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Monitoring protocol for wood-inhabiting fungi in the Alberta Biodiversity Monitoring Program

for the

Alberta Biodiversity Monitoring Program

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1. INTRODUCTION

1.1 Brief introduction to biodiversity in dead wood

Dead wood is a key ecological factor in forest ecosystems. Functionally, it represents an important component of the forest carbon pool. Studies from unmanaged boreal forests indicate that dead wood makes up 20-30 % of the total timber biomass (Linder 1986; Syrjanen et al. 1994; Krankina and Harmon 1995; Sippola et al. 1998), and up to 70 % in recently disturbed areas (Krankina and Harmon 1995). It has been established that the biological diversity in dead wood is very high, and nearly all forest organism groups have species adapted to utilise this historically abundant resource base.

In Scandinavia there is a strong tradition to study biodiversity in dead wood, rooted in classic works on the ecology of wood-inhabiting beetles (Saalas 1917; Palm 1951; Palm 1959), and fungi (Eriksson 1958; Eriksson and Strid 1969). Recently, these data sources, subsequent publications and unpublished data have been compiled in a database on the ecology of more than 3600 species living in dead wood (Dahlberg and Stokland 2004). This database and experts judgements indicate that the total species richness of wood-inhabiting species in Scandinavia is 6000-7000 species (Table 1), corresponding to about 25 % of all forest species in this region, which is dominated by boreal forest. Scandinavia is at the same latitude as Alberta, having the total forest area ca 30 % larger than that for Alberta. Thus, the diversity in dead wood in this region gives a good picture of what can be expected for Alberta.

One species rich organism group in dead wood is the fungi. These are the primary decayers of woody material. Beetles represent another species rich group, many of which are capable of wood degradation (e.g. bark beetles, several longhorn beetles), feed on mycelium in the wood, or predate on larvae of other insects species on dead wood. There are distinct sub-systems among wood-inhabiting organisms like the community of predators, parasites and scavengers living in the galleries of bark beetles (Weslien 1992); insect species living only in fruit-bodies of wood-decaying fungi (Kaila et al. 1994; Økland 1995; Jonsell et al. 1999; Komonen 2001); and a host of parasitic wasp and fly species that parasite on larvae of other wood-inhabiting insects (e.g. Hedqvist 1998). In short, one can say that the organisms living in dead wood form a distinct sub-ecosystem with specialised life forms. To understand this species richness one needs to consider the variety of functional associations to dead wood, which has been always an abundant energy source in forests: Species are specialised to utilise various qualities of dead wood, such as different tree species, decay classes, parts of the tree (twigs/branches/trunks/roots and bark/sapwood/heart wood) as well as different trunk dimensions.

Table 1. Number of wood-associated species in different organism groups in Scandinavia[1]. The numbers are based on counting individual species or expert assessments.

Fungi		*Other species groups*	
Ascomycetes	751	Acarina (Ticks)[2]	300
Basidiomycetes	1270	Nematodes[2]	> 100
Lichens	220	Myxomycetes[2]	150
		Mosses	97
Insects			
Coleoptera (beetles)	1257	*Vertebrates*	*54*
Diptera[2]	500-1200		
Hymenoptera[2]	900-1400	Total	5800-7000
Other insects[2]	> 160		

1) The numbers are based on data from Finland, Norway and Sweden
2) The species numbers in these groups are expert assessments.

Dead wood has been identified as an important component in several forest monitoring schemes in Europe. The Ministerial Conference on the Protection of Forests in Europe (MCPFE) has recently formulated a set of improved

Pan-European indicators for sustainable forest management (MCPFE 2003). Under the section of biological diversity, dead wood is defined as one out of nine indicators. In parallel, and in cooperation with the MCPFE process, the Ministerial process "Environment for Europe" has through the work programme WP-CEBLDF and the BEAR project made an effort to identify indicators for assessing forest biodiversity. The BEAR project has proposed a set of forest biodiversity indicators that includes various dead wood qualities (Larsson 2001). Also the upcoming EU-programme "Forest Focus" identifies dead wood as one of several factors to be monitored (European Commission 2002).

The high number of wood-associated species is one reason to establish dead wood as a biodiversity indicator. Another reason, related to sustainable forest management, is the link between timber extraction and the reduced amount of dead wood in managed compared to unmanaged forests. In Scandinavia, several studies have established that the amount of dead wood in unmanaged boreal forests generally is 60-90 m^3/ha (Siitonen 2001), whereas the average amount of dead wood in landscapes dominated by forest management is 3-10 m^3/ha (Stokland et al. 2003), i.e. a reduction below 10 % of the natural levels. The reduction in the amount of dead wood is a reason for many species to be placed on national Red lists of threatened species. In Sweden, for instance, about 50 % of all red-listed species live in forest ecosystems (Gärdenfors 2000), and 54 % of the red-listed forest species depend upon dead wood (1126 species, Dahlberg and Stokland 2004).

1.2 Knowledge about fungus diversity in Alberta and Canada

Approximately 9600 macrofungus species have been recorded from Canada, and their estimated total number is nearly 20 000 (Ginns et al. 1998). Information on the biogeographical distribution of macrofungi in Alberta has been published for instance by Redhead (1988). However, this far, only checklist of microfungi exists for Alberta, whereas the checklists of macrofungi have not yet been completed. The recent studies show that knowledge on the occurrence of marcofungi of Alberta is still incomplete, and relatively large numbers of new species for the province have been recorded in the latest surveys (Richards and Murray 2002). Few studies have been published on wood-inhabiting fungi from Alberta, but one notable exception is Crites and Dale (1998).

Judging from extant information, the knowledge about wood-inhabiting fungi is relatively weakly developed for Alberta. It is, however possible that the knowledge is better than available publications show, as this citation from Ginns et al.(1998) indicates: "Several thousand unpublished records of fungi from B.C. and Alberta exist in five centres: 1) the National Mycological Herbarium at ECORC, 2) the Herbarium of the Botany Department at the University of British Columbia, 3) the Department of Biological Sciences and Devonian Botanic Garden at the University of Alberta, 4) the Pacific Research Centre, and 5) the Northern Forestry Centre of the Canadian Forestry Service in Edmonton. … However, several of the above centres have already extracted data from the specimen labels. The National Mycological Herbarium has an electronic database containing the collection data for nearly 24,000 specimens added to the National Herbarium since 1989. The collections database at the University of British Columbia contains about 13,000 records on fungi and an additional 35,000 records on lichens. And the Canadian Forestry Service has the locality data for their collections stored electronically and the Pacific Forestry Centre has made its collection data available online."

2. FUNGAL DIVERSITY ON DEAD WOOD IN BOREAL FORESTS

2.1. Different fungus groups - their strengths and weaknesses for long-term monitoring

Fungi are, among Plantae, Animalia, Bacteria and Protoctista, the fifth major life form on the planet. The number of species described by science are about 72 000, but the estimated species number is 1.5 million (Groombridge and Jenkins 2000). Fungi have an important role in the ecosystem functioning as decomposers, pathogens, parasites and symbionts, and they also form an important component of

biological diversity. The systematics of fungi is rapidly developing due to DNA-techniques. The work is at the beginning, but the results indicate that the systematics based on genetic relationships will substantially change the traditional taxonomy based on morphological features (see, e.g., Hibbet and Donoghue 1995; Boidin et al. 1998; Moncalvo et al. 2002; Wagner and Fischer 2002). In new systematics, scientists have not distinguished traditional taxa, but rather phylogenetic lines or clades (Niemelä 2003).

Because the new taxonomic classification is under development, the taxonomy used in this report is based on traditional morphological similarities between fungi. Furthermore, morphological and ecological similarities are still more useful in inventory and monitoring than complicated phylogenetic systematics. The systematics used in this report is simplified after Ahti et al. 1976 and Gilbertson and Ryvarden 1986, 1987. This differs from the newer systematics used, e.g. in Nordic Macromycetes (Hansen and Knudsen 1992, 1997, 2000), but is more easy to understand in a generalized presentation.

The two main divisions of fungi are *Eumycota*, true fungi, and *Myxomycota*, slime moulds. The systematic position of *Myxomycota* is still unclear - it is sometimes placed also in Protoctista or Animal Kingdom. Because of its unclear taxonomic position and difficult identification, *Myxomycota* has been left out of this review. Table 1 gives a generalized presentation of the major groups of fungi in the division of *Eumycota* with their main ecological features and fruit body characteristics, and with their suitability for summer-through long-term monitoring. Family-level information is given only for the orders *Agaricales* and *Aphyllophorales*, for other taxa information is given on higher systematic levels.

The subdivisions *Mastigomycotina* and *Zygomycotina* comprise microscopic fungi that resemble algae. The species in *Mastigomycotina* are parasitic fungi of eucaryotic and blue-green algae; the subdivision is sometimes also classified as protoctists. The subdivision *Zygomycotina* includes human and animal pathogens, saprophytic species in soil, and also mycorrhiza species. The groups are considered not suitable for conventional biodiversity monitoring because of their size and problems of identification.

The subdivision *Ascomycotina* includes a large variety of both micro- and macroscopic species, many of which are of economic importance. The group comprises about 30 000 described species. The species in the classes *Hemiascomycetes, Plectomycetes* and *Ascoloculares* are microscopic, and include for instance yeasts, moulds, mildews and other pathogens in organic tissues. The class *Pyrenomycetes* includes mainly small-size parasites and saprophytes, which are difficult to monitor because of their difficult identification. The species in the class *Discomycetes* are macroscopic, also known as cup fungi. The order *Helotiales* includes small- and medium-size species on ground, plants and debris; most of them are saprotrophic or parasitic. Spores are developing in disk- or goblet-shaped apothecia; many of the species are found in forest environment growing on wood and debris. Similar species are also found in the order *Pezizales*, which also includes morels and false morels (Ahti et al. 1976; Ryman and Holmåsen 1984; Groombridge and Jenkins 2000). The restriction of these species for summer-through monitoring is the short duration of their fruit bodies; many of them exist for a very limited period during the growing season.

The subdivision *Basidiomycotina* includes typical mushrooms, polypores (bracket fungi), puffballs, stinkhorns and rusts and smuts. The total number of described species is over 22 000. The class *Teliomycetes* comprises two orders: *Urediniales* (rusts) and *Ustilaginales* (smuts). Species in both groups are parasites in plants, and many have complicated life cycles with several host plants. Their use in biodiversity monitoring is difficult because of identification problems, complex life cycles and seasonal occurrence. The class *Hymenomycetes* includes two large orders: *Agaricales* and *Aphyllophorales*. In morphological classification, these two groups are separated by their spore-productive structure (hymenium). In traditional classification, the order *Agaricales* (gilled mushrooms) includes species whose hymenium consists of gills, where the spores are produced. However, also family *Boletaceae*, where spores are produced inside pores or tubes, is often included into *Agaricales* because of its phylogenetic

relationship to the group. Most of our edible mushrooms belong to *Agaricales*. The majority of gilled mushrooms are mycorrhiza species, and have an important role as symbionts of trees in forest ecosystems, but in some families also saprotrophic life forms are found. The suitability of *Agaricales* for long-term summer-through monitoring is restricted by the short duration of their fruit bodies (Ahti et al. 1976; Ryman and Holmåsen 1984; Groombridge and Jenkins 2000).

In the order *Aphyllophorales* (sometimes also called *Polyporales*), the hymenium can consist of pores, tubes, teeth or irregular gills. Their fruit bodies are often hard, but they can also be corky, tough or soft. The fruit body can be pileate (protruding), or resupinate (effused). As indicated earlier, the group is taxonomically heterogeneous, including morphologically and ecologically similar species. In most families, fruit bodies are annual and have short duration, and for that reason weakly suited for summer-through monitoring. There are, however, a large number of perennial species or species, where the fruit body lives 2-3 years or more, and which can thus be monitored year round. Perennial species are found especially in the families *Echinodontiaceae*, *Ganodermataceae*, *Hymenochaetaceae*, *Polyporaceae*, *Poriaceae* and *Stereaceae* (the latter is often included into *Corticiaceae*). Most species in *Aphyllophorales* are saprotrophic, utilizing dead organic material, but some are also necrotrophic, acting as pathogens in living trees, and also some mycorrhiza species are found (Ahti et al. 1976; Hansen and Knudsen 1992,1997; Niemelä 1999, 2003).

The term polypore is defined here to comprise wood-inhabiting fungi with pores in their hymenium, and some species with gills, which have traditionally been classified as polypores (e.g., *Daedalea*, *Daedaleopsis*, *Lenzites*, some *Trametes* species). The definitions of species follow mainly those presented in North American Polypores I-II by Gilbertson & Ryvarden (1986, 1987). Polypores are regarded as good objects for long-term monitoring for several reasons. First, polypores include remarkable number of perennial species, which can be inventoried year round. They are mostly wood-decomposing fungi, having an important role in the forest ecosystem as primary decayers. Fruiting bodies of polypores host a large variety of invertebrates, contributing directly to saproxylic diversity in forest ecosystems (see, e.g., Kaila et al. 1994; Økland 1995; Fossli and Andersen 1998; Rukke 2000, Komonen et al. 2000), and they also open pathways for many other saproxylic organisms during the decay process. There is evidence that polypore diversity can be used as a surrogate for species diversity of other saproxylic groups, especially beetles (Jonsson and Jonsell 1999; Similä 2002). In addition, many polypores are relatively easy to find and identify in field, and collecting and handling of samples in simple. Polypores are also used as indicators of environmental changes. Many species are specialized in their substrate and habitat requirements, and environmental changes are reflected in the species composition of communities. These issues are discussed more detailed later in this report.

The class *Gasteromycetes* includes fungi that produce their spores inside the fruiting body, such as puffballs and stinkhorns. They are mostly found on ground, but also on wood and other organic material (Ahti et al. 1976). Annual growth form of fruit body restricts their use in long-term monitoring.

Table 2. A generalized presentation of the major groups of fungi with their main ecological and fruit body characteristics, and estimated suitability for summer-through long-term monitoring. Family-level information is given for the orders *Agaricales* and *Aphyllophorales*, for other taxa information is given on higher systematic levels. - = no assessment of the feature. The systematics are after Ahti et al. 1976 and Gilbertson & Ryvarden 1986, 1987.

***Division*/ Subdivision**	**Class**	**Order**	**Family**	**Substrate/ Environment**	**Ecological niche**	**Duration of fruit body**	**Seasonality**	**Suitability for summer-through long-term monitoring**
Eumycota								
Mastigomycotina				-	parasitic microscopic fungi of eucaryotic algae & blue-green algae	-	-	not suitable
Zygomycotina				-	microscopic pathogens in animals and humans, saprophytics in soil, also mycorrhiza	-	-	not suitable
Ascomycotina	Hemiascomycetes			organic material	yeasts, in living and dead organic material	-	-	not suitable
	Plectomycetes			plants	microscopic pathogens in plant tissues, e.g. mildews	-	-	not suitable
	Ascoloculares			plants	microscopic pathogens in plant tissues	-	-	not suitable
	Pyrenomycetes			debris, insects	saprotrophic or parasites in insects			not suitable
	Discomycetes	Helotiales		ground, plants, debris	saprotrophic or pathogens in plant tissues	mostly annual	growing season	weak
		Pezizales		mainly ground, dead organic material	mainly saprotrophic, also some pathogens	annual	spring, summer	weak
Basidiomycotina	Teliomycetes	Urediniales		plants	parasitic, causing rusts in plant tissues	no basidiocarp	growing season	weak
		Ustilaginales		plants	parasitic, causing smuts in plant tissues	no basidiocarp or annual	growing season	weak
	Hymenomycetes	Agaricales	Agaricaceae	ground, litter	mainly mycorrhizal	annual	late summer-	weak

							autumn	
			Amanitaceae	ground	mainly mycorrhizal, some saprotrophic	annual	summer to autumn	weak
			Bolbitiaceae	humus, organic debris, dead wood	saprotrophic?	annual	summer to autumn	weak
			Boletaceae	ground	mainly mycorrhizal	annual	summer to autumn	weak
			Coprinaceae	ground, rotten wood	saprotrophic	annual	throughout growing season	weak
			Cortinariaceae	ground, some on wood	mainly mycorrhizal	annual	summer to autumn	weak
			Gomphidiaceae	ground	mycorrhizal	annual	autumn	weak
			Hygrophoraceae	ground	mycorrhizal	annual	autumn	weak
			Lepiotaceae	ground	mycorrhical?	annual	summer	weak
			Paxillaceae	ground, wood	mycorrhizal or saprotrophic	annual	autumn	weak
			Pleurotaceae	mainly wood	saprotrophic	annual	autumn	weak
			Pluteaceae	wood	saprotrophic?	annual	autumn	weak
			Rhodophyllaceae (Entolomataceae)	ground	mycorrhizal?	annual	summer-autumn	weak
			Russulaceae	ground	mycorrhizal	annual	summer-autumn	weak
			Strophariaceae	wood, dung, organic material	saprotrophic	annual	summer-autumn	weak
			Tricholomataceae	wood, ground, debris	mainly saproprophic, some symbiotic with lichens	annual	from early spring to early winter	weak
		Aphyllophorales	Albatrellaceae	ground	probably mycorrhizal	annual	growing season	weak
			Auriscalpiaceae	cones	saprotrophic	annual	growing season	weak
			Bankeraceae	ground	mycorrhizal?	annual	growing season	weak
			Boletopsidaceae	ground	mycorrhizal	annual	summer-autumn	weak
			Bondarzewiaceae	wood	saprotrophic	annual	summer-autumn	weak
			Cantharellaceae	ground	mainly saprotrophic, some mycorrhizal	annual	summer-autumn	weak
			Clavariaceae	ground, wood, litter	saprotrophic	annual	summer-autumn	weak

			Clavulinaceae	ground, wood, litter	saprotrophic	annual	summer-autumn	weak
			Coniophoraceae	wood	saprotrophic	annual	growing season	weak
			Corticiaceae	wood, organic litter	mainly saprotrophic, few mycorrhizal	annual	growing season	weak
			Echinodontiaceae	wood	saprotrophic	perennial	growing season	good
			Fistulinaceae	wood	necrotrophic	annual	summer-autumn	weak
			Ganodermataceae	wood	saprotrophic	annual and perennial	varies, perennial round year	perennial:good annual: weak
			Gomphaceae	ground	mycorrhizal	annual	summer	weak
			Hericiaceae	wood	saprotrophic, some necrotrophic	annual	growing season	weak
			Hydnaceae	ground	mycorrhizal	annual	growing season	weak
			Hymenochaetaceae	wood, ground	saprotrophic, some necrotrophic	annual and perennial	varies, perennial round year	perennial:good annual: weak
			Polyporaceae	wood	saprotrophic, some necrotrophic	annual and perennial	varies, perennial round year	perennial:good annual: weak
			Schizophyllaceae	wood	saprotrophic	annual	summer-autumn	weak
			Sparassidaceae	wood, ground	saprotrophic or necrotrophic	annual	summer	weak
			Stereaceae	wood	saprotrophic or necrotrophic	annual and perennial	varies, perennial round year	perennial:good annual: weak
			Thelephoraceae	ground	mycorrhizal	annual	growing season	weak
		Dacrymycetales	Dacrymycetaceae	wood	saprotrophic	annual	growing season	weak
		Tremellales	Tremellaceae	wood, other fungi	saprotrophic or parasitic	annual	growing season	weak
		Auriculariales	Auriculariaceae	wood	saprotrophic	annual	growing season	weak

	Gasteromycetes	Gauteriales		ground	mainly saprotrophic, some are mycorrhizal	annual	growing season	weak
		Hymenogastrales		ground	-	annual	growing season	weak
		Lycoperdales		ground, some on wood	-	annual	growing season	weak
		Melanogastrales		ground	-	annual	growing season	weak
		Nidulariales		wood, organic material	-	annual	growing season	weak
		Phallales		ground, wood	-	annual	growing season	weak
		Podaxales		ground	-	annual	growing season	weak
		Scleroderma tales		ground	-	annual	growing season	weak
		Tulostomatales		ground	-	annual	growing season	weak

Sources:
Ahti et al. 1986
Ryman & Hålmåsen 1992
Gilbertson & Ryvarden 1986, 1987
http://www.hiddenforest.co.nz/fungi
http://www.funet.fi/pub/sci/bio/life/warp/fungi
httphttp://biologi.uio.no/bot/ascomycetes/fungi.html
http://www.forestryimages.org
http://elib.cs.berkeley.edu/cgi/

2.2 Dead wood attributes that are important to fungal diversity

In order to develop proper dead wood biodiversity indicators it is crucial to understand, which qualities of dead wood are important to the wood-inhabiting species. At the beginning of this report, we introduced a Scandinavian database on substrate preferences for wood-inhabiting species. Here, we will highlight some dead wood properties for which this database gives reliable data: type of dead wood, tree species, decay class and dimension. Since the forest area of the Scandinavian countries is comparable to that of Alberta (similar latitude, dominance of boreal forests in both places, roughly similar forest areas), we assume that the patterns described below are very much similar to what can be expected in Alberta. This assumption is further strengthened by the fact that a significant proportion of species are identical in these two regions (about 50 % in the case of polypores, see section 2.3).

