML (UAMH). Reported from cellulosic substrata, including litter (Hayes, 1965) and wood (Mangenot, 1952), worldwide, including Alberta (Sigler and Flis, 1998). Cellulolytic (Savory and Pinion, 1958). Ref.: Domsch et al. (1980).

Chaetomium homopilatum Omrik, 1953, *Mycologia* 47: 749.

Perithecia elongate, with straight terminal hairs, ascospores apiculate, 8.5-10 x 4.5 µm, *Botryotrichum* anamorph. From stage 2 aspen, UEI. Reported from cellulosic substrata, worldwide (von Arx et al., 1986). First report for Canada. Ref.: von Arx et al. (1986).

Coniochaeta ellipsoidea Udagawa, 1967, *Trans. Mycol. Soc. Japan* 8: 51.

Perithecia setose, ascospores ellipsoid, asymmetrical, 20-25 x 10-11.5 µm. From stage 3 spruce, F61. Reported from soil, Japan and Spain (Udagawa and Takada, 1967). First report for North America and from wood. Ref.: Mahoney and LaFavre (1981).

Coniochaeta malacotricha (Auserwald) Traverso, 1907, *Flora Italica Cryptogama* 1: 473.

Perithecia densely setose, ascospores narrow-ellipsoid, 10-12.5 x 5.5-7 µm. From stage 2 spruce, UML (UAMH 9375) and stage 3 spruce, F82. Reported from conifer

wood (Mahoney and LaFavre, 1981; Rogers and Grand, 1971), including *Pinus* (Ontario; Ginns, 1986). First report for western Canada. Ref.: Mahoney and LaFavre (1981).

Coniochaeta saccardoi (Marchal) Cain, 1968, *Bibl. Mycol.* 9: 65.

Perithecia densely setose, ascospores narrow-ellipsoid, 14-17 x 6-7.5 µm. From stage 5 spruce and stage 2 aspen, UEI, stage 1 spruce, F61 and F93, and stage 3 aspen, F82, F93, and H82. Reported from dung, Saskatchewan (Mahoney and LaFavre, 1981; rabbit dung, Saskatchewan (Cain, 1934). First report from wood. Ref.: Mahoney and LaFavre (1981).

***Coniochaeta* sp.**

Perithecia ovoid, setose, ascospores 11.5-14 x 4.5-5.5 µm, *Lecythophora* anamorph. From stage 1 spruce, UML. Ascospores consistently smaller than those of *C. saccardoi,* otherwise similar.

Cryptendoxyla hypophloia Malloch & Cain, 1970, *Can. J. Bot.* 48: 1816.

Ascomata ostiolate, peridium cephalothecoid, ascospores dark brown, long-cylindrical, 4.5-5.5 x 2-3 µm. *Chalara* anamorph. From stage 1 aspen, UEI (UAMH). Previously known only from under bark of a deciduous tree, Ontario (Malloch and Cain, 1970). First report for western Canada. Ref.: Malloch and Cain (1970).

Emericella nidulans (Eidam) Vuillemin, 1927, *Compt. Rend. Hebd. Seances Acad. Mem. Soc. Biol., Paris* 184: 137.

Cleistothecia red-brown, ascospores flanged, 4-6 x 3-4 µm, *Aspergillus* state, conidia rough-walled, globose, on biseriate aspergilla, conidiophores pigmented. From stage 2 aspen, UEI. Known mostly from warm regions (Domsch et al., 1980), but reported for Canada (Bisby et al., 1935) including Alberta (Sigler et al., 1996). Cellulolytic (Marsh et al., 1949; Reese and Levinson, 1952) and possibly ligninolytic (Bull and Carter, 1973). Ref.: Domsch et al. (1980).

Eremomyces bilateralis Malloch & Cain, 1971, *Can. J. Bot.* 49: 849.

Cleistothecia dark, splitting at maturity, ascospores hyaline. From stage 2 aspen, UEI (UAMH 8972, 8973). Reported from herbivore dung in Africa and North America (Malloch and Cain, 1971; Malloch and Sigler, 1988). First report for Canada and from wood. Ref.: Malloch and Cain (1971).

Eupenicillium lapidosum Scott & Stolk, 1967, *Antonie Leeuwenhoek J. Microbiol.* 33: 298.

Cleistothecial, ascospores echinate, 6-6.5 x 4-4.5 µm, with 2 equatorial crests, *Penicillium* anamorph. From stage 3 and 5 spruce, UML, stage 2 aspen, F82, and stage 1 spruce, F83. Reported from soil (Pitt, 1988). First report for western Canada and from wood. Ref.: Pitt (1988).

Eurotium chevalieri Mangin, 1901, *Ann. Sci. Nat. Bot., Ser. 9*, 10: 361.

Ascomata bright yellow, ascospores subglobose, smooth, flanged, 4.5 µm diam. Anamorph in *Aspergillus glaucus* group. From stage 5 spruce, UML. Reported mainly from tropical and subtropical soil (Domsch et al., 1980), but also from air, Alberta (Sigler et al., 1996). Enzymatic capabilities not well defined (Domsch et al., 1980). Ref.: Domsch et al. (1980).

Gelasinospora endodonta (Malloch & Cain) von Arx, 1973, *K. Ned. Akad. Wet. Proc., Ser. C*, 76: 290.

Perithecia pyriform, ascospores black, ellipsoidal, 18.5-22 x 14.5-17 µm, surface with conical pits. From stage 3 spruce, F83. Reported from soil, Australia (Malloch and Cain, 1971). First report for North America and from wood. Ref.: Malloch and Cain (1971).

Gelasinospora retispora Cain, 1950, *Can. J. Res.* 28: 573.

Colonies fast-growing, perithecia dark, ascospores dark, opaque, 28-32 x 14-16 µ m, pitting angular-reticulate. From stage 5 spruce, UEI. Reported from soil and wood, worldwide (Cain, 1950). First report for western Canada. Ref.: Domsch et al. (1980).

Gelasinospora tetrasperma Dowding, 1933, *Can. J. Res.* 9: 294.

Perithecia black, ascospores black, ellipsoidal, 23-27 x 13-16 µm, surface finely pitted. From numerous logs, almost exclusively from bark, from undisturbed, post-fire, and post-harvest sites. Reported previously from herbivore dung, mainly in northern Canada (Cain, 1950). Ref.: Cain (1950).

Gymnoascus reessii Baranetzky, 1872, *Bot. Ztg.* 30: 158.

Colonies slow-growing, cleistothecia small, orange-brown, appendages bifurcate or trifurcate, ascospores oblate, red-brown, smooth, 3-4 x 1.5-2.5 µm. From stages 4 and 5 spruce, UEI (UAMH 8531). Reported from soil and dung, worldwide (Domsch et al., 1980). Enzymatic capabilities not well defined (Kuehn and Orr, 1962). Ref.: Currah (1985).

Gymnoascus uncinatus Eidam, 1880, *Cohn Beitr. Biol. Pfl.* 3: 292.

Cleistothecia yellow-brown, peridial appendages long, uncinate, ascospores oblate, 2-5.5 x 1.5-3 µm. Anamorph resembles *Chrysosporium merdarium* (Link) Carm. From stages 4 and 5 spruce and stage 2 aspen, UEI (UAMH 8530). Reported from dung (Samson, 1972). First report for western Canada and from wood. Weakly cellulolytic. Ref.: Currah (1985).

Kernia retardata Udagawa & Muroi, 1981, *Trans. Mycol. Soc. Japan* 22: 18.

Cleistothecia black, globose, ascospores light brown, ellipsoid, 6-8 x 4.5-5.5 µm. *Scopulariopsis* anamorph. From stages 4 and 5 spruce, UEI (UAMH 9420, 9454). Previously known only from the type, from rice field soil in Japan (Udagawa and Muroi, 1981). First report for North America and from wood. Ref.: Udagawa and Muroi (1981).

Leptosphaerulina argentinensis (Spegazzini) Graham & Luttrell, 1961, *Phytopathol.* 51: 687.

Pseudostromata black, ascospores muriform, with 5 longitudinal and 3 transverse septa, mostly 34 x 12.5 µm. From stage 4 spruce, UEI (UAMH 9507). Previously known as a leaf saprophyte (Graham and Luttrell, 1961). First report from wood. Ref.: Graham and Luttrell (1961).

Microascus albonigrescens (Sopp) Curzi, 1931, *Boll. Staz. Patol. Veg. Roma* 11: 60.

Perithecia black, short-necked, ascospores allantoid-reniform, orange, 3-5 x 2.5-3.5 µm, *Scopulariopsis* anamorph. From stages 2 (UAMH 8487, 8490), 4, and 5 (UAMH 9148) spruce and stage 2 aspen, UEI. Reported from wood, Sweden (CBS catalogue) and litter, Japan (Sigler and Flis, 1998). First report for Canada. Cellulolytic (Abbott, Persoon com.). Ref.: Barron et al. (1961).

Microascus brevicaulis S.P. Abbott, 1998, *Mycologia* 90: 298.

Perithecia black, subglobose, papillate, ascospores reniform, 5-6 x 3.5-4.5 µm, anamorph *Scopulariopsis brevicaulis* (Saccardo) Bainier. From stages 2 and 4 spruce, UEI (UAMH 9387). Previously known from air, birdhouse straw, and housefly larvae, Alberta (Abbott et al., 1998). First report from wood. Weakly cellulolytic (Abbott et al., 1998). Ref.: Abbott et al. (1998).

Microascus cirrosus Curzi, 1930, *Boll. Staz. Patol. Veg. Roma* 10: 302.

Perithecia black, necks hairy and/or twisted, ascospores broadly reniform, 3.5-5.5 x 4-5.5 µm, *Scopulariopsis* anamorph, conidia brown, ellipsoidal. From stages 2 and 4 spruce (UAMH 9153), UEI. Reported from soil and litter, including for Canada (Barron et al., 1961). First report for western Canada and from wood. Weakly cellulolytic (Abbott pers. com.). Ref.: Barron et al. (1961).

Microascus longirostris Zukal, 1885, *Verh. Zool.-Bot. Ges. Wien* 35: 339.

Perithecia black, long-necked, ascospores orange, small, reniform, 3-4 x 2.5 µm, *Scopulariopsis* anamorph. From stage 2 aspen, UEI (UAMH 9151). Reported from wood, dung in Alberta, and air in Saskatchewan (Sigler and Flis, 1998). Weakly cellulolytic (Abbott, pers. com.). Ref.: Barron et al. (1961).

Microascus manginii (Loubière) Curzi, 1931, *Boll. Staz. Patol. Veg. Roma* 11: 60.

Perithecia black, papillate, ascospores orange, reniform, 4-6 x 5.5-5 µm, anamorph *Scopulariopsis candida* (Guégen) Vuillemin. From stages 2 and 4 spruce, UEI (UAMH 9147, 9174). Reported from air and chickens, Alberta and from wood, Ontario (Sigler and Flis, 1998). Weakly cellulolytic (Abbott pers. com.). Ref.: Barron et al. (1961).

Microascus* cf. *nidicola Massee & Salmon, 1901, *Ann. Bot.* 15: 313.

Perithecia black, papillate, ascospores reniform, 7-8 x 1.5-2 µm. From stage 2 spruce (UAMH 9167, 9168) and stage 2 aspen (UAMH 9169), UEI. *Microascus nidicola*

has been reported from dung (Massee and Salmon, 1901) and soil (Barron et al., 1961). Weakly cellulolytic (Abbott, pers. com.). Ref.: Barron et al. (1961).

Microascus singularis (Saccardo) Malloch & Cain, 1971, *Can. J. Bot.* 49: 859.

Perithecia black, short-necked, setose, ascospores orange, broadly reniform, 3-4.5 x 2-3 μm, *Wardomycopsis* anamorph, conidia dark brown, ellipsoidal, truncate. From stage 2 and 5 spruce (UAMH 8618, 9152) and stage 2 aspen (UAMH 9175), UEI. First report for Canada. Reported previously from a barrel bottom, USA (Sigler and Flis, 1998). Weakly cellulolytic (Abbott, pers. com.). Ref.: Malloch and Cain (1971).

Myxotrichum arcticum Udagawa, Uchiyama, & Kamiya, 1994, *Mycotaxon* 52:, 198.

Cleistothecia black, appendages short, curved, ascospores fusiform, 4-6 x 1.5-2 μ m, with longitudinal ridges. Anamorph resembles *Oidiodendron griseum* Robak, arthroconidia from long fertile conidiophore branches or from short branches along geniculate conidiophores. From stage 3 aspen, UML (UAMH 9243), stage 1 aspen, F91, and stage 1 aspen and stages 1 and 3 spruce, F93 (UAMH 9244). First report for Canada and from wood. Previously known only from the type, from soil in Alaska. Cellulolytic (Udagawa et al., 1994). Ref.: Udagawa et al. (1994).

Myxotrichum ochraceum Berkeley & Broome, 1875, *Ann. Nat. Hist. IV* 15: 37.

Cleistothecia black, peridial appendages long, straight, reflexed branching in lower half, ascospores fusiform, 3.5-5 x 1.5-3 μm, with longitudinal ridges, *Malbranchea* anamorph. From stage 2 aspen, UEI (UAMH 9532). Reported previously from wood (Orr et al., 1963), bark, and cardboard (Currah, 1985), mainly from Europe. First report for Canada. Weakly cellulolytic. Ref.: Orr et al. (1963).

Ophiostoma piliferum (Fries) H. & P. Sydow, 1869, *Ann. Mycol.* p. 128.

Perithecia black, long-necked, ascospores hyaline, allantoid. Anamorph *Hyalodendron*-like, but best disposed in *Sporothrix* (Benade et al., 1998). From stage 2 spruce, UML (UAMH 9374). Reported from wood, including spruce (Griffin, 1968) and aspen in Alberta (Hutchison, 1995, unpublished data). Cellulolytic (Upadhyay, 1981). Ref.: Upadhyay (1981).

Ophiostoma stenoceras (Robak) C. Moreau, 1952, *Revue Mycol. Suppl. Colon.* 17: 22.

Perithecia long-necked, ostiolar hairs divergent, ascospores reniform, anamorph *Sporothrix*. From stage 1 spruce, UEI. Reported from softwood, Canada (Ginns, 1986) and air, Alberta (Sigler et al. (1996). Ref.: Upadyay (1981).

***Ophiostoma* sp.**

Perithecia long-necked, ostiolar hairs divergent, ascospores mostly 2 x 1.5 μm, ellipsoid, *Sporothrix* and *Leptographium* anamorphs. From stages 3 and 5 spruce, UEI, and stages 2-4 spruce, UML.

Podospora tetraspora (Winter) Cain, 1962, *Can. J. Bot.* 40: 460.

Perithecia setose, ascospores black, ellipsoid, appendaged. From stage 1 aspen, H82. Previously known from dung (Mirza and Cain, 1969). First report for Canada and from wood. Cellulolytic (Cain, 1962). Ref.: Cain (1962).

Pseudogymnoascus alpinus Müller & von Arx, 1982, *Sydowia* 35: 135.

Cleistothecia bright yellow, ascospores fusoid, 3-5 x 3-4 µm, with longitudinal crests and low, longitudinal ridges. From stage 3 (UAMH 9242) and 5 (UAMH 9241) spruce, UML. Previously known only from the type, from the rhizosphere of *Erica carnea*, from British Columbia (Müller and von Arx, 1982). Weakly cellulolytic. Ref.: Müller and von Arx (1982).

Pseudogymnoascus frigidus (Uchiyama, Udagawa & Kamiya) Lumley, in prep.

Cleistothecia orange-brown, peridial hyphae little differentiated, ascospores fusoid, 4-5 x 3-4 µm, with longitudinal crests and low, longitudinal ridges. From stage 5 spruce, UML (UAMH 9239) and F93 (UAMH 9240). Previously known only from the type, from soil, Japan (Uchiyama et al., 1995). First report for North America and from wood. Cellulolytic (Uchiyama et al., 1995). Ref.: Uchiyama et al. (1995).

Pseudogymnoascus roseus Raillo, 1929, *Zentralbl. Bakteriol. Parasitenkde. Infektionskr. Abt. 1* 78: 515.

Cleistothecia red-brown, appendages short, thin-walled, asperulate, ascospores fusoid, 3-4.5 x 2-2.5 µm, smooth, *Geomyces* anamorph. From stage 3 and 5 spruce, F61, F83, F91, and F93 (UAMH 9222), and stage 3 aspen, UML. Worldwide, including western Canada, from soil (Orr, 1979) and wood (Currah, 1985). Cellulolytic (Raillo, 1929). Ref.: Currah (1985).

***Pseudogymnoascus* sp.**

Cleistothecia olive-green, appendages short, thin-walled, asperulate, ascospores fusoid, 4-5 x 3-4 µm, with a longitudinal crest and low, longitudinal ridges. Anamorph *Ovadendron*-like. From stage 5 spruce, UML (UAMH 9238) and stage 3 spruce, F81 (UAMH 8899). Cellulolytic (Lumley et al., in prep.). Ref.: Lumley et al. (in prep.).

Sordaria fimicola (Rob.) Cesati & DeNotaris, 1863, *Comm. Soc. Crit. Ftal.* 1: 226.

Perithecia pyriform, ascospores black, 23-25 x 16-18 µm, with a gelatinous sheath. From stage 5 spruce, UEI. Reported previously from dung (Cain, 1934) and soil (Sigler and Flis, 1998). First report from wood. Ref.: Cain and Groves (1948).

Sphaerodes fimicola (Hansen) P. Cannon & D. Hawksworth, 1982, *Bot. J. Linn. Soc.* 84: 146.

Perithecia pyriform, peridium translucent, ascospores dark, limoniform. From stage 5 spruce, UEI (UAMH 9369). Reported from dung (Cannon and Hawksworth, 1982) and roots of *Platanthera hyperborea* (Sigler and Flis, 1998). First report from wood. Ref.: Hawksworth (1982).

Strattonia carbonaria (Phillips & Plowright) Lundquist, 1972, *Symb. Bot. Ups.* 20: 269.

Perithecia black, ascospores 18-23 x 9-10 µm, appendages hyaline, triangular. From stage 5 spruce, F61. First report for North America. Known previously from burnt ground or charcoal, Europe (Dennis, 1977). Ref.: Dennis (1977).

Talaromyces retardatus Udagawa, Kamiya, & Osada, 1993, *Trans. Mycol. Soc. Japan* 34: 9.

Cleistothecia yellow or pinkish, ascospores ellipsoid, warted, 3.5-4.5 x 2.5-3 µm, *Penicillium* (biverticillate) anamorph. From stages 4 and 5 spruce, UEI, and stage 3 spruce, UML. Reported from wood, Japan (Udagawa et al., 1993). First report for North America. Ref.: Udagawa et al. (1993).

Talaromyces udagawae Stolk & Samson, 1972, *Stud. Mycol.* 2: 36.

Cleistothecia bright yellow, ascospores 3-4.5 x 2-3 µm, with spiral bands or crests, *Penicillium* state biverticillate. From stage 5 spruce, UEI (UAMH 9338). Reported only from soil, Japan (Stolk and Samson, 1972). First report for North America and from wood. Ref.: Stolk and Samson (1972).

Thielavia terrestris (Apinis) Malloch & Cain, 1972, *Can. J. Bot.* 50: 61.

Heterothallic, ascomata often sterile, black, non-ostiolate, ascospores dark brown, ovoid, 4-6 x 3-4 µm, *Acremonium* anamorph, conidia in short chains or slimy heads. From stages 4 and 5 spruce and stage 2 aspen (UAMH 8975), UEI. Reported from soil and plant debris, including from Canada (Malloch and Cain, 1973). Ref.: Malloch and Cain (1972).

Fungi imperfecti

Acremonium atrogriseum (Panasenko) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 89.

Conidia pale brown, smooth, ellipsoid, 4-5 x 1.5-2 µm. From stage 4 spruce, UEI. Previously known from pine wood, Europe (Gams, 1971), and as an airborne contaminant, Alberta (Sigler and Flis, 1998). Ref.: Gams (1971).

Acremonium bacillisporum (Onions & Barron) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 72.

Conidia bacilliform, in long chains. From stage 5 spruce, UEI (UAMH 9100). Reported as an airborne contaminant, Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Gams (1971).

Acremonium bactrocephalum W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 44.

Phialides up to 30 µm long, conidia 3.5-4 x 0.5-1 µm, ends pointed. From stage 5 spruce, UEI, and stage 3 aspen, H61. Reported from soil, including for Canada (Gams, 1971). First report for western Canada and from wood. Ref.: Gams (1971).

Acremonium butyri (van Beyma) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p.126.

Colonies intense olive-yellow, conidia ellipsoid, 3-7 x 1.5-2.5 µm. From all UML logs and most UEI logs, as well as aspen and spruce logs from post-fire and post-harvest sites. Reported from forest soil associated with white cedar, Canada (Bhatt, 1970), on birch wood, Japan (Sasaki and Yoshida, 1971) and Europe (Sigler and Flis, 1998), and a spruce stump, Europe (ATCC catalogue). Weakly pectinolytic and chitinolytic (Tubaki, 1958). Ref.: Domsch et al. (1980).

Acremonium camptosporum W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 57.

Phialides 10-20 µm, occasionally much longer, conidia 3-3.5 x 1-1.5 µm, mostly curved. From stages 1, 4, and 5 spruce, UEI, from several spruce and aspen in all post-fire sites, H83, and H93. Reported from decaying plant material, South Africa and Europe (Gams, 1971). First report for North America and from wood. Ref.: Gams (1971).

Acremonium cerealis (Karst) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 88.

Phialides roughened, conidia pyriform with truncate base, 4-4.5 x 2-2.5 µm. From stage 1 spruce, UEI. Known from wood and plant debris, mainly Europe (Gams, 1971). First report for North America and from wood. Ref.: Ellis (1971).

Acremonium* cf. *crotocinigenum (Schol-Schwartz) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 112.

Phialides mostly 25-30 x 2-3 µm, conidia 4-5 x 1.5-2 µm. From stage 5 spruce and stage 1 aspen, H93. *Acremonium crotocinigenum* is known mainly from fruiting bodies of wood decay fungi, Europe (Gams, 1971). Ref.: Gams (1971).

Acremonium fusidioides (Nicot) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 25.

Conidia of two types: pigmented and fusiform with truncate ends, 5-6.5 x 1-2 µm; and globose, 3.5-4.5 µm diam, hyaline, and ornamented. From stage 2 and 5 spruce and stage 1 aspen, UEI, and stage 1 aspen, UML. Reported from soil, including for Canada (Domsch et al., 1980), and as an airborne contaminant, Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Domsch et al. (1980).

Acremonium kiliense Grutz, 1925, *Dermat. Wochnschr.* 80: 765.

Colonies pinkish, moist, phialides smooth, inconspicuous, conidia 3-4 x 1.5 µm, cylindrical, chlamydospores occasionally present. From stage 5 spruce and stage 1 aspen, UEI, stages 1 and 3 aspen, UML, stage 3 spruce, F93, and stage 1 aspen, H92 and H93. Reported from soil in Europe and Asia (Gams, 1971). First report from wood. Ligninolytic (Gams, 1971). Ref.: Gams (1971).

Acremonium* cf. *luzulae (Fuckel) W. Gams, 1971 Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 92.

Phialides ornamented, conidia ellipsoid with truncate ends, 3.5-5 x 1-1.5 µm. From stage 2 aspen, UEI. *Acremonium luzulae* has been reported from plant remains, including wood (Dickinson, 1968), worldwide, including North America (Jorgensen and Hodges, 1970). Ref.: Gams (1971).

Acremonium minutisporum (Sukapure & Thirumalachar) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 50.

Phialides up to 40 µm long, conidia 2-2.5 x 1.5 µm, ellipsoid, chlamydospores 3-4 µm diam. From stage 2 spruce and stage 3 aspen, UML, from stages 1 and 5 spruce, F61, stage 1 aspen and stage 3 spruce, F82, and stage 1 aspen, H61. Reported from salt-marsh soil, Asia, and from spruce wood, Nova Scotia (Sigler and Flis, 1998). First report for western Canada. Ref.: Gams (1971).

Acremonium murorum (Corda) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 84.

Conidia subglobose, 3-5.5 x 2-3 µm, in long chains. From stage 5 spruce and stage 2 aspen, UEI. Reported from forest soil (Gochenaur, 1978) and plant remains, including wood (Ellis, 1971), Europe and North America (Domsch et al., 1980). Cellulolytic (Basu and Ghose, 1960). First report for Canada. Ref.: Ellis (1971).

Acremonium persicinum (Nicot) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 75.

Phialides mostly 15-40 µm long, conidia dacryoid, 2.5-3 x 2 µm, in distinct chains. From stage 1 aspen, UML. Reported from soil and other cellulosic substrata (ATCC catalogue), and as a contaminant, Alberta (Sigler and Flis, 1998). Ref.: Gams (1971).

Acremonium polychromum (van Beyma) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 81.

Colony reverse multi-coloured, conidia black, subglobose, 3.5-5 x 3-4 µm. From stage 2 spruce and stages 1 and 3 aspen, UEI, stage 5 spruce, F61, stage 2 aspen, F82, stages 1-3 aspen, H82, and stages 1 (UAMH 8974) and 2 aspen, H93. Reported from soil, air (Ellis, 1971), and, rarely, wood (Gams, 1971), including from Alberta (Sigler and Flis, 1998). Ref.: Ellis (1971).

Acremonium* cf. anam. *Nectria rishbethii Booth, 1959, *Mycol. Pap.* 73: 92.

Phialides mostly 40 x 2 µm, tapered, smooth, conidia variously-shaped, some curved, mostly 4-5 x 1-2.5 µm. From stages 2 and 5 spruce, UEI, stage 4 spruce and stage 2 aspen, UML, stage 3 spruce, F61, stage 1 aspen and stage 3 spruce, F82, stages 1 and 3 aspen, H61, and stage 3 aspen, H82. *Nectria rishbethii* has been reported from soil, Europe (Gams, 1971) and as an airborne contaminant, Canada (Sigler and Flis, 1998). Ref.: Gams (1971).

Acremonium strictum W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 42.

Colonies pink, moist, phialides up to 80 µm, ornamented near the base, conidia elongate-cylindrical, 4.5-5 x 2 µm. From stages 2-4 spruce and stages 2 and 3 aspen, UEI, stages 2 and 5 spruce and stage 1 aspen, UML, stage 5 spruce, F61, stage 3 spruce, F82, stage 1 aspen, H61, stage 3 aspen, H82, and stage 2 aspen, H93. Reported from soil, litter, and from stained wood, North America (Gams, 1971) and as an airborne contaminant, Alberta (Sigler and Flis, 1998). Ref.: Domsch et al. (1980).

***Acremonium* sp.1**

Conidiophores up to 75 µm long, ornamented near the base, conidia subglobose, up to 3.5 µm diam, smooth. From stages 2 and 3 aspen, UEI, and stage 2 spruce, UML.

Acrodictys fuliginosa Sutton, 1976, *Can. J. Bot.* 47: 854.

Conidia over 20 µm long, with three transverse septa. From stage 1 aspen, UEI, stages 1 and 2 aspen, UML and F82, and stage 3 aspen, H62 and H83. Known exclusively from wood of *Populus* spp., Canada (Ellis, 1976). Ref.: Ellis (1976).

Acrodontium* cf. *crateriforme (van Beyma) de Hoog, 1972, *Stud. Mycol.* 1: 26.

Conidiophores unbranched, up to 100 µm long, conidia guttuliform, 4.5-5 x 2-3 µ m. From stage 5 spruce, UML. *Acrodontium crateriforme* has been reported from plant debris, including wood in Alberta (Sigler and Flis, 1998). The similar *Acrodontium intermissum* has been reported from wood, western Canada (Sigler and Flis, 1998), but produces cylindrical conidia. Ref.: de Hoog (1972).

Acrodontium griseum (Fassatiova) de Hoog, 1972, *Stud. Mycol.* 1: 36.

Conidiophores erect, base pigmented, paler toward the apex, conidia subglobose, 2-5 x 2-3 µm. From stage 2 spruce, UML. Reported mainly from wood, Europe (de Hoog, 1972). First report for North America. Ref.: de Hoog (1972).

Acrodontium simplex (Mangenot) de Hoog, 1972, *Stud. Mycol.* 1: 33.

Conidiogenous cells denticulate, conidia subglobose, apiculate, 1.5-3 x 1-2.5 µm. From most all stages spruce (except stage 1) and aspen, UML and UEI, and from many post fire and post harvest sites. Reported mainly from hard- and softwood, Europe (de Hoog, 1972), but also from Alberta (Sigler and Flis, 1998). Ref.: de Hoog (1972).

Alternaria alternata (Fries) Keissler, 1912, *Beih. Bot. Centralbl.* 29: 434.

Conidia in long chains, 20-26 x 9-14 µm, beak short relative to conidium length. From stage 2 spruce and stage 2 aspen, UEI, stage 1 spruce, UML, stage 1 and 5 spruce, F83, stages 1 and 2 aspen, H82 and stage 1 aspen, H93. Reported from plants (Rao, 1969) and forest soil (Singh, 1976), worldwide, especially from cold climates, including Alberta (Sigler and Flis, 1998). Ref.: Ellis (1971).

Arthrinium phaeospermum (Corda) M.B. Ellis, 1965, *Mycol. Pap.* 103: 8.

Conidia dark brown, 8-11.5 µm diam in face view, up to 5-7 µm thick. From stage 2 spruce, UML. Reported mainly from soil, worldwide, including Alberta (Sigler and Flis, 1998), and from wood (Wang, 1965), including aspen (Sigler and Flis, 1998). Cellulolytic (Domsch et al., 1980). Ref.: Ellis (1971).

Arthrobotrys cladodes Drechsler, 1937, *Mycologia* 29: 463.

Conidia pedicillate, 18-25 x 7.5-10 µm. From stages 2 and 3 aspen, UEI, stages 1-3 aspen, UML, stage 5 spruce, F83, stages 1 and 3 aspen, H82, and stage 2 aspen, H83 and H93. Reported from wood of pine, USA (van Oorschot, 1985). First report for Canada. Ref.: van Oorschot (1985).

Arthrobotrys conoides Drechsler, 1937, *Mycologia* 29: 476.

Conidiophores unbranched, conidia 19-32 x 8-14.5 µm, with larger distal cell. From stage 4 spruce, UEI, stages 2 and 3 aspen, UML, and stage 3 aspen, H61 and H83. Reported from soil and dung worldwide, including North America (Domsch et al., 1980), and from a moss-covered log (Haard, 1968). First report for Canada. Ref.: Domsch et al. (1980).

Arthrobotrys oligospora Fres., 1850, *Beitr. Mykol.* 1-2: 18.

Conidia obovoid, 20-25 x 7.5-14 µm, length:width < 2. From stage 3 aspen, F82. Reported from soil worldwide, including Canada (Domsch et al., 1980) and from wood (Sharp, 1975; Haard, 1968). Cellulolytic (Satchuthananthavale and Cooke, 1967). Ref.: van Oorschot (1985).

Arthrobotrys* cf. *straminicola Pidoplichko, 1948, *Mykrobiol. Zh.* 9: 55.

Conidia small (up to 12 x 5.5 µm), with two approximately equal cells. From stage 5 spruce, F61, and stage 3 spruce, F82. Not much literature available for *A. straminicola*. Ref.: van Oorschot (1985)

Arthrographis cuboidea (Saccardo & Ellis) Sigler, 1976, *Mycotaxon* 4: 363.

Colonies yellow, powdery, arthroconidia 2.5-3.5 x 1.5-2.5 µm. From stages 1 (UAMH 9214) and 2 aspen, UEI. Reported from pink stained hardwood and softwood (Sigler and Flis, 1998). Strongly cellulolytic (Sigler and Carmichael, 1976). Ref.: Sigler and Carmichael (1976).

Arthrographis lignicola Sigler, 1983, *Mycotaxon* 18: 502.

Colonies bright yellow, arthroconidia 2-4.5 x 2-3 µm. From stage 1 spruce, F61 and F83. Known only from gymnosperm wood in Alberta and Saskatchewan (Sigler, 1983). Weakly cellulolytic (Sigler, 1983). Ref.: Sigler (1983).

Aspergillus fumigatus Fres., 1863, *Beitr. Mykol.*, 81.

Colonies blue-green, conidiophore vesicles clavate, uniseriate, conidia produced in columns, globose, echinulate, 2.5-3 µm diam. From stages 1 and 4 spruce, UEI, and stages 1 and 3 aspen, H61. Reported from forest soil (Gochenaur and Backus, 1967) and

wood (Flannigan and Sagoo, 1977), including for Canada (Sigler and Flis, 1998). Thermotolerant, pectinolytic (Hamilton and Johnston, 1961), cellulolytic (Domsch et al., 1980), and possibly ligninolytic (Domsch, 1960), caused weight loss in spruce (Ofosu-Asiedu and Smith, 1973) and aspen (Nilsson, 1973). Ref.: Klich and Pitt (1988).

Aspergillus niger van Tieghem, 1867, *Ann. Sci. Nat. Bot.* 8: 240.

Stipes thick-walled, vesicles globose, biseriate, conidia black, globose, 3-4.5 µm, irregularly roughened. From stage 4 spruce and stage 2 aspen, UEI. Reported from soil and plant litter, including wood, worldwide, including Canada (Davidson and Lorti, 1970), and as an airborne contaminant, Alberta (Sigler and Flis, 1998). Ref.: Klich and Pitt (1988).

Aspergillus restrictus G. Smith, 1931, *J. Text. Inst.* 22: 115.

Colonies slow-growing, stipes hyaline, vesicle pyriform, uniseriate, conidia ellipsoid, 5-8 x 3-5 µm, roughened. From stage 3 aspen, H61. Reported mainly from soil, but also from pine wood, Alberta (Sigler and Flis, 1998). Ref.: Klich and Pitt (1988).

Aspergillus ustus (Bainier) Thom & Church, 1926, *The Aspergilli*, 152.

Stipes brown, vesicles globose, conidia globose, 3.5-5 µm diam, roughened. From stage 4 spruce and stages 1 and 2 aspen, UEI, stage 2 aspen, F82 and F93 (UAMH 9499). Reported from soil and as an airborne contaminant, including from Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Klich and Pitt (1988).

Aspergillus versicolor (Vueillemin) Tiraboschi, 1908, *Ann. Bot. (Roma)* 7: 9.

Colonies yellow-green, conidiophore vesicles elongate, conidia globose, 2-4 µm diam, echinulate. From numerous spruce and aspen logs, UEI, UML, and post-fire and post-harvest sites. Reported from soil and dung, worldwide (Domsch et al., 1980). Xerophilic (Moustafa and Al-Musallam, 1975), pectinolytic (Malan and Leone, 1962), weakly cellulolytic (Basu and Ghose, 1960). Ref.: Klich and Pitt (1988).

Aureobasidium pullulans (de Bary) Arnaud, 1910, *Ann. Mycol.* 8: 475.

Colonies slimy, conidia 4-6 x 2-3 µm, produced on denticles or directly from hyphae. From spruce logs, UEI and UML, and from spruce and aspen logs post fire. Reported from soil and wood (Cooke, 1961), worldwide, including Canada (Morrall and Vanterpool, 1968; Widden and Parkinson, 1973; Morrall, 1974; Singh, 1976). Pectinolytic (Smit and Wieringa, 1953), cellulolytic (Flannigan, 1970), and ligninolytic (Black and Dix, 1968), causes a soft-rot of timber (Savory, 1954). Ref.: Hermanides-Nijhof (1977).

Beauveria alba (Limber) Saccas, 1948, *Rev. Mycol.* 13: 64.

Conidiogenous cells in whorls, conidia borne from a "zig-zag" rachis, globose, 2.5-3 µm diam. From stage 4 spruce, UEI. Reported mainly as a contaminant, including from Alberta (Sigler and Flis, 1998). Ref.: de Hoog (1972).

Beauveria bassiana (Bals.) Vuillemin, 1912, *Bull. Soc. Bot. Fr.* 59: 40.

