# Wood-decaying fungi in protected buildings and structures on Svalbard

Johan Mattsson[1], Anne-Cathrine Flyen[2], and Maria Nunez[1]

[1]Mycoteam AS, P.O.Box 5 Blindern, N-0313 Oslo, Norway, E-mail: johan@mycoteam.no, maria@mycoteam.no

[2]NIKU, P.O. Box 736, Sentrum, N-0105 OSLO, Norway, E-mail: anne.flyen@niku.no

Norsk tittel: Råtesopp i fredede bygninger og bygningsmaterialer på Svalbard

Mattsson J, Flyen A-C, Nunez M, 2010. Wood-decaying fungi in protected buildings and structures on Svalbard. Agarica 2010 vol. 29, 5-14.

KEY WORDS
Svalbard, wood-decaying fungi, protected buildings, brown rot, *Leucogyrophana mollis*.

NØKKELORD
Svalbard, råtesopp, fredede bygninger, brunråte, *Leucogyrophana mollis.*

SAMMENDRAG
Svalbard har et kaldt og relativt tørt klima, men til tross for forventet ugunstige vekstforhold viser våre undersøkelser at det er relativt vanlig med råtesoppskader i fredede bygninger og bygningsmaterialer der. Den dominerende soppen i det undersøkte materailet er brunråtesoppen *Leucogyrophana mollis*, men det er også påvist enkelte andre råtesopper. Dette skadebildet skiller seg klart fra skadebildet i fredede bygninger i Antarktis, der det ikke er påvist noen arter av brunråtesopp. Skadene er mest omfattende langs gulv og i tak samt i trematerialer som står i jordkontakt.

ABSTRACT
The Arctic Archipelago Svalbard has a cold and relatively dry climate, but in spite of the expected adverse growing conditions for fungi, the present study shows that decay in protected buildings and building materials is relatively common. *Leucogyrophana mollis* was the dominant brown rot fungus in the investigated material, but a few other brown rot species and also soft-rot decay were found. This pattern of damage, with mainly brown rotting fungi, differs clearly from studies in protected buildings in Antarctica, where no brown rot fungi has been discovered. The observed damages on Svalbard are most extensive along floors and ceilings and in wood that is in contact with soil.

INTRODUCTION
Decay of wood caused by fungi is a normal process at least in temperate and tropic climates (Rayner and Boddy 1988). Since the fungal organisms have a minimum requirement with regard to physical conditions, *i.e.* mainly sufficient access to water and favourable temperatures (Domsch et al. 1980), the extent of biodeterioration is expected to decrease the colder the climate gets.

Spread around the cost of the islands of the Arctic Archipelago Svalbard are several trappers' cabins and buildings related to industrial activities (Fig. 1), mostly from the beginning of 20$^{th}$ century (Dahle et al. 2000). The buildings consist mainly of wooden materials, and they are constructed in an unsophisticated way, with the floor beams lying directly on the permafrost ground and with other wooden materials in direct contact with the soil (Fig. 2). Walls and roofs are either

**Figure 1.** On Svalbard there are many wooden constructions left from earlier industrial activity.

massive timber structures, often covered with wooden panel, or timber frame works with wooden panel on both sides. In some cases the exterior walls are covered by dense bitumen felt in order to prevent the wind from blowing through the walls.

On Svalbard all structures or objects of human activity from before 1946 are considered worthy of preservation and are automatically protected through The Svalbard Environmental Protection Act (2002). Thus all the buildings and structures we investigated, except for one, were protected.

In extreme cold climate, as in Arctic Canada, Svalbard and in Antarctica, few wood-decaying fungi have been found (Friesvad 2008, Blanchette et al. 2008, Kosonen and Huhtinen 2008). Several surveys have shown that the main cause of biodeterioration in Antarctica is soft rot fungi, *e.g. Cadophora* sp. and that no brown rot fungi could be found (Arenz and Blanchette 2009, Arenz et al. 2006, Held et al. 2005, Blanchette et al. 2004). Due to the cold and dry climate on Svalbard it has been generally assumed that biodeterioration followed the same pattern as in Antarctica – mainly a restricted decay caused by soft-rot fungi in direct contact with soil (Mattsson and Flyen, 2008).