Type of dead wood

Standing versus lying dead trees represent quite different habitats for many species. Some organism groups, such as birds and lichens are almost exclusively associated to standing dead trees, whereas others, like fungi and mosses primarily utilise lying dead wood. In the database of 2021 wood-inhabiting fungus species, more than 60 % of the species are found on downed logs and 5 % on standing dead trees, whereas the preferences are indifferent or unknown for a large proportion of the species.

Tree species associations

There are quite different species assemblages in dead wood of coniferous and broad-leaved trees. Of the 2021 wood-inhabiting fungus species, about 60 % are associated to broad-leaved trees, about 25 % are associated to coniferous trees, 10 % are generalists that utilize both broad-leaved and coniferous trees, and the remaining 5 % have unknown host tree association. About 20 % of all saproxylic species shows clear preference for a single host tree (Fig.1). It should be noticed that more than 80 % of the growing stock in Scandinavian countries is coniferous wood mainly represented by two species - *Pinus sylvestris* and *Picea abies* (Stokland et al. 2003). Thus, the relative importance of broad-leaved trees to species diversity in dead wood is much higher than their proportion in the forest landscape. The host association to individual tree species is much lower – about 10 % of the species show clear preferences for individual tree species.

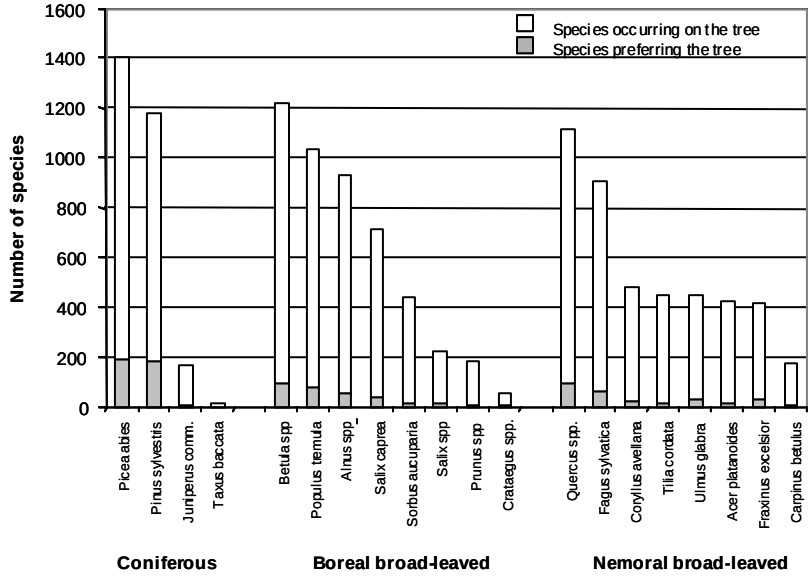


Figure 1. Total number of wood-inhabiting species (including insects) associated to different tree species in Scandinavia.

Decay preferences

There is a distinct species diversity pattern that occurs during the process of wood decomposition. Several species are able to utilize dead wood in living trees (about 4 % of the 2021 wood-inhabiting fungus species). The species number increases rapidly after the tree dies (Fig. 2). In the middle of the process the species richness peaks, and thereafter it decreases gradually as the log becomes completely decomposed (Fig. 2). There is also a distinct species turnover during this process. About 4 % of the species can utilise wood of still living trees, 15 % are early decomposers, 30 % are active in middle of the decomposition process, 10 % are late decomposers, and about 5 are generalists utilizing wood over a broader spectrum of the decomposition process. About 35 % of the fungus species have unknown decay preferences.

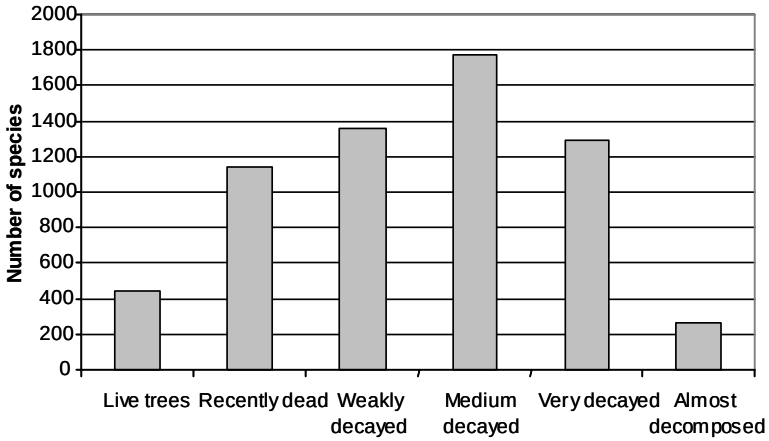


Figure 2. Total number of wood-inhabiting species (including insects) that have been recorded on live trees and different decay stages of dead wood in Scandinavia.

Dimension preferences

The diameter of dead trees is another quality of dead wood that most species respond to. Of the 2021 saproxylic fungus species, nearly 15 % prefer small or small to medium-sized diameters (up to 20 cm). Somewhat more than 20 % of the species prefer diameters larger than 20 cm, and additional 10 % of the species prefer large diameters (> 40 cm). About 20 % of the species are generalists without strong diameter preferences. In reality, all these proportions are larger since the diameter preference is unknown for about 35 % of the species.

Landscape patterns

Different dead wood qualities are not evenly distributed in the forest landscape. Variation is caused by landscape properties such as topography, soil conditions and productivity. The input rate and volume of dead wood varies both temporally and spatially as a consequence of natural disturbance regimes in unmanaged forests, and mainly due to forestry in managed forests. Today, most of the Scandinavian forests are managed, and large areas with low abundance of dead wood and small areas with high abundance of dead wood characterize the landscape (Fig. 3). In Alberta, the expectation is for commercially important forest types that all of the area outside of parks (which comprise 10-15% of the landscape) will be managed for forest production. However, there are some additional deletions (3-8%) from the managed forests due to areas being inaccessible, riparian buffer zones etc. (Schieck, personal communication). Thus, the management regime in Alberta will resemble that of Scandinavia in the future.

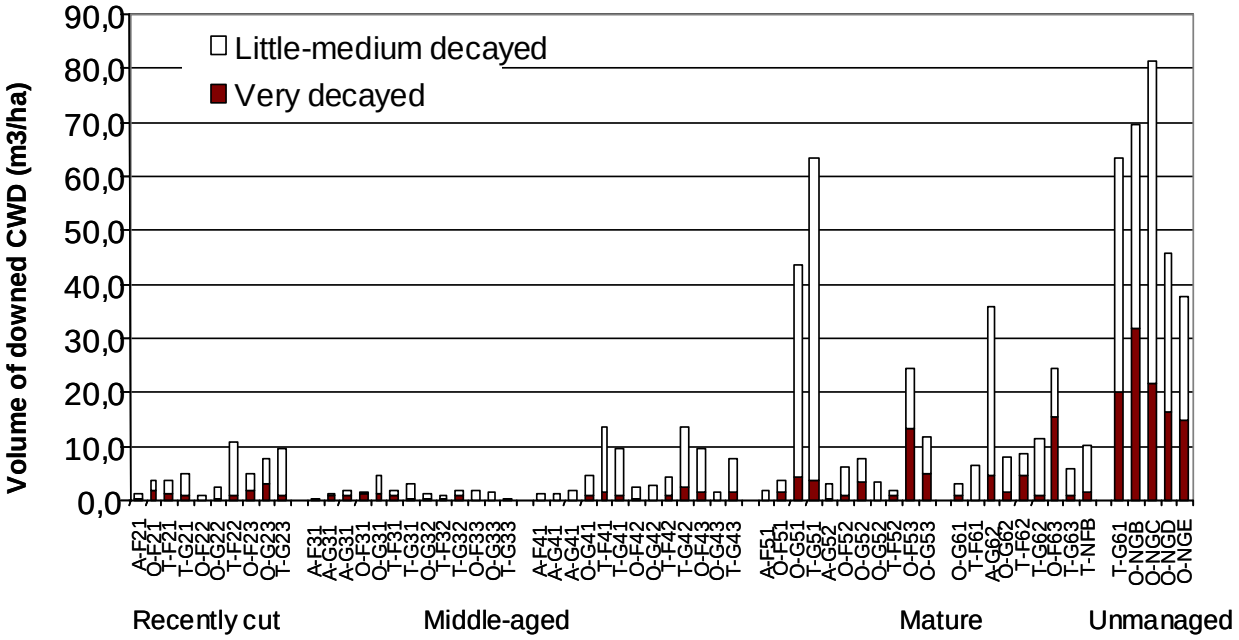


Figure 3. Local abundance of downed dead wood in a stratified sample of National forest inventory plots from different development classes in coniferous stands in SE Norway.

This landscape pattern is important, since scattered presence of suitable dead wood qualities may be insufficient for the presence of common as well as rare wood-associated species. We know from several empirical studies that many species occur frequently in areas with high abundance of suitable dead wood. When suitable wood substrate is sparse, the frequency of a species may be 15-25 % of that found on equal substrates in localities where suitable wood is abundant (Nilsson 1997; Rukke and Midtgaard 1998; Sverdrup-Thygeson and Lindenmayer 2002; Stokland and Kauserud 2003). Other studies have identified 20-30 m^3/ha of dead wood as a threshold level below which many wood-associated species seem to be unable to survive (Økland et al. 1996; Martikainen et al. 2000; Angelstam et al. 2002), but the threshold level may be as high as 70 m^3/ha for very demanding species (Siitonen and Saaristo 2000).

An important message from these studies is that although there is a relationship between dead wood volume and number of saproxylic species, there is no linear relationship between the amount of specific dead wood qualities and the population level of wood-associated species. Thus, one needs to quantify the local abundance of different dead wood qualities in order to predict the presence of wood-associated species.

Other preferences

The purpose of this report is not to make a comprehensive review of all substrate preferences of wood-associated species. Thus, we will only mention that the majority of species show additional preferences, like for different parts of the tree (both vertically from branches to roots, and radially from the bark to the heart wood), hollow trees, microclimate around the dead tree (from sun-exposed to shady) and burned wood. There are also several species that are associated with or successors to other saproxylic organisms; these species are usually very specialized in their host associations (Niemelä et al. 1995).

2.3 Brief comparison of fungi on dead wood in Scandinavia and Canada

Both Scandinavia and Canada are climatically relatively similar, because the two regions are situated at similar latitudes. Alberta and Scandinavia are dominated by a rather continental climate as both areas are situated in a

"rain shadow" of a mountain chain to the west. In general, however, Scandinavia has a more humid climate than Alberta. The two areas belong mainly to the boreal forest zone, and forests in both areas are dominated by coniferous trees, even though the tree species composition is more diverse in Alberta. Furthermore, both areas show a distinctive admixture of broad-leaved forest that increases in frequency towards south. The two regions therefore have some basic similarities, which imply that similarities can be expected in the species composition of fungi.

The species composition of polypores in Europe and North America is well known from identification books,which also include information about the geographical distribution of species (Gilbertson and Ryvarden 1986, 1987; Ryvarden and Gilbertson 1993, 1994). Núñez and Stokland (2000) have made a review of polypore distribution on the northern hemisphere and compared the species composition in East Asia, Europe, Eastern North America and Western North America. They found a broad overlap in species composition between Europe and Western North America. Of 419 species occurring in these two regions 223 (53 %) occur in both areas, 119 (28 %) species are only found in Europe and 77 species (18 %) are only found in W. North America. It is possible that the overlap between Scandinavia and Canada actually is higher than 53 %. Since both regions have been repeatedly glaciated the areas have been colonised by fungi that have good dispersal ability (and many of the species in the two regions have circumpolar distribution). Species confined to one region only tend to have a distribution that is confined to non-glaciated areas where they have survived in refuge areas.

Also for other fungal species groups the species composition between Canada and Scandinavia is similar. This is illustrated by the fact that European identification guides made by Scandinavian mycologists have been used in Canadian studies. For instance, in an inventory of macrofungi in protected areas in Alberta, Richards and Murray (2002) used Scandinavian identification tools for *Cortinarius* fungi prepared by Brandrud et al. 1990-1998.

2.4 Brief description of Alberta forest types and expected fungus diversity patterns

The province of Alberta can be divided into six major natural regions: 1. Boreal forests, 2. Canadian shield, 3. Foothills, 4. Rocky Mountains, 5. Parkland and 6. Grassland. This section describes briefly these regions, their major tree species composition and expected polypore diversity patterns.

As described in Chapter 2.1, most of the fungus taxa are not suitable for summer-through long-term monitoring, and in the following only the expected polypore diversity patterns are reviewed in relation to the tree species composition of different regions. Because neither detailed information on the species compositions of different forest types, nor a checklist or complete review of literature and herbarium collections exists this far, it has not been possible to make detailed estimates of expected diversity patterns in different forest types and regions. Thus, the following review gives a generalised overview of expected diversity patterns in the major natural regions. The monitoring project itself will produce valuable material, which will allow comparisons among different forest types and between disturbed and undisturbed stands.

1. The Boreal Forest Region

This is the largest of the eco-regions, covering over half the area of Alberta. It is a part of the circumpolar belt of boreal forests, characterized by coniferous trees. In Alberta, it consists of lowland plains, hills and wetlands, which vary in their topography, climate and biological features. The region is divided into six sub-regions: Dry Mixedwood, Central Mixedwood, Wetland Mixedwood, Boreal Highlands, Peace River Lowlands, and Subarctic.

Mixed wood forests are characterized by a mosaic of deciduous and coniferous patches. Frequent fires keep the proportion of deciduous trees relatively high. Black spruce (*Picea mariana*), white spruce (*P. glauca*) and balsam fir (*Abies balsamea*) are typical conifers occurring in peatlands and stream valleys, while jack pine (*Pinus banksiana*) prevails on dry, sandy hills. Aspen (*Populus tremuloides*) is found both in pure and mixed stands; other dominant hardwoods are balsam poplar (*P. balsamifera*) and paper birch (*Betula papyrifera*).

Green alder (*Alnus viridis* var. *crispa*) is also found as an admixture. Boreal Highlands have very similar tree species composition, but coniferous forests occupy a larger portion of the landscape. In Peace River Lowlands white spruce has been typical along major rivers, while jack pine is more common on drier hills and hillsides. The Subarctic region is characterized by widespread black spruce forests, but on well-drained sites also mixtures of white spruce, aspen, paper birch and lodgepole pine (*Pinus contorta)* are found (http://collections.ic.gc.ca/abnature/map.htm).

As described in section 2.2, different dead wood attributes affect considerably the species composition of wood-decomposing fungi. The expected polypore diversity patterns vary between forest stands according to the tree species composition, stand age and disturbance. Broad-leaved and coniferous forests differ considerably by their polypore diversity in boreal zone (Dahlberg and Stokland 2004, Sippola et al. 2004). We expect that stands of broad-leaved trees and admixtures of these host clearly different species assemblages compared to coniferous stands. We also expect that the species composition differ distinctly between dry pine forests and moister spruce or fir forests. Stand age and past disturbances from logging operations, fire or storm-felling (through effects on substrate and forest canopy continuity) affect especially the occurrence of species which predominate in late successional stages and are specialized in large-diameter logs and/or require steady, moist microclimate (cf. Bader et al. 1995; Sippola et al. 2001; Penttilä et al. 2004). Species composition in the areas with recent disturbances such as storms, logging or fire are dominated by early decomposers, and fire areas host also species specialized on charred wood (cf. Penttilä and Kotiranta 1996).

The species composition of polypores in Alberta includes many species that are common in all circumpolar area. Typical species on conifers in the boreal region are *Amylocystis lapponica, Antrodia serialis, A. sinuosa, A. variiformis, Dichomitus squalens, Diplomitoporus crustulinus, D. lindbladii, Fomitopsis pinicola, Gloeophyllum protractum, G. sepiarium, Gloeoporus taxicola, Inonotus tomentosus, Oligoporus balsameus, O. caesius, O. fragilis, Perenniporia subacida, Phaeolus schweinitzii, Phellinus chrysoloma, P. pini, P. viticola, Skeletocutis amorpha, S. subincarnata and Trichaptum abietinum;* all these species are either circumpolar or found also in Europe. Typical polypores on deciduous CWD in boreal zone are *Bjerkandera adusta, Ceriporia reticulata, Ceriporiopsis aeneirinus, Cerrena unicolor, Coriolopsis gallica, Daedaleopsis confragosa, Fomes fomentarius, Ganoderma applanatum, Haploporus odorus, Inonotus radiatus, I. rheades, Irpex lacteus, Junghuhnia nitida, Lenzites betulina, Perenniporia tenuis, Phellinus igniarius, P. tremulae, Piptoporus betulinus, Trametes hirsuta, T. versicolor, T. zonatella, Trichaptum biformis, T. subchartaceaus* and *Tyromyces chioneus.* Most of these species are also circumboreal (Gilbertson and Ryvarden 1986).