Colonies powdery, becoming yellowish or pinkish, conidia borne on a denticulate rachis, 2-3 μm diam, conidiogenous cells borne in clusters. From all logs, UEI and UML and from numerous spruce and aspen logs, post-fire and post-harvest. Reported from soil, including forest soil, and most often associated with insects (Clerk and Madelin, 1965). Ref.: de Hoog (1972).

Beauveria cylindrospora (W. Gams) von Arx, 1986, *Mycotaxon* 25:156.

Colonies white, conidiogenous cells with peg-like rachis, conidia cylindrical, straight or slightly curved, 4 x 1-1.5 μm. From stage 2 aspen, H93. No literature available for known substrata. Ref.: von Arx (1986).

Bispora antennata (Persoon) Mason in Hughes, 1953, *Can. J. Bot.* 31: 582.

Colonies black, conidia 2-celled, 10-18.5 x 6.5-7.5 μm brown, with a broad, dark band at the septum. From stages 4 and 5 spruce, UML, and stage 3 aspen, H61. Reported from prostrate hardwood logs, Europe (Ellis, 1971). First report for Canada. Ref.: Ellis (1971).

Bispora betulina (Corda) Hughes, 1958, *Can. J. Bot.* 36: 740.

Conidia 2-celled, 8-12 x 2.5-4 μm, borne in long, simple chains. From late stage spruce and aspen logs, UEI and UML, and stages 3 and 5 spruce, F61. Reported from wood, worldwide, including Canada (Ellis, 1971). Ref.: Ellis (1971).

Blastobotrys nivea von Klopotek, 1967, *Arch. Mikrobiol.* 58: 92.

Conidiophores fragile, up to 200 μm long, primary conidia globose, 2-3.5 μm diam, secondary conidia globose, 2-2.5 μm diam. From stage 4 spruce and stage 2 aspen, UEI. Reported from compost, Europe. First report for North America and from wood. Ref.: de Hoog (1974).

Botryotrichum piluliferum Saccardo & March, 1885, *Bull. Soc. R. Bot. Belg.* 24: 66.

Setae sterile, rough-walled, conidia globose, 8-14 μm diam, thick-walled, produced on racemosely-branched conidiophores. From stages 2 and 5 spruce and stage 2 aspen, UEI, and stage 1 spruce, F61. Reported mainly from dung, but occasionally from soil, worldwide (Domsch et al, 1980). Cellulolytic (Daniels, 1961), ligninolytic (Haider and Domsch, 1969), and chitinolytic (Okafor, 1967), caused weight loss in aspen wood (Merrill, 1966). Ref.: Domsch et al. (1980).

Calcarisporiella thermophila de Hoog, 1974, *Stud. Mycol.* 7: 68.

Conidia long, up to 9 x 2.5 μm, occasionally curved, borne from cylindrical pegs. From stage 3 spruce, F61, and stage 1 spruce, H92. Reported from coal spoils, Europe (de Hoog, 1974). First report for North America and from wood. Ref.: de Hoog (1974).

Calcarisporium arbuscula Preuss, 1851, *Linnaea* 24: 124

Colonies yellowish, conidiogenous cells in whorls, denticulate, conidia ellipsoid to cylindrical, up to 6-10 x 2-4 μm. From stage 2 spruce and stages 1 and 2 aspen, UEI,

stage 3 aspen, UML, and stage 1 aspen, H61. Reported mainly as a parasite on other fungi (Sutton, 1973), but also from wood, Alberta (Sigler and Flis, 1998). Ref.: de Hoog (1974).

Chalara* cf. *cylindrosperma (Corda) Hughes, 1958, *Can. J. Bot.* 36: 747.

Conidiogenous cells tall (up to 150 x 5 μm), multiseptate, brown, conidium size highly variable, usually 5 x 1.5-2.5 μm. From stages 1 and 3 aspen, UEI and F82, and stage 1 aspen F93. *Chalara cylindrosperma* has been commonly reported from wood (Hughes, 1958). Ref.: Nag Raj and Kendrick (1975).

***Chalara* sp. 1**

Conidiogenous cells unbranched, 25-30 x 2-4 μm, inflated in the middle, pale brown, conidia 2.5-3 x 1-2 μm, in long chains. From stages 2-4 spruce, UEI and UML, stage 1 spruce, F61 and F93, and stage 3 spruce, F82, F91, and F93.

Chloridium botryoideum (Corda) Hughes, 1958, *Can. J. Bot.* 36: 748.

Colonies slow-growing, conidiophores pale brown, up to 150 μm long, proliferating sympodially and percurrently, conidia ellipsoid, 2-2.5 x 1-1.5 μm. From stage 5 spruce, UML. Reported from wood and bark of hardwood and softwood, including for Canada (Gams and Holubova-Jechova, 1976). Ref.: Gams and Holubova-Jechova (1976).

Chloridium chlamydosporis (van Beyma) Hughes, 1958, *Can. J. Bot.* 36: 748.

Conidiophores unbranched, conidia ellipsoid, 2-3 x 1-2 μm, chlamydospores numerous, globose. From stages 2-5 spruce, UEI and UML, stages 2 (UAMH 9249) and 3 aspen, UEI, stages 1 and 3 aspen, UML, and from numerous spruce and aspen logs in post-fire and post-harvest sites. Reported from soil and wood, Europe (Gams and Holubova-Jechova, 1976). First report for Canada. Ref.: Gams and Holubova-Jechova (1976).

Chloridium lignicola (Mangenot) W. Gams & Holubova-Jechova, 1976, *Stud. Mycol.* 15: 37.

Conidiophores dark brown, up to 200 μm long, depending on the number of percurrent elongations, phialides with a large, flaring collarette, constricted below, conidia somewhat pigmented, ellipsoid to allantoid, 4-5 x 1.5-2 μm. From stage 1 aspen, UEI and UML. Reported from hardwood, Europe and North America, including eastern Canada (Gams and Holubova-Jechova, 1976). First report for western Canada. Ref.: Gams and Holubova-Jechova (1976).

Chrysosporium* cf. *carmichaelii van Oorschot, 1980, *Stud. Mycol.* 20: 15.

Fertile hyphae curved, interspersed among curved sterile hyphae, aleuroconidia sparsely-roughened, 3.5-5.5 x 3.5 μm, intercalary conidia smooth, 3.5-5.5 x 2-3.5 μm. From stage 4 spruce, UEI and UML. *Chrysosporium carmichaelii* has been reported from human skin, nails, and sputum, including from Alberta (Sigler and Flis, 1998), but also from soil and dung. Ref.: van Oorschot (1980).

Chrysosporium lobatum Scharapov, 1978, *Nov. Sist. Nizshikh Rast.* 15: 144.

Colonies greenish or pinkish, fertile hyphae branching at right angles, aleurioconidia smooth, 2-4.5 x 1.5-3.5 μm, intercalary conidia smooth to echinulate, 3-4.5 x 2-3.5 μm. From stages 2, 4 (UAMH 8724), and 5 spruce, and stages 1 and 3 aspen, UEI. Reported from human skin and nails, including from Alberta (Sigler and Flis, 1998). First report from wood. Cellulolytic (van Oorschot, 1980). Ref.: van Oorschot (1980).

Chrysosporium merdarium (Link) Carmichael, 1962, *Can. J. Bot.* 40: 1160.

Colonies yellow or buff-coloured, aleurioconidia echinulate, 3.5-8 x 3-5.5 μm, intercalary conidia echinulate, 6.5-11 x 4-5.5 μm. From stages 2, 4, and 5 (UAMH 9250) spruce, stages 2 and 3 aspen, UEI, and stage 3 aspen, H61. Reported from soil and dung, North America, including Alberta (Carmichael, 1962). First report from wood. Implicated as anamorph of *G. uncinatus*, but the relationship is still uncertain (Currah, 1985). Cellulolytic. Ref.: van Oorschot (1980).

Chrysosporium sulfureum (Fiedl.) van Oorschot & Samson, 1980, *Stud. Mycol.* 20: 28.

Colonies yellowish, conidia subglobose or obovoid, 3.5-6 x 3-5.5 μm, produced laterally on short protrusions. From stages 2 (UAMH 8725) and 3 aspen, UEI. Reported from a dead frog in the Netherlands and cheese in Switzerland. First report for North America and from wood. Possibly proteolytic (van Oorschot, 1980). Ref.: van Oorschot (1980).

Cladosporium **anam.** ***Amorphotheca resinae*** Parberry, 1969, *Aust. J. Bot.* 17: 331.

Conidiophores long (up to 125 μm), terminal conidia pale brown, globose or ellipsoid, up to 6 μm long. From stage 3 aspen, F83, stage 3 spruce, F91, and stage 2 aspen, H82. Reported from hydrocarbons and burned wood, worldwide (Ellis, 1971). Ligninolytic (Marsden, 1954). Ref.: Ellis (1971).

Cladosporium cladosporioides (Fres.) de Vries, 1952, *Contribution to the knowledge of the genus* Cladosporium *Link ex Fr.*, p. 57.

Conidiophores nodose, conidia 3-9 x 2-4.5 μm. Isolated numerous times from aspen and spruce logs from most sites. Reported mostly from boreal-alpine regions, including Alberta (Sigler and Flis, 1998) and from stored timber (Lagerberg et al., 1928). Ligninolytic, pectinolytic (Domsch and Gams, 1969), and poorly cellulolytic (Eveleigh, 1970). Ref.: Domsch et al. (1980).

Cladosporium elatum (Harz) Nannfeldt, 1934, *Sven. Skogsvardsforen Tidskr.* 32: 397.

Conidia light grey-brown, mostly fusiform, 5-12 x 2-4.5 μm, smooth-walled, occurring in long, branching chains. From stages 1-4 spruce, UEI, stage 3 aspen, UML, and from several spruce and aspen logs from post-fire and post-harvest sites. Reported from wood, Europe (Ellis, 1976). Ref.: Ellis (1976)

Cladosporium herbarum (Persoon) Link, 1821, *Nat. Arr. Br. Pl.* 1: 556.

Conidiophores elongating sympodially, conidia distinctly roughened, 6-18 x 4-8 µm. From stage 4 spruce and stage 2 aspen, UEI, stage 1 spruce, F83 and H92, stage 1 aspen, H61 and H93, and stage 3 aspen, F93. Reported from numerous cellulosic substrata, including wood, especially wood exposed to soil (Gersonde and Kerner-Gang, 1968), worldwide, including Alberta (Sigler and Flis, 1998). Pectinolytic (Malan and Leone, 1962), cellulolytic (Marsh et al., 1949), and probably ligninolytic (Ceruti Scurti et al., 1972). Ref.: Domsch et al. (1980).

Cladosporium sphaerospermum Penzig, 1882, *Michelia* 2: 473.

Conidia globose or subglobose, 3-5 µm diam, finely roughened. From stages 2 and 3 spruce and stages 1 and 2 aspen, UEI, stages 2 and 4 spruce and stage 1 aspen, UML, stages 1 aspen and 3 spruce, F93, stage 1 aspen, H61, stage 5 spruce, H62, and stage 3 aspen, H82. Reported from soil and as an airborne contaminant, worldwide (Domsch et al., 1980), including Alberta (Sigler and Flis, 1998). Weakly cellulolytic (Domsch et al., 1980). Ref.: Ellis (1971).

Clonostachys compactiuscula (Saccardo) D. Hawksworth & W. Gams, 1975, *Trans. Brit. Mycol. Soc.* 64: 90.

Conidia pedicillate, 5.5-8 x 2-3 µm, borne obliquely in chains. From stage 4 and 5 spruce, UEI. Known from hardwood and softwood, mainly Europe (Hawksworth and Punithalingam, 1975). Ref.: Hawksworth and Punithalingam (1975).

Conioscypha varia Shearer, 1973, *Mycologia* 65: 133.

Conidia ellipsoidal with a truncate base, 10-13 x 5-8 µm, borne from a thin-walled "cup". From stages 1 and 2 aspen (UAMH 9469), H82. Reported from submerged wood in the USA and soil in The Netherlands (Ellis, 1976). First report for Canada. Ref.: Ellis (1976).

Cordana pauciseptata Preuss, 1851, *Linnaea* 24: 129.

Conidiophores simple, erect, conidia 2-celled, dark brown, 8-13 x 5.5-7 µm. From stages 2-5 spruce, UEI, stages 4 and 5 spruce and 2 and 3 aspen, UML and F83, stage 1 aspen, F93, stages 1 and 2 aspen, H82, and stage 1 spruce, H92. Reported from bark and wood of hard- and softwoods in Europe and North America (Ellis, 1971). First report for Canada. Ref.: Ellis (1971).

Cylindrocarpon* cf. *candidum (Link) Wollenw., 1926, *Fus. Autogr. Del.* 2: 655.

Colonies yellow-brown, macroconidia mostly 5-septate, up to 35 x 4.5 µm, curved, microconidia mostly 8 x 2 µm. From stage 5 spruce and stage 3 aspen, UEI. *Cylindrocarpon candidum* has been reported from hardwood trees, including *Populus,* worldwide, including North America. Ref.: Booth (1966).

Cylindrotrichum oligospermum (Corda) Bonord., 1851, *Handb. Allg. Mykol.*, p. 88.

Conidiophores long (up to 125 µm), conidia 1-septate, cylindrical, 11-15 x 2-3 µm. From stage 3 aspen, H61, and stage 2 aspen, H93. Reported from wood and bark in

Europe (Ellis, 1971). First report for North America. Ref.: Gams and Holubova-Jechova (1976).

Dactylaria dioscoreae M.B. Ellis, 1976, *More Dematiaceous Hyphomycetes*, p. 171.

Conidiophores up to 150 µm long, dark brown, conidia borne on denticles, hyaline or pale brown, fusoid, up to 3-septate, 20-25 x 4.5-5.5 µm. From stage 1 aspen, F82 and F83. Reported only from leaves of *Dioscorea*, Jamaica and Nigeria (Ellis, 1976). First report for Canada and from wood. Ref.: de Hoog (1985).

Dactylaria lanosa Malla & W. Gams, 1971, *Persoonia* 6: 193.

Conidiogenous cells hyaline, 2 µm wide, conidia borne on short (2 µm) denticles, 1-3-septate, straight, 3-septate conidia 19-22 x 1.5 µm. From stage 2 spruce, UEI. Reported from forest soil and spruce wood (de Hoog, 1985). Ref.: de Hoog (1985).

***Dactylaria* sp. 1**

Conidiophores up to 150 µm long, conidia borne on cylindrical pegs, mostly 3-septate, 20-25 x 3-4 µm, cylindrical, rounded at both ends. From stage 2 aspen, UEI, stages 1-3 aspen, UML, stage 2 aspen, F83, and stage 1 aspen, H83 and H93.

Dendryphiopsis atra (Corda) Hughes, 1953, *Can. J. Bot.* 31: 655.

Conidia dark brown, 2-4 septate, 55-75 x 10-25 µm. From stages 2 and 3 spruce, UEI, stage 2 spruce, UML, stage 3 spruce, F82, stages 1 and 3 aspen, H61, stages 3 aspen and 5 spruce, H62, and stage 1 aspen, H82 and H83. Reported from hardwood, Europe and North America (Ellis, 1971), including Alberta (Sigler and Flis, 1998). Ref.: Ellis (1971).

Dictyosporium oblongum (Fuckel) Hughes, 1958, *Can. J. Bot.* 36: 762.

Conidia irregularly multicellular, black, 30-50 x 10-25 µm, with up to 7 parallel rows of cells. From stage 3 aspen, UML (UAMH 9476) and H61. Reported from wood, Europe and North America (Ellis, 1971). First report for Canada. Ref.: Ellis (1971).

Diplococcium spicatum Grove, 1885, *J. Bot. Lond.* 23: 167.

Colonies dark, conidia 1-septate, 6-9 x 3-4.5 µm, borne in long chains at right angles to the conidiophores. From stage 2 aspen, UML, stage 3 spruce, F82, stage 1 aspen, F93 and stage 2 aspen, H93. Reported from hard- and softwoods, Europe (Ellis, 1971). First report for North America. Ref.: Ellis (1971).

Doratomyces microsporus (Saccardo) Morton & Smith, 1963, *Mycol. Pap.* 8: 77.

Conidia smooth, dark brown, 3-5.5 x 2-3 µm. From stages 4 (UAMH 9143) and 5 spruce, UEI. Reported mostly from dung, but also from forest litter and spruce wood (Morton and Smith, 1963), worldwide (Badura, 1960), including Alberta (Sigler and Flis, 1998). Cellulolytic (Domsch and Gams, 1969), and ligninolytic (Domsch, 1960). Ref.: Morton and Smith (1963).

Doratomyces nanus (Ehrenb.) Morton & Smith, 1963, *Mycol. Pap.* 8: 80.

Conidia large, verrucose, prominently pointed, dark brown, 6-9 x 5-6 µm. From stages 2, 4 (UAMH 8485, 8486), and 5 spruce, and stages 1 and 3 aspen, UEI, stage 5 spruce and stage 2 aspen, UML, stage 3 spruce, F82, and stage 3 aspen, F83 and H61. Reported from decaying plant material and herbivore dung (Morton and Smith, 1963), including from Alberta (Sigler and Flis, 1998). Cellulolytic, causes weight loss in wood (Haider and Domsch, 1969). Ref.: Morton and Smith (1963).

Doratomyces stemonitis (Persoon) Morton & Smith, 1963, *Mycol. Pap.* 8: 70.

Conidia large, ornamented, 6-9 x 4-5 µm, *Echinobotryum* synanamorph, conidia apiculate, 7-12.5 x 6-8.5 µm. From stages 2, 4, and 5 (UAMH 9142) spruce and stage 1 aspen, UEI. Reported from wood, dung, and soil, worldwide (Morton and Smith, 1963), including Alberta (Sigler and Flis, 1998). Cellulolytic (Tribe, 1960) and ligninolytic (Domsch, 1960). Ref.: Morton and Smith (1963).

Endophragmia hyalosperma (Corda) Morgan-Jones & Cole, 1964, *Trans. Brit. Mycol. Soc.* 47: 489.

Conidiophores brown, conidia obovoid, 3 or 4-septate, hyaline, 20-25 x 10-12.5 µ m. From stage 4 spruce, UEI. Reported from plant debris, including hardwood, Europe (Ellis, 1971), and submerged balsa wood, USA (Shearer, 1973). First report for Canada. Ref.: Ellis (1971).

Epicoccum nigrum Link, 1815, *Mag. Naturf. Freunde, Berlin* 7: 32.

Mature conidia globose, muriform, dark-brown, verrucose, 13.5-26 µm diam. From stage 1 spruce, UEI, stage 3 spruce, F83, and stage 1 aspen, H93. Reported from wood and forest soil, including from Alberta (Widden and Parkinson, 1973). Cellulolytic (Moreau et al., 1965) and ligninolytic (Ledingham and Adams, 1942). Ref.: Ellis (1971).

Exophiala jeanselmei (Langeron) McGinnis & Padhye, 1977, *Mycotaxon* 5: 345.

Colonies greyish-black, conidia ellipsoid, hyaline, 3-5 x 1-2 µm, budding cells present. From stage 5 spruce and stage 1 aspen, UML, stage 1 aspen, F93 and H93, stage 3 aspen, H82, and stage 2 aspen, H93. Known previously from soil and rotting wood (de Hoog, 1977), including from Alberta (Sigler and Flis, 1998). Ref.: de Hoog (1977).

Exophiala* cf. *moniliae de Hoog, 1977, *Stud. Mycol.*15: 120.

Conidia ellipsoid, up to 5 µm long, formed on tapered conidiogenous peg. From stage 1 and 4 spruce, UML, stages 1 and 3 spruce, F93, and stage 1 aspen, H61. *Exophiala moniliae* has been reported from wood, human sources, and as a contaminant, including from Alberta (Sigler and Flis, 1998). Ref.: de Hoog (1977).

***Fusarium* sp. 1**

Conidia 1-5 septate, 6-celled conidia 38-40 x 2-3 µm. From stages 2 and 5 spruce and stages 2 and 3 aspen, UEI, stage 3 aspen, F82 and stage 1 aspen, H82 and H93.

Geniculifera* cf. *cystosporia (Duddington) Rifai, 1975, *Mycotaxon* 2: 215.

Conidia 2-celled, 23-30 x 18-24.5 µm, proximal cell very small (5 µm), distal cell much larger (up to 25 µm), no nematode-trapping structures observed. From stage 3 aspen, F82. Very little informatiom is available for *Geniculifera cystospora*. Ref.: van Oorschot (1985).

Geniculosporium* cf. anam. *Hypoxylon serpens (Persoon) Kickx, 1835, *Flore Crypt. Louvain*, 115.

Conidiogenous hyphae pale brown, denticulate, conidia pale brown, subglobose, 3-4 x 2-2.5 µm. From aspen and spruce, UEI, UML, F83, H82, H83, H92, H93. *Hypoxylon serpens* has been reported from wood, including for Canada (Ellis, 1971). Ref.: Ellis (1971).

Geomyces asperulatus Sigler & Carmichael, 1976, *Mycotaxon* 4: 376.

Colonies yellow, conidia yellowish, thick-walled, in long chains, roughened, 2-5 x 1.5-3 µm. From numerous spruce and aspen logs, especially in advanced stages of decomposition, from most sites (UAMH 9032). Reported from forest soil, including for Canada (Sigler and Carmichael, 1976). First report for western Canada and from wood. Cellulolytic (Sigler and Carmichael, 1976). Ref.: Sigler and Carmichael (1976).

Geomyces pannorus (Link) Sigler & Carmichael, 1976, *Mycotaxon* 4: 377.

Colonies grey or whitish, reverse yellow, conidia hyaline, 2.5-4 x 1.5-3 µm, smooth or roughened. From numerous spruce and aspen (UAMH 8688) logs, especially in advanced stages of decomposition, from most sites. Reported mainly from soil and as a laboratory contaminant (Sigler and Flis, 1998), but also from wood, especially from north-temperate regions. Cellulolytic (Nilsson, 1974), caused weight loss in birch and pine wood (Nilsson, 1973). Ref.: Sigler and Carmichael (1976).

Geotrichopsis* cf. *mycoparasitica Tzean & Estey, 1991, *Mycol. Res.* 95: 1350.

Colonies white, arthroconidia dry, schizolytic, 5-14.5 x 1.5-3.5 µm, chlamydospores absent. From stages 1-5 spruce, UEI, stage 5 spruce, UML, and stage 3 spruce, F83. Simple form of conidiogenesis makes determination difficult. *Geotrichopsis mycoparasitica* has been isolated as a parasite on a number of common molds, including several species isolated during this study. Ref.: Tzean and Estey (1991).

Geotrichum candidum Link, 1809, *Mag. Naturf. Freunde, Berlin* 9: 17.

Colonies white, flat, moist, arthroconidia of various sizes and shapes, including globose cells (10-12 µm diam), no asci observed. From stages 2, 4, and 5 spruce, UEI, stage 5 spruce, UML, stages 1 and 3 spruce, F61, stage 3 spruce, F83, stage 1 aspen, F93, H82, and H93, and stage 3 aspen, H61. Reported from numerous sources, including soil, worldwide (de Hoog et al., 1986), including Canada (Sigler and Flis, 1998). Ref.: de Hoog et al. (1986)

Gilmaniella humicola Barron, 1964, *Mycologia* 56: 514.

Conidia large, brown, with a distinct germ pore, 7-9 μm diam. From stage 1 aspen, UML and H93. Reported from dung (Ellis, 1971) and soil, including burnt soil (Cooke, 1970), worldwide, including Alberta (Sigler and Flis, 1998). Highly cellulolytic (Agarwal, 1975), caused weight loss in birch wood (Nilsson, 1973). Ref.: Ellis (1971).

Gliocladium roseum Bainier, 1907, *Bull. Soc. Mycol. Fr.* 23: 98.

Colonies pinkish, conidiophores penicillate or verticillate, conidia 4-7.5 x 3-4.5 μ m. From stages 4 and 5 spruce, UEI, stage 5 spruce, UML, and stage 1 spruce, F61. Worldwide, common in soil, including aspen (Morrall, 1974) and conifer forests (Bhatt, 1970) in Canada, including Alberta (Sigler and Flis, 1998), and from poplar wood (Sigler and Flis, 1998). Pectinolytic (Krehl-Nieffer, 1950), chitinolytic (Jackson, 1965), vigorously cellulolytic (Domsch and Gams, 1969), and possibly ligninolytic (Jackson, 1965). Ref.: Domsch et al. (1981).

Gliocladium viride Matruchot, 1895, *Rev. Gen. Bot.* 7: 328.

Conidiophores penicillate, conidia dark green, ellipsoidal, 3.5-5 x 2.5-3 μm. Isolated mainly from aspen logs, post harvest, but also from post-fire and undisturbed sites, and from several late stage spruce logs. Reported from forest soil in cold regions, including Canada (Domsch et al., 1980), and from poplar wood (Sigler and Flis, 1998). Cellulolytic (Marsh et al., 1949), causes weight loss in hard- and softwoods (Nilsson, 1973). Ref.: Domsch et al. (1980).

Graphium* cf. *calicioides (Fries) Cooke & Massee, 1887, *Grevillea* 16: 11.

Synnemata long (up to 400 μm long, only 15 μm wide), conidia variously-shaped, mostly ellipsoid, 3 x 1.5-2 μm. From stage 3 aspen, UML. *Graphium calicioides* has been commonly reported from rotten wood, Europe (Ellis, 1971). Ref.: Ellis (1971).

Graphium penicilloides Corda, 1837, *Icon. Fung.* 1: 18.

Synnemata short (up to 150 μm tall and 25 μm wide), conidia cylindrical, 3-5 x 1 μm, some *Leptographium*-like conidiogenesis, occasionally appearing arthroconidial. From stages 2 and 3 aspen, UEI, stage 2 aspen, UML, F82, and F83, and stage 3 aspen, F82, H61, and H82. This is a species aggregate (Seifert and Okada, 1993), found on hardwood, Europe and North America (Ellis, 1971). First report for Canada. Ref.: Ellis (1971).

Graphium* cf. *putredinis (Corda) Hughes, 1958, *Can. J. Bot.* 36: 770.

Synnemata very large (up to 1 mm long and 125 μm thick), with a broad, splayed head, conidia 5 x 1-2 μm. From stage 2 spruce, UEI, stages 1-4 spruce, UML, stage 5 spruce, F83, stage 3 spruce, F91 and F93, stage 1 aspen, F91, and stage 3 aspen, H82. *Graphium putredinis* is a species aggregate (Seifert and Okada, 1993), known from wood and soil (ATCC catalogue), Europe, Asia, and North America. Ref.: Seifert and Okada (1993).

***Graphium* sp. 1**

Synnemata long (up to 500 μm), conidia cylindrical (app. 4 x 2.5 μm, exceptionally up to 6 μm), mostly *Leptographium* state present. From stage 5 spruce, UEI and UML, and stage 3 aspen, UEI, H61, H62, H82, and H83.

***Haplographium* sp.**

Conidiophores dark brown, up to 175 x 7 μm, conidia hyaline, ellipsoid to cylindrical, up to 3.5-5 x 1-2 μm. From stage 5 spruce, UEI, stage 4 spruce, UML, and stage 3 spruce, F61 and F82.

Helicoma olivaceum (Karsten) Lindermann, 1929, *Ann. MO. Bot. Gard.* 16: 302.

Conidia helicoid, brown, 9-12-celled, 10-12 μm diam. From stages 1 and 3 aspen, UEI, and stages 2 and 3 aspen, F82. Reported from wood and bark, Europe and North America (Goos, 1986). First report for Canada. Ref.: Goos (1986).

Humicola fuscoatra Traaen, 1914, *Nytt. Mag. Naturvid.*, 52: 3334.

Conidia thin-walled, brown, mostly <11 μm diam, globose to obpyriform, phialoconidia globose, less than 4.5 μm diam. From stage 2 aspen, UML and H82, and stage 1 aspen, F93 and H82. Reported from soil, including forest soil (Söderström, 1975), and plant debris (Ellis, 1971) and dung in Alberta (Sigler and Flis, 1998). First report from wood. Vigorously cellulolytic (Domsch and Gams, 1969). Ref.: Domsch et al. (1980).

Humicola grisea Traaen, 1914, *Nytt. Mag. Naturvid.* 52: 34.

Conidia dark brown, globose, >10 μm diam, thick-walled, phialoconidia not observed. From stage 5 spruce, UEI. Reported from forest soil (Bhatt, 1970) and wood exposed to soil (Sharp, 1975), worldwide, including Alberta (Sigler and Flis, 1998). Vigorously cellulolytic (Domsch et al., 1980), caused weight loss in wood (Kerner-Gang and Schneider, 1969). Ref.: Ellis (1971).

Leptodontidium boreale de Hoog, 1977, *Stud. Mycol.* 15: 53.

Colonies darkening with age, reverse black, conidiogenous cells pale brown, thick-walled, conidia subglobose, 1.5-3 μm diam, produced on a short rachis. From stage 3 aspen, UML, and stage 3 spruce, F82. Previously known only from the type, from a prostrate pine pole in Sweden (de Hoog, 1977). First report for North America. Ref.: de Hoog (1977).

Leptodontidium camptobactrum de Hoog, 1977, *Stud. Mycol.* 15: 46.

Conidia narrow, 3-4.5 x 1-2 μm, hyaline, occasionally curved, produced from inflated conidiogenous cells. From stages 1 and 2 aspen, UEI, stage 2 aspen, UML, stage 5 spruce, F61, stage 1 aspen, F82 and H61, stage 3 aspen, F82, H61 and H82, and stage 2 aspen, F83. Reported from rotten hardwood and softwood, mainly from Europe (de Hoog, 1977). First report for Canada. Ref.: de Hoog (1977).

Leptodontidium elatius (Mangenot) de Hoog var. ***elatius*** de Hoog, 1977, *Stud. Mycol.* 15: 47.

Conidia cylindrical, 3.5-5 x 1-2 μm, produced sympodially in dense clusters at the tapered tip of pigmented conidiophores. Isolated numerous times from aspen and spruce from most sites (UAMH 9247). Reported mainly for Canada, from softwood and hardwood (mainly *Betula lutea* and *Abies balsamea*) (de Hoog, 1977). Caused soft rot in pine blocks (Zabel et al., 1982). Ref.: de Hoog (1977).

Leptographium lundbergii Lagerberg & Melin, 1928, *Sven. Skogsvardforen Tidskr.* 4: 257.

Conidiophores 150-185 x 8-10 μm, conidia 7-9 x 2.5-3 μm, with a truncate base. From stage 2 aspen, UEI. Reported from softwood, including for Canada (ATCC catalogue). Ref.: Ellis (1971).

***Leptographium* sp. 1**

Conidiophores 350-450 x 6-8 μm, thin-walled, pale brown, conidia 5-6 x 1.5-2 μ m, mostly curved and/or bilaterally symmetrical, some with pointed apices. From stage 5 spruce, UML.

***Leptographium* sp. 2**

Conidiophores 75-100 x 3.5 μm, conidia 2.5-3 x 1 μm, *Sporothrix* anamorph, conidiophores up to 75 μm long, conidia 2-2.5 x 1 μm, produced at the apex and at nodes along the condiiophore. From stage 2 spruce, UEI and UML, and stage 4 spruce, UML.

***Leptographium* sp. 3**

Conidiophores 500-600 x 7-13 μm, black, conidia 3-4 x 1.5 μm, many with truncate ends. From stage 5 spruce, F83 and H62, and stage 1 aspen, F91.

***Leptographium* sp. 4**

Conidiophores 150-175 x 4-6 μm, black, heads penicilloid, at least two-staged branched, conidia 2.5 x 1 μm, *Sporothrix* anamorph, conidia larger, 3 x 1.5-2 μm, produced on indeterminate conidiogenous cells. From stage 4 spruce, UML, and stage 1 aspen, H61 and H82.

***Leptographium* sp.5**

Conidiophores up to 300 x 5-6 μm, conidia 3-3.5 x 1.5-2 μm, synanamorph resembles *Sporothrix isarioides*. From stages 4 and 5 spruce, UEI, and stages 1 and 2 aspen and stage 3 spruce, F82.

***Leptographium* sp. 6**

Conidiophores undifferentiated from subtending hyphae, thin-walled, brown, conidia 2.5-3 x 1.5 μm. Isolated numerous times from spruce and aspen logs, especially from UEI and UML.

***Leptographium* sp.7**

Conidiophores 400-500 x 3-3.5 μm, with many septa, conidia globose, 2.5 μm diam, or ellipsoid, 2.5-3 x 2 μm. From aspen and spruce logs from many sites.

***Leptographium* sp. 8**

Conidiophores stout, mostly 30-40 x 4-5 μm, constricted at the septa, conidia curved, 3.5-4 x 1-1.5 μm, but occasionally inflated. From spruce and aspen logs from most sites, especially post-fire sites.

Malbranchea gypsea Sigler & Carmichael, 1976, *Mycotaxon* 4: 455.

Colonies white, arthroconidia narrow, 3-8 x 2–2.5 μm. From stage 4 (UAMH 8726) and 5 spruce, UEI, and stage 5 spruce, UML. Reported mainly from medical sources, but also from soil, North America (Sigler and Flis, 1998). First report for Canada and from wood. Cellulolytic (Sigler and Carmichael, 1976). Ref.: Sigler and Carmichael (1976).

Malbranchea pulchella Saccardo & Penzig, 1882, *Michelia* 2: 638.

Colonies tan, fertile hyphae curved, alternate arthroconidia 2.5-6 x 1.5-3 μm. From stage 5 spruce, UEI and UML, and stage 1 spruce, F61 (UAMH 9101). Reported from cellulosic substrata, including wood, Europe and North America (Sigler and Carmichael, 1976). First report for western Canada. Ref.: Sigler and Carmichael (1976).

Mammaria echinobotryoides Cesati, 1854, *Bot. Ztg.* 12: 190.

Conidia 11-20 x 5-8.5 μm, black, phialoconidia subglobose, hyaline, 1-2 μm diam. From stage 3 aspen, UEI, and stage 1 aspen, F82. Reported from wood and soil, Europe and North America (Ellis, 1971), including Alberta (Sigler and Flis, 1998). Ref.: Hennebert (1968).

Mariannaea elegans (Corda) Samson, 1974, *Stud. Mycol.* 6: 75.

Colonies brownish, with concentric zones, conidiophores tall (up to 1 mm), light brown, tapered phialides borne on whorled branches, conidia 4-6 x 1.5-2.5 μm, borne obliquely in long chains. From stages 2-5 spruce and stage 3 aspen, UEI, and stages 2-5 spruce, UML. Known previously from forest litter and soil, including from Alberta (Sigler and Flis, 1998), and from rotting wood of pine and Douglas fir (Wang and Zabel, 1990). Can cause soft rot (Levy, 1969). Ref.: Samson (1974).

Microsphaeropsis olivacea (Bonord.) Hohn., 1917, *Hedwigia* 59: 267.

Conidia brown, smooth, 4.5-6.5 x 3-4 μm. From stages 1 and 2 spruce and stage 1 aspen, UEI, and stage 1 aspen, UML and F93. Reported from hard- and softwood, worldwide, including elm in Alberta (Sigler and Flis, 1998). Ref.: Sutton (1980).

Monocillium mucidum W. Gams, 1971, *Cephalosporium*-artige Schimmelpilze (Hyphomycetes), p.165.

Phialides unbranched, thick-walled, mostly 25 x 1.5 μm, not tapered, tips expanding and "breaking open", conidia ellipsoid or short-cylindrical, some apiculate,

2.5-3 x 1.5-2 μm. From stage 2 aspen, UEI and F82. Reported from soil, Europe (Gams, 1971) and Japan (Tokumasu, 1973). First report for North America and from wood. Ref.: Gams (1971).

Monodictys glauca (Cooke & Harkness) Hughes, 1958, *Can. J. Bot.* 36: 785.