Earlier records of wood decay fungi on Svalbard include the following species identified on fruiting bodies: *Antrodia serialis*, *Columnocystis abietina*, *Cylindrobasidium evolens*, *Dacryobolus sudans*, *Dacrymyces stillatus*, *Ditiola radicata*, *Gloeophyllum sepiarium*, *Hyphoderma setigerum*, *Sistotrema coroniferum* and *Stereum sanguinolentum* (Gulden and Torkelsen, 1996). Substrate and other relevant information are not reported.

Kosonen and Huhtinen (2008) recorded on twenty-four species of wood-rotting basidiomycetes in 115 samples, mainly sampled from wooden debris in soil contact and from driftwood on the beaches, some of then also with fruiting bodies. The five most abundant species were *Peniophora pithya* (17% of the identified species), *Veluticeps abietina* (11%), *Antrodia serialis* (10%), *Dacryobolus sudans*, *Hyphoderma praetermissum* (both 6%), and *Leucogyrophana mollis (*as *Hypochniciellum molle*, 4%) – all brown rot fungi. Other brown rot fungi were *Antrodia xantha* and *Gloephyllum sepiarium*. Mattsson and Flyen (2008) repor-

**Figure 2.** Wood in soil contact is decayed by both soft-rot and brown-rot fungi.

**Figure 3.** Old materials spread on the ground – a typical sight on Svalbard.

ted that in 54 samples taken from wooden constructions on Svalbard, *Leucogyrophana mollis* somewhat surprisingly occurred in 34 samples. *Coniophora puteana* was found in two samples, and one species in the family *Corticiaceae* was found once. On the arctic island Jan Mayen, with somewhat similar nature and climatic conditions as in parts of Svalbard, Ryvarden and Høiland (2009) found three species of corticiaceous fungi on drift wood: *Hyphoderma argillaceum*, *Hyphoderma praetermissum*, and *Tubilicrinis sororius*.

The objectives of this investigation were to study wood-decaying fungi in the historic structures on Svalbard, to identify the most frequent decay fungi, and to discuss the reasons for the specific pattern of decay at Svalbard.

MATERIALS AND METHODS

In the period 2002-2008, we examined around 100 protected buildings and building remains around the archipelago of Svalbard. Furthermore, in 2009 a total of 24 buildings, building structures and various drift wood were investigated (Fig. 3). On Svalbard, all building materials from 1945 or earlier are protected by law as cultural heritage. Sampling is for that reason strongly regulated, both by size and number. During the field work in 2009 we were restricted only to take a maximum of five samples no larger than 5 x 5 cm, and as thin as possible, from each building – without any dismantling. In addition we only got a limited amount of buildings to examine.

Among the buildings and structures that were investigated, one was a former office building in Longyearbyen that had stayed empty and unheated for several years. Also two buildings with permanent heating in Ny-Ålesund (a domestic house from around 1920 and a research station from 1960's) were examined. The other buildings were old and mostly abandoned trappers' cabins and cabins used as holiday houses, but only rarely. The building remains are to a great extent in soil contact. and generally exposed to the climate as there are no trees around. Almost all buildings and structures are located close to the ocean shore. Every one of the buildings and building remains we have examined were protected by the law except for one, because it was build after 1945.

In total, the material consists of 191 wooden samples of damaged wood and 171 'tape lifts' from wooden surfaces from all over the archipelago sampled in the period of 2002-2009. The locations where samples were taken are shown in Fig. 4. In the 'tape lift' procedure a crystal clear, stichy tape is applied to the wooden surface and the fungal structures on the surface are thus sampled for further identification. The tape need to have good properties suiting both preparation with staining agents and microscopical analyses. The samples are taken from representative areas of the damaged materials and constructions, *i.e.* where the decay is most pronounced.