2. The Canadian Shield Region

The Canadian Shield extends to the north-eastern corner of Alberta. It consists of acid Precambrian bedrock areas in the Kazan Uplands and glaciofluvial area of Athabasca Plain. The forests are dominated by jack pine in dry areas and accompanied occasionally by white spruce. In peatlands, wetlands and riversides black spruce, tamarack (*Larix laricina*), aspen and balsam poplar are found (http://collections.ic.gc.ca/abnature/map.htm). The polypore species composition is probably similar to the boreal zone, but the species composition would presumably be more dominated by species occurring on jack pine and tamarack, such as *Antrodia albobrunnea, A. alpina, A. sinuosa, A. sitchensis* and *Inonotus circinatus.*

3. The Foothills Region

The Foothills Region (Eastern Slopes) is a transition zone between the Boreal Forest and Rocky Mountain Regions. The altitudinal range is 1250-1500 m in the south and 350-1000 m in the north of the region. Large areas in the Lower Foothills sub-region are dominated by lodgepole pine, especially after fire. Also mixtures of lodgepole and jack pine forests occur, as well as mixed forests with white and black spruce, balsam fir, aspen, balsam poplar and paper birch. At the border of Lower and Upper Foothills sub-regions, deciduous trees disappear and the Upper Foothills forests are almost pure coniferous stands dominated by white spruce, black spruce, lodgepole pine and subalpine fir. Engelmann spruce (*Picea engelmannii*) occurs occasionally (http://collections.ic.gc.ca/abnature/map.htm). In the Upper Foothills region, the expected species diversity

pattern will probably be similar to coniferous areas of Boreal Region, whereas the lower areas dominated by lodgepole pine will probably differ from that, especially in burned areas where species on charred CWD such as *Gloeophyllum carbonarium* could be expected to be frequent.

4. Rocky Mountains Region

The Rocky Mountain Region in the western part of Alberta consists of three sub-regions: Montane area, Subalpine area and Alpine area. The north and east slopes of Montane sub-region (about 1000-1600 m) are characterized by Douglas fir (*Pseudotsuga menziesii*), whereas limber pine (*Pinus flexilis*) is found on drier moraine slopes, and white spruce and aspen on mesic sites. The Subalpine region ranges approximately between 1600-2300 m. Dominating tree species are conifers: lodgepole pine, subalpine fir (*Abies lasiocarpa*) and Engelmann spruce, which is forming pure stands in higher elevations. In the upper subalpine zone, whitebark pine (*Pinus albicaulis*) and subalpine larch (*Larix lyallii*) are associated with Engelmann spruce and subalpine fir. Of deciduous trees, Rocky mountain maple (*Acer glabrum*) is found in the southern part of the region, and mountain alder (*Alnus incana* var. *tenuiflora*) as admixture from Montane to Subalpine elevations. The Alpine sub-region lacks trees (http://collections.ic.gc.ca/abnature/map.htm).

Polypore communities in the Rocky Mountain Region comprise partly the same species as the Boreal region, but also differences can be found due to the differences in tree species composition. Typical polypore species on conifers include *Amylocystis lapponica, Antrodia albobrunnea, A. carbonica, A. juniperina, A. serialis, A. sitchensis, A. variiformis, A. xantha, Climacocystis borealis, Cryptoporus volvatus, Dichomitus squalens, Diplomitoporus crustulinus, D. lindbladii, Echinodontium tinctorium, Fomitopsis cajanderi, F. pinicola, F. rosea, Ganoderma oregonense, G. tsugae, Gloeophyllum protractum, G. sepiarium, Heterobasidion annosum, Inonotus circinatus, I. tomentosus, Junghuhnia collabens, J. luteoalba, Oligoporus balsameus, O. fragilis, O. leucospongia, O. obductus, O. placentus, Perenniporia subacida, Phaeolus schweinitzii, Phellinus nigrolimitatus, P. pini, P. viticola, Pycnoporellus alboluteus, Pyroformes demidoffii and Trichaptum abietinum, and* on deciduous CWD *Bjerkandera adusta, Ceriporia reticulata, C. tarda, Ceriporiopsis aeneirina, Cerrena unicolor, Fomes fomentarius, Ganoderma applanatum, G. lucidum, Gloeoporus dichrous, Irpex lacteus, Perenniporia tenuis var. pulchella, Phellinus igniarius, P. tremulae, Polyporus badius, Pyncoporus cinnabarinus, Trametes hirsuta* and *T. versicolor* (Gilbertson and Ryvarden 1986). Species compositions are expected to vary according to the main tree species, particularly if the dominating trees host tree species-specific polypores.

5. The Parkland Region

The Parkland region is a transition zone between the Boreal Forest and the Grassland. It consists of three sub-regions: Central, Foothills and Peace River areas. Aspen and balsam poplar are the dominating tree species. Aspen is found scattered in the southern area bordering the Grassland, but increases towards north, forming closed forests. Balsam poplar and willows (*Salix* sp.) are found in moister places. In the Peace River Parkland sub-region white spruce increases in aspen stands, and the tree species composition resembles those of boreal mixed wood forests (http://collections.ic.gc.ca/abnature/map.htm). Polypore diversity is expected comprise mainly species confined to aspen (e.g., *Ceriporiopsis aeneirina, Perenniporia tenuis var. pulchella* and *Phellinus tremulae*) as well as generalist decomposers of deciduous CWD (e.g., *Bjerkandera adusta, Trametes* species). Due to the general differences in species composition on coniferous and broad-leaved wood, we expect this region to be most deviating in species composition.

6. The Grassland Region

The Grassland is part of the Great Plains, mainly lacking forests, but low shrubs are found in sandy areas, and balsam poplar and some aspen occur in the river valies (http://collections.ic.gc.ca/abnature/map.htm). The wood-decomposing fungi are probably species that are generalists on deciduous CWD. It should be expected, however, that several species with a southern distribution have their northern limit in this region. Thus, one can expect some rare species to occur in this region.

2.5 Polypore species diversity at local and regional levels

(based on Scandinavian experience)

Species composition of polypores at the local level is mainly affected by three elements: tree species composition, disturbance history (including human and natural disturbances) and microclimate. All these elements are intercorrelated: tree species composition (especially in boreal zone) is different in different terrain positions and successional stages of forest development, and the terrain position (sun-exposed or shady) and the canopy cover affect microclimate. Microclimate, which is also affected for instance by precipitation, evaporation, temperature, nearby water bodies, exposition of slope etc., contributes to the decay rate of wood. The frequency and extent of disturbances affects the availability of dead wood, which is crucial for the long-term persistence of polypore communities (Speight 1989; Høiland and Bendiksen 1997; Sippola 2001).

Tree species composition is a major element which affects the composition of local polypore communities. For instance, in a study of pine- and spruce-dominated stands in northeastern Finland, the species compositions differed clearly according to the main tree species. The percentage similarity in the species compositions among spruce-dominated stands was 52-65 %, whereas the similarity between spruce- and pine-dominated stands was 39-46 % (Sippola et al. 2004a). Even in the forests with relatively similar coverage of the main tree species, local differences can be found. For instance, the species composition in woodland key habitats containing a large number of small-diameter deciduous trees the polypore community was dominated by polypores of broad-leaved wood (about 70 % of species), whereas the control areas with similar coverage of living spruce hosted equal numbers of species on coniferous and broad-leaved wood (Sippola et al. 2004b).

As indicated in Chapter 2.2., several quality properties of decomposing wood influence the species composition of polypores. The effects in the changes of CWD qualities can be long-lasting: for instance the gap in the continuity of large-diameter logs due to logging can be detected several decades, even a century, after the disturbance (Bader et al. 1995; Sippola et al. 2001, Stokland 2001). Adequate measurement of CWD at the site level allows compilation of CWD profiles (see Stokland 2001), which gives information about CWD gaps in the past. Several indicator species indicating long-lasting natural forest continuity have been listed for boreal forests; these are used especially in inventories of forest areas which have potential conservation value (Karström 1993; Kotiranta and Niemelä 1996).

The species richness of polypores remains relatively high within the whole boreal zone in Scandinavia. The highest species numbers recorded in the northern boreal zone (80-105 species, Niemelä and Dai 1999; Niemelä et al. 2003) are comparable to those recorded from the southern boreal zone (97-118 species, Kotiranta and Niemelä 1981; Lindblad 1998). The species composition, however, differs to some degree within different regions. Renvall et al. (1991) have introduced a term boreo-continental to refer to species which in Fennoscandia are found in the northeastern parts of the area. Many of these species are those which are listed as old-growth forest indicators, and for some species it is unclear whether their present distribution reflects their real preference of continental circumstances or the present distribution of old-growth forests in Scandinavia. Regional differences are more pronounced when shifting from boreal to temperate zone. The polypore diversity is more diverse in the temperate zone due to the more diverse tree species composition (especially of broad-leaved trees) compared with the boreal zone.

In long-term monitoring, both local and regional changes in the polypore species richness and species composition are detectable with the proposed protocol. The more diverse tree species composition in North America compared with Scandinavia will probably affect the polypore species composition; it can be expected, however, that both local and regional differences in the species compositions are reflected in the similar ways like we observe in Scandivia.

3. OVERVIEW OF EXISTING FUNGUS MONITORING PROTOCOLS

3.1. Survey methods of wood-decomposing fungi

The survey methods of wood-decomposing fungi can be grouped into four categories: 1) opportunistic search of species, 2) time-constrained surveys, 3) substrate-constrained surveys and 4) area-based surveys.

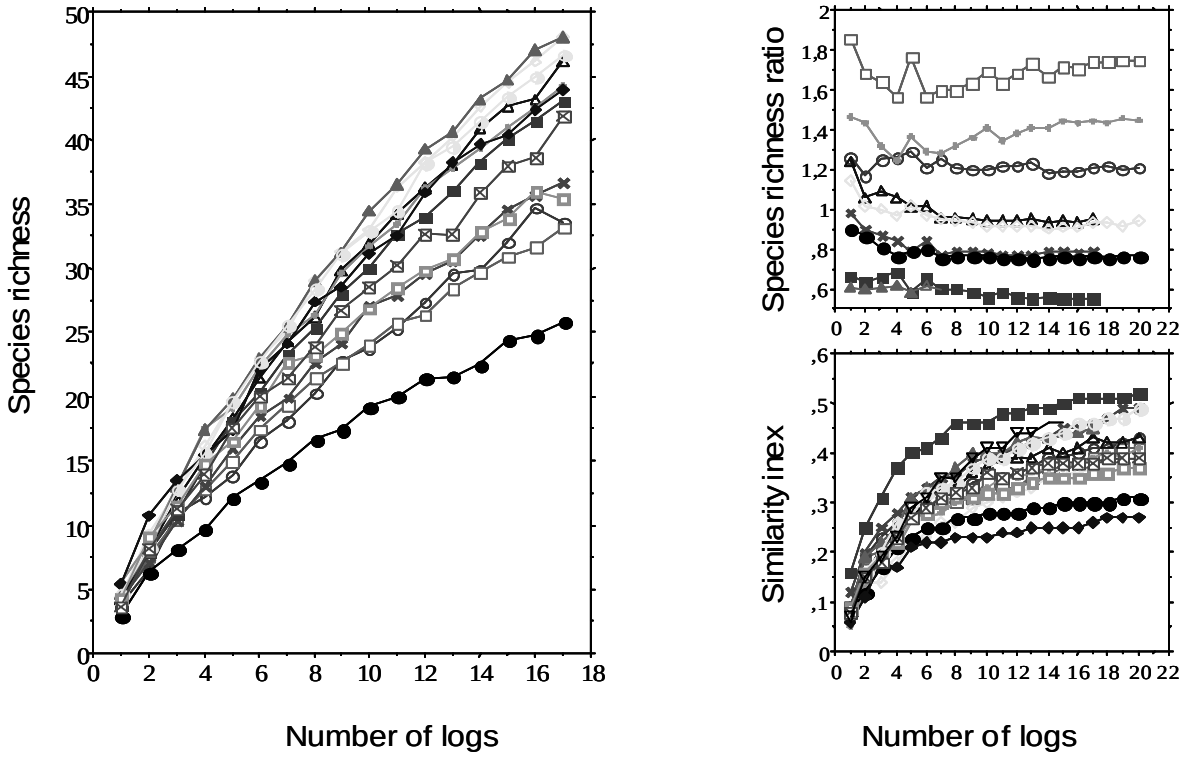
Opportunistic sampling means to carefully walk through a study site to collect visible sporocarps (fruit-bodies). Emphasis is laid on sampling many habitats and substrate qualities to collect a high number of species and presumably get a representative picture of the species composition of the study site. This method has been used in many national or regional inventories (e.g., Kumpulainen et al. 1997; Niemelä and Yu-Cheng Dai 1999; Niemelä et al. 2003). It is usable when an overview of the species composition over a large area is needed in a relatively short time period, or for the searching of rare, threatened or indicator species. Opportunistic sampling allows rough comparisons of the species compositions and species richness of different areas, but no statistical analyses or analyses between species composition and CWD parameters.

Time-constrained searching of species has been used e.g. in comparison of potentially valuable sites for protection (Penttilä 1994) or to detect species richness and species composition of different forest areas (Kotiranta and Niemelä 1981). The disadvantage of this method is that the results depend on the working routine of the observer. This can affect especially the search of resupinate species, which are often hidden under the logs. Furthermore, the size of the area studied directly affects the number of observations, as does the time spent on active search in each area (Kotiranta and Niemelä 1981), making comparisons of data between areas unreliable.

Substrate-constrained surveys allow comparisons of species richness and species composition between different areas in the same number of substrate units. The method has been used for instance in comparisons of different forest site types and management areas (Høiland and Bendiksen 1997), and species composition in different CWD qualities (Renvall 1995; Kauserud 1995; Lindblad 1998; Andersen and Ryvarden 1999; Heilmann-Clausen and Christensen 2003) and before and after forest treatment (Penttilä and Kotiranta 1996). The advantage of the method is that it allows direct comparisons of equal sample sizes, and also re-sampling of sub-samples is possible. The disadvantage is that it does not tell about the substrate availability in the study area (that information must be established separately). If similar CWD qualities are compared (e.g., large-diameter logs), the method will not give an overview of the total species composition of the area.

Area-based surveys are commonly used in polypore surveys. The size and shape of study plots varies considerably between individual surveys from circular plots of different sizes (10 m radius, Sippola et al. 2001; 12.62 m radius, Siitonen et al. 2001) to quadrates or transects (50 x 50 m, Bader et al. 1995; 30 x 100 m, Sippola and Renvall 1999; 2 x 100 m, Nordén et al. 2004; 0.5 ha Stokland 2001). The advantage of the area-based surveys is that they give information on the amount of CWD per area unit, and allow studies on the relationships between CWD quality and species composition. This is essential information in the case of polypores, many of which are specialized to different CWD qualities.

The problem of adequate sample size is concerning most species surveys, including polypores. Because of the random, often aggregated distribution of dead wood in a forest; the total sampling area should be sufficient to cover the natural variation in CWD distribution within a stand. Empirical studies show that an area of several hectares is needed in order to gain a comprehensive picture of the polypore species composition of a forest region. For instance, a total sampling area of three hectares in spruce forests at the border of middle and northern boreal zones revealed the same number of species that were known from the nearby regions in several other studies (Sippola 2001, cf. Penttilä 1994), but a three-hectare sampling area in timberline pine forests, where CWD is scarce and scattered, revealed only 75 % of the pine-inhabiting polypores known from the region

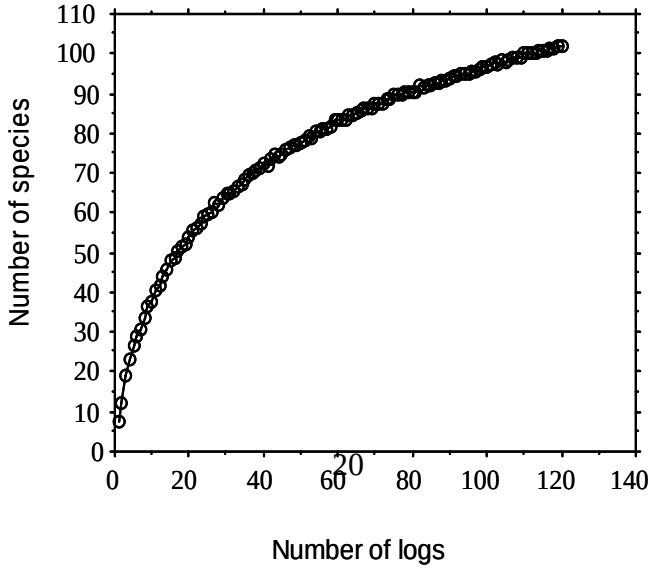


(Sippola and Renvall 1999). Because polypore diversity is connected with the amount and diversity of CWD, some judgements on sufficient sample size for polypore inventory can be made by comparing sampling effort that is sufficient to cover the natural variety of CWD. Case studies and simulation models have revealed that plots should have at least a size of 0.2 ha to document the local abundance and composition of different CWD qualities (Stokland 2001) This sample size is used also in many inventories of saproxylic organisms in Scandinavia (see Ch. 3.2.).

The substrate-based inventories from Scandinavia show that a) the species numbers increases steadily without a clear flattening of the substrate-species curve, even after sampling more than 100 substrate units (Fig. 4); b) the species richness ratio and the similarity index between pairs of samples stabilises rapidly, and in most cases the difference between two sample sites is known when 15 logs have been sampled (Fig 5).

Figure 4. The cumulative number of fungus species as a function of number of logs inspected on a single site in an *Alnus incana* forest. The fungus species include *Polypores*, *Corticoids*, *Agarics*, *Heterobasidiomycetes*, *Hymenochaetaceae* and a few other groups. Data from Kauserud (1995).

Figure 5. The cumulative number of species as a function of number of logs inspected in 13 different sample sites (left). On the right side, these curves are divided by each other to see the ratio between species numbers (top) and the similarity index when comparing pairs of sites (bottom) as a function of sample size (Stokland, unpublished data).