Conidia 8-15 x 6.5-10 μm, black or green-black, 10-15-celled. From stage 2 spruce and stage 2 aspen, UEI. Reported from hardwood, Europe and North America (Ellis, 1971; Gams and Holubova-Jechova, 1971). First report for Canada. Ref.: Ellis (1971).

***Mycogone* sp.**

Conidia 2-celled, distal cell large (5-6 μm diam), globose, spinose, black, proximal cell pale, slightly swollen, much smaller. From stage 1 spruce, F61.

Neta patuxentica Shearer & Crane, 1971, *Mycologia* 63: 241.

Dark, mesh-like hyphae present, conidia hyaline, 1-septate, 10-15 x 3-5 μm. From stage 1 aspen, UEI and UML. Reported from submerged wood, USA, and from litter (de Hoog, 1985). First report for Canada. Ref.: de Hoog (1985).

Nodulisporium* cf. *tuberum (Fontana & Bonfante) de Hoog, 1974, *Stud. Mycol.* 7: 66.

Colonies hyaline, conidiogenous cells cylindrical, base slightly swollen, occasionally branched, conidia hyaline, obovoidal, 4-5 x 2-2.5 μm. From stage 2 spruce, UEI. *Nodulisporium tuberum* known only from *Tuber* sp., Italy (de Hoog, 1974). Ref.: de Hoog (1974).

Oidiodendron griseum Robak, 1934, *Sven. Skogsvardforen Tidskr.* 3,4: 440.

Colonies grey-brown, conidiophores mostly less than 150 μm tall, conidia mostly smooth, greyish, short-cylindrical, 2-3.5 x 1.5-2.5 μm. Isolated many times, from spruce and aspen, mainly from undisturbed and post-fire sites. Reported from forest soil and wood in cold regions, Europe and North America, including Alberta (Sigler and Flis, 1998). Cellulolytic (Domsch, 1960), causes weight loss in hardwoods (Nilsson, 1973). Ref.: Barron (1962).

Oidiodendron maius Barron, 1962, *Can. J. Bot.* 40: 600.

Colonies pale grey or whitish, conidiophores mostly 200-700 μm long, fertile hyphae undulate, conidia smooth, hyaline, globose to short-cylindrical, 2.5-4.5 x 2-2.5 μ m. Isolated mostly from spruce logs from undisturbed and post-fire sites. Reported from peat soil (Domsch et al., 1980), but also from wood, including spruce wood, Canada (Barron, 1962). Ref.: Barron (1962).

Oidiodendron periconioides Morrall, 1968, *Can. J. Bot.* 46: 204.

Colonies grey-green or dark green, fertile hyphae beaded (alternating connectives and developing conidia), conidia globose or subglobose, 2.5-3.5 μm diam, warted (appearing banded under oil). Isolated mainly from late stage spruce logs from

undisturbed (UAMH 9050, 9051) and post-fire sites. Reported from conifer forest soil (Ellis, 1971). First report from wood. Ref.: Ellis (1971).

Oidiodendron* cf. *pilicola Y. Kobayasi, 1969, *Bull. Natl. Sci. Mus. Ser. E (Tokyo)* 12: 424.

Colonies dark brown or black, conidiophores 75-175 µm long, conidia cylindrical, truncate, with frills, smaller than those of *O. truncatum* (3-3.5 x 1.5-2 µm vs. 3.5-6.5 x 2-3 µm). From stage 5 spruce, UEI, and stage 3 spruce, UML. *Oidiodendron pilicola* is known only from forest soil, Europe (Kobayasi, 1969). Ref.: Kobayasi (1969).

Oidiodendron tenuissimum (Peck) Hughes, 1958, *Can. J. Bot.* 36: 790.

Colonies grey-brown, reverse dark, conidia roughened, subglobose, 2-3 µm diam. From stage 4 spruce, UEI, stage 5 spruce (UAMH 9246), UML, and stage 1 aspen, F93. Reported from forest soil and wood, mainly from cold regions, including Canada (Barron, 1962). Causes weight loss in hardwood (Nilsson, 1973). Ref.: Barron (1962).

Oidiodendron truncatum Barron, 1962, *Can. J. Bot.* 40: 602.

Colonies grey-green, conidia barrel-shaped, 3.5-6.5 x 2-3 µm, ends truncate with a darker frill. From stages 4 and 5 spruce and stage 3 aspen (UAMH 9064, 9065), UEI. Reported from soil, Canada, including from an aspen stand (Morrall, 1974). Ref.: Barron (1962).

Ovadendron sulfureo-ochraceum (van Beyma) Sigler & Carmichael, 1976, *Mycotaxon* 4: 392.

Colonies yellow, arthroconidia swollen, smooth, 3-4 x 2-3 µm, produced from short, undulate or coiled hyphae. From stage 4 spruce, UEI, and stage 2 spruce, UML (UAMH 9219, 9220). Previously known only from human sputum and infected eyes (Sigler and Carmichael, 1976). First report for North America and from wood. Ref.: Sigler and Carmichael (1976).

Paecilomyces* cf. *amoeneroseus (P. Henn.) Samson, 1974, *Stud. Mycol.* 6: 37.

Colonies pinkish, conidia subglobose, 2-3 µm diam, in long chains. From stage 5 spruce, UEI, stages 1 and 3 aspen, H61 and H82, and stages 1 and 2 aspen, H93. *Paecilomyces amoeneroseus* is known from lepidopterous and coleopterous larvae, Ghana (Samson, 1974). Ref.: Samson (1974).

Paecilomyces carneus (Duche & Heim) Brown & Smith, 1957, *Trans. Brit. Mycol. Soc.* 40: 70.

Colony reverse dark green, conidia in long chains, ellipsoid, 3-4.5 x 2-3 µm, finely to coarsely roughened. From stage 4 spruce, UEI, stage 2 aspen, H83, and stage 1 aspen, H93. Reported mainly from soil in cold regions, including Canada (Aube and Gagnon, 1971). First report from wood. Chitinolytic (Gray and Baxby, 1968) and cellulolytic (Vesco et al., 1967). Ref.: Samson (1974).

Paecilomyces farinosus (Holm) Brown & Smith, 1957, *Trans. Brit. Mycol. Soc.* 40: 50.

Colonies white, conidia subglobose to ellipsoid, mostly 2.5 x 1.5 µm. From stages 2-5 spruce, UEI, stage 3 aspen, UML and H61, stage 3 spruce, F82, and stage 2 aspen, H93. Reported from insect larvae and pupae (Samson, 1974) and forest soil (Wicklow and Whittingham, 1974), worldwide, including Canada. First report from wood. Caused weight loss in beech wood (Courtois, 1963). Ref.: Samson (1974).

Paecilomyces inflatus (Burnside) Carmichael, 1962, *Can. J. Bot.* 40: 1148.

Monophialidic, conidia subglobose, 2.5-3 x 3.5-4.5 µm, finely roughened. From stages 1, 2, 4, and 5 spruce and stages 2 and 3 aspen, UEI. Reported from forest soil and plant debris, including wood (Samson, 1974), worldwide, including Canada (Barron and Onions, 1966). Ref.: Samson (1974).

Paecilomyces lilacinus (Thom) Samson, 1974, *Stud. Mycol.* 6: 58.

Colonies pinkish, conidiophores rough-walled, conidia in long chains, ellipsoid, smooth-walled, 2-3 x 1.5-2.5 µm. From stage 5 spruce, UEI, stage 3 aspen, H61, and stage 2 aspen, H93. Reported from soil in warm regions, but also reported for Canada (Widden and Parkinson, 1973). First report from wood. Chitinolytic (Okafor, 1967), keratinolytic (Boehme and Ziegler, 1967), and possibly ligninolytic (Knudson, 1913). Ref.: Samson (1974).

Paecilomyces* cf. *sulfurellus (Saccardo) Samson & W. Gams, 1974, *Stud. Mycol.* 6: 67.

Colonies yellowish, phialides produced singly or in penicilloid heads, conidia cylindrical, 2-3 x 1-1.5 µm, occasionally curved. From stage 4 spruce, UEI, and stage 2 aspen, H93. *Paecilomyces sulfurellus* has been reported from wood of *Quercus*, Europe (Samson, 1974). Ref.: Samson (1974).

Paecilomyces variotii Bainier, 1907, *Bull. Trimest. Soc. Mycol. Fr.* 23: 26.

Colonies yellow-brown, conidia ellipsoid, variable in size and shape, mostly 3.5-4.5 x 3 µm, chlamydospores globose, 6-9 µm diam. Isolated numerous times from aspen and spruce from most sites. Reported from soil in warm regions, but also from wood (Shigo, 1971), including that of utility poles (Lopez et al., 1990), where it caused soft-rot. Ref.: Domsch et al. (1980).

Penicillium brevicompactum Dierckx, 1901, *Annls. Soc. Sci. Brux.* 25: 88.

Terverticillate, metulae and rami swollen, conidia ellipsoid, 3.5-4 x 2-2.5µm, finely roughened. From stages 1 and 3 aspen, H61 and stage 2 aspen, H83. Reported mainly from forest soil, Europe (Ramirez, 1982) but is thought to be widespread from many sources (Pitt, 1988), including air in Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Pitt (1988).

Penicillium chrysogenum Thom, 1910, *Bull. Bur. Anim. Ind. U.S. Dep. Agric.* 118: 58.

Terverticillate, heads poorly organized, stipes smooth, conidia subglobose, smooth. From stage 3 aspen, UEI, stage 1 spruce, F61, and stage 1 aspen, F82 and F83.

Reported from plant remains, worldwide (Pitt, 1988), including air and wood in Alberta (Sigler and Flis, 1998). Ref.: Ramirez (1982).

Penicillium citrinum Thom, 1910, *Bull. Bur. Anim. Ind. U.S. Dep. Agric.* 118: 61.

Biverticillate, stipes smooth, metulae long (occasionally appears monoverticillate), conidia ellipsoid, 3-3.5 x 2-2.5 μm. From stages 1-3 spruce and stage 1 aspen, UEI, stage 3 spruce, UML, stage 3 aspen, F82, and stage 5 spruce, F83. Reported from plant remains and soil, worldwide (Pitt, 1988), including air and wood in Alberta (Sigler and Flis, 1998). Ref.: Pitt (1988).

Penicillium claviforme Bainier, 1905, *Bull. Trimest. Soc. Mycol. Fr.* 21: 127.

Synnemata tall (up to 2 cm), conidial heads grey-green, conidia ellipsoid, 3.5 x 2.5 μm, smooth. From stage 4 spruce, UEI. Reported from soil and dung, worldwide (Seifert and Samson, 1985), including soil in Canada (Widden and Parkinson, 1973). First report from wood. Pectinolytic (Niethhammer and Jaeger, 1967) and cellulolytic (Scales, 1915). Ref.: Ramirez (1982).

Penicillium commune Thom, 1910, *Bull. Bur. Anim. Ind. U.S. Dep. Agric.* 118: 56.

Terverticillate, conidia globose, 2.5-3 μm diam, roughened. From stages 1 and 3 aspen, H93. Reported from food and soil, worldwide (Pitt, 1988), including Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Pitt (1988).

Penicillium decumbens Thom, 1910, *Bull. Bur. Anim. U.S. Dep. Agric.* 118: 71.

Monoverticillate, stipes short (up to 80 μm), smooth, conidia ellipsoid, 2.5-3 x 2 μ m. From stage 3 aspen, UML and H61, and stage 5 spruce, F61. Reported from soil and plant remains, worldwide (Pitt, 1988), including air and wood, Alberta (Sigler and Flis, 1998). Ref.: Ramirez (1982).

Penicillium frequentans Westling, 1911, *Ark. Bot.* 11: 133.

Colonies dark green, monoverticillate, stipes vesiculate, conidia globose, 3-3.5 μ m diam, finely roughened. From spruce and aspen logs from most sites. Reported from soil and plant remains, worldwide (Ramirez, 1982). Ref.: Ramirez (1982).

Penicillium funiculosum Thom, 1910, *Bull. Bur. Anim. Ind., U.S. Dept. Agric.*118: 69.

Biverticillate, stipes long, thick-walled, conidia ellipsoid, 2.5-3.5 x 1.5-2.5 μm, sclerotia blackening. From stage 3 aspen, UEI, stages 4 and 5 spruce, UML, and from numerous spruce and aspen logs from post-fire and post-harvest sites. Reported from acid soils, worldwide (Pitt, 1988). First report from wood. Ref.: Ramirez (1982).

Penicillium implicatum Biourge, 1923, *Cellule* 33: 178.

Monoverticillate, vesiculate, conidia globose, 2.5-3 μm diam, finely roughened. From stage 4 spruce and stage 2 aspen, UEI, stage 3 spruce and 1 aspen, UML, and stages 3 and 5 spruce, F61. Reported from dry habitats, including soil (Pitt, 1979) and dried foods, worldwide (Pitt, 1988). First report from wood. Ref.: Ramirez (1982).

Penicillium melinii Thom, 1930, *Penicillia*, p. 273.

Biverticillate (some appearing monoverticillate), stipes smooth, conidia globose, 3.5-4 μm diam. From stage 5 spruce and stage 2 aspen, UEI. Reported from soil (Pitt, 1988), including for North America (Ramirez, 1982). First report for Canada and from wood. Ref.: Ramirez (1982).

Penicillium miczynski Zaleski, 1927, *Bull. Int. Acad. Pol. Sci. Lett. Cl Sci. Math. Nat. Ser. B1*: 482.

Biverticillate (phialide:metulae < 1), stipes smooth, delicate, conidia subglobose, 2.5-3 μm long, smooth or finely roughened. From stages 1 and 3 spruce and stage 1 aspen, UEI, and stage 1 spruce and stages 1-3 aspen, UML. Reported from soil, worldwide (Pitt, 1988), including conifer forest soil (Ramirez, 1982), and from spruce wood, Alberta (Sigler and Flis, 1998). Ref.: Ramirez (1982).

Penicillium minioluteum Dierckx, 1901, *Annls. Soc. Sci. Brux.* 25: 87.

Biverticillate, stipes smooth, conidia globose (2.5-3 μm diam) to ellipsoid (3-3.5 x 2-2.5 μm), finely roughened. From stages 2 and 3 spruce, UEI, stages 3 and 5 spruce, UML and stage 1 spruce, H92. Reported from soil, worldwide (Pitt, 1988), and wood and air, Alberta (Sigler and Flis, 1998). Ref.: Pitt (1988).

Penicillium pinophilum Hedgcock in Thom, 1910, *Bull. Anim. Ind. U.S. Dep. Agric.* 118: 37.

Biverticillate (some terverticillate), conidia subglobose, 2.5-3 μm long, slightly roughened. From all UEI and UML logs, stage 3 spruce, F82, F83, F91 and F93, and stage 5 spruce, F61. Reported from soil and plant remains, worldwide (Pitt, 1988). Ref.: Pitt (1988).

Penicillium raistrickii G. Smith, 1933, *Trans. Brit. Mycol. Soc.* 18: 90.

Biverticillate, stipes long, roughened, conidia ellipsoid, 2-3 μm long, smooth, sclerotia present. From many spruce and aspen logs from undisturbed and post-fire sites. Reported from plant remains, soil, and air, worldwide (Pitt, 1988), including Alberta (Sigler and Flis, 1998). Ref.: Ramirez (1982).

Penicillium rugulosum Thom, 1910, *Bull. Bur. Anim. Ind. U.S. Dep. Agric.* 118: 60.

Biverticillate, conidia ellipsoid, 3-3.5 x 2.5-3μm, roughened, in long chains. From stages 2 and 3 aspen, UEI, and stage 2 aspen, UML. Reported from plant remains and occasionally from soil and air, worldwide (Ramirez, 1982), including Alberta (Sigler and Flis, 1998). Ref.: Pitt (1988).

Penicillium sclerotiorum van Beyma, 1937, *Zentralbl. Bakteriol. Parasitenkd. Infektionskr Abt.1* 96: 418.

Monoverticillate, stipes smooth, conidia ellipsoid, 2.5-3 x 2-2.5μm, sclerotia present. From stage 5 spruce, UEI, stages 4 and 5 spruce, UML, stages 3 and 5 spruce, F61, stage 3 spruce, F82, stage 5 spruce, H62, and stages 2 and 3 aspen, H82. Reported

from plant remains and soil, mainly from tropical regions (Ramirez, 1982), but also for Canada (Sigler and Flis, 1998). Ref.: Pitt (1988).

Penicillium spinulosum Thom, 1910, *Bull. Bur. Anim. Ind. U.S. Dep. Agric.* 118: 76.

Monoverticillate, stipes smooth to finely roughened, vesiculate, conidia globose, 3-3.5 μm diam, spinulose. From stages 1-5 spruce and stage 3 aspen, UEI, stage 5 spruce, UML and H62, and stage 3 spruce, F83. Reported from soil and plant remains, worldwide (Ramirez, 1982), including wood in Alberta (Sigler and Flis, 1998). Ref.: Ramirez (1982).

Penicillium thomii Maire, 1917, *Bull. Soc. Hist. Nat. Afr. Nord.* 8: 189.

Monoverticillate, stipes short, smooth, conidia ellipsoid, 2.5-3 x 2 μm, finely roughened, some asymmetrical. From stages 3-5 spruce, UEI, stages 3 and 5 spruce, and stages 1 and 3 aspen, UML, stage 5 spruce, F61, stage 1 aspen, F91, H61, and H82, stage 1 spruce, F93, and stage 3 aspen, H61 and H82. Reported from forest soil and decaying wood, worldwide (Pitt, 1988), including aspen forest soil, Alberta (Sigler and Flis, 1998). Ref.: Ramirez (1982).

Penicillium variabile Sopp, 1912, *Skr. Videnskabsselsk Khristiana* 11:169.

Biverticillate (some terverticillate), stipes smooth, conidia narrowly-ellipsoid, 3-5 x 2-3 μm, smooth. From stage 1 aspen and spruce, F83. Reported from soil and plant remains, worldwide (Pitt, 1988), including Alberta (Sigler and Flis, 1998). Ref.: Ramirez (1982).

Phialemonium curvatum W. Gams & W.B. Cooke, 1983, *Mycologia* 75: 980.

Conidia allantoid, 4-6 x 1-2 μm, curved. From stage 3 spruce, UEI, stage 2 aspen, UML, and stage 1 spruce, F93. Reported mainly as a contaminant (Gams and McGinnis, 1983), but also from aspen wood in Alberta (Sigler and Flis, 1998). Ref.: Gams and McGinnis (1983).

Phialemonium* cf. *dimorphosporum W. Gams & W.B. Cooke, 1983, *Mycologia* 75: 981.

Conidiophores infrequently formed, conidium size and shape highly variable, mostly 2 sizes, 4-6.5 x 1-2 μm and 2-4 x 1-1.5 μm, ellipsoid or rectangular, occasionally curved. From stage 1 aspen, UEI and F83, and stages 1 spruce and 2 aspen, UML. *Phialemonium dimorphosporum* has been isolated mainly from soil, North America (Gams and McGinnis, 1983), but also from pulp mill slime, New Brunswick (Sigler and Flis, 1998). Ref.: Gams and McGinnis (1983).

***Phialemonium* sp.**

Conidia allantoid or ellipsoid, 4.5-5 x 2-2.5 μm, sclerotia setose, up to 200 μm diam (including setae). From stage 1 spruce, UML, and stage 3 spruce, F61. Resembles *Phialemonium* sp. reported by Wang and Zabel (1990) from creosote-treated utility poles.

Phialocephala dimorphospora Kendrick, 1961, *Can. J. Bot.* 39: 1080.

Conidia of two kinds: ellipsoid, up to 5 x 3 μm; and subglobose, up to 3μm diam. From stage 2 aspen, UEI, stage 2 spruce, UML, and stage 3 aspen, F82. Reported from rotten deciduous wood, Canada (Ellis, 1971). Ref.: Ellis (1976).

Phialocephala fusca Kendrick, 1963, *Can. J. Bot.* 41: 1015.

Colonies dark green-brown, conidiophores 100-250 μm long, conidia pale brown, ellipsoid, 2.5-4 x 1.5-2.5 μm. From stages 3-5 spruce, UEI, stages 2 and 5 spruce and stage 3 aspen, UML, and stage 2 aspen, H82. Reported from hard- and softwood, mainly for Canada (Ellis, 1976; Kendrick, 1963). First report for western Canada. Ref.: Ellis (1976).

Phialocephala virens Siegfried & Siefert, 1992, *Can. J. Bot.* 70: 2485.

Colonies greenish, phialides up to 40 μm long, borne in clusters of up to 12 on short conidiophores, conidia ellipsoid, 2.5-4 x 1.5-2 μm. From stage 1 aspen, UEI, H61, and H93, and stage 2 aspen, H93. Reported from conifer wood in northwest North America, including western Canada (Siegfried et al., 1992). Ref.: Siegfried et al. (1992).

***Phialophora* sp. 1**

Similar to *P. botulispora*, but conidia hyaline, longer (up to 10 x 1.5 μm), distinctly curved, phialides borne in clusters of up to 6, collarettes long (up to 8 μm), not flared. From stage 5 spruce, F61, and stage 3 spruce, F93.

Phialophora americana (Nannfeldt) Hughes, 1958, *Can. J. Bot.* 36: 795.

Colonies grey-black, woolly, conidiophores with deep, darkly-pigmented collarette, conidia ellipsoid, hyaline, 3-5.5 x 1-3 μm. From stages 1-3 aspen, UEI, UML (UAMH 9218), F82, H82, and H83. Reported from soil and wood (Aube and Gagnon, 1971) in Europe and North America, including western Canada (Cole and Kendrick, 1973). Ref.: Ellis (1976).

Phialophora botulispora Cole & Kendrick, 1973, *Mycologia* 65: 678.

Colonies grey-black, conidiophores stout (15-20 x 3.5-5.5 μm), multibranched, phialide base swollen, collarette long, tubular, conidia cylindrical, 3.5-6 x 1-2.5 μm. From stages 2-5 spruce, UEI and UML, stage 2 aspen, UML and F83, and stage 3 spruce, F61 and F83. Reported from soft- and hardwoods (Cole and Kendrick, 1973), including a spruce log, Alberta (Sigler and Flis, 1998). Ref.: Cole and Kendrick (1973).

Phialophora brachyconia W. Gams, 1976, *Stud. Mycol.* 13: 68.

Colonies hyaline, phialides with well-developed collarettes, conidia in chains or slimy heads, dacryoid with a truncate base, 2-3 x 1.5-2.5 μm. From stage 1 spruce, UEI, stage 1 aspen, UML, F93, and H61, and stage 3 aspen, F83. Reported from hardwood, Europe (Gams and Holubova-Jechova, 1976). First report for North America. Ref.: Gams and Holubova-Jechova (1976).

Phialophora fastigiata (Lagerberg & Melin) Conant, 1937, *Mycologia* 29: 598.

Phialides distinctly ventricose, collarette conspicuous, conidia ellipsoid, occasionally curved, 3.5-6.5 x 1.5-3.5 μm. From stage 4 spruce, UML. Reported from wood, including spruce in western Canada (Cole and Kendrick, 1973). Caused weight loss in soft- and hardwood (Morrell and Zabel, 1985). Ref.: Cole and Kendrick (1973).

Phialophora olivacea W. Gams, 1976, *Stud. Mycol.* 13: 65.

Phialides simple, up to 18 x 3 μm, conidia pale brown, in long chains, ellipsoid with truncate base, 3.5-5.5 x 1.5-2 μm. From stages 2 and 4 spruce and 2 and 3 aspen, UEI, stage 2 spruce, UML, stage 3 aspen, F83, and stage 1 spruce, F93. Reported from plant remains, Europe (Gams and Holubova-Jechova, 1976), and from creosote-treated pine poles, North America (Wang and Zabel, 1990). First report for Canada. Ref.: Gams and Holubova-Jechova (1976).

Phialophora oxyspora W. Gams, 1976, *Stud. Mycol.* 13: 64.

Conidiophores unbranched, phialides up to 40 μm long, collarette darker than rest of the phialide, conidia slightly pigmented, in long chains, 4-6 x 1.5 μm, ends pointed. From stage 3 aspen, H82. Reported from soil (Sigler and Flis, 1998) and aphids (Gams and Holubova-Jechova, 1976). First report for North America and from wood. Ref.: Gams and Holubova-Jechova (1976).

Phialophora phaeophora W. Gams, 1976, *Stud. Mycol.* 13: 65.

Phialides dark brown, conidia hyaline, in long chains, dacryoid with a truncate base, up to 3 x 2 μm. From stage 1 spruce, UEI and UML, stage 3 aspen, UML, and stage 3 spruce, F82 and F93. Reported from wood of *Fagus*, Europe, white spruce, British Columbia (Gams and Holubova-Jechova, 1976), and soil, northern Alberta (Sigler and Flis, 1998). Ref.: Gams (1976).

Phialophora richardsiae (Nannfeldt) Conant, 1937, *Mycologia* 29: 598.

Phialides pale brown, collarettes flared, slightly darker than rest of the phialide, conidia of two kinds: globose, 2-3 μm diam; and allantoid, 2.5-5.5 x 1-3 μm. From stages 2 and 3 aspen, UEI. Reported from wood and wood products, worldwide, including Canada (Brewer, 1958). Caused weight loss in hard- and softwood blocks (Wang and Zabel, 1990). Ref.: Cole and Kendrick (1973).

Phoma eupyrena Saccardo, 1879, *Michelia* 1: 525.

Mycelium dark brown, pycnidia papillate, globose, 150-250 μm diam, conidia short-cylindrical, biguttulate, 4-5 x 1.5-2 μm, chlamydospores abundant, in chains. From stages 2 and 3 spruce and stage 2 aspen, UEI, stage 1 spruce, UML, stage 1 aspen, F82, F83, F91, H82 and H93, stage 2 aspen, F83 and H93, and stage 3 aspen, H92. Common from a number of substrata, including soil, and from Canada (Sutton, 1980). Ref.: Sutton (1980).

Pycnidial sp. 1

Colonies black, pycnidia small and long, mostly 40 x 25 μm, aggregated in clusters, conidia ellipsoid, 2.5-3 x 2 μm. From stage 5 spruce, UEI, stages 2-5 spruce, UML, and stage 3 spruce, F83.

Pycnidial sp. 2

Pycnidia globose, 200-300 μm diam, setose (setae 40-45 μm long), conidia cylindrical, 5 x 1.5-2 μm, apiculate or truncate, occasionally curved. From stage 5 spruce, F83, and stage 1 aspen, H61.

Pycnidial sp. 3

Pycnidia globose, 75-150 μm diam, conidia hyaline or pale brown, 2.5-3 x 2.5 μ m, biguttulate, ellipsoid to cylindrical, occasionally curved. From stage 2 spruce, UEI.

Pycnidial sp. 4

Colonies olivaceous-black, mycelium coarse, black, branching hyphae constricted at base, pycnidia subglobose, 75-125 μm diam, papillate, conidia cylindrical, ends truncate, 3-4 x 1 μm. From stage 1 spruce, F61, F83, F91, F93 and H92.

Ramichloridium anceps (Saccardo & Ellis) de Hoog, 1978, *Stud. Mycol.* 15: 77.

Conidiogenous cells dark brown, developing a long rachis, conidia hyaline, globose, up to 3 μm diam. From stages 1 and 3 spruce and stage 3 aspen, UEI, stages 2 and 5 spruce and stage 2 aspen, UML, stage 2 aspen, F83, H82 and H93, and stage 3 aspen, H61. Reported from soil and wood, including *Populus tremuloides* and *Picea engelmannii*, Alberta (de Hoog, 1977). Ref.: de Hoog (1977).

***Ramichloridium* sp.**

Conidia hyaline, occasionally septate, ellipsoid with a truncate base, up to 5 x 2 μ m, produced on a narrow rachis. From stages 1 and 3 spruce, F61, and stage 1 aspen, H83.

Rhinocladiella atrovirens Nannfeldt, 1934, *Sven. Skogsvardsforen Tidskr.* 32: 462.

Conidiogenous hyphae long, indeterminate, denticulate, conidia ellipsoid-lacryform, 3-6 x 1-2 μm. From most logs and from all sites. Reported from wood, including *P. glauca* and *P. tremuloides*, western Canada (de Hoog, 1977). Ref.: de Hoog (1977).

Scopulariopsis asperula (Saccardo) Hughes, 1958, *Can. J. Bot.* 36: 803.

Colonies buff, conidia finely-roughened at maturity, globose, truncate, 5-7.5 μm diam. From stage 2 spruce (UAMH 9144) and stage 3 aspen, UEI. Reported from dung and air, Japan, Europe, and North America (Morton and Smith, 1963), including Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Morton and Smith (1963).

Scopulariopsis brevicaulis (Saccardo) Bainier, 1907, *Bull. Trimest. Soc. Mycol. Fr.* 23: 98.

Colonies tan, annellides somewhat swollen at the base, conidia subglobose or globose, truncate, occasionally pointed, 5.5-8.5 x 4-6 μm, finely to coarsely roughened. From stage 5 spruce (UAMH 9145) and 3 aspen, UEI, stage 2 aspen, UML, stages 1-3 aspen, H61, and stages 1 and 2 aspen, H93. Reported from many cellulosic materials, worldwide (Domsch et al., 1980), including Alberta (Sigler and Flis, 1998). Cellulolytic (Marsh et al., 1949) and ligninolytic (Domsch, 1960). Ref.: Domsch et al. (1980).

Scopulariopsis brumptii Salvanet-Duval, 1935, *These Fac. Pharm. Paris* 23: 58.

Colonies brown, annellides inflated, conidia black, subglobose with a rounded apex, 3.5-6 x 3.5-5 μm. From stages 2 and 5 spruce, and stage 2 aspen (UAMH 8619), UEI and stage 3 aspen, H61. Reported from soil and air, worldwide (Domsch et al., 1980), including Alberta (Sigler and Flis, 1998). First report from wood. Cellulolytic (Gochenaur 1975), chitinolytic (Krempl-Lamprecht, 1961), and possibly ligninolytic (Domsch, 1960). Ref.: Domsch et al. (1980).

Scopulariopsis candida (Guégen) Vuillemin, 1911, *Bull. Soc. Mycol. Fr.* 27: 143.

Colonies pale-buff, conidia subglobose, truncate, 4.5-8 x 4-7.5 μm. From stage 2 spruce and stage 2 aspen (UAMH 9146), UEI. Reported from medical sources, cheese, soil, and wood, Europe and North America (Morton and Smith, 1963), including Alberta (Sigler and Flis, 1998). Ref.: Morton and Smith (1963).

Scopulariopsis chartarum (Smith) Morton & Smith, 1963, *Mycol. Pap.* 86: 64.

Colonies brown-black, conidia broadly ellipsoid to subglobose, 4-5.5 x 3-4 μm. From stage 5 spruce, UEI (UAMH 9173). Reported from soil and air, worldwide, including Canada. First report for western Canada and from wood. Ref.: Morton and Smith (1963).

Scopulariopsis flava (Sopp) Morton & Smith, 1963, *Mycol. Pap.* 86: 43.

Colonies white, conidia subglobose, truncate, finely roughened, 5.5-7.5 x 5-6.5 μ m. From stage 2 (UAMH 9170, 9171, 9172) and 5 (9201) spruce and 2 aspen, UEI, stage 1 aspen, H61 (UAMH 9202), and stage 3 aspen, H92. Reported from soil, USA, and cheese, Europe (Morton and Smith, 1963). First report for Canada and from wood. Ref.: Morton and Smith (1963).

Scytalidium lignicola Pesante, 1957, *Annali Sper. Agr., N.S. 11, Suppl.*, CCLXI.

Colonies pale to dark brown, arthroconidia hyaline, 5-7.5 x 1-2.5μm, brown chlamydospores 6-10 x 4.5-8.5μm, in long chains. Isolated from stages 1-5 spruce, and 1 and 3 aspen, UEI, stages 2-4 spruce and 3 aspen, UML, stage 5 spruce, F61, and stage 1 spruce and 3 aspen, F83 (UAMH 9221). Reported from wood, worldwide (Ellis, 1971), including Alberta (Sigler and Flis, 1998). Ref.: Ellis (1971).

Septomyrothecium* cf. *uniseptatum Matsushima, 1971, *Bull. Nat. Sci. Mus. Tokyo* 14: 469.

Conidiophores branched, conidiogenous cells densely packed, conidia narrowly fusiform, up to 22 x 2.5 µm. From stage 3 aspen, UEI. *Septomyrothecium uniseptatum* is known only from litter of broadleaf trees. Ref.: Carmichael et al. (1980).

Sporothrix curviconia de Hoog, 1974, *Stud. Mycol.* 7: 33.

Colonies white, conidiogenous cells somewhat tapered, conidia hyaline, some guttuliform, 4-5 x 1.5-2 µm, curved, tapered, others subglobose, up to 2.5µm diam. From stage 5 spruce, UEI, stage 1 aspen, F83, and stage 3 aspen, F93. Reported from Ivory Coast (de Hoog, 1974). First report for North America and from wood. Ref.: de Hoog (1974).

Sporothrix fungorum de Hoog & deVries, 1973, *Antonie Leeuwenhoek J. Microbiol.* 39: 158.

Conidiogenous cells fragile, up to 100 µm long, conidia guttuliform, apiculate, 3-4 x 1.5 µm, secondary conidia abundant, subglobose, up to 1.5 µm diam. From stage 2 spruce, UEI. Reported from old fruit bodies of *Fomes* sp., Europe (Sigler and Flis, 1998). First report for Canada and from wood. Ref.: de Hoog (1974).

Sporothrix inflata de Hoog, 1974, *Stud. Mycol.* 7: 34.

Colonies darkening with age, conidiogenous cells tapered, apices swollen, conidia hyaline, apiculate, 4-5 x 1.5-2 µm, lateral blastoconidia thick-walled, brown, globose, 3.5-4 µm diam. From numerous spruce logs from undisturbed and post-fire sites. Reported from soil, Europe (de Hoog, 1974), and from pine wood, British Columbia (Sigler and Flis, 1998). Ref.: de Hoog (1974).

Sporothrix isarioides (Petch) de Hoog, 1974, *Stud. Mycol.* 7: 23.

Colonies white, conidiogenous cells long (up to 125 µm), fragile, often branched, conidia scattered, fusiform, 3-4 x 1.5 µm, slightly apiculate. From stages 1 and 2 aspen and 2 spruce, UEI, stage 1 spruce, F61 and F91, and stage 1 aspen, F82. Reported from insects and as a hyperparasite on other fungi, Sri Lanka and Trinidad (de Hoog, 1974). First report for North America and from wood. Ref.: de Hoog (1974).

Sporothrix* anam. *Ophiostoma microsporum (Davidson) von Arx, 1952, *Antonie Leeuwenhoek J. Microbiol.* 18: 211.

Conidiogenous hyphae short (up to 25 µm), conidia curved, hyaline, 4-4.5 x 2 µm, ellipsoid, occasionally blunt-ended, no secondary conidia observed. From stage 5 spruce, UEI and UML. Previously known from wood of *Quercus*, USA (de Hoog, 1974). First report for Canada. Ref.: de Hoog (1974).

Sporothrix* cf. anam. *Ophiostoma nigrocarpum (Davidson) de Hoog, 1974, *Stud. Mycol.* 7: 62.

Colonies darkening with age, conidiogenous cells short (<20 µm long), usually with apical clusters of conidia, conidia broadly ellipsoid, 3.5-4.5 x 1.5-2 µm. From stages

2 and 4 spruce, UEI, and stages 2 and 5 spruce, UML. *Ophiostoma nigrocarpum* has been reported from softwood, USA (de Hoog, 1974). Ref.: de Hoog (1974).

***Sporothrix* sp. 1**

Colonies white, conidiophores up to 50 µm long, conidia borne in apical clusters, conidia all globose, those borne apically 1.5 µm diam, lateral conidia up to 2 µm diam. From stage 1 aspen, F82.