The sample analyses were done with a light microscope, with up to1000x magnification. The mycological sources used in

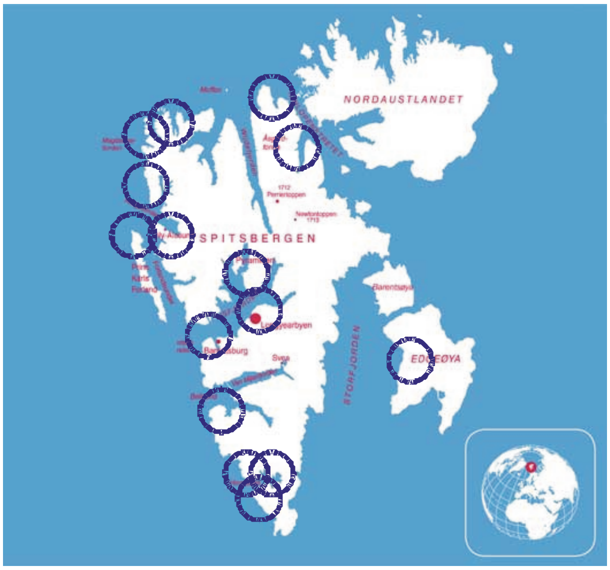


**Figure 4.** Sites where samples have been collected 2002-2009. The map is obtained from Universitetssenteret på Svalbard – UNIS, www.unis.no.

order to identify fungal structures that were found in the wooden cells and surfaces were: Hallenberg and Eriksson (1985), Harmsen (1982), Cockroft (1979), and Eriksson and Ryvarden (1976).

## RESULTS

Fruiting bodies of wood decay fungi were not found. Totally 362 samples from wood were collected, of them 191 wooden samples and 171 'tape lifts'. In 109 of them we found wood-decaying fungi. The most dominating wood decaying fungus was identified as *Leucogyrophana mollis*, which was found in 92 samples (85% of the identified species). The other fungi sampled were *Antrodia serialis* (3 samples), *Coniophora puteana* (2 samples), *Gloeophyllum sepiarium* (1 sample), *Hyphoderma tenue* (1 sample) and *Sistotrema brinkmannii* (2 samples).

The damages observed were mainly on wood in soil contact, but decay also occurred in roofs and walls. *Coniophora puteana* (Fig. 5), Corticiaceae sp., *Sistrotrema brinkmannii*, *Antrodia serialis* and *Gloeophyllum sepiarium* were found in walls and roof constructions.

Occasionally we could observe several species in one and the same sample. Eight of the samples consisted of unidentified species in the family Corticiaceae. In addition several samples were clearly deteriorated but we did not find enough characteristic fungal structures for a positive identification of the species. These samples were mainly collected from materials in contact with the ground. Soft-rot was found in 89 samples and unidentified brown rot fungi were present in 25 samples. These samples were mainly collected from wood in soil contact.

## DISCUSSION

### Environment conditions and establishment of growth

The climate on Svalbard is in general extremely harsh for wood-decaying fungi. To our experience with fungal growth on Svalbard, the climate is crucial in limiting wood decay. Only when the wooden structures and the microclimate offer the most optimal conditions there seems to be a risk of attack

**Figure 5.** Extensive decay by *Coniophora puteana* in a water damaged wall.

(Gobakken et al. 2008). This does also seem to be the conclusion from previous studies by Kosonen and Huhtinen (2008).

The external wooden surfaces are only suitable for biodeterioration to a limited extent. In addition to the extreme climate, this is due to a combination of the drying effect from the wind itself and the influence of ice-crystals blown by the wind, causing surfaces as if scrubbed, *i.e.* defibration of the wood (Blanchette and Farrell 2002). The effect of this is a mechanical erosion of the outer wooden cells through most part of the year. For that reason, successful germination of fungal spores of slow-growing species is almost impossible on an outdoor wooden surface.

| Name | No. of samples |
|---|---|
| *Leucogyrophana mollis* | 92 |
| Soft rot-damage | 89 |
| Unidentified brown rot | 25 |
| Corticiaceae sp. | 8 |
| *Antrodia serialis* | 3 |
| *Coniophora puteana* | 2 |
| *Sistrotrema brinkmannii* | 2 |
| *Gloeophyllum sepiarium* | 1 |
| *Hyphoderma tenue* | 1 |

**Table 1.** Identified and unidentified wood-decaying species.

Fundamental limiting factors for fungal growth on Svalbard are suitable temperatures and water content. The temperature has to be at least above 0º C and the water content in the wood more than 20% (Mattsson 1995). Accordingly, decayed wood is found in areas with a combination of temperature above 0º C and high water content for as long periods as possible. Such conditions are mainly occurring where the wood is in contact with soil that thaws during summer. Other typical sites where we found extensive decay were places close to leakages through roofs and in some cases areas exposed to periods of extra high relative humidity like in crawlspaces.