3.2. Fungus protocols and programmes in Europe

Relatively few long-term monitoring programmes of polypores have been established this far in Europe. In Finland, two large-scale research programmes that include polypores are conducted at present. The study programme Alternatives of silvicultural practices in forest management and their effects on forest production by Finnish Forest Research Institute (FFRI) will produce knowledge about the structure and development of natural forests. This knowledge can be used as reference to improve existing stand-development models, and to revise the guidelines for restoration and biodiversity-oriented silviculture in managed forests. The stand characteristics including dead wood (average values and variation) of natural forests at different site types and in different vegetation zones will be described. The influence of previous cutting on the structure and naturalness of stands, and the re-establishment of natural structures after cutting will be assessed. Growth, mortality, accumulation rate of dead wood, and carbon balance will be studied and modelled, as well as successional trends and regeneration in protected forests in the absence of natural fire regime. The specific links between stand structure and diversity of different species groups will be studied with the emphasis on species that have declined as a result of forest management. The aims and means of restoration will be specified by highlighting the differences between natural and managed forest in those structural features that are the most important for maintaining biodiversity. The study areas include woodland key habitats and production forests in southern and middle boreal forest zone. The polypores are inventoried in 20 m x 100 m transects (0.2 ha) in each study sites, besides of that, all logs exceeding 15 cm DBH are surveyed within the study forest stand (if the stand is several hectares size, a smaller subplot of the area is surveyed). The aim is to repeat the surveys in 10-year intervals (Juha Siitonen, personal communication).

The research project Restoration of forests for species recovery: distance from the source area, amount of dead wood and time since disturbance by Finnish Environment Institute aims at investigating the effects of different restoration methods on species diversity. The effects of different disturbances (prescribed burning, windthrows), amount of CWD and retention trees left on regeneration areas and distance from source areas on species recovery are studied in southern and middle boreal zones. The inventoried species include saproxylic beetles and wood-inhabiting fungi. The size of the study area (0.2 ha) and the methodology are consistent with the previous study by FFRI (Reijo Penttilä, personal communication).

In Sweden, the Swedish National Board of Forestry has conducted a large-scale inventory of woodland key habitats in two phases (1993-1998, 2001-2003). In this project, called The Swedish Woodland Key Habitat Survey, 11.7 million hectares of privately owned forests all over the country have been surveyed to find, delimit and describe key habitats of importance for red-listed species. Potential areas have first been searched from aerial photographs, forest inventories and forest management plans. The areas are then visited in the field. Because it has not been economically possible to systematically search for species during the visit, the fulfilment of key habitat criteria has been assessed on basis of habitat structure and indicators species, which consist of vascular plants, mosses, lichens and fungi. About 200 indicator fungi have been listed; about 30 % of these are wood-decomposing species (www.svo.se/wkh, Norén et al. 2002).

In Norway, a rather large fungus inventory has been carried out in a sub-set of 128 National Forest Inventory plots supplemented with additional plots in old-growth forests. In total, 159 plots were sampled for wood-inhabiting fungi. The purpose of this inventory was to document the effects of natural factors (climatic zones and forest types) as well as forest management (different stand ages, including old-growth unmanaged stands) on the species diversity of wood-inhabiting fungi (Stokland 2001). The method adopted in this inventory included elements both from substrate-constrained and area-based surveys. At each sample site a standard plot of 0.5 ha was established. In cases of very high CWD abundance, the plot size was reduced to 0.25 ha. In a few cases where the CWD abundance was very low (< 15 logs per 0.5 ha), the plot size was increased in a predefined stepwise manner until minimum15 logs were encountered or the plot size reached an upper limit of 1.0 ha. In each plot wood-inhabiting fungi (polypores, corticoids, other aphyllophorales, agarics, heterobasidiomycetes and ascomycetes) were sampled on minimum 15 logs (except in 2 cases where with fewer than 15 logs in 1.0 ha)

once during August to October. In plots with many logs (30-150 logs/plot), a stratified random sub-sample (95-33 %) of the logs were sampled so that the distribution of tree species, decay classes and diameter classes in the sub-sample was similar to that of the plot. Thus, the species richness per unit area was increasingly under-estimated with increasing log abundance. In order to establish comparable data for species richness per unit area, a bootstrap estimate of the number of species per 0.1 ha was produced. The number of species varied from 4 to 112 species per 0.1 ha. Altogether 790 fungus species were recorded, of which 113 were polypores. Within all plots in this study, several macrohabitat attributes were measured or classified: altitude, climatic zone, terrain aspect and exposure, forest type (tree species composition), forest age, standing volume, site quality index, and vegetation cover, snag volume, volume of downed dead wood (subdivided on tree species, decay classes, diameter classes and mortality factor). Furthermore, for each sampled dead wood unit information about tree species, decay class, diameter class, mortality factor, and proportion of log with ground contact were collected.

3.3. Fungus protocols and programmes in North America

Quite recently, Mueller et al. (2004) have made a comprehensive review of inventory and monitoring methods for biodiversity of fungi. This review is mainly written by American mycologists and it reflects the current state-of-the-art in this field. The book contains a special chapter on *Terrestrial and lignicolous (i.e. wood-inhabiting) macrofungi* written by Lodge et al. (2004). In this chapter, there are no references to sampling protocols of wood-inhabiting fungi from North America: “Although numerous standardized surveys have been conducted on terrestrial macrofungi, few have been conducted on the inhabitants of wood. Examples of surveys on wood-inhabiting fungi include the studies of …” (page 160) and then follows references to several North European and tropical studies of which nearly all are conducted by mycologists from Scandinavian countries. We cannot conclude that sampling protocols of wood-inhabiting fungi from North America are non-existing, but it seems reasonable to assume that most experience from this field is to be found in Scandinavia.

The main elements for a sampling protocol of wood-inhabiting fungi recommended by Lodge et al. are that:

- the use of randomly or regularly spaced sub-plots is an effective way to sample fungi on small to medium-sized (1.0-15.0 cm diameter) woody debris.
- it is advantageous to use large woody substrata (i.e. > 15 cm diameter) instead of plots as the sample units for fungi that fruit on those types of substrata.
- some method should be used to estimate the abundance of standing and fallen trees (a particular method is described based on subplots set up along transect lines).
- some method should be used to enable relocation of dead wood units for later re-sampling.
- several macrohabitat parameters should be collected, including forest type, plant association, climatic zone, elevation.
- Several microhabitat parameters should be collected for each sampled dead wood unit, including: substratum class (twig, branch, trunk, stump, root; bark, wood surface), condition (living, dead, dead wood on living tree), position (vertical, prostrate, lying on ground, suspended > 1 m above ground), diameter class (5 classes from 1-2.5 up to > 20 cm), decay class (some tentative, not very operational classes are mentioned as an example).

Concerning sample size, Lodge et al. (2004) stated that 0.1 ha plots will exclude most of the fungi found on large pieces of wood because of the low local frequency of large dead wood units. They recommended instead that fungi on large woody substrata should be sampled on 90 logs with 30 logs in each of three decay classes: recently fallen, medium rotten and thoroughly rotten. No justification is made for this rather large sample size, and we want to add that this recommendation was developed under circumstances where documentation of local species diversity was a focus (to develop a fungus inventory of the Guanacaste Conservation area in Costa Rica). It should also be mentioned that the sample size coincides with that of a quantitative inventory of dead wood fungi carried out in the Guanacaste Conservation area to document local differences between different successional stages and rainfall gradients of tropical forests (Lindblad 2000, 2001).

3.4. Important aspects to include in the ABMP

The main goal of the ABMP is to develop a scientifically credible long-term monitoring programme, which gives information on (cited from the Terms of reference for a potential ABMP fungi protocol, February 2004):

a) presence and abundance of common and relatively common species in one or more fungal species groups,
b) differences in presence and abundance of fungal species among regions in Alberta
c) temporal changes in presence and abundance of fungal species at the provincial and regional scales.

To fulfil these goals in the polypore survey, the main aim is to develop a survey method that gives a reliable picture of the species richness and species composition at a regional scale as well as the abundance of individual species. Furthermore, the data shall facilitate statistical comparisons of species parameters between regions, areas with different management practices and disturbances, and in selected time scale.

Presence and abundance of wood-inhabiting fungi

An important aspect of the ABMP is to quantify the presence and abundance of individual species. It is useful to have a precise definition of the terms presence and abundance. We suggest that **presence** is operationalised as "a categorical variable to be scored at a ABMP site, with the value 1 if the species is observed on at least one sampled dead wood unit and the value 0 if the species is not observed on any sampled unit". Furthermore, we suggest that the **abundance** of a species is operationalised as "a variable quantifying the frequency of a species on a set of sampled dead wood units" (i.e., the occurrence of a species on a piece of CWD is one observation, regarless the number od fruit bodies).

Some examples may illustrate the differences between these two measures: In the Norwegian survey described above, *Oxyporus populinus* and *Pycnoporus cinnabarinus* were both present at 5 of the 159 investigated plots, but they had quite different abundances – the first species was found on 5 logs (i.e. a single log in each plot) whereas the second species was found on 16 logs. Both species are found on various broad-leaved tree species and both occur on early decay stages, but they differ in other respects. *O. populinus* tends to prefer larger dimensions and is also found on dead parts of still living trees. *P. cinnabarinus* prefers small dimensions, and it seems to be an opportunistic species that rapidly colonises several logs in sites where it occurs. This is probably a strategy developed to utilize peaks of dead wood after forest fires, and today the species is often found on logging residues after forestry operations. The two species differ also in their geographical distribution.. *O. populinus* has a distinct southern distribution and is typically found on temperate tree species, whereas *P. cinnabarinus* occurs across the whole boreal region and it utilises boreal as well as temperate tree species. Both species are expected to be found in Alberta as they occur in western North America, and it is reasonable to expect that *P. cinnabarinus* occurs across whole Alberta and *O. populinus* in the southern regions.

Phellinus nigrolimitatus, another species to be expected in Alberta, may serve as an example to illustrate the power of the abundance measure. This species is strictly confined to coniferous wood and it strongly prefers *Picea* wood. In the Norwegian study it was found on 5 out of 1112 *Pinus* logs (i.e. a frequency of 0.4 %) and 85 out of 1463 *Picea* logs (5.8 %), but none out of 1541 investigated broad-leaved logs. In a detailed statistical analysis using logistic regression Stokland and Kauserud (2003) revealed that the species strongly prefers medium to very decayed *Picea* logs of large dimensions (minimum 20 cm diameter). Furthermore, they showed that both natural factors such as increased productivity (positive effect) and forestry (negative effect) had a highly significant additional effect on the frequency of the species. In optimal sites (medium-highly productive unmanaged spruce forests) it was on average found on 35 % of suitable *Picea* logs, and on some sites it was found on more than 50 % of such logs. The species was much less frequent in managed forests, where it occurred on 7 % of the suitable *Picea* logs. The explanation is probably that suitable logs for *P. nigrolimitatus* become too scattered in managed forests, and the species is unable to colonise logs efficiently unless the colonisation distance is quite short. There are several general lessons to be learned from this example: First, the absence observations on logs are equally valuable as presence observations in order to calculate the frequency of

a species. Second, data on different substrate qualities (tree species, decay class, dimension class, etc.) improve the ability to explain frequency differences in subsequent analyses. Third, also stand (locality) variables have significant explanation power for the frequency of a species. Fourth, by measuring the occurrence of species at the scale of individual logs one can subsequently sort out the effect of substrate qualities and the effect of local dead wood abundance (otherwise one will get the rather obvious result that a species is more common in sites with many logs).

Recommendations
Based on this review of existing fungus sampling protocols, we recommend that the following aspects should be included in the ABMP:

1) An area-based survey should be adopted. That is, a similar area should be sampled in all plots that are investigated (whether this area is defined in terms of transect length or a fixed area is less important, see section 6.2 for further details). This will give a standard measure of *species richness* per site that facilitates intuitive comparisons between regions as well as between forest types and stands with different intensities of forest management. A standard sample area will also be the basis for quantifying the *presence of individual species* and their regional distribution patterns.
2) The sample area for wood-inhabiting fungi should ideally be chosen so that one in most sites will encounter minimum 15 logs. Alternatively, one can choose a smaller sample area and miss representative information about the local species composition. It is then important to have many samples per region in order to document the species composition and get a representative picture at this scale of resolution.
3) Individual dead wood units should be a standard sampling unit. This will produce presence/absence data that can be translated into a standard frequency measure that quantifies the *abundance of individual species*. The species frequency per substrate units is a powerful measure to document differences in the abundance of single species across different substrate qualities, different environmental conditions and across time intervals in a monitoring program.
4) Several dead wood (microhabitat) parameters should be recorded for each dead wood unit that is sampled, specifically position (standing/lying), tree species, decay class, diameter class and mortality cause. Such data will greatly improve the ability to interpret observed differences in species abundances across sample sites and time intervals.
5) Several locality or stand (macrohabitat) parameters should be recorder in order to further improve the interpretation of differences in species richness as well as species presence and abundance across sample sites and time intervals. Such parameters should include geographical (climatic) region, altitude, terrain position, forest type (tree species composition), local disturbance history, forest age (development class), and site productivity.
6) The local abundance and qualitative composition of dead wood should be quantified at the site as this has been proven to be a significant predictor of species diversity as well as the frequency of individual species per substrate units. It is important to use a sufficiently large sample area for this purpose (minimum 0.2 ha, see *6.2, transect length* for further details).

Chapters 5 and 6 describe how these recommendations can be implemented within ABMP protocols .

4. SUGGESTED FUNGI TO BE SURVEYED WITHIN THE ABMP

4.1 Description of the life history of polypores

Fungi are primarily heterotrophic organisms, which cannot fix atmospheric carbon dioxide, and are thus dependant on organic compounds absorbed from their environment. Fungi can absorbe organic compounds directly from their substrata, or they may first break them down with extra-cellular enzymes. Saprotrophic fungi use non-living organic material, which is not killed by the fungus itself. Necrotrophic fungi first kill the living

tissue, and then utilize it. Both nutritional modes are found among polypores. Part of wood-decomposing fungi can also be regarded as necro-saprotrophic, first killing the host tree and then utilizing dead organic material. Few polypores are found to be mycorrhiza species (*Albatrellus, Boletopsis, Byssocorticium, Coltricia*). Besides of having mycorrhiza, they probably also are saprotrophic, decomposing litter (Niemelä 1999).

Polypores are principal agents that break down the complex and refractory compounds of wood: cellulose, hemicellulose and lignin. Those compounds are among the most abundant organic material on earth. Polypores, among other wood-decomposing fungi, have thus a vital role in circulation of carbon and nutrients in forest ecosystems (Cooke and Rayner 1984). Depending on the enzymatic compounds of fungi, they break down different fractions of wood. White rot fungi have both cellulase and lignase enzymes. Most of them remove lignin and polysaccharides (cellulose and hemicellulose) at the same rate, some, however, break down lignin at faster rate. The result is soft, spongy, stringy or laminated wood mass, which is usually light in colour. Brown rot is formed when the polysaccharides degrade, but the brown lignin is only slightly influenced. Brown rot is fragile and cracks across the grain. While white rot fungi gradually utilize the woody material completely, brown rot residues are left on forest ground. They are important organic compounds in forest soils, forming e.g. nurseries for tree seedlings. Rot types are important features in identification of polypores (Gilbertson and Ryvarden 1986).

Host specificity of polypores is partly a consequence of the adaptation of fungi to tolerate the toxic compounds of trees, by which they try to protect themselves against fungi. Infection routes are usually specific to fungi, and can happen for instance via surface damages, broken branches etc. In living trees, two infection types are found. Heart-rot fungi are restricted to the non-living heartwood in living hosts, but they do not invade or kill living tissues. Exceptions are few heart-rot fungi (e.g., *Inonotus obliquus*), which are pathogenic, encroaching and killing living sapwood. A relatively small number of polypores are soil-inhabiting root-rot pathogens (e.g., *Heterobasidion annosum, Inonotus tomentosus, Phaeolus schweinizii*). The infection of these fungi occurs either via vegetative mycelium or rhizomorphs, which infect living roots and kill functioning sapwood and cambium in the roots, resulting a death of the host (Cooke and Rayner 1984; Gilbertson and Ryvarden 1986).

Fruit body development among polypores is preceded by a vegetative stage. An important attribute of fungus mycelium is the ability to penetrate and grow in solid substrate, which is achieved both by extracellular enzyme production and by very fine penetrating hyphae (Cooke and Rayner 1984). Interspecific competition is one factor, which restricts establishment and invasion of mycelia in wood. It has been observed, for instance, that many late successional species are more combative than primary decayers (Holmer et al. 1997). Besides of that, physical and chemical properties of the host tree and the microclimate of the growth site govern the community development of wood-inhabiting fungi. The way that the tree died affects the first steps of decomposition, and the primary decomposers largely affect the composition of later decayers (Cooke and Rayner 1984; Renvall 1995; Holmer et al. 1997). A specific group of polypores are those species, which are successors of certain preceding fungi. These species usually emerge only after the preceding fungus has died. At least twenty that kind of polypores are found in boreal forests (Niemelä et al.1995).

The fruit bodies of polypores can be annual or perennial. Most of the annual species produce their fruit-bodies in late summer or autumn, and moisture and temperature strongly affect the occurrence of fruit bodies. Annual fruit bodies are not formed every year if the environmental conditions are unfavourable. Perennial fruit bodies can last from 2-3 years up to even 30-50 years. Relatively little is known this far about how the succession of mycelia affects the fruit body production, but once present, fruit bodies can be regarded indicators of the reproductive ability of the fungi (Niemelä 2003; Renvall 1995).

Decomposing wood is a temporal resource for polypores. Some species, for instance early decomposers, seem to live a relatively short time in their substrate, and they are rapidly replaced by other species. The mycelia of fungi preferring mid and late successional stages may live in a large-diameter trunk for decades, especially in boreal and sub-boreal zones, where decomposition is slow, but finally the fungus has to find a new substrate. Dispersal

of polypores can be restricted either by dispersal and establishment problems, or by the availability of suitable substrate. The dominant mode of dispersal in polypores is via haploid airborne basidiospores, but there may be some dispersal with the help of insects (Nordén 2000). Spatial and temporal availability of suitable substrate is necessary to ensure the survival of polypore populations in a forest stand. Breaks in the continuity of CWD because of forestry or other disturbance factors may be reflected in the polypore species diversity of a stand for a long period of time (Bader et al. 1995; Sippola et al 2001). Also fragmentation and other landscape-level effects may affect polypore populations through lowered or hindered dispersal (Högberg and Stenlid 1999).

4.2 Proposed monitored fungus elements

In chapter 2 we identified polypores as a suitable group of fungi to be monitored in the ABMP. This group of fungi comprises about 300 species in Western North America, and we assume that more than 200 species occur in Alberta. From a monitoring point of view the polypores should be divided into two: a) perennial species and annual species that are identifiable the following years, and b) annual species that produce fruit-bodies that are only present parts of the year. The species in the first group have the important property that their detectability is similar throughout the year. The species in the second group typically start producing fruit-bodies in summer (some also in spring) and their detectability is highest from late August until the logs are covered by snow.