Sporotrichum versisporum (Lloyd) Stalpers, 1984, *Stud. Mycol.* 24: 25.

Conidia up to 12 x 8 µm, thick-walled, no chlamydospores or clamp connections observed. From stages 1 and 3 aspen, UEI, stage 2 aspen, UML, and stage 1 aspen, F83. Reported from soft- and hardwood, worldwide (Stalpers, 1984). Ref.: Stalpers (1984).

Stachybotrys chartarum (Ehrenb.) Hughes, 1958, *Can. J. Bot.* 36: 815.

Conidia 7.5-11 x 4-6 µm, inconsistently roughened, black, aggregated in slimy masses. From stage 2 aspen, UEI. Reported from plant matter, worldwide, including forest soil in Canada (Bhatt, 1970) and indoor wood in Alberta (Sigler and Flis, 1998). Cellulolytic (White et al., 1948), pectinolytic (Cochrane, 1958), chitinolytic (Domsch, 1960), and possibly ligninolytic (Ceruti Scurti et al., 1972). Ref.: Domsch et al. (1980)

Taeniolella stilbospora (Corda) Hughes, 1958, *Can. J. Bot.* 36: 817.

Colonies dark, velvety, conidiophores caespitose, conidia dark brown, up to 15-septate, up to 10 µm diam, length varies with number of cells. From stage 3 spruce, F61, and stage 3 aspen, H61. Common from hardwoods, including *Populus* in North America (Ellis, 1971). Ref.: Ellis (1971).

Thysanophora penicilloides (Roum.) Kendrick, 1961, *Can. J. Bot.* 39: 820.

Colonies dark, sclerotia black, conidiophore stipes brown, up to 1 mm long, conidia subglobose to ellipsoid, finely roughened, 2-4.5 x 1.5-2.5 µm. From stages 2 and 4 spruce, and stage 3 aspen, UEI, and stages 1, 2, 3 (UAMH 9248), and 5 spruce and stages 1-3 aspen, UML. Reported from softwood and soil, worldwide (Ellis, 1971), including Alberta (Sigler and Flis, 1998). Ref.: Ellis (1971).

Torula herbarum* forma *quaternella Saccardo, 1913, *Ann. Mycol.* 11: 556.

Conidia 3 or 4 celled, 11-18 x 4.5-5.5 µm. From stages 1 and 2 spruce, UEI. Reported mainly from the tropics (Ellis, 1971), although *T. herbarum* (Persoon) Link has been reported from air, Alberta (Sigler and Flis, 1998). First report of *T. herbarum* f. *quaternella* for Canada and from wood. Ref.: Ellis (1971).

Torulomyces lagena Delitsch, 1943, *Systematik der Schimmelpilze*, p. 91.

Conidiogenous cells *Acremonium*-like, thin-walled, somewhat swollen near apex, conidia in connected chains, globose, roughened, up to 3µm diam. From stages 1-5 spruce and 2 and 3 aspen, UEI, stage 1 spruce, F61, and stage 3 aspen, F82 and H61. Previously isolated mostly from soil, including Canada (Widden and Parkinson, 1973), but also from a spruce stump, Alberta (Sigler and Flis, 1998). Ref.: Domsch et al. (1980).

Trichoderma hamatum (Bonord.) Bainier, 1906, *Bull. Trimest. Soc. Mycol. Fr.* 22: 131.

Colonies dark green, conidiophores with sterile elongations, conidia ellipsoid, smooth, 2.5-4.5 x 1.5-2.5 μm, dark green. From stage 3 spruce, UEI. Reported from soil, worldwide, including conifer forest soil, Canada. Cellulolytic (Domsch and Gams, 1969). Ref.: Rifai (1969).

Trichoderma harzianum Rifai, 1969, *Mycol. Pap.* 116: 38.

Colonies green, conidia ovoid, dark green, smooth, 2.5-3.5 x 2.5-3 μm. Isolated numerous times from spruce and aspen logs from undisturbed, post-fire, and post-harvest sites. Reported from soil and wood, worldwide (Domsch et al., 1981), and from various sources in Alberta (Sigler and Flis, 1998). Cellulolytic (Parke, 1976). Ref.: Rifai (1969).

Trichoderma polysporum (Link) Rifai, 1969, *Mycol. Pap.* 116: 18.

Colonies white, conidiophores with coiled sterile elongations, conidia white, smooth, 2.5-3.5 x 1.5-2 μm. From numerous spruce (UAMH 9154) and aspen logs from undisturbed and post-fire sites. Reported from soil and plant debris, worldwide (Rifai, 1969), including Alberta (Sigler and Flis, 1998). Cellulolytic (Park, 1976) and chitinolytic (Jackson, 1965), caused weight loss in hardwoods (Nilsson, 1973). Ref.: Rifai (1969).

Trichoderma viride Persoon, 1801, *Syn. Meth. Fung.*, p. 231.

Colonies dark green, conidia green, globose or subglobose, 3-4.5 μm long, roughenings sometimes only visible under oil. From most logs in most sites. Reported from soil and wood, worldwide (Mangenot, 1952), including aspen wood in Alberta (Sigler and Flis, 1998). Pectinolytic (Borut and Johnson, 1962), cellulolytic (Flannigan, 1970), chitinolytic (Gray and Baxby, 1968), and ligninolytic (Fischer, 1953), causes weight loss in wood (Merrill, 1966). Ref.: Rifai (1969).

Tritirachium* cf. *oryzae (Vincens) de Hoog, 1972, *Stud. Mycol.* 1: 22.

Colonies pale, pinkish, conidia, 2-3 x 1.5-2.5 μm, borne on a narrow (approx.1 μ m), geniculate rachis. From stages 1 and 3 spruce and 1 aspen, F93, and stages 1 and 2 aspen, H82. *Tritirachium oryzae* has been reported many times from cellulosic substrata, including wood of *Salix* spp., mainly Europe and Asia (de Hoog, 1972). Ref.: de Hoog (1972).

Truncatella angustata (Persoon) Hughes, 1958, *Can. J. Bot.* 36: 822.

Conidia 4-celled, middle 2 cells dark brown, outer 2 cells hyaline, overall up to 18 x 8 μm, (2-4) basal appendages up to 25μm long. From stage 3 aspen, UEI, H61, and H92, and stage 2 aspen, H93. Previous reported from plant remains, worldwide (Sutton, 1980), and as a contaminant (Sigler and Flis, 1998). Ref.: Sutton (1980).

Ulocladium botrytis Preuss, 1851, *Linnaea* 24: 111.

Colonies black, conidia broadly ellipsoid, verrucose, muriform, 13-21 x 8.5-14.5 μm. From stage 5 spruce, UEI, stage 3 aspen, UEI, F83, and H82, and stage 1 aspen, H61,

H82, and H93. Reported from plant debris, worldwide (Ellis, 1971), including Alberta (Sigler and Flis, 1998). Ref.: Ellis (1971).

Ulocladium consortiale (Thum.) Simmons, 1967, *Mycologia,* 59: 84.

Conidia brown, minutely roughened, 14-26 x 11-14 µm. From stage 4 spruce, UEI, and stage 1 aspen, F93. Reported from cellulosic substrata, including leaf litter and soil, worldwide, including Canada (Ellis, 1971), and air, Alberta (Sigler and Flis, 1998). First report from wood. Cellulolytic (White et al., 1948). Ref.: Ellis (1971).

Veronaea* cf. *coprophila (Subram. & Lodha) M.B. Ellis, 1976, *More Dematiaceous Hyphomycetes*, p. 210.

Conidiophores dark brown, lighter near the apex, branching subapically, conidia septate, brown, ellipsoid with a somewhat apiculate and truncate base, 6.5-8 x 2-3 µm. From stage 2 aspen, UEI, and stage 3 aspen, UML. *Veronaea coprophila* is known only from goat dung in India (Ellis, 1976). Ref.: Ellis (1976).

Verticillium catenulatum (Kamyschko) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes),* p. 190.

Conidia catenulate, subglobose, apiculate, 3-3.5 x 1.5-2.5 µm, chlamydospores small (up to 25 µm diam), few-celled. From stages 1-3 aspen, UEI, stage 2 aspen, F82, stages 1 and 3 aspen, H61, and stages 2 and 3 aspen, H83. Reported from forest soil, worldwide (Domsch et al., 1980), including Canada (Barron and Onions, 1966). First report from wood. Ref.: Gams (1971).

Verticillium chlamydosporium Goddard, 1913, *Bot. Gaz.* 56: 275.

Dictyochlamydospores present, conidia ellipsoid, 3-3.5 x 1.5-2 µm, in slimy heads. Isolated many times from undisturbed, post-fire and post-harvest sites. Reported from forest soil (Chen, 1966), worldwide, including western Canada (Sigler and Flis, 1998). Cellulolytic (Gochenaur, 1975) and chitinolytic (Jackson, 1965). Ref.: Domsch et al. (1980).

Verticillium cyclosporum (Grove) Mason & Hughes, 1951, *Mycol. Pap.* 45: 18.

Conidiophores pale brown, verticillately branched, phialides with small collarette, conidia oblong to globose, up to 2.5µm diam. From stage 3 aspen, H82. Reported mainly from hardwood, Europe (Ellis, 1971). First report for Canada. Ref.: Gams and Holubova-Jechova (1976).

Verticillium fungicola (Preuss) Hassebr., 1936, *Phytopath. Z.* 9: 514.

Conidiophores erect, conidia ellipsoid to short-cylindrical, 4-5.5 x 1.5-2.5 µm. From stage 5 spruce and stage 2 aspen, UEI, stage 3 aspen, UML, F83, H61, H82, stage 2 aspen, F82 and F83, and stage 1 aspen, H61 and H82. Reported as a mushroom parasite, Europe (Gams, 1971). First report for North America and from wood. Ref.: Domsch et al. (1980).

Verticillium lamellicola (F.E.V. Smith) W. Gams, 1971, Cephalosporium-*artige Schimmelpilze (Hyphomycetes)*, p. 183.

Conidium size and shape variable, mostly narrow-fusiform, 7-9.5 x 1-1.5 μm. From stages 1 and 4 spruce and stage 3 aspen, UEI, stages 2 and 3 aspen, UML, and stage 1 spruce, F61 and F83. Reported as a fungal parasite, worldwide, including Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Gams (1971).

Verticillium lecanii (Zimm.) Viégas, 1939, *Rev. Inst. Café Sao Paolo* 14: 754.

Conidiophores prostrate, not well distinguished, conidia cylindrical with rounded ends. From stage 2 spruce, UML. Reported as an insect and fungus parasite in soil and litter, worldwide, including Alberta (Sigler and Flis, 1998). First report from wood. Cellulolytic (Domsch, 1960) and pectinolytic (Leal and Villanueva, 1962). Ref.: Domsch et al. (1980).

Verticillium* cf. *lindauianum Bubak, 1914, *Ann. Mycol.* 12: 210.

Phialides in whorls of 3 or 4, pointed slightly upward, conidia globose to ellipsoid, 2-3 μm diam. From stage 4 spruce, UEI, stages 1 and 3 aspen, H61, and stage 3 aspen, H82. *Verticillium lindauianum* has been reported as a parasite of slime molds (Gams, 1971). Ref.: Gams (1971).

Verticillium psalliotae Treschow, 1941, *Dansk Botan. Ark.* 11: 7.

Phialides in whorls of 3 or 4, conidia fusiform, ends pointed, 4.5-5.5 x 1.5-2.5 μm (in some isolates up to 10 μm long). From stages 2, 4, and 5 spruce, UEI, and stage 1 aspen, F83. Reported as an insect and mushroom parasite, worldwide (Domsch et al., 1980), including Alberta (Sigler and Flis, 1998). Ref.: Gams (1971).

Verticillium tenerum Nees, 1851, *Handb. Allg. Mykol.*, 92.

Colonies orange, conidiophores verticillately branched, conidia 3.5-5 x 2-2.5 μm, red-brown in mass. From stage 1 spruce, UEI (UAMH 9381). Reported from soil and plant remains, worldwide, including forest soil, Canada (Widden and Parkinson, 1973). Pectinolytic (Krehl-Nieffer, 1950), cellulolytic (Domsch, 1960), chitinolytic (Okafor, 1967), and probably ligninolytic (Domsch, 1960), causes weight loss in hardwood (Haider and Domsch, 1969). Ref.: Gams (1971).

Verticillium tenuissimum Corda, 1837, *Icon. Fung.* 1: 20.

Colonies dark grey-brown, conidiophores up to 300 μm long, dark and swollen at the base, conidia borne from collarettes, cylindrical, 2-4 x 1-2 μm. From stage 2-4 spruce, UEI and UML, and stage 1 aspen, F93. Reported from hard- and softwood, Europe (Ellis, 1971). Ref.: Ellis (1971).

Volutella ciliata Alb. & Schwartz : Fries, 1832, *Syst. Mycol.* 3: 466.

Sporodochia short-stalked, setae hyaline, conidia ellipsoid, smooth, 4-7.5 x 1.5-2.5 μm. From stage 5 spruce, UEI. Reported from temperate forest soil, including that of aspen (Visser and Parkinson, 1975), worldwide, including Alberta (Sigler and Flis, 1998).

First report from wood. Cellulolytic (Domsch and Gams, 1969). Ref.: Domsch et al. (1980).

Wardomyces humicola Hennebert & Barron, 1962, *Can. J. Bot.* 40: 1209.

Conidiophores much branched, conidia 2-celled, 9.5-12 x 2.5-5 μm, distal cell dark brown, up to 7.5 μm long, proximal cell pale, up to 4 μm long. From stages 2 (UAMH 8489), 4, and 5 (UAMH 9368) spruce, UEI, stages 4 and 5 spruce, UML, stage 3 spruce, F82, and stage 1 aspen, H83. Reported from soil, Canada (Hennebert, 1962). First report from wood. Ref.: Hennebert (1968).

Wardomyces inflatus (Marchal) Hennebert, 1968, *Trans. Brit. Mycol. Soc.* 51: 755.

Conidiogenous cells inflated, up to 6.5 μm long, conidia ellipsoidal, truncate at the base, 5-7 x 3-4 μm. From stage 4 spruce and stage 2 aspen (UAMH 8488), UEI, and stage 4 spruce, UML. Reported from wood and soil, Europe and North America (Ellis, 1971), including Alberta (Sigler and Flis, 1998). Ref.: Ellis (1971).

Zygomycetes

Absidia cylindrospora Hagem, 1908, *Norweg. Mucor.*, p. 45.

Sporangiophores in whorls of 2 or 3, sporangiospores cylindrical, 3-6 x 2-3.5 μm. From stage 4 spruce and stage 1 aspen, UEI, and stage 3 spruce, UML. Reported mostly from forest soil, worldwide (Domsch et al., 1980). Ligninolytic (Ceruti Scurti et al., 1972). Ref.: Domsch et al. (1980).

Absidia glauca Hagem, 1908, *Norweg. Mucor.*, p. 42.

Sporangiophores in whorls mostly of 2 or, less commonly, of 3, sporangiospores globose, 2.5-4.5 μm diam. From most aspen and spruce logs, UEI and UML, and from stage 5 spruce, F83, stage 3 aspen, F93 and H82, and stage 1 aspen, F93. Reported from forest soil, worldwide, including Canada (Ellis and Hesseltine, 1965), and from air, Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Domsch et al. (1980).

Coemansia aciculifera Thaxter, 1943, *Farlowia* 1: 64.

Sporangiola 13-23.5 x 1-2 μm, produced on sporocladia. From stage 3 aspen, UEI. Little information available for *C. aciculifera*. First report from wood. Ref.: Zycha and Siepmann (1969).

Cunninghamella elegans Lendner, 1908, *Mucor. Suisse*, p. 159.

Sporangiola globose, 7-11 μm diam, or ellipsoid, 9-13 x 6-10 μm, produced on denticulate sporangiophores. From stages 4 and 5 spruce and stages 2 and 3 aspen, UEI, stage 5 spruce, F61, stages 1 and 3 aspen, H61 and H82, and stage 1 spruce, H92. Reported from forest soil, worldwide, especially in moist habitats (Orpurt and Curtis, 1957). First report from wood. Pectinolytic (Krehl-Nieffer, 1950) and proteinolytic (Janke and Holzer, 1929). Ref.: Domsch et al. (1980).

Mortierella* cf. *acuminata Linneman, 1941, *Pflanzenforsch.* 23: 21.

Sporangiophores unbranched, sporangia single-spored, ornamented, 13-17 µm diam. From stage 2 spruce, UEI. Simple sporogenesis makes disinction among species in Section Stylospora difficult. Ref.: Zycha and Siepmann (1969).

Mortierella* cf. *alliacea Linneman, 1963, *Zentralbl. Bakteriol. Parasitenkde. Infektionskr. Abt. 1* 107: 225.

Sporangiophores up to 250 µm long, swollen at the base, spores short-cylindrical, 2.5-4 x 4.5-6 µm. From stage 3 spruce, F61, and stage 3 aspen, F83. *Mortierella alliacea* has been reported from plant remains, Europe (Zycha and Siepmann, 1969). Ref.: Zycha and Siepmann (1969).

Mortierella alpina Peyronel, 1913, *Germi atmosferici, Diss. Padova*, p.17.

Sporangiophores simple, base swollen, sporangiospores ellipsoid, 3.5-4.5 x 1.5-2 µm. From stages 4 and 5 spruce, UEI, stages 2 and 3 aspen, UML, stage 3 spruce, UML, F61, and F82, stage 5 spruce, F61, stages 1-3 aspen, F82, and stage 3 aspen, F83 and H83. Reported mostly from cold habitats (Nicholls, 1956), under spruce (Mosca, 1956) and after burning (Jorgensen and Hodges, 1970). First report from wood. Chitinolytic (Gray and Baxby, 1968). Ref.: Domsch et al. (1980).

Mortierella bainieri Cost., 1889, *Bull. Soc. Mycol. Fr.* 4: 150.

Sporangiophores up to 2 mm long, basitonously branched, sporangiospores elongate, 6.5-9 x 3-5 µm. From stages 1-5 spruce and stage 3 aspen, UEI, stages 1-4 spruce and 2 and 3 aspen, UML, stage 3 spruce, F61, stages 2 and 3 aspen, F83 and H82, and stages 1-3 aspen, H83. Reported from soil in temperate regions, including forest soil (Badura, 1960), and on decaying agarics (Zycha et al., 1969). First report from wood. Ref.: Domsch et al. (1980).

Mortierella elongata Linneman, 1941, *Mucorineen-Gatt.* Mortierella, p. 43.

Sporangiophores basitonously branched, up to 500 µm long, chlamydospores present, sporangiospores ellipsoid, 7-12 x 4-5.5 µm. From stage 5 spruce and stage 3 aspen, UEI, stages 2 and 3 aspen, H82, and stage 3 aspen, H83. Reported from forest soils, including mixedwoods, worldwide (Hendrix et al., 1971), including Alberta (Sigler and Flis, 1998). First report from wood. Weakly pectinolytic (Domsch and Gams, 1969) and chitinolytic (Jackson, 1965). Ref.: Zycha and Siepmann (1969).

Mortierella exigua Linneman, 1941, *Mucorineen-Gatt.* Mortierella, p. 44.

Sporangiophores acrotonously branched, sporangiospores cylindrical, 5.5-11 x 3.5-5.5 µm, chlamydospores globose, up to 30 µm diam. From stage 4 spruce, UEI, stage 1 spruce, F61, and stage 3 aspen, F82 and H61. Reported mainly from forest soil in cold regions (Domsch et al., 1981). First report for North America and from wood. Chitinolytic (Domsch, 1960). Ref.: Domsch et al. (1980).

Mortierella gamsii Milko, 1974, *Opredel. Mukoral. Gribov.*, p. 76.

Sporangiophores acrotonously branched, with projections at sporangiophore tips, sporangiospores globose or subglobose, 8-11 μm diam. From stage 4 and 5 spruce and stage 3 aspen, UEI, stage 3 spruce, F61, and stage 3 aspen, F93 and H62. Reported from forest soil, especially in colder regions (Domsch et al., 1980), including Alberta (Sigler and Flis, 1998). First report from wood. Chitinolytic (Jackson, 1965). Ref.: Domsch et al. (1980).

Mortierella horticola Linneman, 1941, *Pflanzenforsch.* 23: 21.

Sporangiophores 35-100 μm long, sporangia single-spored, ornamented, 6-12 μm diam. From stage 5 spruce, UML. Reported from soil, Europe (Domsch et al. (1980). First report for North America and from wood. Ref.: Domsch et al. (1980).

Mortierella humilis Linneman, 1936, *Flora* 130: 309.

Sporangiophores up to 250 μm long, basitonously branched, sporangia 1-spored, ornamented, 7-11 μm. From stage 4 spruce, UEI, and stages 2 and 3 aspen, UML. Previously known mainly from forest soil in cold regions (Domsch et al., 1981). First report from wood. Chitinolytic (Jackson, 1965). Ref.: Domsch et al. (1980).

Mortierella hyalina (Harz) W. Gams, 1970, *Nova Hedwig.* 18: 13.

Colonies slow-growing, sporangiophores up to 700 μm long, basitonously branched, apophyses 10-12 μm diam, subglobose, spores somewhat angular, chlamydospores in chains, 5-25 μm diam. From stages 4 and 5 spruce, UEI, stage 5 spruce, UML, and stage 3 spruce, F82. Reported from forest soils, worldwide (Domsch et al., 1980), including from Alberta (Sigler and Flis, 1998). First report from wood. Pectinolytic (Domsch and Gams, 1969). Ref.: Domsch et al. (1980).

Mortierella isabellina Oudemans, 1902, *Arch. Neerl. Sci. Exact. Nat.* 7: 276.

Sporangiophores basitonously branched, sporangiospores angular, sub-globose, 1.5-2.5 μm long. From stages 3-5 spruce, UEI, stage 3 aspen, UML and H83, and stage 1 aspen, F93. Reported from forest soil including spruce (Mosca, 1956) and aspen in Canada (Morrall, 1974). First report from wood. Ref.: Domsch et al. (1980).

Mortierella jenkini (Smith) Naumov, 1935, *Opredel. Mukorovych (Mucorales)* 2: 97.

Sporangiospores 3-5 x 2-3 μm. From stage 2 spruce, UEI, and stages 2 and 3 aspen, H83. Reported from soil, including under spruce, Europe (Zycha and Siepmann, 1969), and from a rotting *Populus* log, B.C. (Sigler and Flis, 1998). Ref.: Zycha and Siepmann (1969).

Mortierella minutissima van Tiegham, 1876, *Ann. Sc. Nat. 6, Ser. 4*: 385.

Sporangiophores basitonously branched, up to 350 μm long and 13 μm thick, spores subglobose or globose, 3-7 μm diam. From stage 4 spruce, UEI, and stage 5 spruce, F61. Reported from forest soil, worldwide (Domsch et al., 1980). First report for Canada and from wood. Ref.: Domsch et al. (1980).

Mortierella nana Linneman, 1941, *Mucorineen-Gatt.* Mortierella, p. 16.

Sporangiophores verticillately branched, sporangia single-spored, globose, 5-8 μm diam. From stage 4 spruce, UEI. Reported from forest soil, including aspen (Morrall, 1974) and spruce (Soederstroem, 1975), worldwide, including Canada (Morrall, 1974). First report from wood. Ref.: Domsch et al. (1980).

Mortierella parvispora Linneman, 1941, *Mucorineen-Gatt.* Mortierella, p. 53.

Sporangiophores acrotonously branched, spores globose, 2-3 μm. From stages 4 and 5 spruce and stage 3 aspen, UEI, stages 3 and 5 spruce, UML, and stages 2 and 3 aspen, F83. Reported from acid forest soils in cool, temperate zones, especially Europe, but also North America (Balasooriya and Parkinson, 1967). First report from wood. Pectinolytic (Dickinson and Boardman, 1970). Ref.: Domsch et al. (1980).

Mortierella pulchella Linneman, 1941, *Pflanzenforch.* 23: 41.

Sporangiophores acrotonously branched, sporangiospores ovoid, 2-2.5 x 1.5 μm. From stage 4 spruce, UEI. Reported from soil, Europe (ATCC catalogue), including under spruce (Zycha and Siepmann, 1969). First report from wood. Ref.: Zycha and Siepmann (1969). Ref.: Zycha and Siepmann (1969).

Mortierella ramanniana (Moller) Linneman, 1941, *Pflanzenforch.* 23: 19.

Sporangia pink, sporangiospores short-cylindrical, 2.5-6 x 1.5-3 μm, chlamydospores abundant, up to 200 μm diam. Isolated numerous times from spruce and aspen logs, especially in late stages, from undisturbed, post-fire, and post-harvest sites. Reported from cold, acidic soils, worldwide (Domsch et al., 1980), including Canada (Morrall and Vanterpool, 1968; Morrall, 1974; Singh, 1976). First report from wood. Pectinolytic (Jeffreys et al., 1953). Ref.: Domsch et al. (1980).

Mortierella vinacea Dixon-Stewart, 1932, *Trans. Brit. Mycol. Soc.* 17: 213.

Sporangia pink, sporangiospores angular, 3-6.5 μm diam, chlamydospores sparse, less than 15 μm diam. From stage 5 spruce, UML, and stage 3 spruce, F82. Reported mostly from moist, acidic forest soils, including Canada (Morrall, 1974; Singh, 1976), and after prescribed burning (Jorgensen and Hodges, 1970). First report from wood. Pectinolytic, cellulolytic, but only in presence of high nitrogen levels (Domsch et al., 1980). Ref.: Domsch et al. (1980).

Mucor hiemalis Wehmer, 1903, *Ann. Mycol.* 1: 39.

Sporangia yellow-brown, sporangiophores sympodially branched, sporangiospores ellipsoid, 5-7.5 x 3-5.5 μm. From many spruce and aspen logs, from undisturbed, post-fire, and post-harvest sites. Reported from soil, worldwide (Domsch et al., 1980). First report from wood. Pectinolytic (Domsch and Gams, 1969), chitinolytic (Domsch and Gams, 1968), and cellulolytic (Loub, 1963). Ref.: Domsch et al. (1980).

Mucor mucedo Fres., 1850, *Beitr. Mykol.*, p. 7.

Sporangium wall spinulose, sporangiospores broadly ellipsoid, 9-12.5 x 5-7.5 μm. From stages 4 and 5 spruce, UEI. Reported from dung but also from hardwood forest soil

(Huang and Schmitt, 1975), worldwide (Domsch et al., 1980), including Alberta (Sigler and Flis, 1998). First report from wood. Proteinolytic (Stern, 1952). Ref.: Domsch et al. (1980).

Mucor plumbeus Bonord., 1864, *Abh. Naturf. Ges. Halle*, 8: 19.

Columellae with apical projections, sporangium wall spinulose, sporangiospores globose, 6-9.5 µm diam. From stage 2 spruce and stages 1-3 aspen, UEI, stage 2 spruce and stage 1 aspen, UML, and stage 3 spruce and stage 3 aspen, F82. Reported from soil and air, worldwide (Domsch et al., 1980), including Alberta (Sigler and Flis, 1998). First report from wood. Ref.: Domsch et al. (1980).

Mucor racemosus Fres., 1850, *Beitr. Mycol.*, p. 12.

Colonies greyish, sporangiospores ovoid, 4.5-8 x 4.5-7 µm, chlamydospores in sporangiophores subglobose, up to 15 µm diam. From several spruce and aspen logs from undisturbed, post-fire, and post-harvest sites. Reported from soil and plant remains, worldwide (Domsch et al., 1980). First report for Canada and from wood. Ref.: Domsch et al (1980).

Mucor recurvus Butler, 1952, *Mycologia* 44: 56.

Sporangium wall finely ornamented, sporangiospores ellipsoidal, 14.5-19 x 6.5-8 µm. From stage 4 spruce, UEI and UML. Reported from soil and wood, including North America (Schipper, 1978). First report for Canada. Ref.: Schipper (1978).

Rhizopus oryzae Went & Prinsen Geerlings, 1895, *Kon. Ak. Wetensk. Amsterdam*, p. 4.

Sporangiophores often arising from stolons, rhizoids few times branched, sporangiospores subglobose, 6.5-9 µm diam. From stage 1 aspen, UML. Reported mostly from soil in tropical or subtropical regions, but also for North America (Diener et al., 1976), and as an airborne contaminant, Alberta (Sigler and Flis, 1998). First report from wood. Cellulolytic (Reese and Mandels, 1959) and possibly lignolytic (Ceruti Scurti et al., 1972). Ref.: Domsch et al. (1980).

Rhizopus stolonifer (Ehrenb.:Fries) Vuillemin, 1902, *Revue Mycol.* 24:54.

Sporangiophores in whorls, rhizoids many-branched, sporangiospores black, subglobose, 6-12.5 x 5-8 µm, ridged. From stages 4 and 5 spruce, UEI, stage 5 spruce, F83, and stage 1 aspen, H61 and H82. Reported from forest soil, worldwide, including Canada (Aube and Gagnon, 1971), and as an airborne contaminant, including from Alberta (Sigler and Flis, 1998). First report from wood. Pectinolytic (Malan et al., 1969) and chitinolytic (Domsch, 1960). Ref.: Domsch et al. (1980).

Thamnidium elegans Link, 1809, *Berlin Mag. Natf. Fr.* 3: 31.

Sporophores many times dichotomously branched, sporangia and sporangiola present, sporangiospores subglobose, 5.5-13 x 4-6.5 µm. From stage 4 spruce and stage 2 aspen, UEI, and stage 5 spruce, F83. Reported from soil in cold regions, including Canada (Hesseltine and Anderson, 1956) and as an airborne contaminant, Alberta (Sigler

and Flis, 1998). First report from wood. Enzymatic capabilities not well defined. Ref.: Benny (1992).

Discussion

The few reports of microfungi from naturally decomposing wood that exist (Crane et al., 1996; Crawford et al., 1990) refer to a relatively small number of species. For isolation of fungi during this study, wood samples were plated directly onto six different media to allow the growth of a broad range of fungi, including slow- and fast-growing species. Malt extract agar and cornmeal agar are non-selective media that allowed the growth of a broad spectrum of fungi. These media were especially effective for isolating from wood with few species. The addition of benomyl to MEA allowed for better selection for zygomycetes by inhibiting the growth of ascomycetes and fungi imperfecti. Similarly, Mycobiotic agar inhibited the growth of most fungi, but allowed the growth of certain ascomycetes, especially those from the Onygenales and Microascales, which were common components of the communities and allowed a better understanding of the ecology of these fungi. For wood with many species, tapwater agar and MEA with rose bengal retarded the growth of fast-growing species, especially zygomycetes, so that slow-growing species could be observed.

Stage of decomposition and log species affect the number and taxa of species recovered. Overall, species richness increased with stage of decomposition and spruce wood yielded more species than similar-stage aspen wood. Additionally, zygomycetes and ascomycetes became proportionately more abundant during the later stages (Fig. 2.2). The late stages (4 and 5 for spruce and 3 for aspen) had an abundance of species normally isolated from soil. This included *Geomyces pannorus* (Fig. 2.3g), *Mariannaea elegans* (Fig. 2.4b), *Mortierella ramanniana* (Fig. 2.4e), *Trichoderma polysporum* (Fig. 2.5f), and *Verticillium chlamydosporium* (Fig. 2.5h).

Overall, number of records was highest for late stage logs and higher for spruce than for aspen (Fig. 2.2). Additionally, the impact of harvest was greatest on the abundance of zygomycetes and ascomycetes (Fig. 2.7). The reason for the decline in ascomycetes and zygomycetes may be attributable to changes in the wood as a microhabitat, or as a consequence of differences in type of post-disturbance residual logs. Specifically, type of disturbance influences the classes and species of logs found and, consequently, the communities of fungi. Harvest sites are more likely to have aspen left behind than spruce and some species, such as *Phialophora americana*, were specific to aspen logs (Fig. 2.5a) and found in greater numbers in post-harvest sites. Similarly, a number of other species, including *Chloridium chlamydosporis*, *Mariannaea elegans*, *Oidiodendron periconioides*, and *Scytalidium lignicola*, were found mostly or exclusively on spruce and were more likely to be recovered from sites with more spruce (undisturbed and post-fire sites). The inconsistency in stages of decomposition of residual logs among disturbed sites also influenced the species present. *Acremonium butyri* (Fig. 2.3a), *Acrodontium simplex* (Fig. 2.3b), *Chloridium chlamydosporis* (Fig. 2.3c), and *Cordana pauciseptata* (Fig. 2.3d) all demonstrated specificity to certain stages of decomposition. Although the nature of the relationship is unclear, there is evidence that decomposition

microfungus communities vary with the type of slash left after logging, which in turn may affect the soil mycoflora and contribution of nutrients to forest soil.

Several trends were apparent for generic abundance (Fig. 2.6), although it should be noted that, because these are form-genera, generalizations must be made with caution. Species of *Acremonium*, *Cladosporium*, *Leptographium*, *Penicillium*, *Trichoderma*, and *Verticillium* were isolated with equal frequency from all sites. However, species of *Aspergillus*, *Gliocladium*, *Paecilomyces*, and *Phialophora* were most abundant in post-harvest sites, and *Chrysosporium* spp., *Oidiodendron* spp., and *Sporothrix* spp. were virtually absent from post-harvest sites. *Arthrobotrys* spp. and *Graphium* spp. were in very low numbers from post-fire site logs. These differences are at least partly a consequence of disturbance. *Chrysosporium* spp., for example, were as common in undisturbed sites on aspen as on spruce (e.g., *Chrysosporium merdarium*, Fig. 2.3d). The differences in others, however, can be accounted for by specificity to log species. *Oidiodendron* spp and *Sporothrix* spp., for example, were much more abundant on spruce logs and virtually absent from post-harvest sites, where spruce logs are less common than aspen.

Table 2.1. Summary of site characteristics and logs sampled (MDT – mean daily temperature, in degrees; MAP – mean annual precipitation, in millimetres; DD>5 – degree-days> 5°C).

Site	Location (latitude, longitude)	Description	MDT	MAP	DD>5	log classes sampled
UML	50 km N Mariana Lake (56°16'N, 111°40'W)	undisturbed for at least 90 years, some human activity	0.6	361.0	1252.9	all
UEI	NE corner, Elk Island National Park (53°40'N, 112°48'W)	undisturbed for at least 120 years, large populations of elk and bison	2.3	325.8	1470.1	all
F61	10 km S Slave Lake (55°14'N, 114°55'W)	burned in 1961	0.7	346.1	1212.6	1,3,5 spruce
F82	near Little Buffalo (56°28'N, 116°50'W)	burned in 1982	0.2	256.4	1239.1	3 spruce; 1,2,3 aspen
F83	53 km S Fort MacMurray (56°17'N, 111°51'W)	burned in 1982	0.2	332.8	1289.7	1,3,5 spruce; 1,2,3 aspen
F91	53 km S Fort MacMurray (56°19'N, 111°48'W)	burned in 1995	0.2	332.8	1289.7	1,5 spruce; 1 aspen
F93	95 km S Fort MacMurray (56°13'N, 111°53'W)	burned in 1995	0.2	332.8	1289.7	1,3 spruce; 1,2,3 aspen
H61	10 km N Slave Lake (55°36'N, 114°56'W)	harvested in 1968	0.7	346.1	1212.6	1,3 aspen
H62	15 km N Slave Lake (55°30'N, 114°13'W)	harvested in 1968	0.7	346.1	1212.6	5 spruce;3 aspen

H82	30 km N Slave Lake (55°40'N, 114°42'W)	harvested in 1982	0.6	331.9	1315.2	1,2,3 aspen
H83	10 km N Slave Lake (55°35'N, 114°30'W)	harvested in 1982	0.7	346.1	1212.6	1,2,3 aspen
H92	15 km NW Calling Lake (55°26'N, 113°33'W)	harvested in 1995	0.3	356.2	1202.7	3 spruce; 1,3, aspen
H93	Lawrence Lake Recreation Area (55°04'N, 113°49'W)	harvested in 1995	0.3	356.2	1202.7	1,2 aspen

Figure 2.1. Map of Alberta showing location of study sites (Elk Island – 1, Mariana Lake – a, Slave Lake – 4-8, Little Buffalo – 9, Calling Lake – 2,3).