Even if conditions for wood-decaying fungi are marginal, we have observed that local attacks of *Coniophora puteana* can be extensive, showing that the ecological condition for growth of fungi in buildings on Svalbard occasionally can be very favourable (Fig. 5). In one case of established growth of *C. puteana*, in an unheated trapper's cabin, we could even observe a considerable growth of the same fungus after one year on a new, sterilized wood sample that had been placed in contact with the attacked wood. This shows that local contamination happens to new material and further that the development can be relatively fast.

There is a very restricted amount of natural substrates for wood-decaying fungi on Svalbard, since woody plants are restricted to dwarf willows (*Salix* spp.) and a few small bushes of dwarf birches (*Betula nana*) (Kosonen and Huhtinen 2008, Friesvad 2008). The closest natural habitat for these fungi is more than 700 km away, on mainland Norway. Accordingly, it can only be expected a very low number of spores from wood-decaying fungi on the islands and hence a very restricted risk for fungal decay of building materials. The limited number of records of brown rot fungi other than *L. mollis* in our material indicates that these fungi can have been introduced to Svalbard together with building materials that regularly are shipped from the Norwegian mainland. The frequent occurrence of *L. mollis* on Svalbard, with considerably higher numbers than on the Norwegian mainland (se Table 2, below), does in our opinion indicate that this species may have a natural occurrence in the soil on Svalbard.

**Figure 6.** Typical growth conditions for *Leucogyrophana mollis* in lower part of walls, close to soil.

**The dominance of brown rot fungi**

Blanchette et al. (2008) reported that they did not find any brown rot fungi in their material of decayed wood in Arctic Canada and damages found in Antarctica are caused by few species of soft rot fungi (Arenz and Blanchette 2009, Arenz et al. 2006, Held et al. 2005, Blanchette et al. 2004). On Svalbard, we found brown rot fungi to dominate and that the most common fungus causing decay of wood indeed was the brown rot fungus *Leucogyrophana mollis* (Figs. 6, 7).

In general there are few reports of occurrence of *L. mollis* from Svalbard and other polar regions. One reason could be that this fungus can be hard to identify without extensive knowledge and mycological experience, due to the fact that it rarely produces fruiting bodies in buildings. Kosonen and Huhtinen (2008) reported *L. mollis* from Svalbard (as *Hypochniciellum molle*) in five of their 115 samples (= 4.3%).

Alfredsen et al. (2005) found that the most abundant genera in wooden samples from buildings in Norway (collected during 2001-2003 (n = 3434)) were *Antrodia* spp. (18.4%), closely followed by *Coniophora puteana* (16.3%) and *Serpula lacrymans* (16.0%). Furthermore, soft rot fungi (unidentified) occurred in 15.8% of the cases, species in Corticiaceae in 5.7%, *Leucogyrophana mollis* in 2.0%, and unidentified white rot fungi in 0.3% of the cases. Finally, there was a group of unidentified decay fungi in 17.0% of the samples. We found a strongly different pattern of distribution in our samples from Svalbard (Table 2).

One factor that might partly explain the successful growth for *L. mollis* on Svalbard can be its pigmented, thick-walled chlamydospores, because they probably provide resistance against UV-light, cold climate and dry periods (Fig. 8).