The polypores with perennial fruit-bodies should be regarded as the core group of fungi in the ABMP and they should have priority over other species in subsequent identification and data analysis. Recording species in the other group will add valuable information, and they should also be sampled. From a practical point of view it will be necessary to sample all species encountered, as it may be difficult to tell whether an encountered fruit-body is annual or perennial when the species is unknown. We have prepared a list of 72 polypore species that have been encountered or can be expected to occur in Alberta that also are perennial species or annual species that can be identified next year (Appendix 1). The species represent different ecological groups and deadwood elements, and allow comparisons in the diversity of the following elements:

Species on coniferous vs. species on deciduous wood

About 50 % of the target species are living completely or mainly on coniferous CWD, 35 % completely or mainly on deciduous CWD, and the remaining 15 % on both. The polypore composition represents species on all main tree species found in the province, and allows comparisons of diversity differences among the main forest types. The composition of target species also allows detecting changes in the polypore communities within the monitored plots due to changes in tree species composition after disturbance (forest fire, plantations etc.)

Early vs. mid and late decomposers

The species composition of polypores varies according to the decay stage of CWD. Early decomposers occupy recently dead CWD, and are followed by mid and late decayers. The mid and late stages of CWD generally host the highest diversity of wood-inhabiting fungi, and many rare and threatened species on boreal forests are confined on these decay stages (Bader et al. 1995; Renvall 1995; Kotiranta and Niemelä 1996; Høiland and Bendiksen 1997; Penttilä et al. 2004). Forestry operations, which destroy and hinder formation of mid- and late-stage CWD, decrease the diversity of polypores, which is clearly seen in Fennoscandian boreal forests (e.g., Bader et al. 1995; Sippola et al. 2001).

Species preferring different diameter classes

Some polypores are confined to, or preferring specific diameter classes of CWD. Polypore species composition on large-diameter trunks differs from species composition on smaller-diameter CWD. Some rare and threatened species are found in all diameter classes, but it seems that many rare and threatened species of old-growth forests are confined to large-diameter logs. The areas with successive forestry operations or fires often lack large-diameter trees. In the regions being in intensive forestry use, species confined to large-diameter trunks suffer, which has decreased species diversity in many areas in Fennoscandia (Bader et al.1995; Lindblad 1998).

Common vs. rare species
Relatively little is known on the polypore communities of Alberta this far (Richards and Murray 2002), and it is not possible to indicate specific rare or threatened species at the moment. Many of the target species are rare or threatened in Fennoscandia. The data gathered in the monitoring programme allow to detect possible rare species and to follow their status in Alberta.

Fungi on living trees
The target species list includes about ten species which occur on living trees. Most of those are pathogens and some are harmful for forest industry (e.g. *Heterobasidion annosum, Fomes fomentarius, Phellinus tremulae*). Most of them are relatively common species, but for instance *Haploporus odorus*, which grows on S*alix*, is threatened in many Fennoscandian countries.

4.3 Feasibility of polypore inventory in ABMP

In chapter two, we identified polypores and some corticoid fungi with perennial fruit-bodies (i.e. they are present for more than one year) or large annual fruit bodies that are present (although dead) the subsequent summer as suitable in a monitoring programme. The main reason for selecting these species is that they are visible all year round, and that the probability of observing them is similar at all seasons (a property that is normally *not* found among fungi which typically have short-lived fruit-bodies that occur irregular both within and between years).

A biodiversity monitoring program is expensive and time-consuming to run. It is therefore critical to know in advance that suggested elements to be monitored actually are worthy to monitor, that the expected results will fulfil important statistical criteria, that there are experts available to secure that the monitoring program can be conducted, and that the proposed survey is reasonable cost-effective. In this section we consider such aspects, partly based on the literature review in chapter 1-3, and partly based on the outline of the fungus inventory in ch. 5-8.

The guiding principles for the ABMP
These guiding principles (http://www.abmp.arc.ab.ca/ABMPSummary.pdf) outline some general criteria that form the basis of the entire program. Here we will shortly comment on how the polypores fit to these criteria.

a) Monitoring of polypores will use a common standardised methodology (see ch. 5) that is identical across the entire monitoring network. The methodology is also in accordance with international methodology that has been used and is recommended by several experts.
b) Monitoring is only carried out in terrestrial system (no polypores are found on woody material in aquatic systems, but there is a minor fraction (< 1 %) of wood-inhabiting species living on dead wood in water.
c) The actual monitoring is carried out at three spatial scales: 1) individual dead wood units, 2) on a collection of dead wood units within a monitoring site (alpha diversity), and 3) at the regional level, which allows to cover the natural variability among the sites and stands (beta diversity). Data can furthermore be grouped according to historical land use classes, natural disturbances etc. for further interpretation of trends.
d) The monitoring will occur in locations with a wide range of historical uses (including reference sites with limited human influence), according to the general design of the system. The polypores include several species that are good indicators of human influence in forest ecosystems and comprise species that react both positively and negatively on different forest management regimes as well as other forms of forest disturbances (fire, storm fellings, etc.).
e) Polypores represent highly diverse taxonomic groups that live in dead wood. The biodiversity in dead wood represents a distinct sub-ecosystem, with a food web at 4-5 different trophical levels.
f) Estimation of natural variability can be conducted based on samples from non-disturbed reference areas.

Monitoring perennial vs. annual species
The monitoring schedule of the ABMP requires that the monitored elements should be detectable through the whole inventory season. In comparing data between the sites, datasets with perennial species and species with fruit bodies that are identifiable over winter are directly comparable among the sites. Additional collection of

annual species will considerably broaden the picture of fungal biodiversity at local and regional levels. It would be optimal if the sampling of annual species (i.e., inventories from mid-August until the appearance of snow cover) would take place in all major biogeographical regions, and that the inventories could be repeated in each region during different years. This would allow compilation of regional datasets of annual species where annual variation due to precipitation and other outer factors could be equalized, and the regional diversity of annual species could be analysed.

The statistical criteria of ABMP

The statistical requirement for the ABMP is to have the capability of detecting a change of 3 % per year after 15 years of survey, that is an accumulated change of nearly 40 % if the change is linear. This change should be detected for:

i) species richness of the target group
ii) population density for selected species
iii) physical/structural characteristics of the habitat (of the target group)

Similarly, the ABMP should be capable to detect a two-fold difference between regions for the same three aspects. These differences should be detected with at least 90 % certainty ($\beta = 0.1$), and with less than 10 % probability of declaring a difference when there really was none ($\alpha = 0.1$).

Statistical considerations for species richness

By assuming that fungi are sampled on logs encountered along a transect line of 100 m per sampling site, this corresponds to a sampling area of ca. 0.1 ha and one will on average encounter 15 logs per sample site (Jim Schieck personal communication; the figure is obtained from a pilot study of 34 sample sites). Based on experience from Norway (se description of this survey above), one can then expect an average number of 4.8 polypore species per site including annual species. Furthermore, one can expect that the species number is 0 or 1 in about 10 % of the sample sites (a 10 % percentile of 0.8 species), and that there is more than 11 species in the 10 % most species rich sites (a 90 % percentile of 11.4 species). The statistical distribution will be unimodal, but skewed towards low values as the 50 % percentile (the median) in the Norwegian dataset was 3.2 species. We have not performed a rigorous statistical analysis of this material, but it seems reasonable that a change of nearly 40 % can be detected with a statistical power that is better than 0.1 for the α– and β-values. Notice that the number of species to be detected in the Alberta plots will be substantially fewer in the datasets where the annual species are left out. When making a comparison between regions, the sample size per region will be lower, but on the other hand a two-fold difference is rather large, and should be detectable with α– and β-values of 0.1 based on sample sizes of some 100 plots per region.

Statistical considerations for individual species

The requirement of detecting a nearly 40 % change for a single species over a period of 15 years with ($\beta = 0.1$, $\alpha = 0.1$) will highly depend upon the number of observations of the species in question. Similar assessments have been carried out in bird monitoring surveys. In order to meet this requirement about 50 real sample points is necessary for individual species. A real sample point means that the sample point is within the geographical distribution of the species and that the sample site fulfils the habitat preferences of the species. The requirement of minimum 50 real sample points will definitely be met by the most common species, but for rare species the number of sample points will be insufficient, even if the total number of sample sites in the ABMP will be 1656 sites as planned. In the rather large scaled survey from Norway 159 sites and 4146 logs were inspected for fungi and 113 polypore species were encountered. However, only five species were encountered in more than 50 sample sites. In this survey, on average 26 logs were investigated per site. If the full set of 1656 ABMP sample sites have an average of 15 logs per site, one can then expect about 40 polypore species (including annual species) to occur in more than 50 sample sites. This species number will be in the range of 10-20 if only perennial species are considered.

Cost-efficiency
Based on Scandinavian experiences, it is possible to conduct the survey using the proposed method on DWM on the average time of 1-2 hours per site. There will, however, be differences in the required time depending on the amount of dead wood on the sample site. A test period at the beginning of the field season is recommended to figure out the actual time needed. Recording and sampling polypores during the snag and living tree survey should cost very little extra time (because no fungi are present on most snags and live trees), provided that the sample bags have been labelled in advance.

Laboratory identification of fungi requires additional time. The exact time budget is difficult to establish, but we assume that most species should be possible to identify in the lab in 1-2 hours/site for a trained expert.

Identification by field staff and experts
Polypores as a collective group of fungi are easily identifiable in the field by their relatively large, easily observed fruit-bodies with a poroid hymenium (the spore-producing under surface of the fruit-body). A minor fraction of the species does not have a poroid, but instead a gilled or spiky hymenium. These species show so close resemblance to the typical appearance of polypores that these species are not over-looked. Even a non-expert can learn during a few hours to separate the polypores from other fungi growing on dead wood.

It is also possible to learn certain field identification of a rather large number of species. Some species are so typical that once one has seen them in field (or on a photo) one can easily identify the species afterwards. Several additional species can be identified securely in field after some instructions by an experienced mycologist who can point out variation in the visual appearance and criteria to separate the species from possible confusion candidates. Identification books like the local field guide (Schalkwijk-Barendsen, HME. 1991) and the CD-rom *Polypores of Finland* would help to identify the commonest species. A reference collection made from the collected material established by experts after the first field season would help further identification.

There is, however, a distinct proportion of the species for which certain identification must be carried out in laboratory by means of microscope. This represents expert knowledge, but identification books for the polypores of North America exists, and there is available international expert knowledge to back up and help local experts in Alberta/Canada (see ch. 8 for furter detais).

5. PROPOSED FIELD PROTOCOLS FOR FUNGUS SURVEYS

5.1 Sampling design at an ABMP site

Based on the summing up at the end of ch. 3, we recommend fungi to be sampled on a well-defined set of logs within an ABMP site. We also recommend that fungus sampling is closely connected to the dead wood inventory and takes advantage of the work carried out in this module. The ABMP dead wood inventory is based on a line-intersect sampling method (see ch. 6). In short, this method records all downed wood crossing a sampling line. Data obtained through this method can be transformed to volume of dead wood per area unit. By sampling fungus on downed wood recorded through this method one obtains species data for a well-defined set of logs (the logs encountered along the transect and their characteristics) and for a rather well-defined area (correlating with the transect length). By sampling fungi on logs along a transect length of 100 m one is sampling an area of about 0.1 ha (depending on the average length of the logs).

The number of snags and logs within a full 1 ha sample site will vary from less than 10 at sites with a long history of forestry and wood extraction to more than 300 in highly productive old-growth forest sites. The experience from ABMP based on a pilot study of 34 sample sites is that there are approximately 15 (range 0 and 40) pieces of DWM > 7cm sampled along a transect length of 100 m, and about 40 (range 3 and 125) pieces of DWM between 2 and 7 cm diameter sampled at each ABMP forest site (Jim Schieck, personal communication).

In order to establish a representative picture of the *local species composition*, all dead wood units should be sampled in plots with very low abundance of dead wood (i.e. less than 10 within the 1 ha plot). But in plots rich in dead wood units it is sufficient to sample a subset of the dead wood (i.e. the logs encountered along the transect lines are sufficient). In order to establish *quantitative monitoring data for individual fungus species* it is sufficient to sample enough sites and suitable dead wood units across all sample sites (or each region for regional resolution). Also for establishing a comparable measure of *local species richness* it is sufficient to sample the logs encountered along a 100 m transect length (se section 3.2 for details on the number of species to be expected). Since there is no requirement to establish data on the local species composition of fungi in the ABMP, it is sufficient to sample the logs encountered along a total transect length of 100 m. Notice, however, that we recommend downed logs to be sampled along a total transect length of 200 m in the dead wood inventory (see section 6.2) to get reliable data on local abundance and diversity of dead wood.

Sampling procedure

Logs (Coarse woody debris, CWD). All downed logs with a basal diameter > 10 cm encountered along the transect lines should be investigated for polypores. There is an international agreement on using 10 cm as a threshold value for separating between coarse and fine woody debris as this represents a breakpoint in wood decomposition rate (Harmon and Sexton 1996). The underlying reason is that dead wood below this limit has mostly sapwood (decomposing faster) and it has larger surface to volume ratio that affects moisture retention. This value is also used as a standard breakpoint when grouping wood into two major habitat classes for wood-inhabiting species (Kruys and Jonsson 1999; Stokland 2001). We strongly recommend that this threshold value is used also in Alberta in order to establish internationally harmonised data. Most fruit-bodies of polypores are found underneath downed logs. For small logs it is most efficient to inspect the underside by rolling the logs over (roll them back to original position after inspection). For larger logs, the under surface is efficiently inspected by a mirror (that also adds light to the dark under side). It is essential to record several dead wood attributes for each sampled log for subsequent data analysis. Standard attributes include: tree species, decay class, diameter class, breakage class (mortality factor). These dead wood attributes are very similar to those obtained in the dead wood survey and the definition of attribute values should be standardised between the dead wood survey and the fungus survey (see ch. 6 for suggested modifications in dead wood classification). *It is critically important to record and classify downed logs along the transect, even if no fungi are observed on them.* For the purpose of quantifying the frequency of species, absence observations are equally important as presence observations (see section 3.4).

Small logs (Fine woody debris, FWD)

Small diameter dead wood is not important as substrate for polypore fungi, even though some common primary decomposers such as *Trichaptum abietinum* are commonly found on FWD. Instead, FWD is important for other fungi groups like Corticoid fungi and Ascomycetes, especially in managed forests (Kruys and Jonsson 1999). As the FWD fraction is of least importance (for the polypores) it can be left out from the fungus inventory. If FWD is included, one can sample fungi along one 25 m transect length (on average one can expect to encounter 10 FWD units, Jim Schieck personal communication). We expect that the polypores encountered on FWD comprise of 1-3 common primary decayers, and no species are found on the large majority of the FWD pieces.

Snags

We recommend that all recorded snags (large, medium-sized and small) to be inspected for fungi during the live tree and snag inventory. Notice that only a small proportion of snags can be expected to have fungi. In a Norwegian case study of 170 snags, 18 % of the snags had polypore fruit-bodies (Stokland, unpublished data). Furthermore, most polypores on snags are easily identifiable species (nearly all were one out of the tree species *Fomitopsis pinicola, Fomes fomentarius* or *Piptoporus betulinus*), as the difficult resupinate species nearly always occur on downed logs. Since snags are identified to tree species and measured, the observer will always stand close to the snags. Recording polypores and taking samples from the snags will cost little extra time. It will not require an extra field form, just two extra columns in the snag/tree form: one to write down the name of the species if it is possible to identify (3+3 letters, e.g. FOMFOM), and the second column to the sample number if

the species is not identified in the field (the bags should be labelled in advance like in the downed wood survey). This method gives the opportunity to check later how many trees/snags hosted a polypore species.

Live tree
Wood-decaying fungi may also be found on live trees, and then nearly always on old and/or large trees. They may occur on dead branches as well as on the trunk and live branches, especially on broad-leaved trees. We recommend that only the large trees from the snag/large tree inventory are inspected for occurrence of fungi. Binoculars should be used to improve identification from the ground. No data exist on the occurrence of fungi on live trees, but we expect that, on average, much less than 1 % of the trees > 25 cm will have fruit-bodies of fungi (normally live trees grow much larger than 25 cm in DBH before they develop the conditions where fungi develop fruit bodies). The proportion of large, live broad-leaved trees with polypores may sometimes be higher than 1 %, but this percentage will probably be much lower than 1 % for coniferous trees. On the list of potential perennial target species (Appendix 1) the proportion of species found on live trees is 14 %. Recording fungi on live trees should be carried out during the tree/snag inventory using the same procedure as for snags.

Coordination with the dead wood survey
The sampling protocol of wood-inhabiting fungi should be closely coordinated with the sampling protocol for dead wood resources (snags and downed logs) and large trees. First of all, the parameters used to characterise dead wood should be standardised between these two protocols to obtain synergy. If so, the dead wood inventory will quantify the amount of habitat for the fungi, and the fungus inventory will produce data that tells the importance of various dead wood qualities for the associated biodiversity. We have suggested some modifications in the dead wood parameters in chapter 6. These suggestions will also make ABMP dead wood data harmonised with similar datasets from the US and Europe.

5.2 Field forms

For fungi sampled on snags and large live trees one should use the field form used in the snag/live tree inventory. This field form needs two additional columns: a) one to record species if it is possible to identify it the field (usually, a 3 + 3 abbreviation of the latin name of the species is used, e.g. FOMFOM for *Fomes fomentarius*) and b) one to record the serial number for collected specimen.

Another form is necessary to record dead wood attributes and species/specimens that are encountered on downed wood. The header of this field form should identify the sample site, sampling date,collector(s) and the coordinates of the site. For each record one should have the following fields:

- transect and transect position, i.e. distance (in m) from transect start)
- dead wood parameters
- species identified in field. Normally this will be 0-2 species, occasionally up to 4-5 species per log).
- Interval of serial numbers collected for laboratory identification.
- rot type. If the rot type (W = white, B = brown) caused by the fungus is easily recognized, this should be recorded to help later identification
- space for remarks. Special remarks can be written e.g. of the odour or change of colour of the fruit body, growth on charred CWD etc.

An outline of this form is presented in Appendix 2.

In the sampling forms it is very important to record “no fungi found” in order to separate between missing observations and zero observations on sampled large trees, snags and logs. In the subsequent data analysis the numerous zero observations are extremely valuable for calculating the occurrence frequency of the species, see Stokland and Kauserud (2003) for this kind of analysis.

Dead wood parameters
These should include the following parameters:

- CWD no. This running number is a link between CWD and species information, and helps for instance in checking the records. If there are several fungus species found on a same piece of CWD, the CWD number should be same for all those.
- CWD type (log, branch, stump)
- tree species
- mortality factor (see Ch. 6.2. Dry snags can be left out from fungus survey on downed wood material)
- decay class (see Ch. 6.2)
- basal diameter of log top, diameter of log
- log length

For details on alternative parameter values, see recommendations made in chapter 6.

5.3 Sampling window

For perennial polypores, the full season is acceptable for fungus sampling. The optimal sampling window is from mid May to the end of August (due to long duration of daylight and presumably best working conditions), but sampling is possible until the snow cover appears. Fungi sampled on snags and large live trees should be conducted in spring at the same visit as the snag/live tree inventory.

The optimal sampling window for annual polypores will be mid August to the end of October or the time when the snow cover appears.