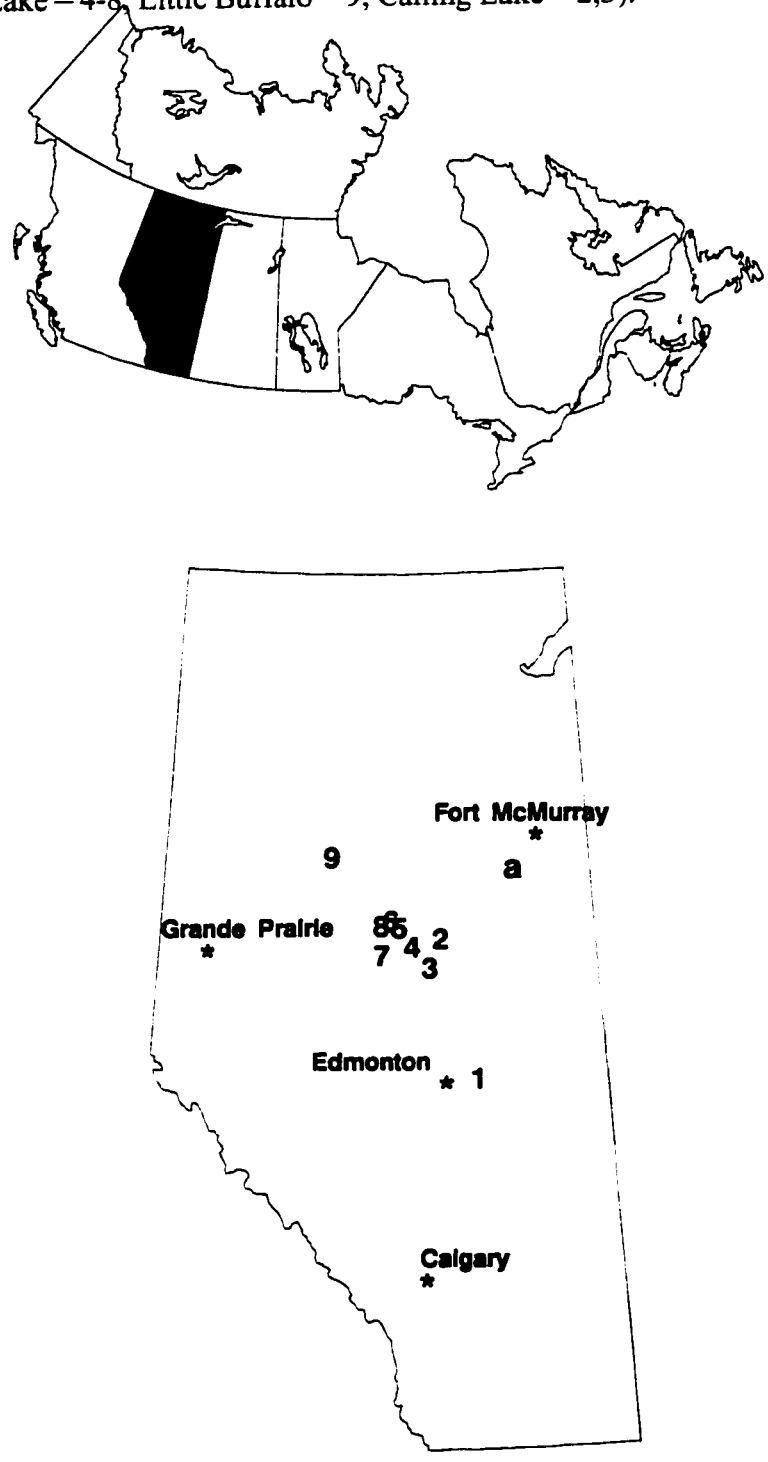


Figure 2.2. Average number of records per sample for logs, from all sites, of aspen (as) and spruce (sp) at various stages of decomposition, summarized for fungi imperfecti (grey), ascomycetes (white), and zygomycetes (grey) based on totals from all six isolation media.

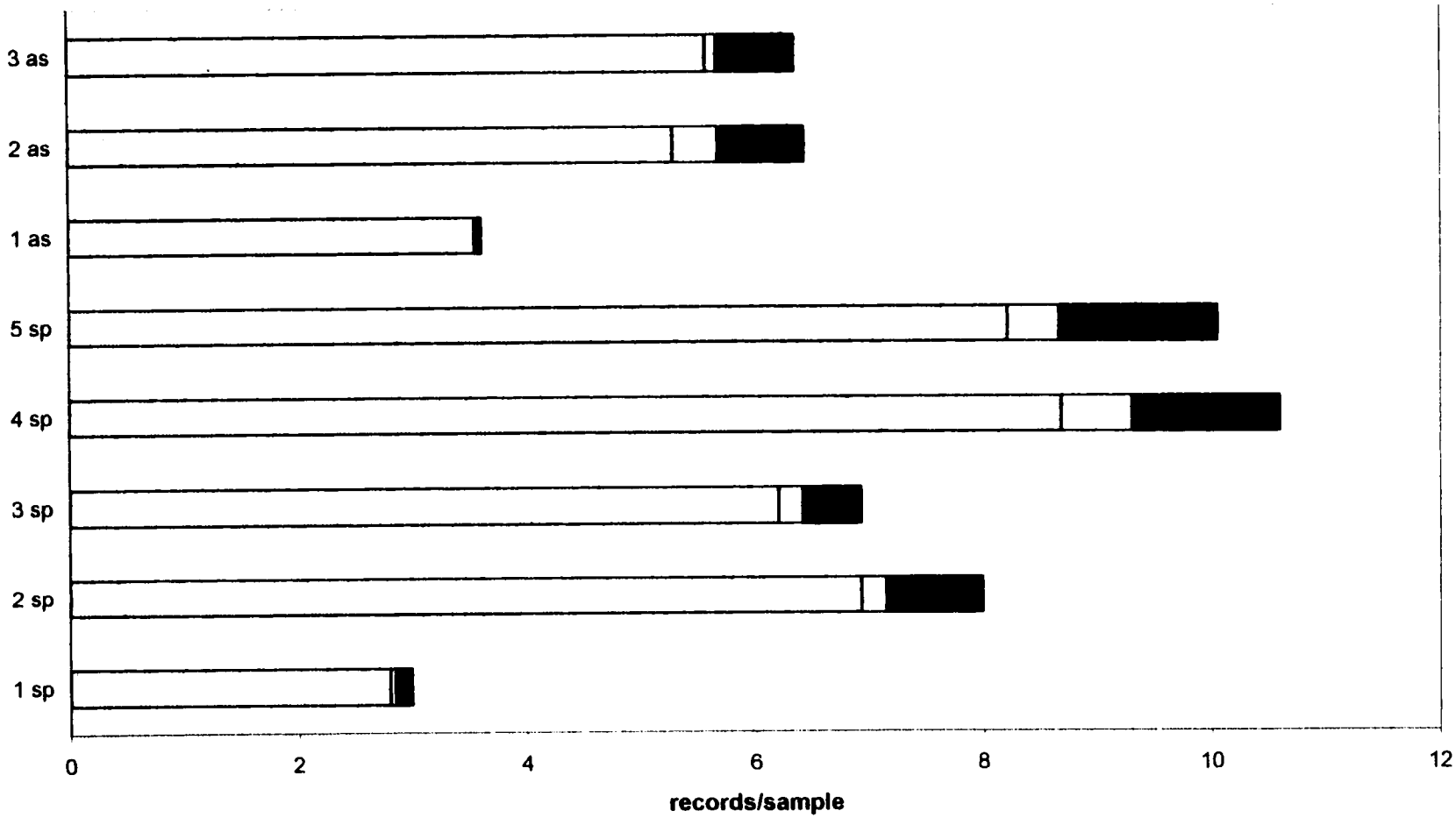


Figure 2.3a-h. Number of records for species from spruce (sp) and aspen (as) logs at various stages of decomposition from undisturbed sites at Elk Island National Park (grey) and Mariana Lake (black). Log classes are a combination of log species (spruce - "sp", aspen - "as") and decomposition stage.

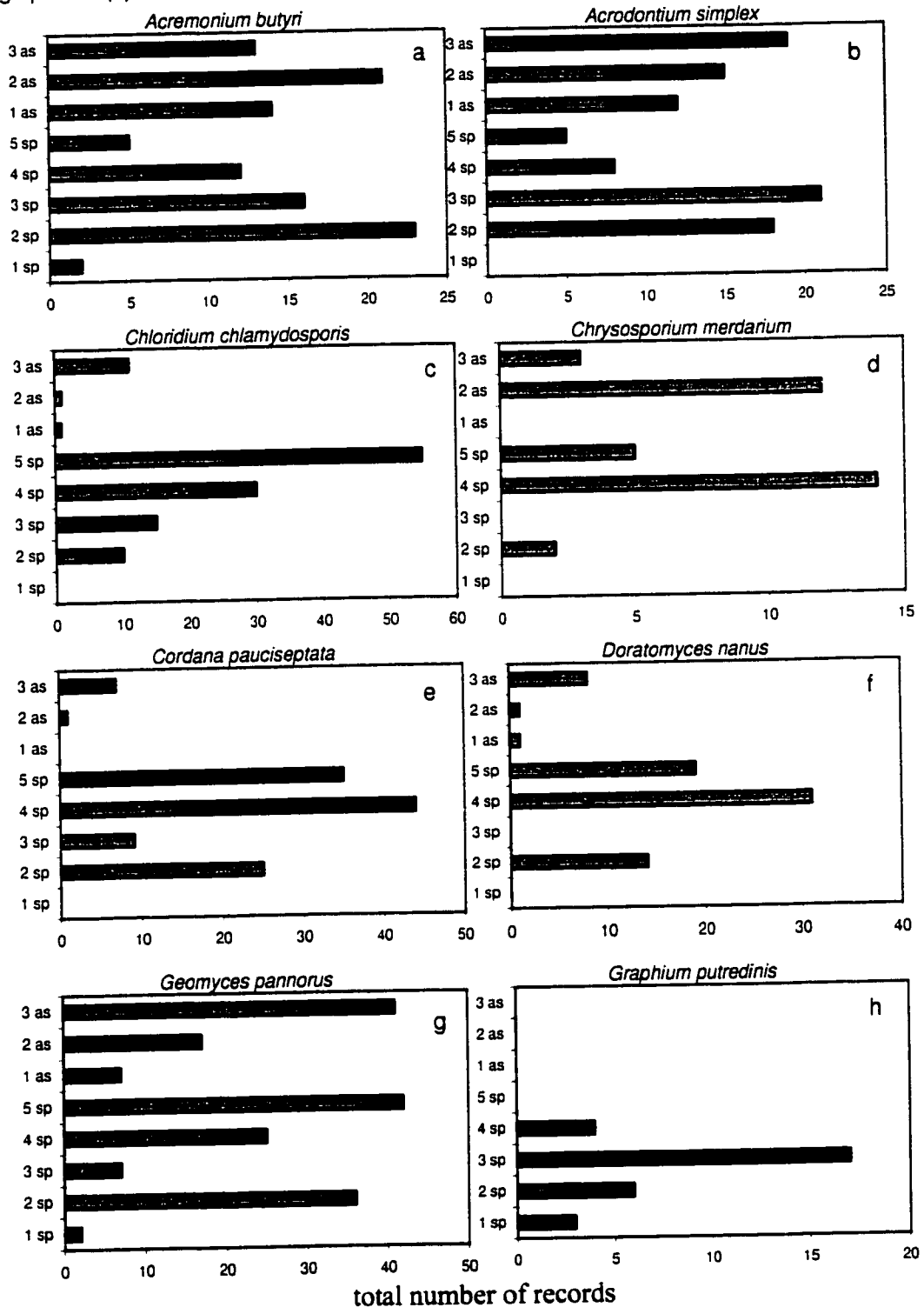


Figure 2.4a-h. Number of records for species from spruce (sp) and aspen (as) logs at various stages of decomposition from undisturbed sites at Elk Island National Park (grey) and Mariana Lake (black). Log classes are a combination of log species (spruce - "sp", aspen - "as") and decomposition stage.

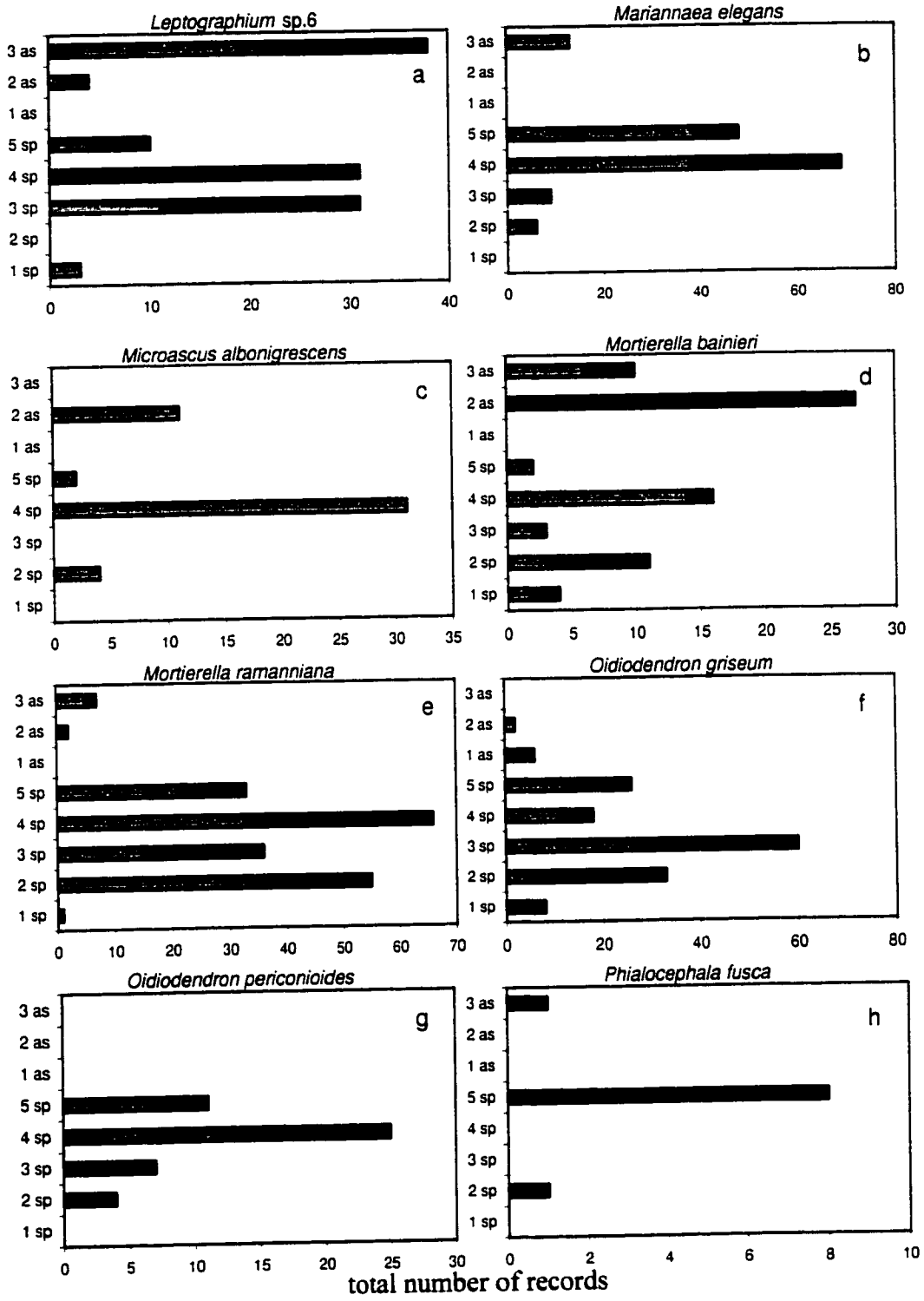


Figure 2.5a-h. Number of records for species from spruce (sp) and aspen (as) logs at various stages of decomposition from undisturbed sites at Elk Island National Park (grey) and Mariana Lake (black). Log classes are a combination of log species (spruce - "sp", aspen - "as") and decomposition stage.

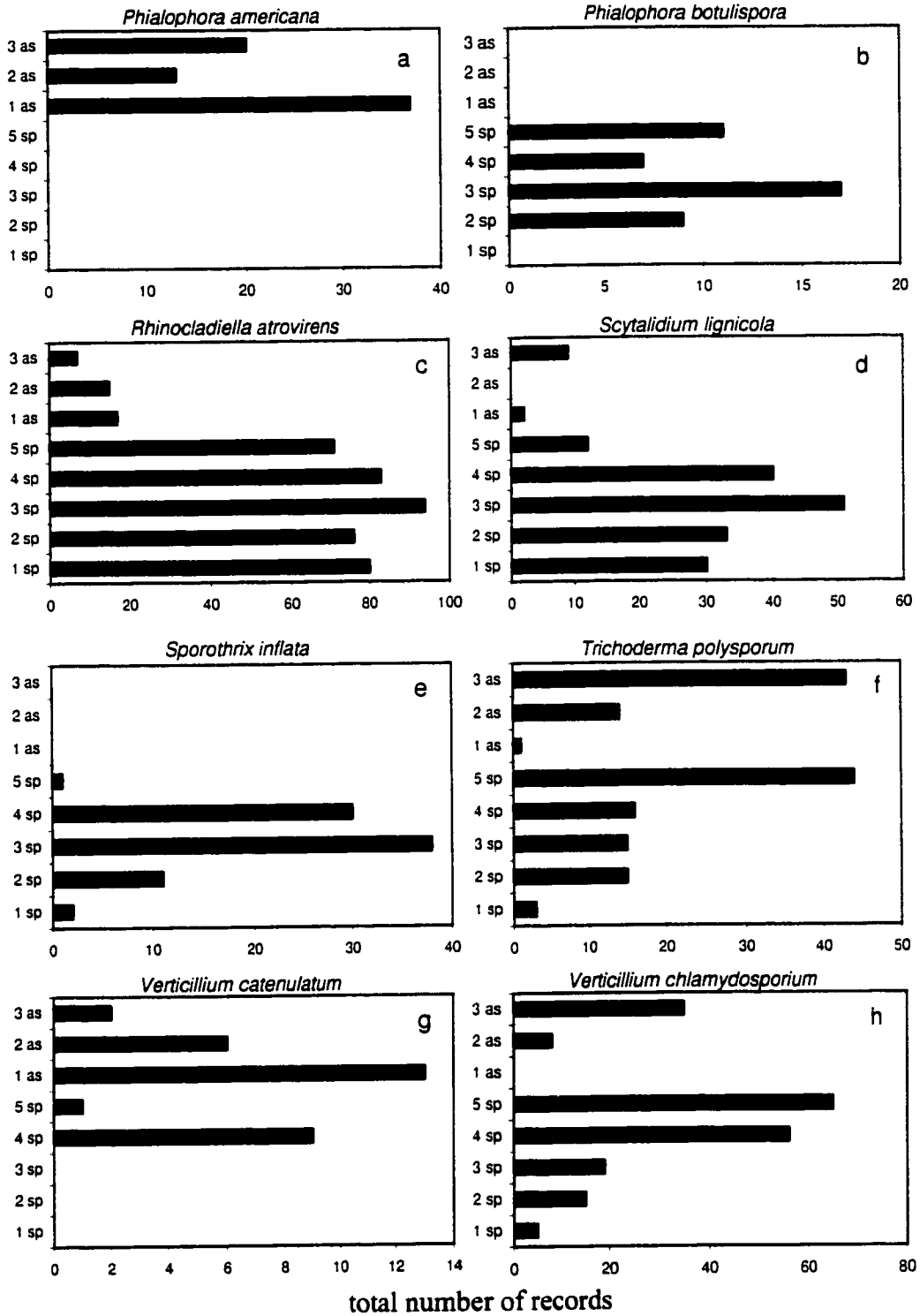


Figure 2.6. Average number of records, per sample, for the most common genera common to undisturbed (black), post-fire (white), and post-harvest (grey) sites in northern Alberta.

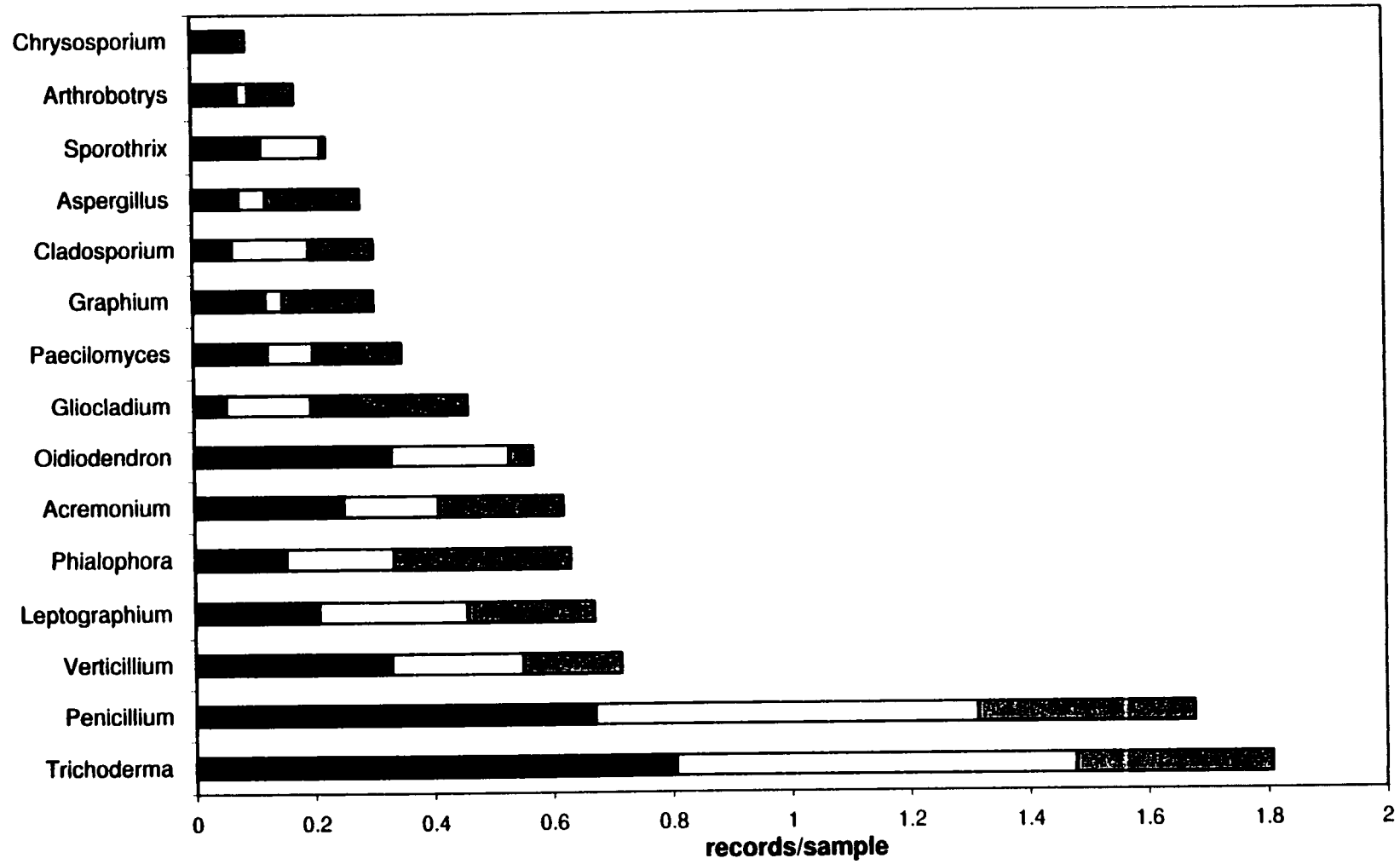
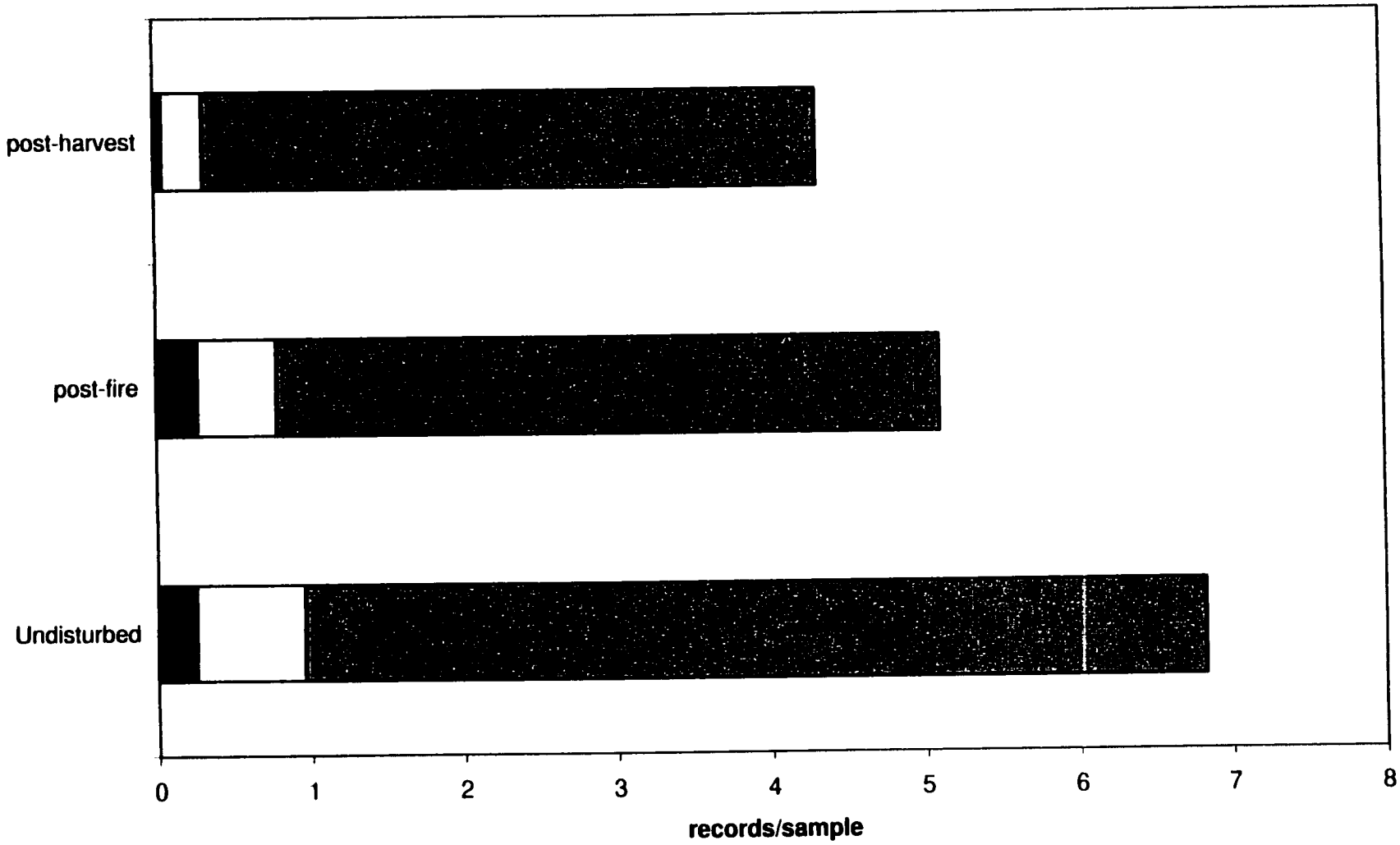


Figure 2.7. Average number of records, per sample, of ascomycetes (black), zygomycetes (white), and fungi imperfecti (grey) from undisturbed, post-fire, and post-harvest sites in northern Alberta.



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Chapter 3. Revisions and additions to the genus *Pseudogymnoascus*

Introduction

The *Myxotrichaceae* was described by Currah (1985) to include cellulosic *Onygenales* having reddish to dark brown peridial hyphae, fusoid ascospores, and arthroconidial anamorphs, and included the genera *Myxotrichum*, *Byssoascus*, and *Pseudogymnoascus*. Recent evidence suggests that the members of the *Myxotrichaceae* are more closely related phylogenetically to members of the *Leotiales* (inoperculate discomycetes) than to members of other onygenalean families (Hambleton, 1998). Ascomata of *Pseudogymnoascus* are discrete and composed of yellowish or reddish brown hyphae often with short echinulate appendages. The type species, *P. roseus*, has smooth ascospores and a *Geomyces* anamorph. However, species added to the genus differ in having ornamented ascospores and some lack an anamorph.

In 1993, Udagawa et al. added a fourth genus to the *Myxotrichaceae*, *Gymnostellatospora*, with a single species, *G. japonica*, distinguished by fusiform ascospores having longitudinal wing-like flanges and irregular ridges. They noted affinities to *Myxotrichum* and *Byssoascus* in the ridged ascospores but affinity to *Pseudogymnoascus* in the ascomatal coloration and peridial morphology. They considered their taxon distinct from *Pseudogymnoascus* because the type species, *P. roseus*, has smooth ascospores. The two species of *Gymnostellatospora* described are known thus far only from soil in Japan: *G. japonica* from forest and grassland soil and the psychrophilic *G. frigida* from forest soil (Uchiyama et al., 1995). Ascospores of *G. frigida* have a longitudinal flange and irregular ridges on the convex surface but lack wing-like flanges. These species are similar to *Pseudogymnoascus alpinus* and *P. dendroideus*, which differ from *P. roseus* in having yellowish ascomata and ascospores with a longitudinal band and irregular ridges. Among this group, only *P. dendroideus* has been reported to have an arthroconidial anamorph. The habitats of *Gymnostellatospora* and *Pseudogymnoascus* species are also similar because both are cellulosic and are associated with soil, roots, or plant debris especially in the boreal forest.

Study of microfungi from decaying wood in Alberta, Canada yielded several isolates of ascomycetes having fusiform, flanged or ridged ascospores. Because of overlapping characteristics, these isolates were difficult to place confidently in either genus and provided an opportunity for a reevaluation of the characters delimiting these genera. *Pseudogymnoascus* is emended to include species formerly disposed in *Gymnostellatospora*, a new species and new records are described and a key to the species is provided.

Materials and methods

Samples of wood (approximately 1 g each) from decayed logs of white spruce *(Picea glauca)* were surface-sterilized by briefly flaming, and then spread onto cornmeal agar (CMA, Difco Laboratories, Detroit, MI) and malt extract agar (MEA, 1.5 % Difco malt extract, 1.5 % Difco agar). Plates were incubated at room temperature (RT) in the dark and transfers of hyphae growing from the wood fragments were made as appropriate over a period of 18 months. Isolates were subcultured onto MEA and incubated at RT and at

15 °C, and onto CMA, cereal agar (CER, Kane et al., 1997), and oatmeal agar (OAT, Kane et al., 1997) at RT. All isolates are maintained as living cultures and dried specimens, at the University of Alberta Microfungus Collection and Herbarium (UAMH).

All colony descriptions are based on growth for 6 weeks at RT unless otherwise noted. Cellulolytic ability was assayed using the method of Smith (1977) but modified by using Mirashigo and Skoog's (Sigma M6899) basal salts medium. Molten basal salts medium (10 ml) was poured into 50 ml screw-cap test tubes and the tubes were autoclaved for 12 minutes at 121 °C. One ml of a molten 2% suspension (w:v) of cellulose azure (Difco) in basal salts medium was added to each of the cooled test tubes. Test tubes were inoculated with small blocks of mycelium taken from the perimeters of colonies growing on MEA and incubated in the dark at RT for 12 weeks. Cellulolytic ability was reported as negative, weakly positive (some diffusion of azure into medium), or strongly positive (most of the azure released into the agar).

Microscopy

Specimens were processed for scanning electron microscopy in two ways. Ascospores were prepared by FAA fixation, dehydration in a graded ethanol series, critical point dried, and coated with gold. Fresh ascomata were mounted on a freezing stage and frozen with liquid nitrogen to prevent disruption of delicate peridial elements and asci. Images were obtained using a JEOL JSM-6301FXV scanning electron microscope. For light microscopy, ascomata and slide culture preparations were mounted in either acid fuchsin or polyvinyl alcohol (recipes and procedures in Kane et al., 1997) and photographed, under Nomarski Differential Interference Contrast, using an Olympus BH-2 compound microscope and PM-10AK camera unit.

Taxonomy

Pseudogymnoascus Raillo, *Zentralbl. Bakteriol. Parasitenkde* 78: 520 (1929). emend. Lumley

=*Gymnostellatospora* Udagawa, Uchiyama, & Kamiya, *Mycotaxon* 48: 158 (1993).

Ascomata discrete and globose or confluent, pink, red-brown, brown, yellow, yellow-brown, or orange. Peridium reticulate or little differentiated, appendages lacking or thin-walled, asperulate, unbranched. Asci 8-spored, globose or subglobose. Ascospores ellipsoid to fusiform, occasionally flattened on one side, smooth or with one longitudinal band and/or wing-like flanges or irregular ridges on the convex surface, hyaline to pale yellow or pale pink. Anamorph alternate arthroconidia assignable to *Geomyces* or *Ovadendron* or lacking.

TYPE SPECIES: *Pseudogymnoascus roseus* Raillo

Species of *Pseudogymnoascus* are considered congeneric on the basis of: 1) pale, fusoid or somewhat ellipsoid ascospores that are smooth or ornamented with a longitudinal band and/or wing-like flanges or irregular ridges on the convex surface; 2) anamorph, when present, consisting of alternate arthroconidia; 3) cellulolytic ability; 4)

peridium, when differentiated, consisting of thick-walled, anastomosing hyphae, often with swollen nodes; 5) appendages, when present, thin-walled, asperulate, and originating from dichotomously-branched peridial hyphae.

Comments. Raillo described two species, *P. roseus* and *P. vinaceus* but failed to designate a type species or to deposit material. The distinction between *P. roseus* and *P. vinaceus* is tenuous given that Raillo described them as having different ascomatal colors ("roseis" for *P. roseus* and "flavoroseis" for *P. vinaceus*) but the ascospore size and shape and the original drawings are virtually identical. Kuehn (1958), followed by Orr (1979), considered *P. roseus* and *P. vinaceus* distinct and listed *P. vinaceus* as the type, but provided no justification. However, Samson (1972) chose *P. roseus* as the type species and treated *P. vinaceus* as a synonym and this has been followed by von Arx (1974, 1987) and Currah (1985). Even though, as Orr (1979) has pointed out, Kuehn's designation of *P. vinaceus* is the earliest and should be followed according to Article 9 of the current International Code of Botanical Nomenclature, Samson selected a neotype for *P. roseus* and the latter species has been more widely accepted as the type species. Apinis (1964) reduced *Pseudogymnoascus* to subgeneric rank in *Gymnoascus*, but Samson noted that Apinis's observations might have been made on a misidentified *Gymnoascus reessii*. Cejp and Milko (1966) considered the genus distinct and described a third species, *P. caucasicus*. Samson (1972) and later Currah (1985) considered *Pseudogymnoascus* distinct from *Gymnoascus* based on fusoid rather than oblate ascospores. Samson further distinguished the genera by the loosely coiled ascogonia of the former compared with the swollen antheridium and coiled ascogonium of *Gymnoascus*.