**Figure 7.** Extensive brownrot decay in upper part of wall caused by *Leucogyrophana mollis*.

| Identified species | Norway (n=3434) | Svalbard (n=108) |
|---|---|---|
| *Antrodia* sp. | 18.4% | 1.3% |
| *Coniophora puteana* | 16.3% | 0.9% |
| Corticiaceae sp. | 5.7% | 3.6% |
| *Gloeophyllum sepiarium* | 2.9% | 0.4% |
| *Leucogyrophana mollis* | 2.0% | 41.3% |
| *Serpula lacrymans* | 16.4% | - |
| *Sistrotrema brinkmannii* | 0.1% | 0.9% |

**Table 2.** Occurrence of wood-decaying fungi in buildings in Norway (Alfredsen et al. 2005) and Svalbard (this paper).

**Building ecology and *Leucogyrophana mollis***

From his studies in Denmark, Harmsen (1982) reported findings of *L. mollis* on beams and boards of coniferous wood, mainly from moist floors, windows and studwork. The species was found in 24% of the collected samples, often together with *Coniophora puteana*.

In Norway, including the archipelago of Svalbard, mycologists at Mycoteam have recorded *L. mollis* in 328 samples from building materials during the period 2001-2009 (Alfredsen et al. 2005 and this paper). Overall, the most common habitats in buildings (of samples with information about where the samples were taken) are transitions between outer wall and ground (26.1 %), cellars (25.8 %), roofs (18.3 %) and wooden floors (17.5 %). We usually find the fungus growing solitarily, as is the case of all Svalbard collections, and not together with *Coniophora puteana* as observed by Harmsen (1982). However, the brown rot caused by *L. mollis* often is reminiscent of the one produced by *C. puteana*.

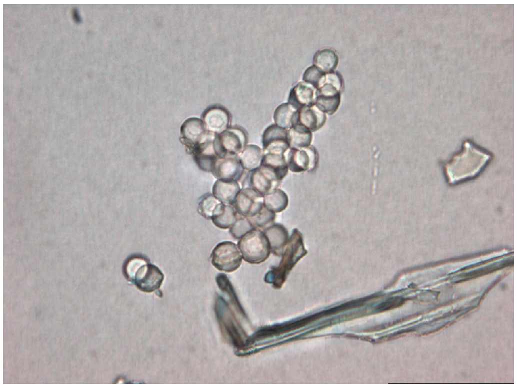

**Figure 8.** Chlamydospores of *Leucogyrophana mollis*.

On Svalbard, *L. mollis* has been proven to grow in roof constructions, walls, floors and in soil contact. A common factor in all cases is that the materials have been wet, at least in periods, for a long time. Many buildings and much material here are originally from early 20th century, and since the buildings in general have been in restricted use moisture conditions have probably been stable for many years. In such materials, we often find high water content and a low to moderate temperature. Due to the fact that the examined buildings on Svalbard are constructed more or less directly on the permafrost and are only occasionally heated, a stable, high water content is clearly the dominant ecological condition for most of the decayed wooden material we found.

In mainland Norway we have observed mycelium and chlamydospores of *Leucogyrophana mollis* in experiments with buried parts of non-treated, vertical pine posts in direct contact with soil after one year of field trial (Mycoteam, unpublished). The ecological requirements for *L. mollis* are still relatively unknown, but our observations will probably help to explain occurrence and distribution of damages caused by this fungus in buildings.

**Taxonomic considerations**

In 1821 the Swedish mycologist Fries described the fungus *Thelephora mollis* as being membranous, reddish-ochraceous, and growing on pine trunks. Because the species has thick-walled basidiospores that become grey-blue in Melzer's reagent, Parmasto (1967) included it in *Leucogyrophana*.

In 'building mycology' the species is known as *Leucogyrophana mollis*. A description of the fungus together with ecological observations can be found in Harmsen (1982). When fruiting bodies are missing, an important identification character is the presence of thick-walled, yellowish chlamydospores. These are produced by the vegetative mycelium, and are usually found in large amounts on the timber surface (Fig. 8). But production of chlamydospores is also common in other *Leucogyrophana* species, for example *L. subillaqueata* (Eriksson and Ryvarden 1976).