5.4 Collecting, handling and storage of samples

Fungus species that are not identified with certainty in the field should be sampled for laboratory identification. For species with small fruit bodies, a single fruit body should be collected. For species with large fruit bodies (e.g. *Fomitopsis*, several *Phellinus* species), one should chop off a piece of the fruit body. In both cases it is important to collect (a piece of) a fruit body with *well-developed hymenium*, that is the poroid surface beneath the fruit body that produces the spores. This is important in order to have well-developed spores in the sample – spore size and shape is often a diagnostic identification criterion. For large fruit-bodies it is convenient to chop off half of the fruit body, to see visual characteristics later. Is it recommended to collect samples from all fungi specimens that look like a unique species on each piece of dead wood that is sampled, and establish the species identity in the lab. There is no requirement for field staff to "know" the fungi species. However, it is still useful to record easily identifiable species in the field without sampling them. That will reduce the volume of samples and save labour in the field (fewer samples to carry and dry in the evening), in subsequent sample treatment, and in the laboratory identification phase. There is also an extra premium as field workers tend to regard species identification as interesting and positive (variation in the work, enhanced knowledge).

Samples are placed in individual paper bags (ca. 15x20 cm) with a pre-printed serial number. The serial number should run through all the sites and years to avoid confusion. Different sampling procedures can be in indicated in the serial number by a letter, e.g. D = downed woody material, S = snag, L = live trees, and each procedure can have the running number of their own. Paper bags should be folded in order to prevent the sample to fall out of the bag. An ordinary shopping bag of plastic is sufficient for packing the load of paper bags for transportation out of the sample site.

At the end of the day all paper bags should be opened and the samples should be dried for some days in a dry, warm place in order to prevent moulds developing on the samples. The drying can be speeded up with a small portable dryer, being particularly useful for large specimens. Drying overnight (9-12 hours) in medium warmth (about +40 ^{o}C or 104 ^{o}F) is usually sufficient time in the dryer. When the specimens are taken out from the bags, they should be put on a small piece of paper with the sample number. This should follow the sample all the time. After drying, the samples should be placed back into their original paper bags with the sample number.

Before long-term storage, the fungus samples should be placed in a deep freezer for 3-5 days in order to kill insect larvae that may occur in the fungus samples. It is advantageous to have a maximum temperature shock for the larvae. This freezing procedure can take place several weeks after the actual collection. The purpose is to prevent larvae from eating up the samples during long-term storage.

5.5 Necessary field equipment

Equipment list for a single ABMP visit

Sampling equipment

- a handlens (portable on a string around neck) to detect if the fungus belongs to polypores (the pores in the hymenium can sometimes be very small) and to help identification
- 2 robust knives (to have a backup if one is lost)
- 2 mirrors (ca. 15 cm diameter) for convenient inspection of underside of logs
- binocular for possible ground identification of fungi on large live trees
- paper bags (ca. 15x20 cm) with pre-printed serial number
- 2 plastic bags (ordinary shopping bags) for bringing paper bags out of sample site
- lead pencil or water-proof pen for making comments on paper bags.

Handling of samples

A small portable dryer is very useful to the get the samples dry. Drying should be done as soon as possible after returning from field, to keep the tissue and the spores identifiable. Drying overnight is usually enough to dry the samples.

5.6 Time budget

Sampling snags and large trees

Experience from a pilot survey of 34 ABMP sites indicates an average of 10 snags and 20 large trees are sampled per site. We assume that an average of 5 seconds are needed per snag to observe and record absence of fungi. Presence of fungi (typically 1, rarely 2 or more species per snag) will need identification or sampling and recording. This takes about 1 minute per snag. Experience from a Norwegian study indicates that fungi are found on ca. 20 % of the snags. This indicates an average extra time of ca. 3 minutes for the snags per plot. It will probably go equally fast to observe absence of fungi on large, live coniferous trees as they normally have no dead parts with fungi. Large broad-leaved trees, on the other hand, often tend to have dead branches where fungi sometimes occur, and broad-leaved trees will take somewhat more time to observe, perhaps some 10-15 seconds on average per tree. Since coniferous trees are much more common than broad-leaved trees, we expect the average time to observe and record absence of fungi will take some 6-7 seconds on large trees. Observing and recording presence of fungi will probably take about 1-2 minutes per tree. We expect that fungi on average will be observed on less than one large tree per plot. Thus, the time needed to record fungi on large live trees will, on average, take about 3 minutes extra per plot.

It is difficult to judge whether the 34 plots investigated in the pilot survey are representative for all 1656 ABMP sites. If that is the case, the total extra time needed for fungus sampling on snags and large live trees will be about 6 minutes per site.

Sampling downed wood

Inspection of dead wood will always start by laying out measuring tape along the four 25 m transects. This takes some 5-10 min, even if no logs are present in the plot. Experience from a pilot survey of 34 ABMP sites indicates that an average of 15 downed logs are encountered per site. The time needed for sampling downed wood on an average site like this will take about 1 hr and 15 min according to the following schedule. Most of the time will be used simply to inspect logs for presence of fungi. Logs that are so small that they can be rolled over will take about 1 minute to inspect per log. For larger logs, one needs to move (crawl) slowly along the full

length of the log and watch the under surface directly by eye or by means of a mirror. One also needs to jump regularly over to the other side in order to check along both sides of the trunk. We have no exact time budget for this inspection time, but it will probably be around 5 min on average per log (perhaps somewhat less). Normally, the majority of the logs (perhaps 2/3) will be too large to be rolled over, and we assume that the inspection time will be about 1 hr/site. A Norwegian study of 4146 logs produced 2682 records of polypores, including annual species (where one record was one individual species on a log). This indicates that on average one polypore record is made on 2 out of 3 logs. Specimen preparation (or identification) and recording in the field form takes about one minute per sample, i.e. a total time of 10 minutes/site. Measuring and recording the downed wood parameters (basal and top diameter, length, decay stage and mortality type) will take about 2-3 minutes/DWM. We estimate that altogether the fungus survey would take on average about 1 h 40 min. – 2 h/site (100 m transect).

6. SUGGESTED MODIFICATIONS IN THE DEAD WOOD PROTOCOL

The ABMP has developed a sampling protocol for dead wood resources. This is described in the Field and Laboratory Data Collection Protocols (Stambaugh and Schieck 2003). The deadwood protocol includes an inventory of all snags (> 25 cm DBH) within a 0.5 ha plot and smaller snags in 10x10 m or 5x5 m sub-plots. Furthermore, downed woody material (> 7 cm diameter) is sampled using a line-intercept transect method with 4 transects, each 25 m long.

We recommend the dead wood inventory to be modified somewhat, partly to improve the basis for the fungus inventory and partly to improve the dead wood inventory as such. These recommendations are based on experiences from dead wood monitoring in National Forest Inventories in Scandinavian countries and USA as well as fungus inventory projects in Scandinavia. If these recommendations are followed, the usefulness of the data will increase considerably and results from ABMP will be closer to international harmonisation standards that are under development.

6.1 Snag and large tree inventory

A sampling plot of 0.5 ha will function well. Snags (standing dead tree) are grouped into two based on the criterion of being intact or broken below the canopy. In both groups a 3-grade classification system for decay status is used. We do not suggest any changes of these classes, but their definitions should be slightly modified. The 80 % bark cover criterion can be quite misleading as a snag may loose nearly all bark less than one year after the tree died. This happens regularly in cases where bark beetles attack weakened trees and the beetles are subsequently attacked by woodpecker(s) that rip off all bark when predating on the beetle larvae. In other cases a tree may have all bark intact many years after the tree died (e.g. birch) and the wood itself may be significantly decayed. We simply suggest that the bark cover criterion is removed, and that the distinction between the second and third stage is defined according to wood decay as already stated in the definitions.

Ideally, the height of the snags should be measured in order to facilitate volume estimation. With the additional information that a snag is intact one can estimate the expected height from the DBH based on allometric relationships. In the cases of broken snags, there is no information on whether a small or large proportion of the snag is missing. In most cases the snags are broken somewhere along the trunk. Thus, there is a potential for bias in the estimate of snag volumes. One could, as a thumb of rule, assume that 50 % of the volume is missing for broken snags. This assumption can be improved considerably by a quick visual judgement in the field. The observer simply assesses to the nearest 10 % how large proportion of the snag that is present. A trained observer will normally do this judgement within an error of +/- one step on a 10 % interval scale and will only need a few

seconds to observe and record this judgement. One can, however expect significant personal variation, and a calibration session for field workers is worthwhile.

No modifications are recommended to the large tree inventory.

Recommendations: We recommend that bark cover is removed as a criterion for separating between the second and third decay classes of snags (but keep the decay classes unchanged). Add a new parameter for broken snags – the proportion of the snag that is present (using a 10 % interval scale).

6.2 Downed wood inventory

The downed wood inventory is based upon the line-intersect sampling method using four 25 m line transects.

The current version of the downed wood inventory has some drawbacks:

- The data obtained can not be used to calculate volume per area of different qualities of downed wood material
- The total transect length (100 m) is probably too short to produce reliable data on local abundance and qualitative composition of dead wood.
- Important dead wood qualities for wood-associated biodiversity are missing.

We suggest several modifications in this part of the inventory, especially that the total transect length is increased, that the length as well as the mid and maximum diameter of each log are measured, that the decay class system is modified, and that mortality factor for dead wood is added as a new parameter.

The Line-intersect sampling method

The line intersect sampling (LIS) method was introduced by Warren and Olsen (1964) to estimate the volume of logging residue in harvested forests. This method was more efficient than more time-consuming and costly plot-based methods. Warren and Olsen also developed a simple volume-per-unit-area formula based on this inventory method. During the next ten years the inventory method and associated formulas were developed until DeVries (1973, 1979) made the following generalised formula:

$$\text{Attribute-per-unit-area} = \pi/2L\Sigma\mathbf{x_i}/l_i$$

Where L is the total length of the transect line (or sum of transect intervals within a plot), l_i is the length of the individual log piece, and **x** is the dead wood quantity or quality of interest. This formula can be used to calculate per-unite-area of *any* characteristic of downed woody material if the corresponding data is collected for each tally log. Waddell (2002) gives a comprehensive summary of the history of the LIS method, its application in forestry and use for several specific characteristics. The volume is an obvious dead wood characteristic, and relevant measurements should be taken in order to estimate volume of individual dead wood pieces. The volume of dead wood is often subdivided into different categories of interest such as decay class, tree species group, and diameter class to facilitate comparison among habitat types and geographical areas (including international comparison). If the adopted decay class system translates into quantities of dry density loss (see *decay class* later in this section) one can also calculate carbon pool tied up in the dead wood.

The VanWagener (1968) formula represents an alternative to the DeVries formula. This formula only needs the trunk diameter at the line intersection point to calculate volumes of dead wood. The line intersect diameter is not sufficient to reliably measure the volume of individual logs nor the total volume of logs along a short transect length. In a large sample, however, the VanWagener formula produces reliable and unbiased estimates of downed wood volume as the average intersection diameter will approach the average mid diameter of the sampled logs. Due to quick data sampling this method is commonly used in forest inventories and the resulting data are adequate for several purposes. In the context of a biodiversity inventory this method has two important drawbacks:

1) No reliable information is obtained about the distribution of downed logs on different diameter classes.
2) No reliable information is obtained about the local abundance and qualitative composition of dead wood.

In section 2.2 we highlighted the importance of these two aspects (local abundance and qualitative composition under the heading *Landscape patterns*) for wood-inhabiting species. In addition to the information presented in 2.2, we would like to emphasise that it is very valuable to know the diameter distribution of dead wood in completely unmanaged forests that still can be found in a significant proportion of Alberta. When the first and second pass of logging has moved across the state during the next 100 years, it is certain that the dimensions and local abundances of dead wood will decrease, and it is very likely that these reductions will affect the species diversity of wood-inhabiting organisms. In Sweden, it has been shown that species preferring dead wood of large diameters are over-represented on the national red list. One can expect a similar development in Alberta and a biodiversity monitoring program should be fine-tuned in order to pick up both the development of large diameter wood as well as the associated species depending upon these dimensions.

Recommendation: we recommend downed wood to be measured in a manner that subsequently allows the usage of the DeVries formula for calculating dead wood volumes (this implies specifically that the length of individual dead wood pieces is measured). This formula is more general with a wider spectrum of usages and it facilitates accurate measurement of local abundance of various dead wood qualities. Although this will increase the time budget somewhat, the value of the output data from the ABMP will increase considerably.

Transect length
In chapter 2.2 (*Landscape patterns*), we emphasised the importance of local abundance and qualitative composition of dead wood for the occurrence of wood-inhabiting species. The importance of the local abundance of dead wood is related to population dynamics of wood-inhabiting species, their dispersal ability and their habitat requirements for viable populations. In Scandinavia, the National Forest Inventories are using sample plots of 0.025-0.05 ha. Due to the high number of plots, they produce reliable regional and national estimates of various dead wood qualities. A 0.05 ha plot does not properly measure the local abundance and qualitative composition of dead wood, however. In a Norwegian case study a subset of the NFI plots were enlarged to 0.5 ha (Fig. 6) for estimating local abundance of dead wood and making a biodiversity inventory. A simulation study based on these plots revealed that plots should have at least a size of 0.2 ha to establish a *dead wood profile* that documents the local abundance and composition of different CWD qualities (Stokland 2001). See also Stokland et al. (2004) for further details.

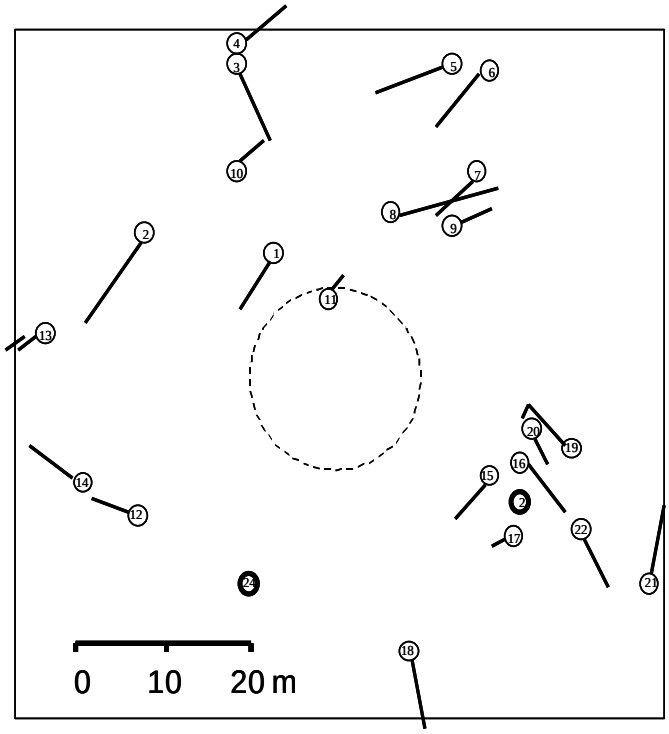


Figure 6. A NFI plot of 0.025 ha enlarged to 0.5 ha for estimating local abundance of dead wood. The circular symbols with numbers represent the position of the basis of individual CWD units. The attached lines indicate the direction and length of downed logs. Symbols without lines represent snags.

A total transect length of 100 m will record downed logs corresponding to a sample area somewhat less than 0.1 ha (assuming an average log length shorter than 20 m). Thus, in order to establish reliable information about *local* abundance and qualitative composition of downed woody material, the transect length should be increased to 200 m. It should be noticed that this transect length will bring the ABMP data in close correspondence with the USDA Forest Inventory and Analysis program that is using a total transect length of 255 m distributed across 5 subplots within each periodic inventory plot (Waddell 2002). The detailed layout of subplots and transects is not significant in this context, the important factor is to encounter a sufficient number of logs to cover the local variation of tree species, decay classes and diameter classes.

Recommendation: we recommend that the total transect length is increased to 200 m by doubling the length of the four 25 m transect lines. We are aware that longer transects will extend the sampling time. If the Science Committee decides to stay with 100 m of transect, the ABMP will loose the possibility to make reliable dead wood profiles for individual plots. The dead wood profile facilitates forest history interpretation for the recent 200-500 years (Stokland 2001) and it is a highly significant explanation factor for both species richness of fungi (Stokland 2001) as well as occurrence of individual species (Stokland and Kauserud 2003, see also the example of *Phellinus nigrolimitatus* in section 3.4).

Inclusion of coarse logs (>= 10 cm)
As stated above, there is an international agreement on using 10 cm as a threshold value for separating between coarse and fine woody debris (see 5.1, section *sampling procedure*). In the dead wood protocol it is stated that "Measure and record each piece of DWM > 7 cm diameter at the point at which the piece … intersects the transect". We strongly recommend that logs with smaller diameters at the intersection point are included *if the maximum (basal) diameter is >= 10 cm*. This means that the whole volume of such logs goes into the volume in the same manner as for snags (which is also common practice when calculating standing volume of live trees). It

is logically inconsistent if a large log is included when the basal part is crossing the transect line, but not if the top is crossing the line. This adjustment of the inclusion criterion probably has negligible influence on the time budget. A few logs will be excluded compared to the current version (those with the maximum diameter < 10 cm) and a few logs will be included (those > 10 cm for which the top section < 7 cm diameter is crossing the line). On most logs the top is actually missing (either because it broke off in a previous snag phase or because the top tends to decompose very rapidly on fallen trees). Thus, these exchanges will probably balance each other, and the net effect may be that fewer logs are measured. Field staff measuring diameters will rapidly develop a very good visual judgement of 10 cm diameter (+/- 0.5 cm) and it is rarely necessary to actually measure the basal diameter to tell whether it is larger or smaller than 10 cm (but see below where we recommend that the basal diameter is measured).

To keep consistency in the system, the inclusion criterion for fine woody debris should be *included if the maximum (basal) diameter is < 10 cm*. That will remove large trees where the top is crossing the line from the fine woody debris fraction (which is logical), and it will move some small logs from the coarse to the fine wood fraction where they are tallied instead of measuring..

Furthermore we recommend that whole logs broken into pieces is considered and included in the volume measure if it is obvious that the pieces belong to the same tree. This will require very little extra time, as very few logs are broken (less than 10 %).

Recommendation: We recommend that ABMP adjusts the inclusion criterion for coarse and fine woody debris along the transect line by considering the basal diameter (using 10 cm as a standard limit), and not the diameter at the intersection point. Consider the whole trunk in cases of broken logs, not only the piece crossing the line.

Tree species
The attribute values for tree species seem adequate and we fully support the distinction between broadleaved and coniferous trees for unidentified logs. We have no knowledge about identification criteria for Canadian tree species when dead, but for obvious reasons the downed logs become increasingly more difficult to identify with the advance of the decay process. A very good identification criterion is the bark surface and structure. With a little experience one can often identify tree species of very decayed logs based on bark remains. If no bark is found along the trunk one should try to locate the stump as one often can find pieces of bark here.