Raillo described the ascospores as "ovoideis vel globosis". No mention is made of spores being smooth or of an anamorph, two characteristics later used by Udagawa et al.. (1993) to separate *Gymnostellatospora*. In their circumscriptions of *Pseudogymnoascus*, Samson (1972), Orr (1979), and later Currah (1985) described the ascospores as smooth and the anamorph as usually present and as arthro- and aleurioconidia (Samson 1972, Orr 1979) or as a *Geomyces* state (Currah 1985). Müller and von Arx (1980) described *P. alpinus* as lacking an anamorph and as having ascospores with two or three longitudinal flanges, very similar to those of *Gymnostellatospora japonica*, the type species of *Gymnostellatospora*. Von Arx (1987) included species with flanged ascospores in his description of *Pseudogymnoascus* and indicated a correlation between the lack of an anamorph and ornamented ascospores. However, Locquin-Linard (1982) had previously described *P. dendroideus* with an arthroconidial anamorph and with ascospores having a longitudinal band and surface striations.

The anamorph of *P. roseus* is *G. vinaceus*. Although Carmichael (1962) reduced the genus *Geomyces* to synonymy with *Chrysosporium*, Sigler and Carmichael (1976) reinstated it with three species: *G. pannorum* (as type), *G. vinaceus*, and *G. asperulatus*. In *Geomyces*, short, narrow conidiophores branch acutely at the tip, sometimes verticillately. Conidia are formed at the tip, on the sides, and in an intercalary position to form short chains of cuneiform or barrel shaped alternate arthroconidia. Although the microscopic morphology is rather uniform among the species, considerable colonial plasticity is observed especially among isolates belonging to *G. pannorum*. Nonetheless, teleomorphic isolates are consistently associated with purplish red or reddish brown colonial colors especially on OAT at 18 °C. Van Oorschot treated *G. vinaceus* as a variety

of *G. pannorum*, but there seems little rationale for this decision. *G. pannorum* has a wide distribution in cold temperate soils, is cellulosic and is commonly encountered from human cutaneous specimens (Sigler, 1997). The genus *Ovadendron* (Sigler and Carmichael, 1976) was described for the single species *O. sulphureo-ochraceum*. Similar to *Geomyces*, alternate arthroconidia are broader than the intervening cells, but they are formed on short, solitary lateral branches that are often undulate or loosely coiled, and the erect conidiophores are lacking. To date, *O. sulphureo-ochraceum* has been found only from human sources where it is known as a rare pathogen (Lee, Grossniklaus, Capone, Padhye, and Sekhon, 1995, Sigler and Carmichael, 1976, Sigler, 1997). The anamorph of the new species *P. canadensis* is placed in *Ovadendron* and new records of *O. sulphureo-ochraceum* from rotting wood are reported here.

Five species of *Pseudogymnoascus* are accepted here and another three are of uncertain status. *P. bhattii* Samson was reported to produce fusoid, smooth ascospores within yellow-brown ascomata without appendages and to lack an anamorph. Orr (1979) treated *P. bhattii* as a synonym of *P. vinaceus* and the ex-type culture is listed under this name in the American Type Culture Collection (ATCC 28807), whereas Currah (1985) treated it as a synonym of *P. roseus*. The ex-type culture has not been examined in this study. *P. caucasicus* was reported from forest soil, but the ex-type culture (UAMH 3886, ATCC 28808) has failed to ascosporulate. Orr (1979) has suggested that the authors originally had a mixed culture. Prior attempts to obtain authentic material of *P. dendroideus* were unsuccessful; however, the ascospore dimensions as reported (6-7 x 4.5-5 μm) are larger than all other species.

Pseudogymnoascus canadensis Lumley, sp. nov. Figs. 3.1-3.6

Coloniae diam. 3.5-5 cm post 42 dies, in MEA incrementum suppressius, mycelium hyaline, maximam partem submersum, tamen elementa aeria adsunt, pars aversa flavea ad brunneo-olivaria, saepe fuscior in centro, praecipue in CER et CMA. Ascomata abundantia, discreta vel in cumulos 2-3 (4) coninentes confluentia, primum alba, quando maturant fusco-olivario-viridia ad brunneo-olivaria, plerumque intra 21 dies, 150-250 (-300) μm diam. Peridium bene evolutum, hyphae crasse-tunicatae, leves, 1.5-2 μm diam., exigue tumidae circa nodum, partes extremae dichotomiter ramosae, appendices ad 35 μm longae, saepe tortae, tenuiter tunicatae, exigue asperulatae, aseptatae.

Asci cum 8 sporis, oblongi, 8 x 6 μm, breviter stipitati, evanescentes. Ascosporae fusiformes, 3.5-4 x 1.5-2 μm, hyalinae, cum 1-3 cristis longitudinalibus sub luce microscopii S-curvatis apparentibus, sub SEM dorsa irregularia et longitudinalia amplius adsunt. Anamorphi abundanter effusi, praecipue in OAT et CER, *Ovadendro* similes, alterne arthroconidiales, conidia flavea, 3.5 x 2.5 μm, crescunt in hyphis fertilibus rectis vel rare curvatis. Cellulolytica.

HOLOTYPUS. CANADA. ALBERTA: circa 50 km trans lacum Mariana ad septentrionem versus, in loco 25 ante annis conflagrato, cultura cerealis-cellophanis exsiccata ex ligno bene putrefacto et tenuiter cremato Piceae glaucae, 26 Julius 1996, *Trevor Lumley* (UAMH 8899).

Colonies on MEA at RT and at 15 °C similar, 3.5-4.5 cm diam., mycelium mostly submerged but with some aerial growth, reverse yellow, brown in the center. Ascomata abundant, discrete or, rarely, in clusters of 2-3 (-4), olive-green to olive-brown when mature, maturing within 2 or 3 weeks. Colonies on OAT with a diam. of 4-5 cm, mycelium hyaline, thin, mostly submerged, reverse yellow to olive-brown, darker at the center, ascomata abundant, forming a dense mat, yellow at the colony periphery, discrete or, more often, in patches of 3-5 confluent ascomata, maturing within three weeks. CER colonies 6-7 cm mycelium hyaline, margin submerged, more aerial growth near the center, reverse darkening near the center, ascomata sparse, maturing very slowly and occurring as bright yellow patches, immature after six weeks. CMA colonies 3-4 cm mycelium dark yellow-brown, mostly submerged with some yellow aerial patches, reverse dark yellow-brown, ascomata abundant but diffuse, maturing within 4 weeks.

Ascomata white when young, turning bright yellow and eventually dark olive-brown when mature, 150-250 μm diam.. Asci 8-spored, subglobose, 8 x 6 μm, short-stipitate, evanescent. Ascospores fusiform, 3.5-4 x 1.5-2 μm, hyaline, with 1 circumlongitudinal flange up to 0.5 μm in width, or occasionally with 3 flanges appearing stellate in end view, with numerous irregular ridges under SEM. Peridium well-developed, hyphae thick-walled, smooth or asperulate, 1.5-2 μm diam., slightly swollen at the nodes, appendages often up to 35 μm long, emanating from dichotomously-branched peridial hyphae, endings often coiled, thin-walled, slightly asperulate, aseptate. Anamorph consisting of alternate arthroconidia produced on fertile hyphae that are straight or, rarely, curved, resembling *Ovadendron*. Arthroconidia yellowish, 3.5 x 2.5 μ m. Strongly cellulolytic.

HOLOTYPE. CANADA. ALBERTA: ca. 50 km N of Mariana Lake, 25-year-old fire site, as dried culture from well-rotted log *Picea glauca*, some charring, 26 Jul. 1996, *Trevor Lumley* (UAMH 8899).

Paratype. CANADA, ALBERTA: 100 km N Mariana Lake, well decomposed log of *Picea glauca*, August 1996, *Trevor Lumley* (UAMH 9238).

Comments. Ascospores of *P. canadensis* and *P. japonicus* are similar in ornamentation, but differ in width of the longitudinal band (0.5μm wide in *P. canadensis* and up to 1.0 μm wide in *P. japonicus*). The ascomata of *P. canadensis* are also larger, the peridial hyphae are more highly branched and narrower (1.5-2.0 μm compared to 2.0-3.0 μm in *P. japonicus*), and the appendages are longer, thinner, and occasionally spiralled. Additionally, *P. japonicus* lacks an anamorph.

Although the alternate arthroconidia of *P. canadensis* resemble those of the *Geomyces* state of *P. roseus*, erect conidiophores with acute, verticillate fertile branches are lacking, hence the anamorph of *P. canadensis* is considered closer to *Ovadendron* in which swollen arthroconidia develop retrogressively on solitary lateral branches. Locquin-Linard (1982) noted the affinity of the anamorph of *P. dendroideus* to *Geomyces* but her drawing of a solitary lateral hypha forming arthroconidia is more similar to the anamorph of *P. canadensis*. The anamorph of *P. canadensis* is dissimilar to *O. sulphureo-ochraceum* in lacking the coiled lateral branches. The ecology and distribution of the

latter is poorly known since few records are available. It should be noted, however, that isolates representing the latter species were also isolated from spruce wood during this study (UAMH 9219, 9220).

Pseudogymnoascus alpinus Müller & von Arx, *Sydowia* 35: 135 (1982). Figs. 3.7, 3.8

Colonies on MEA 2-2.5 cm diam., mycelium mostly submerged, reverse uncolored except at the center where yellow-brown patches appear. Ascomata dense, confluent, white or bright yellow, maturing within 3 weeks. Growth on OAT restricted, diam. 1-2, mycelium hyaline, thin, mostly submerged, some fluffy yellow patches, often in concentric rings. Ascomata sparse, white at first, becoming bright yellow in some strains, maturing within three weeks. On MEA at 15 °C, colonies 2.5-3 cm diam., mycelium hyaline, mostly submerged, reverse yellow-brown. Ascomata in small patches at the center of the colony. dense, confluent, white to bright yellow, maturing within 4 weeks.

Ascomata confluent or discrete in irregular patches up to 1 mm across, remaining white or turning bright yellow within 2 weeks, but maturing more slowly, usually within 3-4 weeks, in regular patches up to 1 mm across without distinct peridial hyphae or appendages. Asci borne singly amongst loose fertile hyphae, 8-spored, subglobose to oblong, 8 x 6 µm, short-stipitate, evanescent. Ascospores fusiform, 3-4 x 2.5-3 µm, hyaline, with 1 circumlongitudinal flange approximately 0.1 µm thick and 0.5 µm wide, or occasionally with 3 flanges, appearing stellate in end view, and numerous irregular ridges under SEM. Weakly cellulolytic.

Specimens examined. CANADA, ALBERTA: 100 km N Mariana Lake, nearly-humified log *Picea glauca*, Jul. 1996, *Trevor Lumley* (UAMH 9241); well-rotted log *Picea glauca*, Jul. 1996, *Trevor Lumley* (UAMH 9242): Mount Allen, alpine soil (3-8 cm depth), Nov 1971, (UAMH 9430, CBS 620.81) (ex-type).

Comments. P. alpinus can be easily recognized by its psychrophilic habit showing enhanced growth at 15 °C compared to RT, relatively slow growth at RT, white or bright yellow ascomata, either discrete or confluent, and ascospores with a distinct longitudinal band and irregular ridges. The Alberta wood isolates differed from the ex-type strain only in that ascomata in the former are bright yellow on MEA, CMA, and CER, whereas the latter produces white ascomata on these media. Ascospores of *P. japonicus* and *P. canadensis* are similar to those of *P. alpinus*, but ascomata of the two former species are discrete and composed of brownish peridial hyphae. In contrast, the ascomata of *P. alpinus* although discrete, are composed of clusters of asci within scarcely differentiated hyphae. These structures are similar to those of *Gymnascella* spp. (*Gymnoascaceae*) but ascospores of the latter are oblate, although some species, including *G. dankaliensis* (Castellani) Currah and *G. littoralis* (Orr) Currah, have ascospores with equatorial flanges or ridges (Currah, 1985). Ascospores of *P. alpinus* also resemble those of some species of *Talaromyces* such as *T. stipitatus* C.R. Benjamin in having a longitudinal flange (Stolk and Samson, 1972), but this species and others in the genus produce phialidic anamorphs and asci in chains (Tzean, Chen, and Shiu, 1992).

Pseudogymnoascus frigidus (Uchiyama, Kamiya & Udagawa) Lumley, comb. nov. Figs. 3.9, 3.10.

≡ *Gymnostellatospora frigida* Uchiyama, Kamiya & Udagawa, *Mycoscience* 36: 3 (1995).

Growth on MEA 4.5-5.0 cm diam., mycelium mostly submerged with some patches of aerial growth, reverse yellowish, brown in the center. Ascomata abundant, discrete, orange-brown when mature, usually within 2 weeks. Growth on OAT restricted, up to 3 cm diam., mycelium hyaline, thin, mostly submerged, reverse orange-yellow, brown in the center, ascomata abundant, discrete or, rarely, confluent, orange-brown when mature, maturing within three weeks. MEA at 15 °C colonies 4--4.5 cm diam., mycelium mostly submerged, reverse pale yellow, darker yellow at the center, ascomata abundant, discrete or confluent in clusters of 3 or 4, deep yellow-orange when mature, usually by 4 weeks. Ascomata 100-200 μm diam., white or light orange when young, deep orange-brown when mature, peridial hyphae 1.5-2.0 μm diam., nodes slightly swollen, appendages infrequent but distinct from peridial hyphae, thin-walled, asperulate, occasionally undulate, up to 12 μm long, Asci, 8-spored, subglobose to pyriform, 7--8 x 5-5.5 μm, short-stipitate, evanescent. Ascospores fusiform, 3.5-4 x 2--3 μm, hyaline, with longitudinal ridges that are difficult to observe under oil immersion. Anamorph not observed. Weakly cellulolytic.

Specimens examined. CANADA, ALBERTA: 100 km N Mariana Lake, well rotted wood *Picea glauca*, Jul. 1996, *Trevor Lumley* (UAMH 9240; UAMH 9239); JAPAN, HOKKAIDO: forest soil, *S. Uchiyama* BF44675 (UAMH 9304) (ex-type of *Gymnostellatospora frigida*).

Comments. Prior to this study, *P. frigidus* had been isolated only once, from forest soil in Hokkaido, Japan. Uchiyama et al. (1995) report the distinguishing features of this species to be its psychrophilic habit with growth and production of fertile ascomata enhanced at 15 °C, and ascospores ornamented with irregular ridges and lacking the longitudinal band. The yellow-brown to yellow-orange ascomata also help to distinguish *P. frigidus*. Our isolates are consistent with ex-type in the production of fusoid ascospores with shallow, longitudinal ridges and orange-brown ascomata, but there are several differences that do not appear to be significant enough to warrant description of a new species. The ex-type (BF 44675) differs from UAMH 9239 and 9240 in: 1) having a margin that is glabrous, yellow-brown, and submerged rather than bright yellow and distinct on OAT at RT, 2) having colonies that are significantly smaller after three and six weeks, 3) in producing dark brown colonies, that are almost black in reverse rather than only slightly pigmented on MEA, 4) having ascospores that are consistently larger (4-5 μm compared with 3-5 μm, respectively). UAMH 9239 and 9240 grew more slowly at 15 °C on MEA and produced fewer ascomata which matured more slowly than those of BF44675.

Pseudogymnoascus japonicus (Udagawa, Uchiyama, & Kamiya) Lumley, comb. nov. Figs. 3.11.

≡ *Gymnostellatospora japonica* Udagawa, Uchiyama & Kamiya, *Mycotaxon* 58: 159 (1993).

Ascomata discrete or confluent, 100-200 μm diam., yellow-brown to red-brown, peridial hyphae thick-walled, asperulate; appendages arising as free apices of peridial hyphae. Asci 8-spored, subglobose, 5-8 x 5-7 μm, evanescent. Ascospores fusiform, 3-4 μm x 1.5-2 μm, hyaline, with 1 circumlongitudinal flange, or occasionally 3 flanges appearing stellate in end view, and many low, longitudinal ridges. No anamorph observed. Cellulolytic (Udagawa et al., 1993).

Specimen examined. JAPAN: cultura exsiccata from forest soil, Feb., 1990, *S. Udagawa* BF 24290 (Holotype of *G. japonica*).

Comments: The description of *P. japonicus* given by Udagawa et al. (1993) is summarized above for the purpose of comparison, but no living culture was available for study. This species differs from *P. alpinus* by virtue of thick-walled peridial hyphae and better growth at room temperature (Udagawa et al., 1993), and from *P. canadensis* by its red-brown ascomata and lack of anamorph. *P. frigidus* is also similar, but has smaller ascospores with only longitudinal ridges.

Pseudogymnoascus roseus Raillo, *Zentralbl Bakteriol Parasitenkde Infektionskr.* 78: 250 (1929). Figs. 3.12.

=*Gymnoascus rhousiogongylinus* Wener & Cain, *Canadian Journal of Botany* 48: 325 (1970).

=*Gymnoascus roseus* (Raillo) Apinis, *Mycological Papers* 96: 8 (1964).

=*Pseudogymnoascus vinaceus* Raillo, *Zentrlbl Bakteriol Parasitenkde Infectionskr.*78: 250 (1929).

≡*Gymnoascus vinaceus* (Raillo) Apinis, *Mycological Papers* 96: 9 (1964).

Colonies on OAT 2-3 cm diam., mycelium hyaline, thin, mostly submerged, reverse in various shades of brown or red-brown. Ascomata abundant, discrete or confluent, often forming a dense mat, maturing within 2 weeks. MEA colonies 2-3 cm diam., reverse brown. Ascomata abundant, discrete, brown or red-brown, maturing within two weeks. MEA at 15 °C, colonies 3-4 cm diam., mycelium hyaline, mostly submerged, occasionally with some aerial patches, reverse light brown. Ascomata abundant, discrete or with occasional confluent patches, deep red-brown, maturing within 3 weeks.

Ascomata discrete or confluent, white at first, turning pink to pink-brown or red-brown with age. Peridium reticulate, hyphae thick-walled, smooth or slightly verrucose, apices dichotomizing and giving rise to thin-walled, clavate, asperulate appendages. Asci 8-spored, globose to sub-globose, 7-9 x 4-7 μm, evanescent. Ascospores fusiform, occasionally flattened on 1 side, 2.5-3.5 x 1.5-2.5 μm, appearing smooth by light microscopy but finely wrinkled by SEM. Anamorph *Geomyces vinaceus* (Dal Vesco, 1957, Sigler and Carmichael, 1976, Orr, 1979). Strongly cellulolytic.

Comments. Colonies of *P. roseus* vary in color, extent of peridium development, and amount of anamorph development which may account for color differences noted by many authors and used by some to distinguish *P. roseus* from *P. vinaceus*. The rate of peridium maturity also varies and affects colony color. Although the asci and ascospores mature within 2-3 weeks on most media, the peridia may develop more slowly, with some

isolates (e.g., UAMH 1990) requiring another 3-4 weeks for peridia to mature. Isolates with peridia that develop slowly appear light pink and turn red-brown only after many weeks in culture. Color also varies from light pink to wine-colored on different media for the same amount of time, exemplified by UAMH 9163, which is light pink on CER after 21 d and a dark, wine color after the same amount of time on OAT. This casts some additional doubt on Raillo's distinction between *P. roseus* and *P. vinaceus* which, in his descriptions, only differ in the color of the colonies. The use of other characteristics to distinguish *P. roseus* from *P. vinaceus*, such as the lack of appendages and anamorph in *P. vinaceus* (Orr, 1979) is difficult to trace. These differences, however, can probably be accounted for by intraspecific variation, as illustrated by the number of intermediate forms.

Specimens examined. USA. WISCONSIN: soil, *G.F. Orr* (UAMH 1990); JAPAN: soil, *S.I. Udagawa* (UAMH 2005 = NHL 2284); CANADA. ONTARIO: forest soil near Parry Sound, *H.M. Wener* (ex-type of *G. rhousiogongylinus* UAMH 3337 = CBS 722.69 = ATCC 18970); ALBERTA: 100 km N Mariana Lake, nearly humified log *Picea glauca*, Jul. 1997, *Trevor Lumley* (UAMH 9222); porcupine dung, *G.F. Orr 3729* (UAMH 3875); NORTHWEST TERRITORIES; Norman Wells; oil soaked soil, *D. Westlake NWF 78* (UAMH 4055).

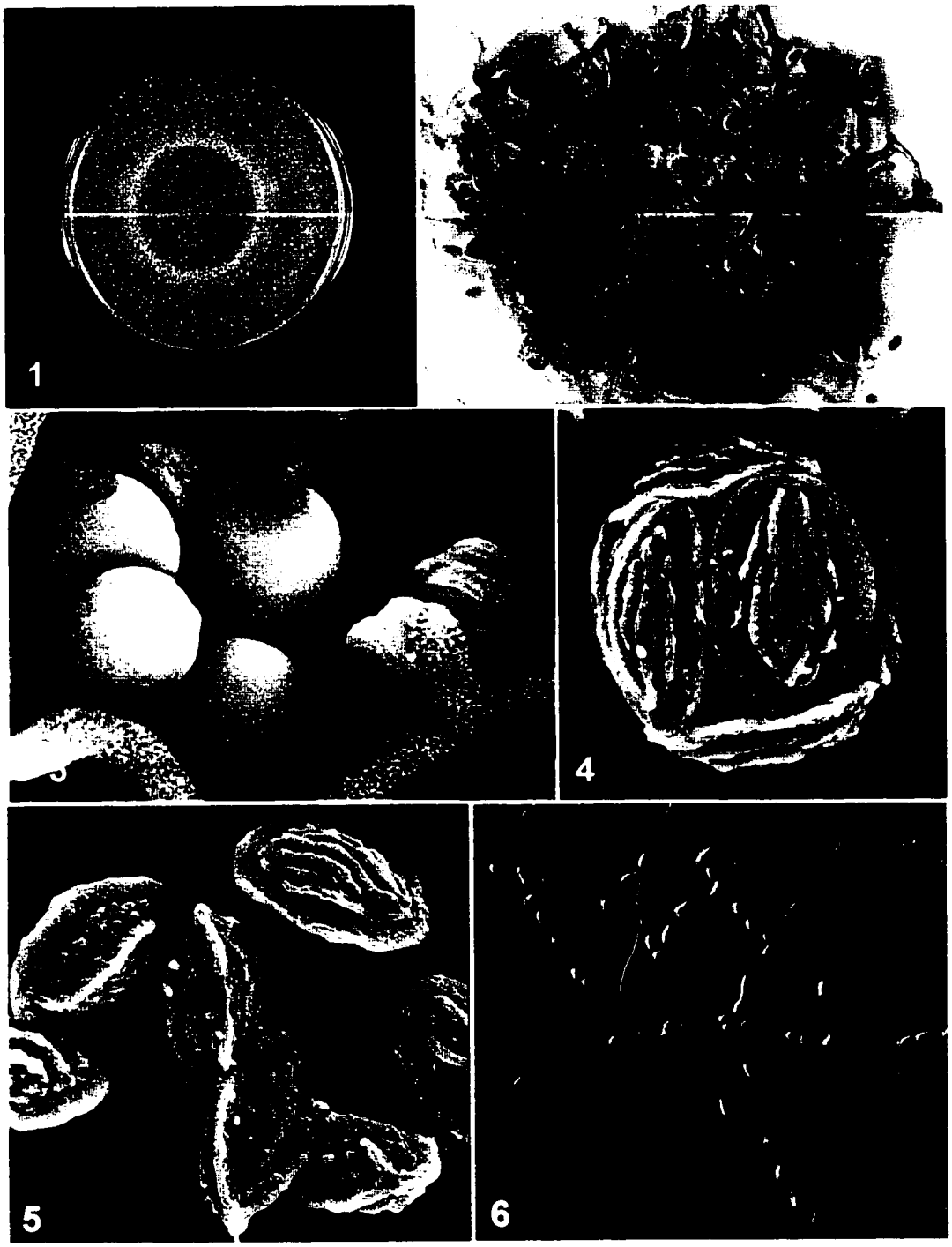
KEY TO *PSEUDOGYMNOASCUS* SPECIES

1 Ascomata discrete or confluent, in brown or yellow shades; peridial hyphae thick-walled, anastomosing, apices often clavate, thin-walled, asperulate; ascospores smooth or flanged; growth > 1 cm at 28 d; anamorph present or absent.....2
Ascomata mostly confluent, white or yellow; peridial hyphae mostly indistinguishable from vegetative hyphae, apices indistinct; ascospores flanged; growth slow (< 1 cm at 28 d); anamorph absent..... *alpinus*

2(1) Anamorph present; growth rapid (>4 cm at 28 d on OAT).....3
Anamorph absent; growth 2-4 cm at 28 d on OAT.....4

3(2). Ascomata red-brown; anamorph *Geomyces* ; ascospores smooth-walled.....*roseus*
Ascomata yellow-green; anamorph *Ovadendron*; ascospores with 1-3 longitudinal flanges and numerous low, longitudinal ridges.....*canadensis*

4(2) Ascomata orange-brown; ascospores occasionally with 1-3 longitudinal flanges but usually only with shallow, longitudinal ridges; growth 2-3 cm at 28 d *.frigidus*
Ascomata yellow-brown to red-brown; ascospores with 1-3 longitudinal flanges; growth rapid (> 3 cm at 28 d).....*japonicus*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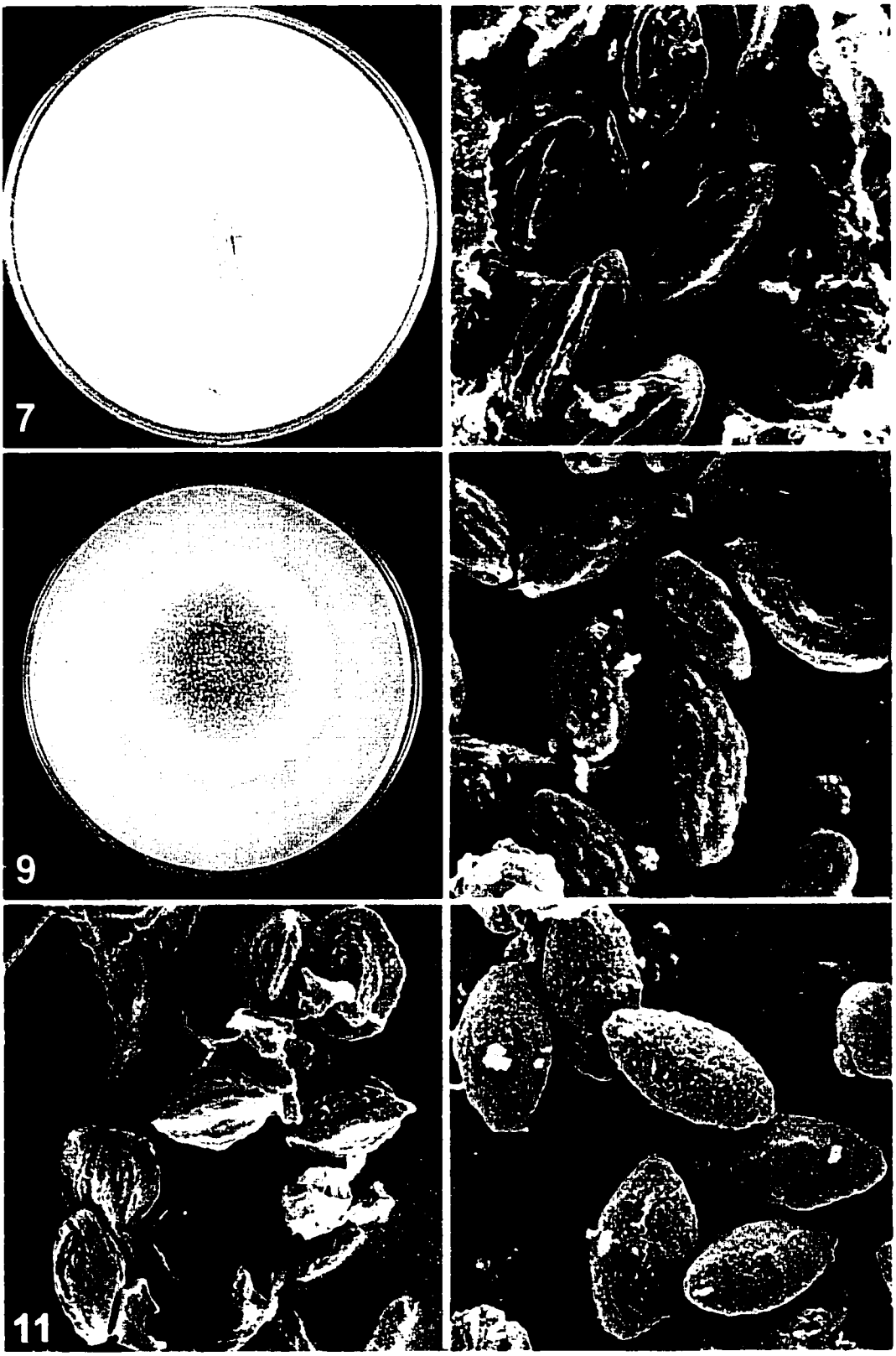
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Chapter 4. Microfungus communities of rotting wood in disturbed and undisturbed sites in the boreal mixed-wood region of northern Alberta, Canada.

Introduction

The decomposition of wood, which constitutes a large proportion of plant biomass in the boreal forest, is an important component of the carbon cycle and contributes to the integrity of forest soil. The agents of decomposition break up components of wood, thereby releasing some of the carbon as CO_2 and generating humus. The complexity of cellulose and lignin limits decomposition to relatively few species of fungi and bacteria. The literature concerning the fungi associated with rotting wood deals with basidiomycetes from early stages of decomposition (Boddy et al., 1987; Boddy and Rayner, 1984; Martin and Gilbertson, 1978; Rayner and Boddy, 1988; Shigo, 1972), but some ascomycetes, fungi imperfecti, and zygomycetes have been reported (Chapela, 1989; Crane et al., 1996; Good and Nelson, 1962), especially from later stages of decomposition (Crawford et al., 1990). The species involved in these communities (community composition) and how their numbers change as decomposition proceeds (succession) or in response to environmental variables, are largely unknown.

Tree removal and wildfire have been shown to affect vegetation (Ahlgren, 1960; Outcalt and White, 1981), bird (Attiwill, 1994), and soil microbial (Grier, 1975) diversity. Very little is known, however, about the effects of disturbance on fungus communities. The prevalence of specific macroscopic ascomycete species in post-fire soil has been well-documented (Egger, 1986), as has a decrease in heterogeneity and in species number for soil microfungi (ascomycetes, zygomycetes, and fungi imperfecti) in post-fire soil (Widden and Parkinson, 1975). Studies of the effect of tree harvest on fungus communities have focused on the effect of fungi on seedling regeneration, specifically the impact of this disturbance on ectomycorrhizal species (Bradbury, 1998; Bradbury et al., 1998).

Physicochemical changes in wood with decomposition have been well-documented (Sollins, 1982). Water accumulates from early to advanced stages (Jurgensen, et al., 1984; Larsen et al., 1978) and nitrogen accumulates largely through the action of non-symbiotic nitrogen-fixing bacteria (Dix and Webster, 1995). The extent to which these or other environmental factors influence wood decomposition is unknown and succession of these communities has not been demonstrated.

The purpose of this study was to identify wood decomposition communities and evaluate the impact of log and site variables on these communities. The first hypothesis was that morphologically distinct decay stages display unique assemblages of fungi, and that successionary changes in microfungus communities occur concurrently with changes in log characteristics. The second hypothesis was that microfungus communities are affected by log and/or site variables. The first objective was to identify the microfungi associated with rotting spruce and aspen logs in the boreal forest in northern Alberta. The second objective was to determine whether morphologically distinct decay stages had characteristic communities and, consequently, whether succession was occuring. The third objective was to determine whether different log species had different communities, and the fourth and final objective was to assess the influence of other log and site variables on these communities.

Materials and Methods

Study sites

Sites were located in the southern boreal mixed-wood of Alberta (Table 4.1) as follows: one undisturbed site at Elk Island (UEI) (site 1 in Fig. 4.1); four sites near Mariana Lake (sites included as "a"), including one undisturbed (UML), and three post-fire (F83, F91, and F93); five near Slave Lake (sites 4-8), including one post-fire (F61) and four post-harvest (H61, H62, H82, and H83); one post-fire near Little Buffalo (F82, site 9); one post-harvest near Calling Lake (H91, site 2); and one post-harvest near the Lawrence Lake Recreation area (H93, site 3).

Climatic variables (mean daily temperature, MDT; mean annual precipitation, MAP; and degree-days greater than 5 °C, DD>5) are 30-year means taken from the nearest permanent weather station (Anonymous, 1982). MDT decreased northward, with Elk Island National Park (EINP) having the only MDT greater than 1 °C. MAP was highest at Mariana Lake and lowest at Little Buffalo (Table 4.1). DD>5 was highest at EINP (1470.1) and lowest in the Slave and Calling Lakes area (1212.6 and 1202.7, respectively).

Sampling

Eight log classes were defined, five for white spruce (*Picea glauca* (Moench) Voss) and three for aspen (*Populus tremuloides* Michx.). White spruce decay stages were chosen as from Sollins (1982), i.e. stage 1, bark and all branches intact, stage 2, fine branches lost and bark loosening, stage 3, most bark and branches gone, stage 4, bark and branches gone and wood softened, and stage 5, wood crumbly, usually moss-covered, and sunken into the humus. Aspen logs were more difficult to assign stages to, so only three were designated. Stage 1 aspen had bark and branches intact, stage 2 had no branches and occasionally some bark, and stage 3 was moss-covered, stringy, and sunken into the humus.

From undisturbed sites, stages 1, 2, and 3 spruce, and stages 1 and 2 aspen logs were sampled by cutting (with an ethanol-sterilized bow-saw to avoid cross-contamination) six 5-10 cm thick disks at 1 m intervals along the length of the log, beginning at approximately 1 m from the base of the tree. Disks were bagged and transported back to the lab where they were put immediately in cold storage, and were processed within 48 hours after collection. From disks, ten samples were taken along a vertical transect at 10 equidistant points. The first sample was taken from the top of each disk and included bark, if present. The last sample was taken from the part of the disk closest to the ground. Wood from late stage logs was collected by taking the first sample from the top of the log (in the field), and then excavating a hole through the centre, and taking 2-3 cm^3 samples at 9 equidistant points, with the last sample coming from the bottom of the log.

Wood from fire and harvest sites was similarly sampled, but only three disks from each log and only five samples from each disk were collected to accommodate a larger number of sites. In addition, not all log classes (log species and stage of decomposition)

were present at all sites, and consequently the number of logs per site varied depending on the availability of each log class (Table 1).

Isolation

Wood from disks was extracted by shaving off a thin layer of wood using an ethanol-sterilized chisel, and extracting a 1 cm^3 sample from the underlying wood. All samples were surface sterilized by brief flame exposure, broken using a sterile scalpel, and plated, five to ten pieces per plate, onto each of six media: malt extract agar (MEA, 1.5 % malt extract, Difco, Detroit, USA, 1.5% Difco agar, w:v), tapwater agar (1.5 % agar w:v in water), cornmeal agar (Difco), MEA with benomyl (4 ppm), MEA with rose bengal (50 ppm), and Mycobiotic® agar (Difco). Tetracycline (0.01%) was added to all media to inhibit bacterial growth.

Identification and culture maintenance

Primary isolation plates were assessed for fungal growth after four weeks and again every 8-12 weeks for 18-24 months, depending on the condition of the plates. Fungi were identified directly from primary isolation plates or from pure cultures. Only fungi producing distinctive micromorphological features were enumerated. Of the fungi not dealt with here, yeasts constituted approximately 5-10 % of records, basidiomycetes 10-15 %, and sterile, non-basidiomycetes 5 %. Where sporulation was slow or conidia were produced in small numbers, slide cultures were employed using the cover slip sandwich technique (Sigler 1993). Representatives of some species were accessioned, including live cultures, at the University of Alberta Microfungus Collection and Herbarium (UAMH) or, as microscope slides, at the University of Alberta Cryptogam Herbarium (ALTA).

Analyses

Percent frequency of isolation (PFI) for each species was calculated as the number of records of a species / number of samples, x 100, and was used for all analyses with the exception of species richness. Species richness was calculated as the mean of number of species per sample. Species diversity was calculated using the Shannon-Weaver (1964) index.

Cluster analysis was performed using PFI and unweighted arithmetic averaging, with community similarity assessed using the Bray-Curtis similarity coefficient (Bray and Curtis, 1957), a divisive hierarchical algorithm that clusters sites according to the ratio of number of species in common with species not in common, weighted by abundance value, in this case by PFI values. Canonical Correspondence Analysis (CCA) of logs was performed using CANOCO (ter Braak, 1992) which ordinates communities and environmental variables, such that relative position of communities reflects similarity/dissimilarity, and environmental variables are represented by vectors, the relative significance of each indicated by their length and direction. Environmental variables included four nominal (log species, log stage of decomposition, type of site disturbance, and time since site disturbance) and four quantitative (MDT, MAP, DD>5,

log moisture, and log diameter). Pearson correlation coefficients ("*r*") between all variables as well as the first and second axes were generated from ordinations. Correlations between climatic variables (MDT, MAP, and DD>5C) and site variables (time since disturbance and disturbance type) are considered coincidental and not analyzed further.

Log diameter was taken as an average of diameters from each disk on a log and is summarized for each stage of decomposition. Moisture content of samples was determined, as a percentage of fresh weight, by weighing 10-20 g from each disk, drying for seven days at 50 °C, and weighing again, and is summarized as a mean of all sample moistures.

Results

Approximately 10 000 records were obtained, comprising 292 identified species (Table 4.3, including 41 species of ascomycetes, 29 zygomycetes, and 222 fungi imperfecti. *Rhinocladiella atrovirens* and *Trichoderma viride* were the only two species with an overall percent frequency of isolation (PFI) greater than 25 % (39.2 and 50.8, respectively). All other species had PFI values less than 10, with the exception of *Scytalidium lignicola* (12.5), *Verticillium chlamydosporium* (17.6), *Absidia glauca* (10.0), *Beauveria bassiana* (13.9), *Cordana paucispetata* (10.2), *Geomyces pannorus* (14.4), *Mortierella ramanniana* (17.7), *Oidiodendron griseum* (12.7), *Penicillium pinophilum* (19.3), and *Trichoderma polysporum* (11.1). A large percentage of species (64.6%) had PFI values of less than one.

Means for log moisture and diameter are summarized for log classes (Table 4.2). Overall, spruce logs had greater diameter than aspen, and moisture increased with stage of decomposition.

Overall, species richness (Table 4.4) was highest in the undisturbed sites (I.e. UEI and UML) (5.2 and 4.0 species/sample), followed by the 28-year-old fire (F61) and harvest (H61 and H62) sites (3.8, 3.6, and 3.5), followed by the 14-year-old fire (F82 and F83) and harvest (H82 and H83) sites (2.3, 2.5, 2.9, and 2.1), and finally by the most recent fire (F91 and F93) sites (2.1 and 2.3) and one newly-harvested (H92) site (0.9). The other recently-harvested site had a high richness value (3.0). Species diversity was also highest in undisturbed sites (3.8 and 3.4) and generally lower in post-harvest sites ($2.1 - 3.2$) than in post-fire sites ($2.9 - 3.3$) and, in both cases, the lowest diversity value came from a most recently disturbed site.

CCA ordination of logs from undisturbed sites (UEI and UML) (Fig. 4.2, eigenvalues: axis 1 = 0.387, axis 2 = 0.321) showed a gradient of early to late stage decomposition, and stage of decomposition was significantly correlated with axis 2 ($P<.001$). Extension of the "stage" vector in both directions showed a gradient from early to late stage for aspen (Fig. 4.3) and spruce (Fig. 4.4). Moisture was significantly correlated with axis 1 ($P<.001$) and moisture and stage of decomposition were significantly correlated with each other ($P<.001$)(Table 4.5).

Cluster analysis of all logs (Fig. 4.5) produced distinct spruce and aspen groups, so that spruce log communities were at the top of the diagram, while aspen log communities were at the bottom. The exceptions were "UEI 3as", which was among the

spruce log communities, and "F83 1sp", "H92 1sp", and "H62 5sp", which were found among the aspen log communities.

CCA ordination of all logs (Fig. 4.6, eigenvalues: axis 1 = 0.335, axis 2 = 0.283) showed spruce logs to the left of axis 2 and aspen logs to the right. Axis 1 was significantly correlated to log diameter (P<.001) and log species (P<.001), and axis 2 was correlated to stage of decomposition (P<.001), MDT (P<.001), and DD>5 (P<.001) (Table 4.6). Additionally, moisture was correlated with log diameter (P<.005) and stage of decomposition (P<.005), and MDT (P<.001). Log diameter was also correlated with MDT (P<.005) (Table 4.6).

Discussion

Ordination of undisturbed site logs (Figs. 4.2-4.4) and cluster analysis (Fig. 4.5) and ordination (Fig. 4.6) of all logs showed that log species had the greatest influence (see Tables 4.5 and 4.6) on similarity/dissimilarity of communities, clearly separating aspen and spruce logs. The reason for the difference in communities is that many fungus species are specific to log types (see Chapter 2), especially hardwood or softwood, probably as a consequence of the differences in wood chemistry. Although not reported here, a number of species were found exclusively on aspen (e.g., *Phialophora americana*) or spruce (e.g., *Phialophora botulispora*) logs.

Ordination of communities from undisturbed site logs confirmed that morphologically distinct decomposition stages had distinct communities with evidence of succession, i.e. from one stage to the next. Logs that were most similar in decomposition stage were closer together in the ordination, and stage of decomposition was significantly correlated to axis 2 (Figs. 4.2-4.4, Table 4.5). Additionally, some genera of fungi were most common on early, intermediate, or late stage logs and contributed to succession. Although not illustrated here, species of *Aureobasidium* and *Cladosporium* were found mostly on stage 1 spruce logs and *Microsphaeropsis olivacea* was found on stage 1 logs of both spruce and aspen. Similarly, *Chloridium chlamydosporis*, *Mariannaea elegans*, *Oidiodendron periconioides*, and *Verticillium chlamydosporium* became more abundant with later stages of decomposition. *Phialocephala fusca* was found almost exclusively on late stage logs of spruce and aspen.

Succession in plant communities usually refers to an orderly progression of changes, beginning with a pioneer community and culminating in a climax community. Among fungi, substrate succession is more commonly encountered (Butcher, 1968; Clubbe, 1980) and is common among saprobic fungi, including those communities associated with plant and animal remains and animal excreta. Moisture may be a significant driving force behind succession in wood decomposition microfungus communities. Newly-fallen logs contain relatively little moisture, much less than humus or soil (Day, 1963). Water content in these logs produces a water potential that inhibits the growth of most fungi (Jurgensen et al., 1992; Larsen et al., 1982). Over the course of decomposition water accumulates from incipient to advanced stages of decomposition, and five to ten-fold increases from early to late stages are common (Jurgensen et al., 1992; Larsen et al., 1982) probably as a consequence of the increased water absorption capacity of more porous decomposed wood (see Table 4.2). Moisture was a significant

environmental variable and contributed directly or indirectly to all ordinations (Tables 4.5, 4.6).

The number of species per sample was higher for both undisturbed sites than for all disturbed sites. There are several potential causes for these differences. Foremost among them is the lack of certain decomposition stages in some sites (Table 4.1). Specifically, type of disturbance influences the stages and species of logs found and, consequently, the microfungus species found at a site. Harvest sites are more likely to have aspen left behind than spruce and some species, such as *Phialophora americana*, were specific to aspen logs and found in greater numbers in post-harvest sites (Table 4.3). Similarly, a number of other species, including *Chloridium chlamydosporis*, *Mariannaea elegans*, *Oidiodendron periconioides*, and *Scytalidium lignicola* were found mostly or exclusively on spruce and were more likely to be recovered from sites with more spruce (undisturbed and post-fire sites). However, logs of similar classes had greater species richness in undisturbed sites. There was also a general trend toward an increase in species richness with time post-disturbance (Table 4.4).

Diversity in some community types has also been shown to be lower after disturbance (Bissett and Parkinson, 1979; Odum, 1985), as a consequence of the dominance of very few species after the disturbance event. However, Grime (1974) hypothesized that, in some cases, disturbance increases the number of ruderal species, which may cause a corresponding increase in diversity. Results from this study showed a diversity value only marginally higher in undisturbed sites. There were, however, a large number of records and species recovered from post-harvest sites that could be considered ruderal. For example, the PFI of *Aspergillus versicolor*, *Cladosporium cladosporoides*, *Acremonium polychromum*, and *Scopulariopsis brevicaulis* were much higher in newly-harvested sites than in any other site type (Table 4.3). These species produce large numbers of airborne spores, and are commonly encountered airborne contaminants.

In summary, the analysis of microfungus communities of decomposing wood of white spruce and aspen indicate that: 1/ these communities are different for different log species, 2/ morphologically distinct decay stages have characteristic communities with succession of microfungus communities from early to late stages of decomposition, 3/ log moisture is a significant driving force behind community formation, as shown by its significance in all ordinations, either directly or indirectly, and 4/ disturbance affects communities by a/ affecting logs present (see also Agee and Huff, 1987), and b/ affecting the communities from similar log classes from disturbed sites.

Table 4.1. Summary of site characteristics and logs sampled (MDT – mean daily temperature, in degrees; MAP – mean annual precipitation, in millimetres; DD>5 – degree-days> 5°C).

Site	Location (latitude, longitude)	Description	MDT	MAP	DD>5	log classes sampled
UML	50 km N Mariana Lake (56°16'N, 111°40'W)	undisturbed for at least 90 years, some human activity	0.6	361.0	1252.9	all
UEI	NE corner, Elk Island National Park (53°40'N, 112°48'W)	undisturbed for at least 120 years, large populations of elk and bison	2.3	325.8	1470.1	all
F61	10 km S Slave Lake (55°14'N, 114°55'W)	burned in 1961	0.7	346.1	1212.6	1,3,5 spruce
F82	near Little Buffalo (56°28'N, 116°50'W)	burned in 1982	0.2	256.4	1239.1	3 spruce;1-3 aspen
F83	53 km S Fort MacMurray (56°17'N, 111°51'W)	burned in 1982	0.2	332.8	1289.7	1,3,5 spruce;1-3 aspen
F91	53 km S Fort MacMurray (56°19'N, 111°48'W)	burned in 1995	0.2	332.8	1289.7	1,5 spruce;1 aspen
F93	95 km S Fort MacMurray (56°13'N, 111°53'W)	burned in 1995	0.2	332.8	1289.7	1,3 spruce;1-3 aspen
H61	10 km N Slave Lake (55°36'N, 114°56'W)	harvested in 1968	0.7	346.1	1212.6	1,3 aspen
H62	15 km N Slave Lake (55°30'N, 114°13'W)	harvested in 1968	0.7	346.1	1212.6	5 spruce;3 aspen

H82	30 km N Slave Lake (55°40'N, 114°42'W)	harvested in 1982	0.6	331.9	1315.2	1-3 aspen
H83	10 km N Slave Lake (55°35'N, 114°30'W)	harvested in 1982	0.7	346.1	1212.6	1-3 aspen
H92	15 km NW Calling Lake (55°26'N, 113°33'W)	harvested in 1995	0.3	356.2	1202.7	3 spruce; 1,3 aspen
H93	Lawrence Lake Recreation Area (55°04'N, 113°49'W)	harvested in 1995	0.3	356.2	1202.7	1,2 aspen

Table 4.2. Mean moisture and diameter (± s.d.), by decomposition stage, for five decomposition classes of spruce (n=24) and three decomposition classes for aspen (n=27) sampled in northern Alberta.

log species	stage of decomposition	moisture (%)	diameter (cm)
spruce	1	31.2 ± 4.7	22.3 ± 5.5
	2	38.5 ± 3.5	25.0 ± 4.2
	3	42.7 ± 3.1	20.9 ± 2.9
	4	54.5 ± 5.0	22.6 ± 6.4
	5	61.7 ± 3.7	19.2 ± 3.7
aspen	1	31.5 ± 7.3	18.5 ± 2.5
	2	44.9 ± 9.6	15.5 ± 3.7
	3	68.1 ± 5.9	17.2 ± 3.4

Table 4.3. Percent frequency of isolation of microfungus species found in 13 habitats in northern Alberta. UEI = undisturbed, Elk Island, UML = undisturbed, Mariana Lake, F (61-93) = sites disturbed by fire, and H (61-93) = sites disturbed by fire, and H (61-93) = sites disturbed by harvesting.

Species	UEI	UML	F61	F82	F83	F91	F93	H61	H62	H82	H83	H92	H93	total
Trichoderma viride (Gray) Pers.	44.6	61.0	44.4	28.3	72.2	55.6	75.0	6.7	36.7	42.2		31.1	23.3	50.8
Rhinocladiella atrovirens Nannf.	42.7	49.6	53.3	20.0	22.2	31.1	41.7	13.3	43.3	22.2	20.0	31.1		39.2
Penicillium pinophilum Hedgcock	19.0	32.3	17.8	3.3	8.9	17.8	15.0	3.3		2.2	13.3			19.3
Mortierella ramanniana (Moller) Linnem.	22.7	19.0	33.3	8.3	24.4	6.7	16.7	13.3	10.0	6.7				17.7
Verticillium chlamydosporium Goddard	22.5	19.8	28.9	6.7	15.6	11.1	16.7		20.0	11.1	8.9	8.9		17.6
Geomyces pannorus (Link) Sigler & Carm.	31.9	5.0	4.4	13.3	11.1	6.7	3.3	36.7	3.3	2.2			3.3	14.4
Beauveria bassiana (Bals.) Vuill.	24.2	10.4	11.1	10.0	3.3			43.3	13.3	11.1	6.7		10.0	13.9
Oidiodendron griseum Robak	11.5	20.4	13.3		5.6	31.1	13.3		3.3	2.2		6.7		12.7
Scytalidium lignicola Pesante	20.8	16.0	2.2		6.7		1.7	3.3		2.2				12.5
Trichoderma polysporum (Link) Rifai	10.4	21.0		3.3	10.0	6.7	3.3				2.2			11.1
Phialophora americana (Nannf.) Hughes	7.5	7.1		31.7	11.1		8.3	30.0	10.0	42.2	28.9	4.4	46.7	10.9
Cordana pauciseptata Preuss	10.2	15.0			28.9		3.3			11.1		2.2		10.3
Absidia glauca Hagem	24.8	5.2												10.0
Penicillium raistrickii G. Sm.	13.1	9.4	26.7	6.7	16.7	17.8							6.7	9.9

Mariannaea elegans (Corda) Samson	19.2	11.0												9.7
Acremonium butyri (van Beyma) W. Gams	14.0	8.1	4.4	3.3	5.6	2.2	16.7	20.0	6.7	4.4	6.7			9.5
Chloridium chlamydosporis (Van Beyma) Hughes	12.7	12.9	8.9	1.7	4.4	6.7	3.3	3.3	6.7		2.2		3.3	9.5
Acrodontium simplex (Mangenot) de Hoog	9.8	10.6	13.3		6.7	6.7		6.7	40.0	11.1			3.3	8.9
Gliocladium viride Matr.	0.6	7.7		33.3	14.4	2.2		6.7	76.7	6.7	57.8	6.7	6.7	8.9
Leptographium sp6	8.3	16.0	2.2					10.0		15.6	2.2		3.3	8.7
Leptodontium elatius (Mangenot) de Hoog	4.4	7.9	8.9	30.0	12.2		5.0	36.7	16.7	15.6	11.1		6.7	8.3
Trichoderma harzianum Rifai	17.1	2.7	2.2	1.7	7.8	2.2	3.3	10.0					3.3	7.6
Sporothrix inflata de Hoog	9.0	8.1	35.6	3.3	1.1	2.2	5.0							7.0
Paecilomyces variotii Bain.	5.6	7.9	11.1	1.7	4.4	22.2	3.3	3.3	3.3	6.7		4.4	3.3	6.3
Mortierella bainieri Cost.	6.0	9.2	6.7		2.2			3.3		6.7	26.7			6.3
Aspergillus versicolor (Vuill.) Tiraboschi	10.6	0.2	20.0	5.0				6.7	6.7	28.9			36.7	6.1
Leptographium sp8	1.7	2.7			33.3	11.1	20.0	3.3		15.6	6.7	6.7	33.3	6.1
Doratomyces nanus (Ehrenb.) Morton & Smith	15.0	0.4		3.3	2.2			6.7						5.3
Mucor hiemalis Wehmer	7.9	2.3	8.9	10.0	4.4		1.7	20.0	3.3	2.2		2.2		4.9
Penicillium funiculosum Thom	0.2	0.6	15.6	33.3	16.7		38.3	30.0	10.0	15.6				4.9
Penicillium thomii Maire	2.3	5.2	2.2			31.1	10.0	6.7		24.4				4.7
Oidiodendron periconioides Morrall	4.6	5.2	4.4		1.1	2.2	28.3							4.5

Graphium penicilloides Corda	1.0	9.0		3.3	2.2			26.7		15.6				4.5
Mucor racemosus Fres.	2.9	3.1	11.1	3.3	7.8	22.2	15.0			2.2				4.2
Acremonium strictum W. Gams	7.5	3.5	2.2	3.3				3.3		4.4			3.3	4.0
Ophiostoma sp.	2.3	8.5				2.2	1.7			6.7				3.8
Penicillium glabrum (Wehmer) Westling	10.6	1.3												3.8
Thysanophora penicilloides (Roum.) Kendrick	2.1	9.6												3.7
Leptographium sp7	2.9	3.3	17.8	1.7	10.0			6.7	13.3					3.6
Penicillium commune Thom												13.3		3.5
Penicillium miczynski Zaleski	5.4	5.4												3.5
Gelasinospora tetrasperma Dowding	0.6	6.7	2.2	5.0	4.4		10.0	3.3			2.2			3.4
Microascus albonigrescens (Sopp) Curzi	10.0			1.7				6.7						3.4
Phoma eupyrena Sacc.	3.3	0.8		11.7	10.0	4.4				8.9		2.2	26.7	3.4
Arthrobotrys conoides Drechsler	0.6	8.3						10.0			8.9			3.3
Phialophora botulispora Cole & Kendrick	3.1	6.3	4.4		2.2									3.3
Cladosporium sphaerospermum Penz.	6.0	1.7					10.0	3.3	3.3	4.4				3.1
Geomyces asperulatus Sigler & Carm.	4.2	2.5	4.4	1.7			8.3	13.3		6.7				3.1
Cladosporium cladosporoides (Fres.) deVries	1.3	0.6	6.7	10.0	6.7	8.9	5.0	10.0	16.7	2.2			16.7	3.0
Graphium sp1	5.2	0.4						3.3	10.0	8.9	20.0		3.3	3.0

Penicillium spinulosum Thom	6.5	1.3			1.1				20.0						2.9
Phialocephala fusca Kendrick	6.7	2.1								2.2					2.9
Arthrobotrys cladodes Drechsler	5.8	0.6			1.1					17.8	2.2			3.3	2.8
Verticillium catenulatum (Kamyschko) W. Gams	4.6	1.9		1.7				16.7					2.2		2.8
Aureobasidium pullulans Viala & Boyer	1.5	0.4	8.9	1.7	21.1	8.9	5.0						2.2		2.7
Chrysosporium merdarium (Link) Carm.	7.5							6.7							2.5
Mortierella parvispora Linnem.	3.5	3.5			4.4										2.5
Chalara sp1	5.2	0.6	2.2	1.7		2.2	10.0								2.5
Graphium cf. *putredinis* (Corda) Hughes	0.4	5.8			1.1	6.7	1.7			2.2					2.4
Mucor plumbeus Bonord.	5.4	1.0		8.3											2.4
Oidiodendron maius Barron	4.4	1.5		1.7	1.1	2.2	1.7	6.7					4.4		2.4
Trichoderma koningii Oudem.	1.3	2.7	4.4						3.3	2.2	6.7	17.8	10.0		2.3
Mortierella alpina Peyronel	1.5	1.5	6.7	20.0	1.1			10.0			2.2				2.3
Botryotrichum piluliferum Sacc. & March.	6.7		2.2												2.2
Penicillium chrysogenum Thom	4.2		11.1	8.3	3.3										2.2
Scopulariopsis brumptii Salvanet-Duval	6.7										2.2				2.2
Oidiodendron truncatum Barron	6.5														2.1
Paecilomyces inflatus (Burns) Carm.	6.5														2.1

Verticillium psalliotae Treschow	5.0				7.8							2.1
Acremonium polychromum (van Beyma) W. Gams	1.3	0.2	2.2	3.3					13.3		43.3	1.9
Bispora betulina (Corda) Hughes	3.3	0.6	20.0									1.9
Ophiostoma stenoceras (Robak) C. Moreau	2.7	1.3	4.4		5.6						3.3	1.8
Wardomyces humicola Henneb. & Barron	4.8	0.4		1.7								1.8
Acremonium cf. anam *Nectria rishbethii* Booth	2.1	1.3	2.2	8.3				6.7	4.4			1.7
Cunninghamella elegans Lendner	4.2		2.2					6.7	4.4		3.3	1.7
Penicillium implicatum Biourge	3.8	0.8	8.9									1.7
Scopulariopsis brevicaulis (Sacc.) Bain.	2.7	0.2							11.1		23.3	1.7
Pseudogymnoascus roseus Raillo	0.2	0.2	2.2		4.4	26.7	10.0					1.7
Verticillium fungicola (Preuss) Hassebr.	1.5	0.8		1.7	4.4			23.3	4.4			1.7
Verticillium lamellicola (F.E.V. Smith) W. Gams	2.3	1.5	2.2		6.7							1.7
Leptographium sp2	0.6	4.4										1.6
Acremonium camptosporum W. Gams	1.7		2.2	5.0	3.3	2.2	5.0			4.4		1.5
Chrysosporium lobatum Scharapov	4.8											1.5
Leptodontium camptobactrum de Hoog	1.5	0.4	2.2	5.0	2.2			23.3	2.2			1.5
Torulomyces lagena Delitch	4.0		2.2	1.7				3.3	2.2			1.5
Mortierella isabellina Oud. & Koning.	4.0	0.2					1.7			2.2		1.5

Ramichloridium anceps (Sacc. & Ellis) de Hoog	1.3	1.9			2.2			3.3		2.2			10.0	1.5
Aspergillus ustus (Bain.) Thom & Church	3.8			3.3									3.3	1.4
Cladosporium elatum (Harz) Nannf.	2.3	0.2		1.7	3.3	4.4		3.3					3.3	1.3
Fusarium spl	2.9			3.3						4.4			6.7	1.3
Penicillium minioluteum Dierckx	0.4	3.1										6.7		1.3
Dendryphiopsis atra (Corda) Hughes	1.5	0.2		1.7				6.7	13.3	4.4	2.2			1.2
Gliocladium roseum Bainier	1.7	0.2	17.8	1.7										1.2
Geotrichum candidum Link	1.5	0.2	6.7		1.1		3.3	3.3		2.2			3.3	1.1
Paecilomyces farinosus (Holm) A.H.S. Brown & G. Sm.	2.3	0.2		1.7				6.7					6.7	1.1
Phialophora brachyconia W. Gams	0.2	1.9			1.1		1.7	16.7						1.1
Sporothrix isarioides (Petch) de Hoog	1.7	1.0	2.2	1.7		4.4								1.1
Tritirachium dependens Limb.	2.3		11.1					3.3						1.1
Acremonium kiliense Grutz	1.9	0.6					1.7					2.2	6.7	1.1
Byssochlamys cf. *fulvus* Oliver & Smith	0.2	0.8				8.9	10.0							1.0
Geotrichopsis cf. *mycoparasitica* Tzean & Estey	2.3	0.6			1.1									1.0
Gymnoascus uncinatus Eidam	3.1													1.0
pycnidial spl	0.2	2.5			2.2									1.0
Alternaria alternata (Fr.) Kessler	0.8	0.2			5.6					4.4			6.7	0.9

Microsphaeropsis olivacea (Bonord.) Hohn.	2.1	0.4					3.3							0.9
Phialophora olivacea W. Gams	2.3	0.2			1.1		1.7							0.9
Coniochaeta saccardoi (March.) Cain	0.8		4.4	1.7			8.3			2.2				0.9
Penicillium citrinum Thom	2.1	0.2		1.7	1.1									0.9
Phialocephala virens Siegfried & Siefert	0.8							6.7					23.3	0.9
Phialophora phaeophora W. Gams	0.2	0.6		13.3			1.7							0.9
Graphium cf. *calicioides* (Fr.) Cooke & Massee		2.5												0.8
Verticillium tenuissimum Corda	0.8	1.5					1.7							0.8
Arthrographis cuboidea (Sacc. & Ellis) Sigler	2.3													0.7
Chalara cf. *cylindrosperma* (Corda) Hughes	0.8			8.3			3.3							0.7
Cladosporium herbarum (Pers.) Link	1.0				1.1		3.3	3.3				2.2	3.3	0.7
Malbranchea flocciformis Sigler & carm.	2.3													0.7
Monodictys glauca (Cooke & Harkn.) Hughes	2.3													0.7
Mortierella gamsii Milko	1.5		4.4				1.7		3.3					0.7
pycnidial sp4			6.7		2.2	2.2	1.7					8.9		0.7
Torula herbarum Sacc.	2.3													0.7
Wardomyces inflatus (March.) Henneb.	1.9	0.4									2.2			0.7
Acremonium minutisporum (Sukap. & Thirum.) W. Gams		0.8	4.4	3.3				6.7						0.7

Blastobotrys nivea v. Klopotek	2.1												0.7
Dactylaria sp. 1	0.8	0.6			1.1					2.2		3.3	0.7
Geniculosporium cf. *serpens* (Pers.) Kickx	0.4	0.4			2.2				2.2	2.2	2.2	3.3	0.7
Humicola fuscoatra Traaen		1.0				1.7			8.9				0.7
Paecilomyces carneus (Duche & Heim) A.H.S. Brown	1.7									2.2		3.3	0.7
Paecilomyces cf. *amoeneroseus* (P. Henn.) Samson	0.4						13.3		4.4			6.7	0.7
Paecilomyces lilacinus (Thom) Samson	0.2						23.3					6.7	0.7
Penicillium sclerotiorum van Beyma	0.2	0.6	4.4	1.7				3.3	4.4				0.7
Scopulariopsis candida (Guegen) Vuill.	2.1												0.7
Sporotrichum versisporum (Lloyd) Stalpers	0.8	1.0			1.1								0.7
Ulocladium botrytis Preuss	0.8				1.1		3.3		6.7			3.3	0.7
Acrodictys fuliginosa Sutton	0.6	0.4		3.3				3.3		2.2			0.6
Diplococcium spicatum Grove		1.0		1.7		3.3						3.3	0.6
Eupenicillium lapidosum Scott & Stolk		1.3		5.0									0.6
Phialemonium dimorphosporum W. Gams & W.B. Cooke	1.0	0.6			1.1								0.6
Sporothrix microsporum (Davidson) von Arx	1.0	0.8											0.6
Acremonium fusidoides (Nicot) W. Gams	1.5	0.2											0.5
Doratomyces stemonitis (Pers.) Morton & Smith	1.7												0.5

Exophiala moniliae de Hoog		0.6				3.3	10.0						0.5
Haplographium sp.	0.8	0.4	2.2	1.7									0.5
Leptographium sp5	0.8			6.7									0.5
Penicillium brevicompactum Dierckx							20.0		4.4				0.5
Penicillium variabile Sopp					8.9								0.5
Rhizopus stolonifer (Ehrenb.:Fr.) Vuill.	0.6				2.2		3.3		4.4				0.5
Taeniolella stilbospora (Corda) Hughes			15.6				3.3						0.5
Calcarisporium arbuscula Preuss	0.8	0.2					6.7						0.5
Chrysosporium carmichaelii van Oorschot	1.3	0.2											0.5
Exophiala jeanselmii (Langeron) McGinnis & Padhye		0.6				1.7					2.2	6.7	0.5
Leptographium sp4		0.4					13.3		2.2				0.5
Mortierella humilis Linnem.	0.6	0.8											0.5
Penicillium rugulosum Thom	1.3	0.2											0.5
Scopulariopsis flava (Sopp) Morton & Smith	1.0						3.3				2.2		0.5
Talaromyces retardatus Udagawa, Kamiya, & Osada	0.8					5.0							0.5
Tritirachium oryzae (Vincens) de Hoog						5.0			8.9				0.5
Verticillium lecanii (Zimm.) Viegas		1.5											0.5
Absidia cylindrospora Hagem	0.4	0.8											0.4

Acremonium sp1	1.0	0.2													0.4
Aspergillus fumigatus Fres.	0.6							10.0							0.4
Chrysosporium sulfureum (Fiedl.) van Oorschot & Samson	1.3														0.4
Leptographium sp3					4.4	2.2			3.3						0.4
Mortierella elongata Linnem.	0.4										4.4	4.4			0.4
Mortierella exigua Linnem.	0.4		4.4	1.7				3.3							0.4
Myxotrichum ochraceum Berk. & Broome	1.3														0.4
Oidiodendron cf. *pilicola* Y. Kobayasi	0.6	0.6													0.4
Oidiodendron tenuissimum (Peck.) Hughes	0.4	0.4					3.3								0.4
Sporothrix cf. *nigrocarpum* (Davidson) de Hoog	0.4	0.4												6.7	0.4
Stachybotrys atra Corda	1.3														0.4
Thamnidium elegans Link	1.0				1.1										0.4
Truncatella angustata (Pers.) Hughes	0.6							3.3					2.2	3.3	0.4
Arthroderma curreyi Berk.	0.8													3.3	0.3
Dactylaria lanosa Malla & W. Gams	1.0														0.3
Leptodontium boreale de Hoog		0.2		6.7											0.3
Mortierella jenkini (Smith) Naumov	0.6											4.4			0.3
Myxotrichum arcticum Udagawa, Uchiyama, & Kamiya		0.2				2.2	5.0								0.3

pycnidial sp2				3.3		6.7				0.3
Veronaea cf. *coprophila* (Subram. & Lodha) M.B. Ellis	0.4	0.6								0.3
Paecilomyces sulfurellus (Sacc.) Samson & W. Gams	0.2								6.7	0.3
Arthrographis lignicola Sigler			2.2	3.3						0.3
Epicoccum nigrum Link	0.2			1.1					6.7	0.3
Eremomyces bilateralis Malloch & Cain	0.8									0.3
Gilmaniella humicola Barron		0.6							3.3	0.3
Helicoma olivaceum (Karsten) Linder.	0.4			3.3						0.3
Malbranchea gypsea Sigler & Carm.	0.6	0.2								0.3
Mortierella hyalina (Harz) W. Gams	0.8									0.3
Mortierella vinacea Dixon-Stewart		0.4		3.3						0.3
Mycogone sp.			8.9							0.3
Neta patuxentica Shearer & Crane	0.2	0.2				3.3		2.2		0.3
Penicillium decumbens Thom		0.4	2.2			3.3				0.3
Phialemonium curvatum W. Gams & W.B. Cooke	0.2	0.4			1.7					0.3
Phialemonium sp.		0.2	6.7							0.3
Phialophora richardsiae (Nannf.) Conant	0.8									0.3
Pseudogymnoascus frigidus (Uchiyama et al.) Lumley		0.8								0.3

Sordaria humana (Fuckel) Winter	0.8								0.3
Acremonium cf. *crotocinigenum* (Schol-Schwartz) W. Gams	0.2								0.2
Acrodontium griseum (Fassatiova) de Hoog		0.6							0.2
Arthrobotrys cf. *straminicola* Pidoplichko			4.4	1.7					0.2
Aspergillus restrictus G. Sm.						10.0			0.2
Bispora antennata (Pers.) Mason		0.4				3.3			0.2
Chaetomium funicola Cooke	0.2							4.4	0.2
Cladosporium resinae Parberry					1.1	2.2		2.2	0.2
Conioscypha varia Shearer								6.7	0.2
Cylindrocarpon cf. *candidum* (Link) Wollenw.	0.6								0.2
Dactylaria dioscoreae M.B. Ellis				3.3	1.1				0.2
Dictyosporium oblongum (Fuckel) Hughes		0.4				3.3			0.2
Mammaria echinobotryoides Ces.	0.4			1.7					0.2
Microascus cirrosus Curzi	0.6								0.2
Microascus singularis (Sacc.) Malloch & Cain	0.6								0.2
Mucor recurvus Butler	0.2	0.2		1.7					0.2
Nodulisporium sp1	0.6								0.2
Penicillium melinii Thom	0.6								0.2

Phialocephala dimorphospora Kendrick	0.2	0.2		1.7								0.2
Ramichloridium sp.			4.4						2.2			0.2
Sporothrix curviconia de Hoog	0.2				1.1	1.7						0.2
Thielavia terrestris (Apinis) Malloch & Cain	0.6											0.2
Verticillium cf. *lindauianum* Bubak	0.2						3.3	2.2				0.2
Verticillium cyclosporum (Grove) Mason & Hughes								2.2				0.2
Acremonium bactrocephalum W. Gams	0.2											0.1
Acremonium cerealis (Karst) W. Gams	0.4											0.1
Acremonium murorum (Corda) W. Gams	0.4											0.1
Arthrobotrys oligospora Fres.				3.3								0.1
Aspergillus niger van Tiegham	0.4											0.1
Beauveria alba (Limlber) Saccas	0.4											0.1
Calcarisporiella thermophila de Hoog			2.2							2.2		0.1
Cephalosporiopsis sp.	0.4											0.1
Chaetomium globosum Kunze:Fr.	0.2	0.2										0.1
Clonostachys compactiuscula (Sacc.) D. Hawksw. & W. Gams	0.4											0.1
Coniochaeta malacotricha (Auserwald) Traverso		0.2		1.7								0.1
Cylindrotrichum oligospermum (Corda) Bonord.							3.3				3.3	0.1

Doratomyces microsporus (Sacc.) Morton & Smith	0.4						0.1
Humicola grisea Traaen	0.4						0.1
Kernia retardata Udagawa & Muroi	0.2		2.2				0.1
Microascus brevicaulis S.P. Abbott	0.4						0.1
Microascus longirostris Zukal	0.4						0.1
Microascus manginii (Loubiere) Curzi	0.4						0.1
Microascus nidicola Massee & Salmon	0.4						0.1
Monacrosporium sp.	0.4						0.1
Monocillium mucidum W. Gams	0.2			1.7			0.1
Mortierella cf. *alliacea* Linnem.			2.2		1.1		0.1
Mortierella horticola Linnem.		0.4					0.1
Mortierella minutissima van Tieghem	0.2		2.2				0.1
Mortierella nana Linneman	0.4						0.1
Mucor mucedo Fres.	0.4						0.1
Ophiostoma piliferum (Fr.) H. & P. Syd.		0.4					0.1
Ovadendron sulfureoochraceum (van Beyma) Sigler & Carm.	0.2	0.2					0.1
Penicillium claviforme Bain.	0.4						0.1
Phialophora oxyspora W. Gams						4.4	0.1

Phialophora sp1			2.2		1.7		0.1
Pseudogymnoascus sp.		0.0					0.1
Sordaria fimicola (Rob.) Ces. & DeNot	0.4						0.1
Trichoderma hamatum (Bonord.) Bain.		0.4					0.1
Trichosporonoides sp1		0.2		1.7			0.1
Ulocladium consortiale (Thum.) Simmons	0.2				1.7		0.1
Acremonium atrogriseum (Panasenko) W. Gams	0.2						0.1
Acremonium bacillosporum (Onions & Barron) W. Gams	0.2						0.1
Acremonium persicinum (Nicot) W. Gams		0.2					0.1
Acrodontium cf. *crateriforme* (Fassatiova) de Hoog		0.2					0.1
Arthrinium phaeospermum (Corda) M.B. Ellis		0.2					0.1
Beauveria cylindrospora W. Gams						3.3	0.1
Chloridium botryoideum (Corda) Hughes		0.2					0.1
Chloridium lignicola (Mangenot) W. Gams		0.2					0.1
Coemansia aciculifera Thaxter	0.2						0.1
Coniochaeta ellipsoidea Udagawa			2.2				0.1
Emericella nidulans (Eidam) Vuill.	0.2						0.1
Endophragmia hyalosperma (Corda) Morgan-Jones & Cole	0.2						0.1

Eurotium chevalieri Mangin		0.2				0.1
Gelasinospora endodonta (Malloch & Cain) von Arx			1.7			0.1
Geniculifera cf. *cystosporia* (Duddington) Rifai			1.7			0.1
Gymnoascus reessii Baranetzky	0.6					0.1
Leptographium lundbergii Lagerb. & Melin	0.2					0.1
Leptographium sp1		0.2				0.1
Leptosphaerulina argentinensis (Speg.) Graham & Luttrell	0.2					0.1
Malbranchea pulchella Sacc. & Penz.			2.2			0.1
Mortierella cf. *acuminata* Linnem.	0.2					0.1
Mortierella pulchella Linnem.	0.2					0.1
Nodulisporium cf. *tuberum* (Fontana & Bonfante) de Hoog	0.2					0.1
Penicillium frequentans Westling	0.2					0.1
Phialophora fastigiata (Lagerberg & melin) Conant		0.2				0.1
Podospora tetraspora (Winter) Cain					2.2	0.1
Pragmopycnis sp.	0.2					0.1
Pseudogymnoascus alpinus Muller & von Arx		0.2				0.1
pycnidial sp3	0.2					0.1
Rhizopus oryzae Went & Prinsen Geerlings		0.2				0.1

Septomyrothecium cf. *uniseptatum* Matsushima	0.2				0.1
Sphaerodes fimicola (Hansen) D. Hawksworth	0.2				0.1
Sporothrix fungorum de Hoog & de Vries	0.2				0.1
Sporothrix sp1			1.7		0.1
Strattonia carbonaria (Phillips & Plowright) Lundquist		2.2			0.1
Talaromyces udagawae Stolk & Samson	0.2				0.1
Verticimonosporium sp.		0.2			0.1
Volutella ciliata Alb. & Schw.:Fr.	0.2				0.1

Table 4.4. Microfungal species richness and diversity (Shannon) from undisturbed ("U"), post-fire ("F"), and post-harvest ("H") sites in northern Alberta. Post-fire post-harvest sites were disturbed in 1968 (F61, H61, and H62), 1982 (F82, F83, H82, and H83), or 1995 (F91, F93, H92, and H93).