Diameters
In order to calculate the approximate volume of dead wood, one needs to measure the length and the mid diameter (DBH for entire standing and fallen dead trees, because the volumes are calculated from taper curve tables). Furthermore, it is recommended to measure the basal (maximum) diameter and the top diameter to produce more precise volume calculations (Harmon and Sexton 1996, see also Waddell 2002 for measuring branching trunks). As long as one measures the log length, there is little additional time cost for measuring the mid diameter. First one measures the length, next calculates the mid length by head, and finally scrolls back the measuring tape to the mid length (while the tape is still hooked to the log basis) and measures this diameter. Measuring the mid diameter makes the transect line diameter superfluous. The time needed to measure and record a diameter is roughly 10 seconds. Measuring the log length takes somewhat less than one second per meter (the average time needed to walk along the log) plus ca. 10 sec to read and record the length. Altogether, a trained person will probably need one minute extra per log to record the length, basal diameter and mid diameter (leaving out the transect diameter). This will add on average 15 min per site for a 100 m transect length (based on information that the average number of logs on an ABMP site is 15).

In addition to achieve good volume estimates, there is another important argument to measure the maximum diameter, i.e. at the log basis. The trunk diameter is an important habitat parameter for wood-inhabiting species, since many species depend upon large diameters. The diameter where the log crosses the transect line cannot be used to group the logs into dimension classes.

Recommendations: We strongly recommend that the length, basal diameter and mid diameter of the logs are measured. We also recommend the top diameter to be measured. One should seriously consider the benefits of better dead wood measurements, not only the time costs. We are aware of the increased sampling time resulting from these recommendations. If the Science Committee decides to stay with the existing protocol, the ABMP will loose the possibility to calculate volume of downed wood per individual sample plot. Notice from the DeVries formula given above that the length of individual logs is needed for this purpose. The basal diameter is needed to sort the volume into dimension classes – the transect line diameter cannot be used for this purpose.

Decay class

The stage of decay is a very important dead wood quality for predicting the associated species composition. In the current version, ABMP is using a system with 7 classes. The system has previously been evaluated by Lee et al. (not dated) who recommended simplifying the system to 3 classes. We agree with Lee et al. that the system is too detailed, but a system of 3 classes may be too coarse. We recommend instead a system with 5 classes that has been adopted in Scandinavia (Stokland 2001; Stokland et al. 2003). This classification system corresponds closely to the 5-class system used in the American Forest Inventory and Analysis program (Waddell 2002). The relationship between these 5 classes and the degree of decomposition in terms of dry density loss has been quantified in Scandinavia (Næsset 1999). This makes the classification system suitable also for quantifying carbon pools. The visual appearance of the 5 classes used in Scandinavia is illustrated in figure 7 and the classes are characterised as described in table 3. The classes are defined by means of easily observed criteria that closely reflect the degree of decomposition of a log.

We will argue that the criteria used for defining the 7 classes in the current ABMP protocol may be misleading for judging the degree of decay, and they may even be conflicting within a decay class as they are used now. The cover of vascular plants and mosses should not be used to assess degree of decomposition. Cover of vascular plants depends partly on the degree of ground contact (which correlates closely with degree of decomposition), but also on the presence of vascular plants with vegetative colonisation by means of stolons. If such plants are present at the site they may easily start colonising before stage 5 (current ABMP system), but if absent at the site, they cannot colonise at all. Moss cover also depends upon degree of ground contact, and their growth rate highly depends upon local as well as regional climatic factors. As mentioned above for snags, the bark cover can vary substantially with the degree of decay (and within decay classes), and especially between different trees species. In ABMP class 3 it will normally be a conflict between “”some large branches remaining” (implicit statement: most medium-sized and large branches are gone) and “wood hard”. Branches normally fall off due to rot at the branch base. When these points are so rotten that the branches fall off, the wood (trunk) also has started to rot and becomes soft, i.e. it is no longer hard. In short, we are convinced that the proposed 5-class system better reflects the degree of decomposition, and it will probably be easier to use for field staff as the criteria are easy to observe and they are not highly variable nor conflicting.

Recommendation: we recommend that the decay classification system is simplified and adjusted using criteria that better reflect the actual degree of decay of the downed logs. This change of classification system will have no influence on time used for decay classification – it will simply improve the ABMP data and make the results better harmonised with data from other countries.

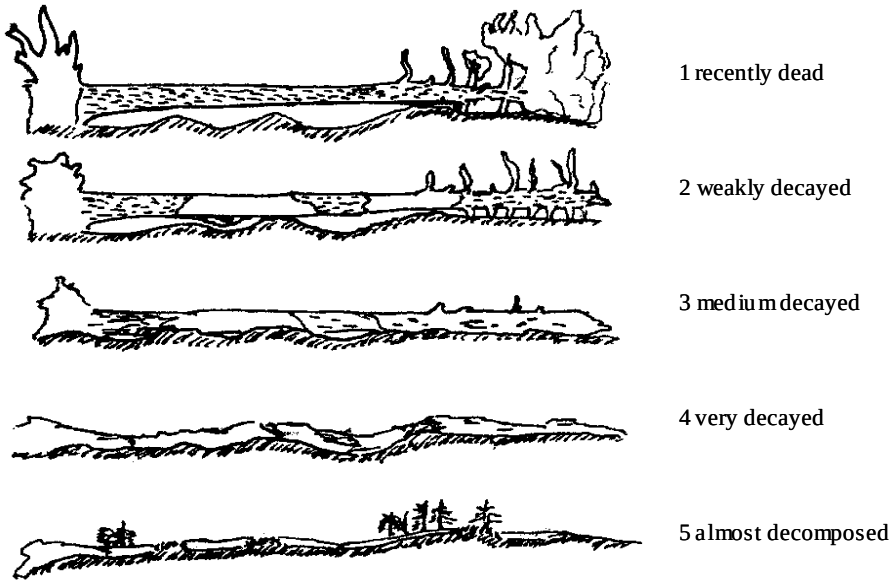


Figure 7. Visual appearance of the five decay classes used in the Norwegian NFI. See table 3 for a description of the classes.

Table 3. Criteria used to decide decay classes in the 5-class classification system used in Scandinavia. The proportions of initial dry density remaining are presented to indicate the degree of decay and are not used as a criterion for decay classification. These values are interpreted by the authors based on Næsset (1999).

Decay class	
Recently dead	bark normally attached to the wood. Hardly any fungus mycelium developed under patches of loose bark; 100-95 % of the initial dry density.
Weakly decayed	loose bark, normally well developed fungus mycelium between bark and wood. The rot extends less than 3 cm radially into the wood (as measured by pushing a knife into the wood); approximately 95-75 % of the initial dry density.
Medium decayed	the rot extends more than 3 cm into the wood, but the log still has a hard core and it is supported by stones, humps, etc. on the forest floor; approximately 75-50 % of the initial dry density.
Very decayed	rotten throughout the log, whole knife penetrates into the wood. The log is shaped by the contours of the forest floor and the cross-section is often collapsed to an ellipsoid; approximately 50-25 % of the initial dry density.
Almost decomposed	the log is completely decomposed in sections, and the log outline is strongly fragmented and the wood disintegrates when lifted. The remaining parts are often overgrown; approximately 25-5 % of the initial dry density.

Mortality type

There is increasing evidence that the mortality cause of dead wood is significant for the occurrence of several fungi, as well as insect species (Heilmann-Clausen 2003). Based on the experience from more than 4000 logs in a Scandinavian study (Stokland et al. 2004), the mortality types listed in table 4 and illustrated in Fig. 8 have proven to be a robust classification system. The term *mortality cause* is avoided, because several mortality factors may be involved for single trees (e.g. drought and insect attacks), or specific causes may be difficult to separate (e.g. snow load and wind). The mortality type is useful for separating between natural mortality and dead wood left behind as logging residuals. The different alternatives are easily observed and on average it takes about 5 seconds per log to observe and record the mortality type.

Recommendation: we strongly recommend that mortality type is included as a new parameter to classify downed wood.

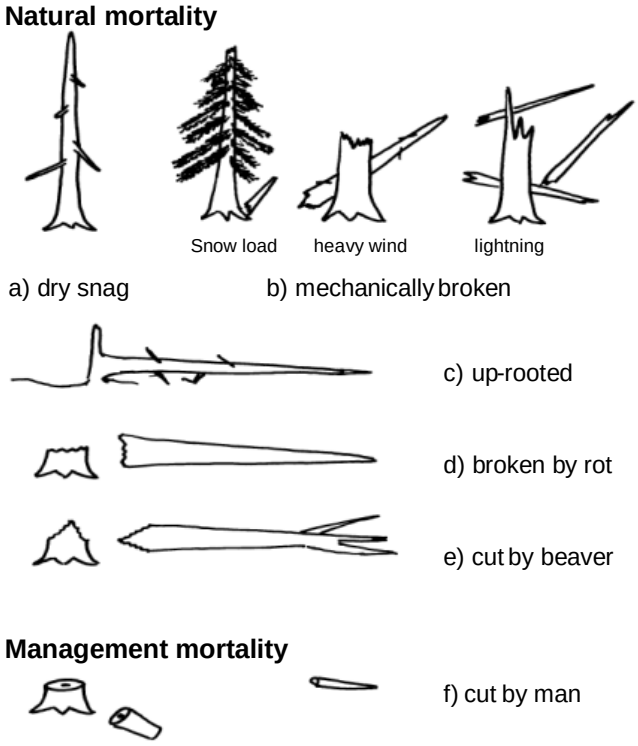


Figure 8. Visual appearance of different mortality factors.

Table 4. Criteria used to decide different mortality types. See also Fig. 8 for the visual appearance of the classes.

a) dry snag	standing dead tree; mortality cause: competition, drought, insect/fungus attacks
b) mechanically broken	splintered fracture surface; mortality cause: snow load, heavy wind, lightning
c) up-rooted	trunk intact, root uplifted; mortality cause: heavy wind
d) broken by rot	irregular fracture surface; mortality cause: often a previous dry snag, broken by rot
e) broken by beaver	tooth marks from beaver; mortality cause: the animal
f) cut by man	fracture surface even or with axe marks; mortality cause: cut by means of saw or axe
g) fire marks	standing dead tree with fire marks; mortality cause: forest fire
h) unknown, natural	fracture surface decomposed; possible to exclude cut by man
i) unknown	fracture surface highly decomposed; impossible to assess

7. LABORATORY PROTOCOL

7.1 Handling of specimens

The ordinary steps in handling of specimens returning from field work includes:

i. Placing the specimens in a freezer for 3 days (to kill insect larvae).
ii. Packaging of specimens in boxes for long-term storage.
iii. Identification of specimens.
iv. Making a proper reference collection of identified specimens.

Preparing for long-term storage

As soon as collected specimens return from fieldwork they should be placed in a deep freezer for at least 3 days to kill insect larvae. Before putting the samples in the freezer, the specimens should have room temperature to give the larvae a maximum temperature shock that kills them. After this treatment, the specimens should be packed in carton boxes for long-term storage in room temperature. The specimens should be kept sorted according to their collection number, and the interval of specimen numbers contained in a box should be written on the box.

Identification of specimens

This is a typical winter activity that requires expert competence. Make sure that all locality and substrate (log and snag) data have been digitised and is available on a list of specimens before identification is planned to start. Substrate information will be helpful in the identification of substrate specific species.

Reference collection

After identification, the identified specimens should be labelled properly and stored in reference collections. Two or three reference collections should be established:

a) a reference collection for field workers to assist identification of species.
b) a reference collection for Canadian expert(s) that carry out microscope identification (if this is another person than field workers)
c) a reference collection in a national (Alberta state) natural history museum to document the species within the scientific community.

A data program should be developed to produce labels and data files for input to databases associated to the reference collections.

7.2 Identification of specimens

The laboratory identification of collected specimens should be performed in two (sometimes three) steps where unknown or difficult specimens are passed over to the next expertise level:

1) by specially trained field workers
2) by Canadian expert(s), preferably situated in Alberta
3) by international expert(s)

Trained field workers

Many polypore species are easily identified. The growth forms of polypore fruit bodies are characteristic for each species. Host tree species, rot type, shape and size of fruit body, odour, colour, size and shape of pores or gills, softness, hairs, etc. are macroscopic features which help identification. Sometimes internal variation and similarities with other resembling species can make macroscopic identification difficult, especially in the case of resupinate species. In these cases collection of fruit bodies for microscopic identification is necessary (Niemelä 2003). It is realistic to develop routines where specially trained field workers learn macroscopic identification with the help of CD-rom, photo guides and a reference collection. Besides, some simple chemical tests e.g. with KOH could be done. Preferably already the first year, but absolutely after an initial year of macroscopic

identification, it is possible and desirable for 2-3 persons to learn microscopic identification. This will bring down the costs (as external experts will be more expensive) and it is also necessary in order to build up identification capacity associated to the ABMP.

Canadian expert(s)
Especially in the first years, it will be necessary to have a large number of specimens identified by a trained mycologist who knows the identification criteria of microscopic identification. The ideal situation would be if ABMP could establish an agreement/contract with one or more mycological expert(s) in Alberta that is working at an institution with a fungus herbarium. The main responsibility of these experts would be to identify specimens that need microscopic identification. The experts can also verify or correct uncertain identification by the trained field workers. It is perhaps relevant to double check "certain" identifications by the field workers. The experts should also double-check all specimens in the reference collection used by the field workers. During a period of some 2-3 years these experts should transfer their expertise in microscopic identification to the field workers or some other persons who can carry out microscopic identification on a long-term agreement (e.g. for 5-year periods).

It would be an advantage if these experts work in Alberta. That would facilitate near contact with the field workers. It would be natural that these experts would have the additional responsibility to curate a collection of ABMP samples as a part of an official Alberta state reference collection for fungi (see section 7.3).

International expert(s)
At the final level, Prof. Leif Ryvarden has expressed his willingness to play the role as a backup expert to identify/verify rare or difficult species. Leif Ryvarden is a world top expert in polypore identification. He is the author of the North American identification book on polypores (together with Gilbertson), and he will also be co-author of a planned revised polypore identification guide. Ryvarden is also willing to visit Alberta for initial training of persons both for field and laboratory identification of wood-inhabiting fungi.

Identification tools - necessary equipment
Ideally a phase-contrast microscope should be used for identification, but other microscopes may also serve the purpose of identification. Several chemicals are needed to mount and stain preparations, see Ryvarden and Gilbertson (1993) for techniques and list of chemicals needed in microscopic identification.

Gilbertson and Ryvarden (1986, 1987) will be the standard references for polypore identification – both macroscopic and microscopic identification. Updated material for some species is available from articles in peer-reviewed journals.

7.3 Making and maintaining reference collections
The local inventory team should build up a reference collection for comparison and improving their identification skills.

A small sample set of common species should also be deposited in an official Alberta state reference collection. All samples of rare species should be deposited in an Alberta state reference collection. Some of these samples should be split to have reference samples also of rare species at the disposal for local inventory teams.

7.4 Time budget
Specimen handling
Collected specimens can be treated as bulk material (as long as they are kept sorted according to the collection number). The procedure of handling the specimens as described in section 7.1 i. and ii. to the stage of identification will need on average some 10 minutes per site.

Identification
Based on Scandinavian experience, one can expect to obtain on average 0.65 records of polypore fungi per investigated log. A Norwegian study of 4146 logs produced 2682 records of polypores, including annual species (where one record was one individual species on a log). The number of samples will be slightly higher than this, as one regularly will sample the same species twice on a log (such "double-sampling" is left out in the 2682 figure). On the other hand, once a species is identified from a log or a sampling site one rapidly identifies additional specimens of the same species.

The average number of logs per ABMP site can be expected to be around 15 when inspecting the logs along a 100 m transect length, i.e. one can expect about 10 polypore records per site. Above (section 4.2) we estimated that the average number of species per ABMP site can be expected to be 4.8 species (including annual species), i.e. about 5 "new" species identifications. To be conservative, one can assume that 4 out of 10 records and 1-2 species per site already is identified in the field or rapidly (less than one minute) without the need of microscope in the lab. Thus, one can expect that some 6 records and 3-4 species need identification by means of microscope. By definition, most species on a site will be common ones that are easily recognised by an experienced expert on polypore identification (often also in cases of microscopic identification). Experience from microscope identification indicates that some 10-15 minutes are needed on average per species identification. All this implies a total time budget of 1-1.5 hrs/site for identification of all records (including annual species). At the beginning the time use will perhaps be closer to 2 hrs/site, but the time use will probably soon drop below 1.5 hrs/site.

Assuming that proper software is developed to produce labels and data records for reference collections, the identification time also includes preparing specimens for final storage in reference collections.

Preparing specimens for reference collection
This requires a load of reference collection envelopes and a fixed cost (plus maintenance) of software to produce labels and database input files. The running cost will per haps be some 2-5 CAD per site.

8. IDENTIFICATION TOOLS AND TRAINING OF PERSONNEL

8.1. Photo guide and field identification

Of the 72 perennial species listed in Appendix 1, about half are easy to recognize in field, and about 80 % are relatively easily recognized with some training. The local field guide (Schalkwijk-Barendsen, HME. 1991) would be a useful inclusion for training field personnel. There is also an excellent photo guide and study material available on CD-rom. This CD-rom, called Polypores of Finland (Niemelä and Meike 1999, ISBN 951-45-9028-7), covers about 70 % of the species on the list. Besides of the photos, the CD-rom has descriptions and definitions of species in English. The CD-rom is available from the Finnish Museum of Natural History with reasonable price. For the rest of the species, photographs and other identification material is available through Internet and field guides.

Based on recommendations from one of the reviewers we suggest that fruit bodies of polypores should be mounted onto a cork-board with nails along with their names. This makes an excellent display that reinforces rapid and correct identification of polypores in the field. This decreases the number of samples that have to be collected and carried back to the lab. It also makes identification of specimens brought back to the lab quicker. A photo album will be helpful, but consider also making posters from the photos as well to be placed in the office/lab areas of the field workers. A picture or a specimen on a cork board creates a good search image.

8.2 Field technicians and field identification

Identification of polypores in the field will greatly reduce the amount of subsequent work that needs to be done in the lab. We suggest that ABMP train the field personnel to be able to identify as many polypores in the field as possible to reduce subsequent lab work by highly trained mycologists. This will speed up the identification progress and greatly reduce the costs as well. Training of field technicians for field and laboratory identification can be done in two phases. The first training period could be connected to the field testing of the protocol in spring/early summer in 2005. This period could be 1-2 week long. Another training period could be arranged in fall 2006 (1-2 weeks) to teach selected field staff members the basics of macro- and microscopic identification in the lab.

Presently, for mosses and lichens, the field crews in the ABMP collect all the target species. Since they do not "know" the species, they simply collect all specimens that "look" like new species at each micro-habitat. This means that more specimens are collected than necessary, but it eliminates the need for field staff to identify the specimens in the field. The samples are then stored and later identified in the lab. In August, the field staff receives a 1-day workshop to learn the common species. They then identify these common species (this includes 40-50 species and about 75% of the specimens). The "more difficult" specimens are packaged and sent to experts for identification. This process speeds up field collection and has proven to be cost effective. This procedure will also work well for the fungi, but we recommend 1-2 days for teaching macroscopic identification and one week to learn and become familiar with microscopic identification.