	UEI	**UML**	**F61**	**F82**	**F83**	**F91**	**F93**	**H61**	**H62**	**H82**	**H83**	**H92**	**H93**
total number of records	2513	1930	113	139	226	127	171	108	105	131	96	42	90
total number of species	126	72	37	37	42	28	40	36	23	38	23	13	27
average number of records/sample	5.2	4.0	3.8	2.3	2.5	2.1	2.3	3.6	3.5	2.9	2.1	0.9	3.0
diversity	3.79	3.36	3.22	3.06	3.27	2.88	3.21	3.20	2.65	3.25	2.41	2.08	2.85

Table 4.5. Correlation matrix for ordination (CCA) axes and log characteristics (moisture, decomposition stage, species, and diameter) from ordination of undisturbed site logs (UML and UEI). *P<0.01, **P<0.005, ***P<0.001.

	axis 1	**axis 2**	**moisture**	**diameter**	**stage**
axis 2	-0.02				
moisture	-0.64***	-0.18			
diameter	-0.31	-0.34	0.23		
stage	-0.34	-0.52**	0.87***	0.11	
species	0.74***	0.30	-0.15	-0.46*	-0.03

Table 4.6. Correlation matrix for ordination (CCA) axes, log characteristics, climatic variables, and time since disturbance (time) from ordination of all logs (n=51). *P<0.01, **P<0.005, ***P<0.001.

	axis 1	axis 2	moisture	diameter	stage	species	MDT	MAP	DD>5
axis 2	0.01								
moisture	0.11	-0.27							
diameter	-0.50***	0.30	-0.42**						
stage	-0.03	0.58***	0.36**	-0.03					
species	0.87***	0.01	0.15	-0.49***	-0.06				
MDT	-0.27	0.72***	-0.59***	0.42**	0.17	-0.20			
MAP	-0.32	-0.03	-0.22	0.02	-0.08	-0.09	0.10		
DD>5	0.02	0.70***	-0.30	0.12	0.22	-0.12	0.64***	-0.25	

Figure 4.1. Map of Alberta showing location of study sites (Elk Island – 1, Mariana Lake – a, Slave Lake – 4-8, Little Buffalo – 9, Calling Lake – 2,3).

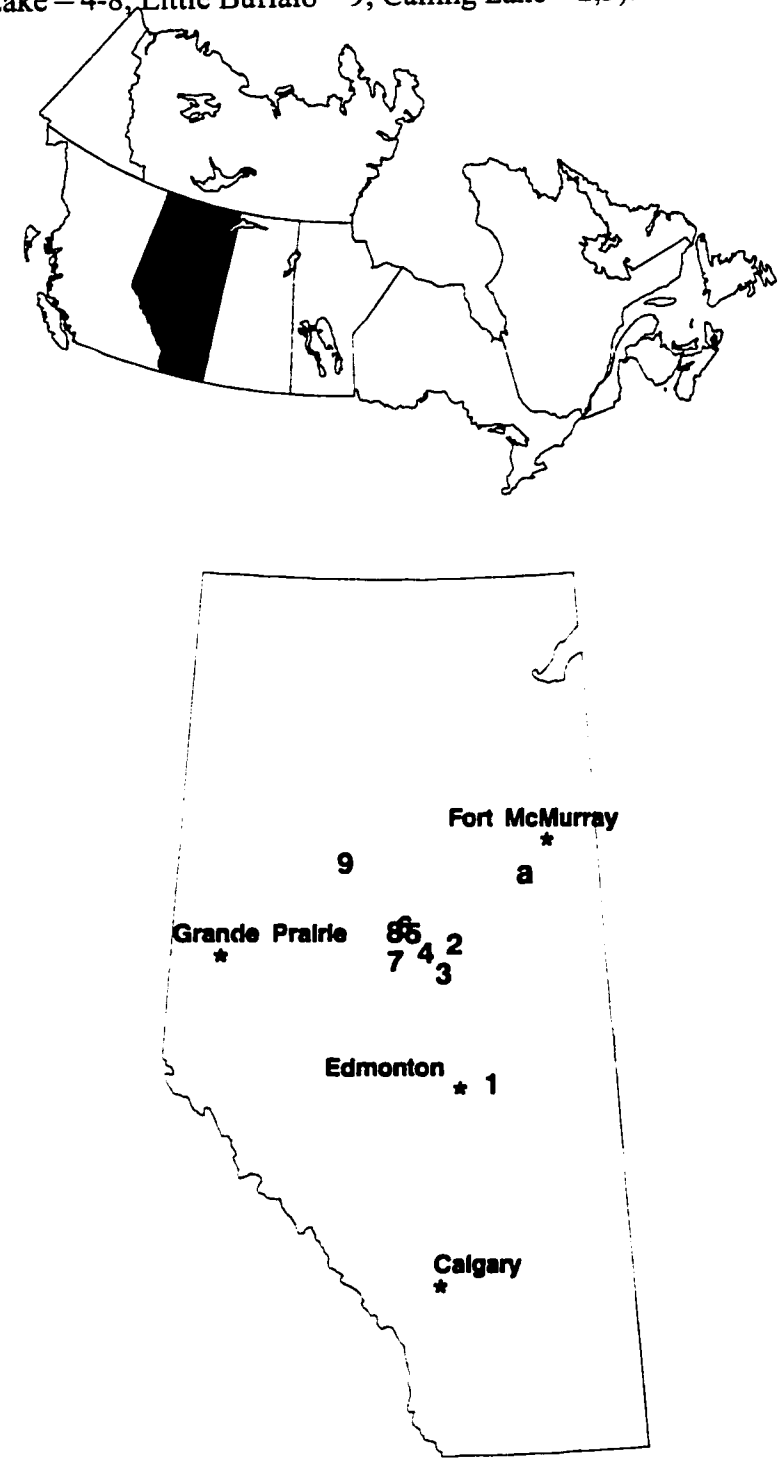


Figure 4.2. CCA ordination of microfungus communities from spruce (spr) and aspen (asp) logs at various stages of decomposition from undisturbed sites in Elk Island National Park (UEI) and Mariana Lake (UML).

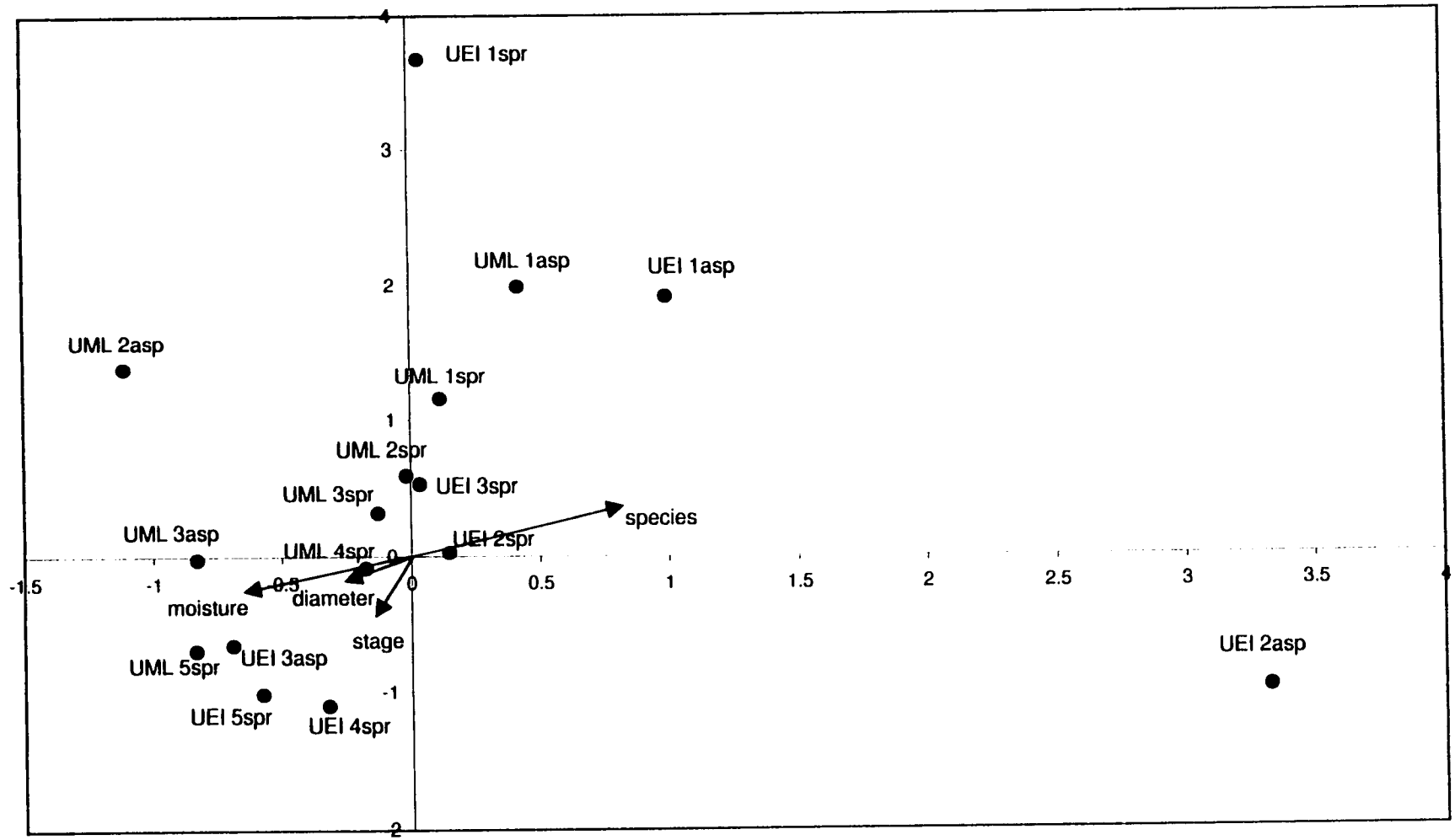


Figure 4.3. CCA ordination of microfungus communities from spruce (spr) and aspen (asp) logs at various stages of decomposition from undisturbed sites in Elk Island National Park (UEI) and Mariana Lake (UML). Vector for "stage of decomposition" is extended (dashed line) and joined to aspen logs to show position with respect to that vector.

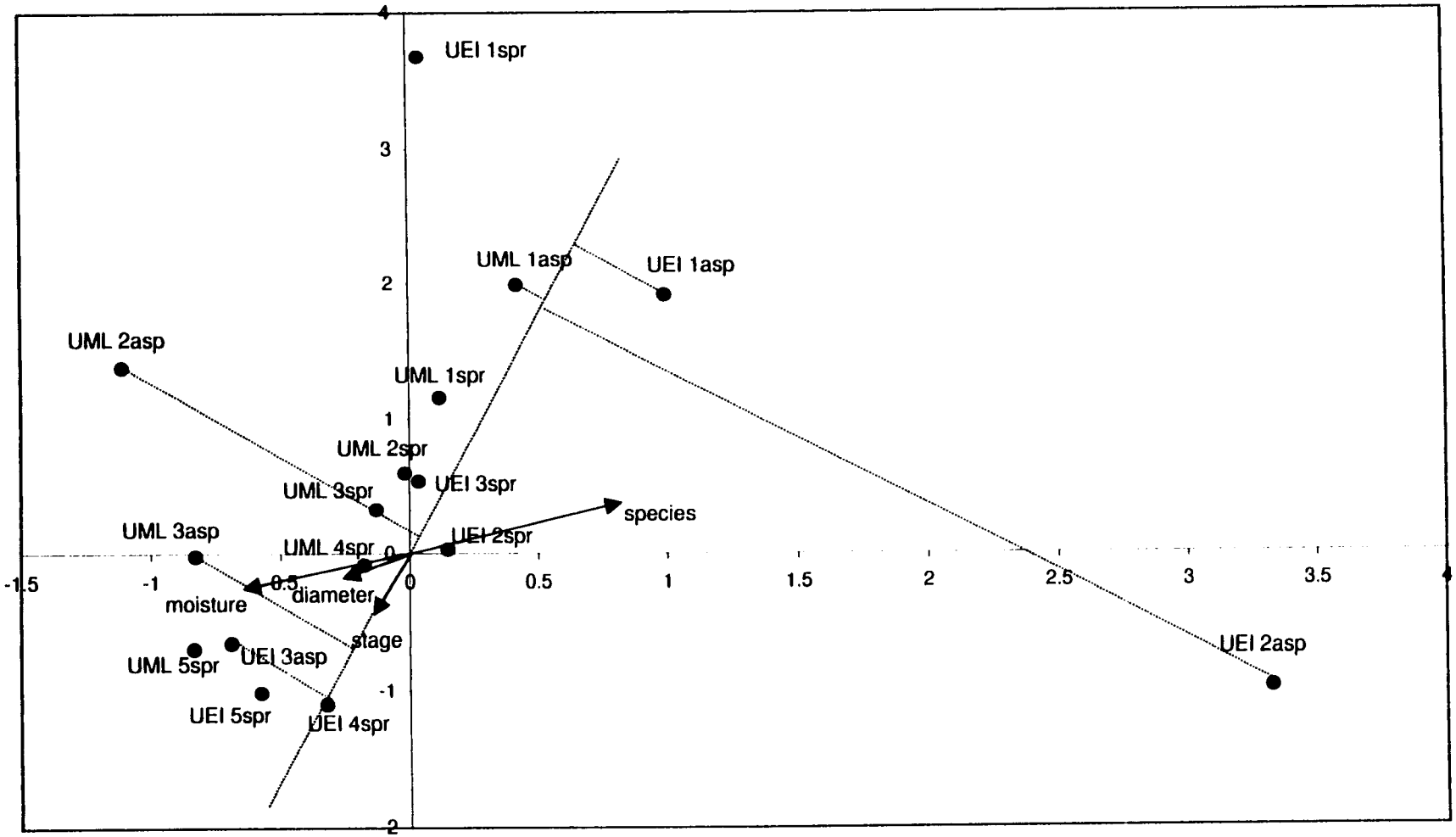


Figure 4.4. CCA ordination of microfungus communities from spruce (spr) and aspen (asp) logs at various stages of decomposition from undisturbed sites in Elk Island National Park (UEI) and Mariana Lake (UML). Vector for "stage of decomposition" is extended (dashed line) and joined to spruce logs to show position with respect to that vector.

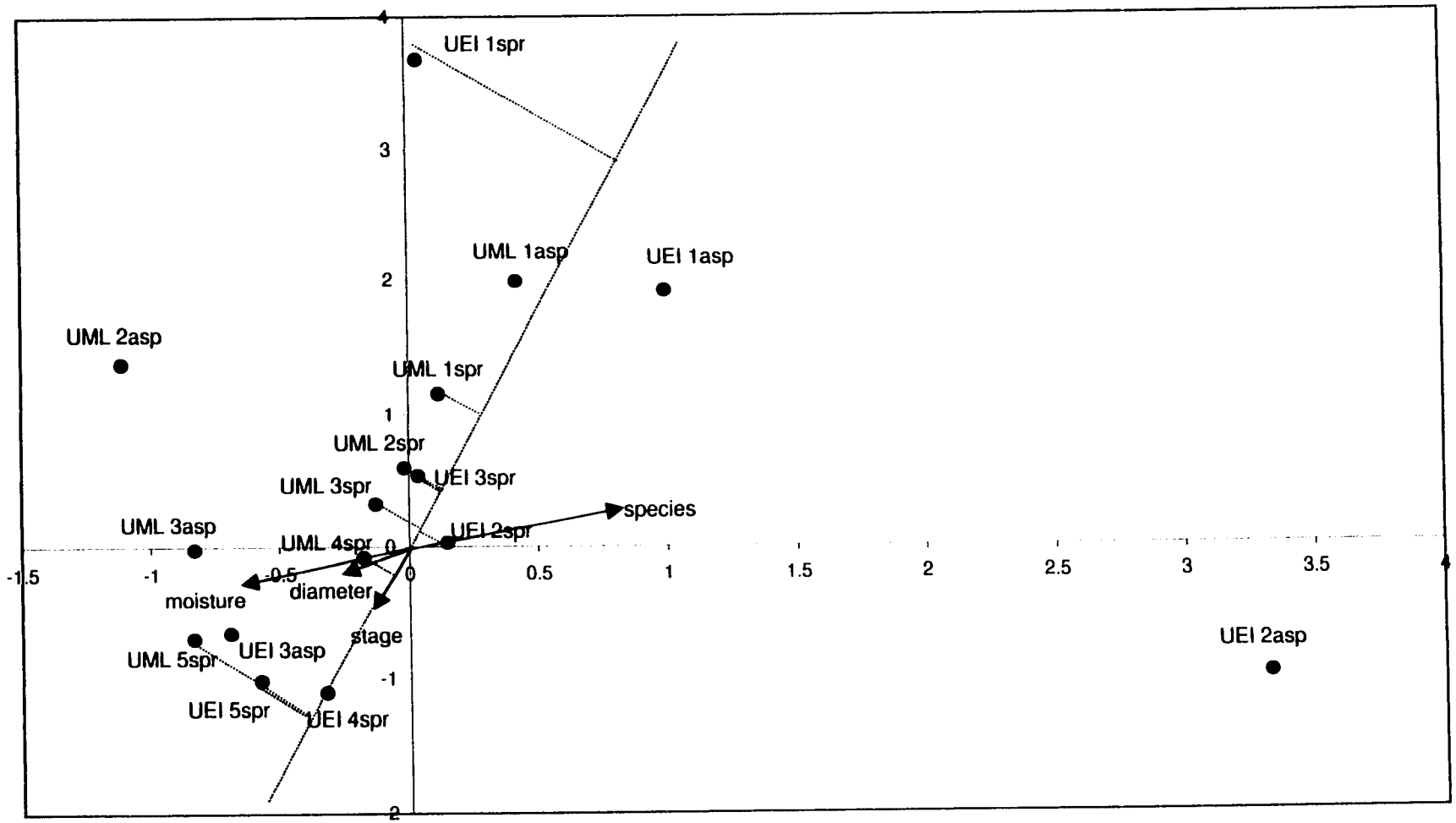


Figure 4.5. Cluster analysis (unweighted arithmetic averaging) of microfungus community similarity (Bray-Curtis) for logs from undisturbed (U), post-fire (F), and post-harvest (H) sites. Site number is followed by stage of decomposition (1-5 for spruce, 1-3 for aspen) and log species ("as" for aspen, "sp" for spruce).

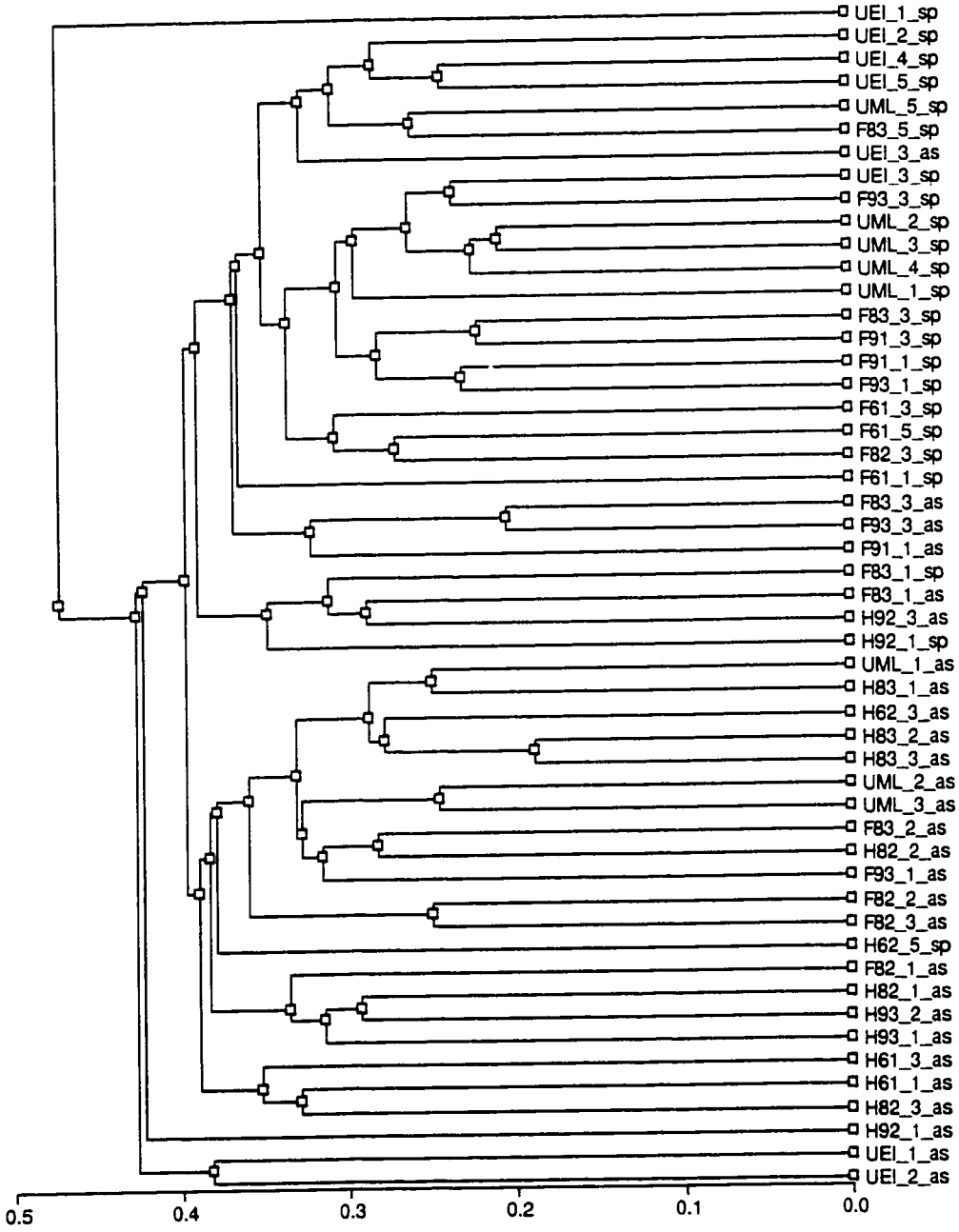
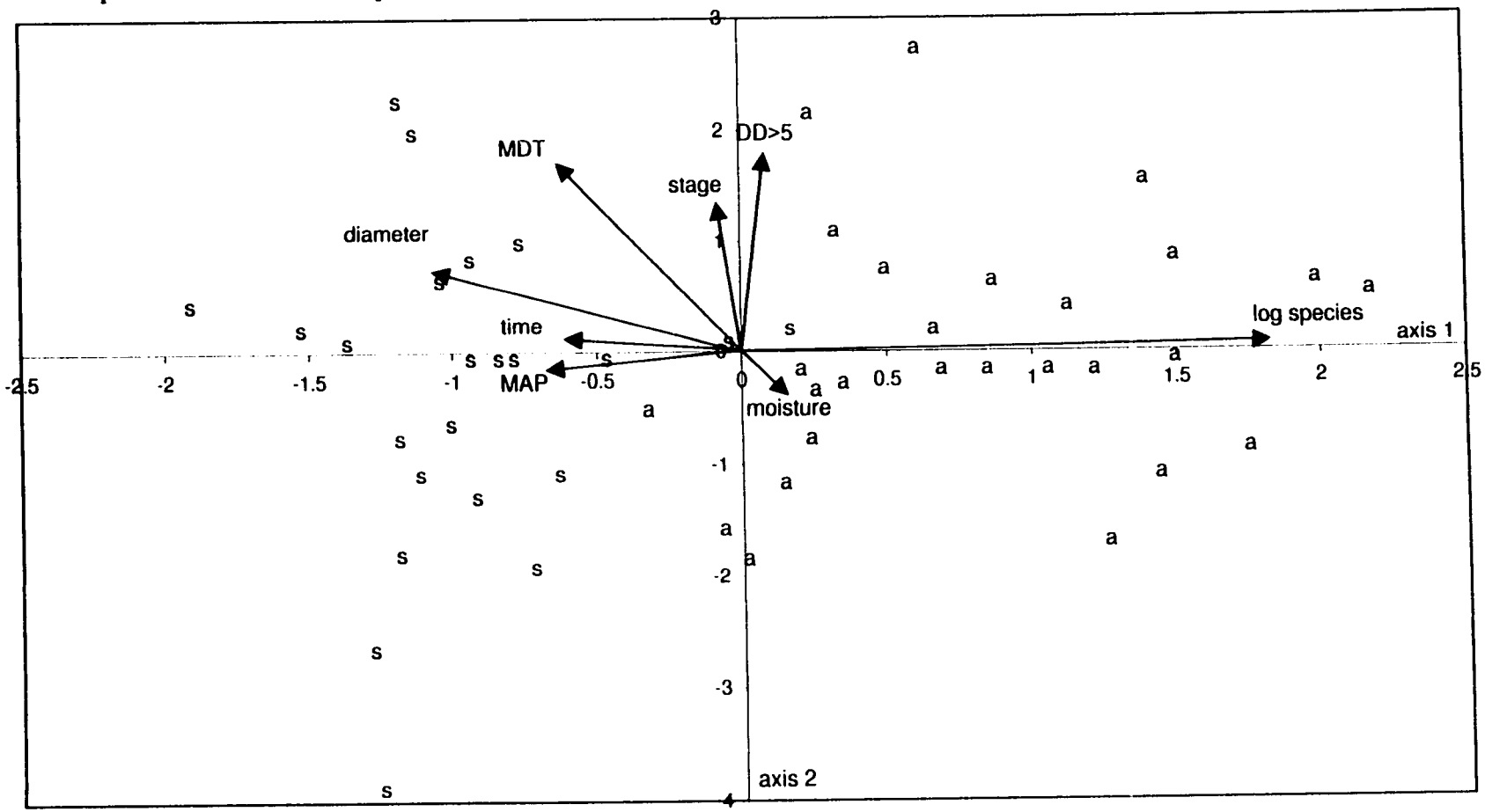


Figure 4.6. CCA ordination of microfungus communities from spruce (s) and aspen (a) logs at various stages of decomposition in undisturbed, post-fire, and post-harvest sites in northern Alberta.



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Chapter 5. Summary and conclusions

The information available about the microfungi of naturally decomposing logs comes from studies that have relied on a limited number of samples, and have consequently yielded a small number of species (e.g., Crawford et al., 1990; Nikolayevskaya and Chastookhin, 1945), or comes from studies of mycoflora of wooden stakes (Clubbe, 1980; Butcher, 1968). Over the course of this study, efforts were made to recover as many fungal species as possible. Intensive sampling of each log, including the use of six isolation media provided a good cross-section of fungi, including commonly reported taxa, such as *Trichoderma* and *Penicillium* species, but also rarely reported species. The long incubation time (up to 18 months) was also important for isolation of certain fungi (e.g., Microascales, Onygenales, and related anamorphs), presumably because they grow or sporulate slowly.

Before now, our understanding of wood decay fungi was largely limited to those found at early decomposition stages, and especially basidiomycetes. This research allows a better appreciation of the diversity of fungi found associated with wood at all stages of decomposition. Nearly 300 species were recovered (chapter 2), including a number of taxa thought to be rare or not previously isolated from wood. Among the rare taxa were species of *Pseudogymnoascus* and *Gymnostellatospora* that were, with the exception of *P. roseus*, known from few collections worldwide. The isolates from wood provided information that led to a synonymization of these two genera and description of a new species (chapter 3). Interestingly, these and several other ascomycete species are known mainly or entirely from collections from similar latitudes in Japan, suggesting a correlation to cold climates, and grow or sporulate better at colder temperatures (e.g., *Pseudogymnoascus frigidus*).

Perhaps the most interesting outcome of this research was that microfungus communities were correlated with log species and stage of decomposition. Although not surprising, this is the first time that enough data have been gathered to confirm specificity, or at least affinity, of species of microfungi to log class. Cluster analysis of microfungus communities from logs showed distinct spruce and aspen groupings. Ordination of logs (CCA) confirmed that log species had the greatest influence on the formation of communities and that communities from spruce and aspen logs were influenced by different environmental factors.

Type of disturbance (fire and harvest) and time since disturbance influenced communities, as demonstrated by species richness and community composition. Mean number of species per sample was highest for undisturbed sites (4.6) and lowest in the most recently disturbed sites ($2.0 - 2.2$) with an increase over time following disturbance. Species diversity (Shannon) was highest in undisturbed sites and lowest among disturbed sites, but showed no significant trend with time post-disturbance. Post-harvest treatments often include removal of woody debris (Crawford et al., 1990) which may ultimately affect the microfungus communities of soil.

Log moisture proved to be an important environmental variable. It had a significant impact on communities, as demonstrated by ordination of logs from undisturbed sites, and was significantly correlated with log diameter and stage of decomposition. It was also correlated with climatic variables in an ordination of all logs

sampled. Accumulation of moisture with decomposition has been previously demonstrated, and evidence is presented here to suggest that other variables, including stage of decomposition and climatic variables, affect communities by affecting log moisture.

Succession of microfungus communities as logs decompose was confirmed by the greater similarity of communities associated with logs more similar in stage of decomposition, as shown by ordination of undisturbed site logs. Early stage logs were often dominated especially by wet-spored taxa, such as species of *Phialophora* and *Gliocladium*, which may reflect the phoretic dispersal of these fungi soon after the tree falls to the ground. Soft-rot fungi, such as *Chaetomium* spp., were most abundant during the intermediate stages in spruce, and stages 1 and 2 in aspen. These fungi probably facilitated the accumulation of moisture and depleted much of the cellulose. The intermediate to late stages in both aspen and spruce were the most species-rich and provided many types of fungi, including zygomycetes and fungi imperfecti. Dematiaceous hyphomycetes were most abundant during the intermediate stages, although the reason for this is unclear. The late stage logs were dominated by zygomycetes and species of *Penicillium* and *Trichoderma*, all of which are commonly isolated from soil. Undoubtedly, late stage communities are influenced by, and contribute to, soil communities.

Closer examination of late stage communities suggests that log decomposition, and other types of substrate succession, may bear a closer resemblance to seral succession than previously thought. The distinction between the two types of succession is thought to be the lack of a climax community in the breakdown of a substrate (or, more appropriately, a "substratum"), but this may be a function of our misunderstanding of what happens to wood as it becomes humified. In other words, the breakdown of wood, and all other organic debris, contributes to what we commonly understand to be soil or humus communities, which themselves may be at equilibrium, or "climax".

One consequence of the altered microbiology of rotting wood is its ability to act as a rooting medium ("nurse logs") for forest plants, including ericads, orchids, and conifers, seeds of which may be unable to germinate in duff. Possible reasons for the preferential success of nurse log plants include differences in moisture, nutrient levels, and pH, but the microbiology of rotting wood undoubtedly affects the growth of nurse log plants, as fungi can be advantageous (mycorrhizal) or deleterious (pathogenic). *Oidiodendron* spp., for example, have been isolated from the rhizospheres of plants, and have been implicated in mycorrhiza formation in some ericads. During this study, *Geomyces pannorus*, *Oidiodendron* spp., *Pseudogymnoascus roseus*, and *Phialophora* spp., were all recovered from late stage logs, are cellulolytic, and have been isolated from the roots of gymnosperm seedlings. The contribution of wood decomposition fungi to plant success, or failure, needs further investigation, and with more information now available, comparison can be made between those fungi found in nurse log seedling roots and those found in wood. It is possible that these fungi are capable of a biphasic assimilation of carbon, from cellulolysis or from a facultative symbiosis with log-rooted plants.

Biodiversity, at least in terms of species richness, has become a globally important phenomenon, and must be considered in any floristic study. The concept of a global

understanding of biodiversity is prone to bias that stems from varying degrees of sampling effort, and by the nature of the organisms themselves. In no other discipline is this problem more evident than microbiology. Understanding the diversity of microbes requires a great deal of effort for sampling and expertise for identification. Consequently, it has proven difficult to determine how much sampling effort is required for a good estimate of diversity. Estimates for microfungi range from 16-27 species/ 100 isolates, but may be higher in less stable ecosystems or decrease with age. In this study, where sampling effort was great, only 3.2 species / 100 isolates were obtained. Additionally, only 2-3% of species recovered are probably new to science, much lower than the current estimate of 95% species unknown. It should be noted, however, that this is based on a global scale, with most new species coming from the tropics.

Future research should aim at alleviating problems with sampling design, specifically the lack of certain log classes from post-disturbance sites should be corrected. The lack of certain log classes from some sites limited the accuracy of comparison from some variables. In addition, sampling from undisturbed sites should be replicated to provide a more convincing comparison of log species and stage of decomposition from undisturbed sites. The number of logs sampled was limited by the amount of time required to process samples. Future studies should also include basidiomycetes and yeasts. These fungi are difficult to identify in pure culture, but are important components of wood decomposition fungus communities. A joint effort including experts in identification of these fungi would provide a more comprehensive understanding of fungal communities, and may help to explain the changes in numbers of microfungi, especially during the early stages.

The large data set generated during this research provided much information about the effects of log, site, and climatic variables, on communities of wood decomposition microfungi, but there is still some analysis remaining. Species ordinations and an analysis of functional groups (e.g., wet- vs. dry-spored, dematiaceous vs. hyaline, cellulolytic vs. non-cellulolytic) including changes in their numbers attributable to log or site characteristics, will provide information that is central to the understanding of the colonization process. Of particular interest is the effect of disturbance type (fire and harvest) on the number of wet or dry spored species. Proportional differences may reflect effects of disturbance on vectors, such as wind and invertebrates. A spatial pattern analysis (SPA) will also provide clues about colonization. Wood samples taken from closer to the ground may consistently give different species than those taken from the top of the log. SPA will provide insight into the colonization source and "population" dynamics of a species.

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