8.3 Budget for enhancing identification competence

The budget comprises of the travel and salary costs of experts hired for the field test and lab training period. Because the expenses are much dependent where the expert(s) are hired and what their salary/cost requirements are, no exact budget can be given. See, however, some suggestions in chapter 10.

9. FIELD TESTING AND ASSESSMENT OF STATISTICAL POWER

9.1 Needed field testing

A field test of the proposed method in real plots is necessary. Our experience in outlining the field protocols is that plans made without real testing in field circumstances may fail to cover important aspects simply because it is difficult to anticipate all variation and special circumstances which are found in nature. This is especially true when research or monitoring is conduced in several and very different habitat types. Second, in the proposed field protocol, all assumptions concerning time use are based on experience from Scandinavia (with some input on abundance of dead wood from Alberta). It is therefore highly relevant to assess these time budgets based on experience from ABMP plots. Third, a major purpose of a field test is to provide material for statistical testing, to see if the collected material is sufficient for proper statistical treatment of data between the sites and the regions. Fourth, in the case of ABMP where field staff is not specifically trained to monitor polyporous fungi, it will be useful to give practical training for the staff how to search, collect and handle species and give practical hints and guidance for identification of species.

In addition to these points, three independent referees as well as the ABMP Science committee have indicated that various aspects of the proposed methodology need local verification, testing and final adjustments before it is ready for operative use.

9.1.1 The fungus sampling protocol

Time budget. This is probably the most important aspect to evaluate in a field test. The time usage for sampling and measuring fungi along a 100 m transect will vary substantially according to the number of downed logs that are encountered. This test should be conducted in various forest types (pine dominated, spruce/fir dominated,

broad-leaved dominated) and forests with different disturbance history (from natural unmanaged forests to forests with a long management and timber extraction history, high-low fire frequency). This will capture the full variation in amount of downed woody material and it will show the variation and average time budget for the proposed methodology.

Adequacy of sampled material. The number of fungus records and the number of encountered species will become evident if some 15-20 plots are investigated. It should be a goal to obtain sufficient data to test if the amount of collected material will fulfil the statistical requirements of ABMP. In this report we have argued that an average of 15 logs per plot should be a sampling target. It should be assessed a) if this is realistic based on a 100 m transect length and b) if the number of obtained fungus samples verify the relevance of 15 logs as an average sample target.

Time budget, convenience of sampling fungi on snags and live trees. For a limited number of plots (e.g. some 5-10 plots), the time usage for the snag and live tree inventory should be measured with and without sampling fungi as described in this protocol. This should be done both by an experienced and an untrained person. The convenience of the additional fungus sampling should be assessed.

Adequacy of field forms. It is necessary to test how well the outlined field forms fulfils their purposes, and make necessary modifications to the forms.

9.1.2 The dead wood material (DWM) protocol

Appropriate transect length. The transect length is critical for assessing both the local abundance and diversity of downed woody material (tree species, decay classes, dimension classes). This local abundance and diversity is a significant predictor of species occurrences in addition to the quality of the individual logs where the fungi are sampled. Thus, it is very important to identify an appropriate transect length that captures this variation. We suggest that a total transect length of 300 m is established for each plot in the field test. Then one can evaluate to which degree a 100 m and a 200 m transect length capture the variation obtained by an even longer transect.

Time budget of few and many measurement variables. A standard Canadian line transect inventory of DWM would identify the tree species, the decay class and measure the log diameter at the transect line. We have suggested that the following parameters should be added: basal diameter, top diameter and log length, and we have estimated the additional time usage to be 15-30 min. on average for 100 m transects. We suggest that for some 10-20 plots both parameter sets are measured to estimate the real time difference. We also suggest a variety of the first method to be tested, namely to add a visual assessment of the basal diameter when standing at the transect line. The reasoning for this variety is that the basal diameter is a very important substrate parameter - a quick and rough estimate of this parameter (into 10 cm intervals) is far more valuable than no information.

9.1.3 Training field staff

Searching and specimen handling. This part of the field test should focus on how to search for polypores in field, and how to collect and handle samples.

Fungus identification. It would be very useful to start teaching the field staff identification of the commonest polypore species during this field test. Large capacity of field identification will greatly reduce subsequent work and reduce overall costs significantly.

Assess species list in Appendix 1. This Appendix outlines many of the species that should be expected in ABMP. One should compare appendix 1 with the species encountered in field, and make necessary additions to the proposed list.

Ideally, field-testing should be done at least in three different forest site types with different tree species composition. This would allow detecting how well the protocol is functioning in different circumstances. A test period of 2-3 weeks is suggested. We suggest that one forest type is investigated rather thoroughly (i.e. some 10 sample sites) to get a better empirical basis for statistical assessments. It is preferable that several of the test sites are actual ABMP sample sites, but in order to reduce travel time, additional test sites nearby ordinary ABMP sites can be established for the purpose of getting more data.

9.2 Data needed to assess the statistical power of the suggested field protocol

The statistical power requirements in the ABMP is that a major change shall be detected with a specified statistical certainty (for details see section 4.3, *statistical considerations* …) for

- species richness
- population density (presence and abundance) of selected species

In order to detect a specified difference in species richness between two samples (either in space or time) it is necessary to know the statistical properties of the samples, decide relevant testing method(s) and determine sample sizes needed to meet the statistical power criteria. The ability to detect population density differences of individual species is very much dependent upon the number of localities with the occurrence of the species. By using sample data from the suggested number of ABMP sites and a large data set from Scandinavia we can assess this as described below.

Altogether some 20 sites should be sampled for fungi in 2005 according to the protocol described in this report. These sites should represent different forest types (pine forest, spruce/fir forest and broad-leaved forest). Then we can judge to what degree the forests of Alberta resemble corresponding Scandinavian forests, and make rather precise assessments of statistical power based on the pilot data from Alberta and comparable data from Scandinavia. This is outlined in section 9.4 below.

9.3 Timing of field test

The field test should take place in the same time window as the planned monitoring program in full operation, at the beginning of the field season in spring or early summer 2005. Because the proposed protocol is connected with the measurement of both trees and snags and down deadwood material, it should be done at the same time with these protocols to avoid double work. An expert of the method should follow the field staff and test the protocol with them, and teach them the searching, sampling and sample handling methods.

Scandinavian experts can help with laboratory identification of the samples from the field test by the end of September 2005. The analysis of the statistical power of the method can be done by the end of November 2005. A Canadian reference collection from the collected material can be initiated with a separate agreement. A two-week training period for macroscopic and microscopic identification of the species can be arranged during the fall 2006 if the ABMP decides to forward with the fungus protocol.

9.4 Assessment of statistical power

In this report we have made some superficial judgements concerning statistical power. These judgements are basically grounded in a comparable large data set from Norway (160 sample sites), but we do not know to which degree these judgements actually fit to the situation in Alberta. Based on the empirical data that is established in the field test, we can do much better judgements and realistic power assessments.

First we will quantify the difference between Alberta and Scandinavia in the number of species encountered per sample site (taking into consideration the number of investigated dead wood units). Based on this comparison we can adjust the Scandinavian data set to represent a simulated data set from Alberta. Since the power parameters are related to sample size, we can use the simulated data set to assess the α- and β-values as functions of sample size.

For individual species, we will compare both the *presence* (number of sites with the species present) and *abundance* (number of sampled logs with species present) data between Alberta and Norway. Based on this comparison we can scale up the data from the field test and make much better judgements concerning the number of species that can be expected to be encountered in different abundance classes (1-10 sample sites, 11-20 sample sites, … etc.). Furthermore we can use the Norwegian data set to assess the statistical power of example species within each of these abundance classes.

Since a full-scale data set already exist in a digitised format that is well suited for these statistical analyses, the specific assessments can be carried out during some few days. We suggest that the resulting report should be written as an appendix to this fungus protocol and therefore it can be rather short as the background information is already presented in this report. We assume that salary for about 1,5 weeks is needed to perform these analyses and write a summary report. This assumes that all necessary data from the field test is prepared in a digitised format (this activity is NOT included in the field budget).

10. TOTAL BUDGET

In the following budget we summarise the estimated time budget of the fieldwork. This time budget shows the time expected to be used on average for fungus sampling at one site (i.e. travelling into and out of the sample site is not included). The time budget is split into snag/live tree sampling and downed wood sampling, because we recommend these fractions to be sampled separately. We have also estimated the extra time needed to measure some additional parameters in accordance with or recommended adjustments of downed dead wood.

The variable costs in the laboratory phase are figures that can be expected after a while when experience and working routine is well established (e.g. near end of the first winter with ordinary laboratory work).

The fixed costs of the field test, assessment of statistical power and identification training are some preliminary guesses of minimum costs. Real expenses will probably become somewhat higher.

Variable cost in fieldwork	
Preparing collection bags with reference number	5 min/site
Fungus sampling, snags and large trees	6 min/site
Fungus sampling, downed wood	1 hr 15 min/site
Additional parameters, dead wood protocol	30-45 min/site
Doubling transect length, dead wood protocol	?
Variable cost in laboratory work	
Specimen handling	10 min/site
Specimen identification	1 hr 30 min/site
Preparing specimens for reference collection	3 CAD/site
Fixed costs	
Photo guide	? CAD
Field testing, 3 Scandinavian experts	9031 CAD
Assessing statistical power	5000 CAD
Identification training	3000 CAD
Software and database development, ref.collection	? CAD

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Appendix 1.

Proposed polypore species to be included into the monitoring programme. The occurrence of species in Alberta is indicated by a question mark when it is very probable, but no literature reference has been found.

Species	Occurrence in Alberta	Duration of basidiocarps	Tree species	Rot type	Growth form	Distribution in North America
Antrodia albobrunnea	*	1-2 years	Pinus (Abies, Larix, Picea, Pseudotsuga, Tsuga	brown	resupinate	circumpolar in boreal zone
A. alpina	?	perennial	Pinus, Larix	brown	resupinate	Northern Rocky Mountains, Alps in Europe
A. carbonica	?	1-several years	Pseudotsuga, Picea, Pinus, Thuja, Tsuga	brown	resupinate	W.N. Am. up to British Columbia
A. crassa (Amyloporia c.)	?	perennial	Pinus, Picea, Abies, Larix, (Juniperus, Taxus)	brown	resupinate	Western coniferous forests (circumpolar)
A. heteromorpha	*	1-some yrs	conifers, hardwood	brown	half-resupinate	circumpolar in boreal zone
A. malicola	*	1-2 years	Acer, Betula, Fagus, Populus, Salix, other angiosp.	brown	resupinate	occasional in WNA
A. serialis	*	1-2 years	conifers, sometimes hardwood	brown	resupinate	in coniferous forests all over N.A.
A. sinuosa	*	1-some yrs	Abies, Larix, Picea, Pinus, Pseudotsuga	brown	resupinate	circumpolar in boreal zone
A. sitchensis (Amyloporia s.)	*	annual-perennial	conifers Abies, Larix, Picea, Pinus, Psuedotsuga	brown	resupinate	coniferous forests in WNA
A. xantha (Amyloporia x.)	*	1-some yrs	conifers, rarely on hardwood	brown	resupinate	circumboreal
Cerrena unicolor	*	perennial	Betula, other hardwood	white	pileate	widely distributed in NA
Datronia mollis	?	annual-perennial	hardwood	white	pileate, occasionally resupinate	northern forest region of NA
D. stereoides	*	perennial	Populus, Betula, other hardwood	white	half-reupinate	widely distributed in NA
Dichomitus squalens	*	annual-2nd year	conifers	white	pileate, semi-resupinate	widespread in coniferous zone of NA
Diplomitoporus lindbladii	*	annual -2nd year	Abies, Larix, Picea,Populus, Betula, Pseudotsuga, Tsuga	white	resupinate	circumpolar in boreal zone
Echinodontium tinctorium	*	perennial	Abies, Tsuga, rarely other conifers	heartrot in living conifers	pileate	throughout the range of fir and hemlock in WNA
Fomes fomentarius	*	perennial	Betula, Alnus, other hardwood	white	pileate	common in Canada
Fomitopsis cajanderi	*	perennial	conifers, esp. on Douglas fir, occasionally on hardwood	brown	pileate, occ. resupinate	coniferous forests throughout NA
F. officinalis	*	perennial	western larch, Douglas fir, other conifers	brown	pileate	western US and Canada
F. pinicola	*	perennial	conifers, occasionally aspen and birch	brown	pileate	widely distributed in coniferous forests in NA
F. rosea	*	perennial	Douglas fir, spruce, other conifers, quaking aspen	brown	pileate	throughout coniferous zone in NA
Ganoderma applanatum (=G. lipsiense)	*	perennial	Populus tremuloides, other hardwood, conifers	white	pileate	cosmopolitan species
Gloeophyllum abietinum	*	perennial	conifers	brown	pileate	one occurrence in Alberta
G. carbonarium	?	?	on burned or charred conifers	brown	pileate-resupinate	California, British Columbia
G. odoratum	?	perennial	conifers	brown	pileate	unclear, probably confused with G. protractum
G. protractum	*	perennial	conifers	brown	pileate	widespread in NA, esp. in coniferous zone
G. sepiarium	*	perennial	conifers, rarely on hardwood	brown	pileate	widespread in NA, circumglobal
Haploporus odorus	*	perennial	living Salix, also Fraxinus	white	pileate	recently recorded from NA
Heterobasidion annosum	?	perennial	living and dead conifers	white pocket rot	resupinate-pileate	throughout coniferous zone, not common in

							central RM
Inonotus obliquus	*		annual, but sterile conks perennial	Betula, rarely other hardwood	white	resupinate	throughout NA,
Lenzites betulina	*		1-2 yrs	Betula, sometimes other hardwood and conifers	white	pileate	widely distributed in NA
Oxyporus corticola (=Rigidoporus corticola)	*		annual-2-3 yrs	hardwood (aspen) and conifers	white	resupinate	throughout NA, circumglobal
O. nobilissimus	?		perennial	Tsuga heterophylla, Abies procera	?	pileate	Oregon, Washington
O. populinus	?		perennial	living hardwood, esp. sugar maple	white	pileate	eastern NA, British Columbia
Perenniporia medulla-panis	?		annual-perennial	hardwood (Alnus, Querqus, Salix)	white	resupinate	eastern NA, British Columbia
P. subacida	?		perennial	Pinus ponderosa,Abies, Picea, Larix, also on hardwood	white	resupinate	throughout NA
P. tenuis (var. pulchella)	*		perennial	Aspen, other hardwood	white	resupinate	throughout NA in aspen forests
Phellinus chrysoloma	*		perennial	Picea, all genera of Pinaceae	white	pileate-resupinate	cosmopolitan species
P. conchatus	?		perennial	hardwood (Alnus, Betula, Populus, Salix)	white	pileate-resupinate	rarely found in West
P. ferreus	*		perennial	hardwood and conifers	white	resupinate	widely distributed in NA, cosmopolitan species
P. ferrugineofuscus	*		annual-perennial	conifers, esp. spruce and fir	white	resupinate	widely distributed in boreal zone, cosmopolitan species
P. ferruginosus	*		annual-perennial	hardwood and conifers	white	resupinate	widely distributed in NA, cosmopolitan species
P. gilvus	?		annual-perennial	hardwood, rarely on conifers	white	pileate	rare in central Rocky Mountains
P. hartigii	?		perennial	conifers, esp.Tsuga	white	resupinate (-pileate?)	cf. P. robustus
P. igniarius	*		perennial	hardwood	white	pileate	transcontinental
P. laevigatus	*		perennial	Betula, other hardwood, also reported from Picea	white	resupinate	widely distributed in NA
P. lundellii	?		perennial	Betula, Alnus	white	half-resupinate	probably transcontinental
P. nigrolimitatus	*		perennial	Picea, also other conifers	white	resupinate	common in spruce-fir zone in West
P. occidentalis	?		perennial	restricted to Crataegus	white	pileate	
P. pini	*		perennial	living conifers	white	pileate	widespred in coniferous zone of NA
P. prunicola	?		perennial	restricted to Prunus	white	resupinate	probably throughout northern USA & south. Canada
P. punctatus	*		perennial	hardwood and conifers	white	resupinate	widespread, circumglobal
P. repandus	?		perennial	conifers	white	resupinate (rarely pileate)	NW USA and British Columbia
P. tremulae	*		perennial	Populus tremuloides & P. grandidentata	white	pileate	wherever Aspen occurs
P. viticola	*		perennial	conifers, sometimes on hardwood	white	resupinate	widely distributed in NA
Piptoporus betulinus	*		annual, but recognizable 2nd year	Betula	brown	pileate	circumboreal
Pycnoporus cinnabarinus	?		annual, but recognizable 2nd year	Hardwood, rarely on conifers	white	pileate	circumboreal
Pyrofomes demidoffii	?	prob.not	perennial	Juniper	white	pileate	
Rigidoporus crocatus	?		perennial	Abies, Picea, Pinus, Pseudotsuga,Thuja, Tsuga,Betula	white	resupinate	widely distributed in NA
Skeletocutis lenis (Diplomitoporus lenis)	*		perennial	conifers	white	resupinate	widely distributed in NA
Skeletocutis nivea	?		annual-2nd year	hardwood, rarely on	white	resupinate-	eastern and western NA

			conifers		pileate	
S. ochroalba	?	annual-perennial	Picea glauca, possibly P. mariana	white	resupinate-pileate	?
S. stellae	*	perennial	Picea, other conifers	white	resupinate	in boreal zone
Trametes cervina	?	annual-2-3 yrs	hardwood (oak)	white	pileate	
T. hirsuta	*	annual-2-3-yrs	hardwood	white	pileate	throughout NA
T. menziezii	??					
T. ochracea	*	annual-2yrs	hardwood, rarely on conifers	white	pileate	widely distributed in NA coniferous forests
T. suaveolens	*	annual-2 yrs	Salix, Populus, Betula, Abies	white	pileate	widely distributed in NA
Trichaptum abietinum	*	annual, but recognizable 2nd year	conifers	white	pileate	circumglobal
T. biforme	*	annual, but recognizable 2nd year	hardwood, rarely on conifers	white	pileate	circumglobal
T. fuscoviolaceum	*	annual, but recognizable 2nd year	Pinus, Abies, Tsuga	white	pileate	circumglobal
T. laricinum	*	annual, but recognizable 2nd year	conifers	white	pileate	widely distributed in NA

Appendix 2. Outline of field form to sample fungi on downed logs.

Area				Site			Date		Worker				
Coordinates													
transect	transect position	CWD no	CWD type	Tree species	Mortality type	Decay stage	Basal diam.	Top diam.	Length	Fungus species	Sample no	Rot type	Remarks