According to Index Fungorum (2010), the current name for the fungus is *Amylocorticiellum molle* (Fr.) Spirin & Zmitr. *Leucogyrophana subillaqueata* (Litsch.) Jülich, which is similar to *L. molli*s by having basidiospores with a grey Meltzer reaction, producing chlamydospores, and causing brown rot, is also included in the genus *Amylocorticiellum*. Recently however, both species have been placed in the new order Amylocorticiales, phylogenetically at the base of *Agaricales* and *Boletales* (Binder et al. 2009), but in two different genera. Since the name *Leucogyrophana mollis* is widely used in 'building mycology', we have preferred to use this name until further phylogenetic analyses place this species more accurately. The family *Coniophoraceae*, which includes the *Serpula*, *Coniophora* and *Leucogyrophana* species, has been shown to belong in *Boletales* by DNA-analyses (Binder and Hibbett 2006).

**Detection of damages**

Wood-decaying fungi mainly grow inside wooden materials, especially in dry and cold climates (Mattsson 1995). Under favourable conditions the fungi can be seen on the surface, but this is not common. This fact leads to a clear need for destructive methods in order to reveal and sample fungal attacks. However, on Svalbard, all building materials from 1945 or earlier are protected by law as cultural heritage. Sampling is for that reason strongly regulated, both by size and number. For instance, during the field work in 2009 we were restricted only to take a maximum of five samples no larger than 5 x 5 cm, and as thin as possible, from each building – without any dismantling. In addition we only got a limited amount of buildings to examine. Following the protection regulations, permissions of sampling and dismantling are only given after a specific application for each building and it is hardly possible to get an extended permission during field work. Since a need for sampling and dismantling only is encountered during the actual survey, the limitations considerably reduced our possibility to investigate and reveal damages under roofing and inside walls and under floors. This is clearly not an optimal way to detect occurrence and extension of damages and variation in fungal attacks.The restrictions set by the conservations laws make it very hard to perform a comprehensive and thorough building survey of the historical buildings on Svalbard. The result is that many damages remain undiscovered. The practical impact of this is an incomplete understanding of the biodeterioration of the cultural heritage. This is unfortunate since the result can be ongoing decay and inadequate measures for their conservation. We have taken samples for further analysis from several damages and the results from this work may give new knowledge about occurring decay problems.

CONCLUSION

Biodeterioration in Arctic regions has earlier been regarded as a minor problem due to extremely low temperature and dry conditions. The maintenance and administrative handling of the cultural heritage in this region has been influenced by this opinion. However, our research has shown that the microclimate in both buildings and materials can be surprisingly favourable for biological activity. The effect of decay of building materials leads to a need for repair work and improvement of the constructions in order to prevent further development of decay. To optimize the results of building survey studies like ours, an improvement of the conditions for sampling is necessary.

Since low temperature is the main limiting factor for growth of fungi on Svalbard, it can be expected that any climate changes in direction of higher temperatures will increase the risk for biodeterioration in the wooden materials on Svalbard.

ACKNOWLEDGMENT
We would like to thank Svalbard Environmental Protection Fund for financial support for the field work and the mycological laboratory at Mycoteam for support with analyses of all samples.

REFERENCES

Alfredsen G, Solheim H, Jenssen KM, 2005. Evaluation of decay fungi in Norwegian buildings. International Research Group on Wood Protection, IRG/WP 05-10562.

Arenz BE, Held BW, Jurgens JA, Farrell RL, Blanchette RA, 2006. Fungal diversity on soils and historic wood from the Ross Sea Region of Antarctica. Soil Biology & Biochemistry 38, 3057-3064.

Arenz BE, Blanchette R, 2009. Investigations of fungal diversity in wooden structures and soils at historic sites on the Antarctic Peninsula. Can. J. Microbiol. 55, 46-56.

Binder M, Hibbett DS, 2006. Molecular systematics and biological diversification of Boletales. Mycologia 98(6), 971-981.

Binder M, Larsson K-H, Matheny PB, Hibbett DS, 2009. Amylocorticiales ord. Nov. and Jaapiales ord. Nov.: Early-diverging clades of Agaricomycetidae were dominated by corticioid forms. Mycologia, 102(4), 2010, pp.000-000.10.3852/09-288

Blanchette R, Farrell RL, 2002. Defibration of wood in the expedition huts of Antarctica: an unusual deterioration process occurring in the polar environment. Polar Record 38(207), 313-3223.

Blanchette R, Held BW, Jurgens JA, 2008. Norhumberland House, Fort Conger and the Peary Huts in the Canadian High Arctic: Current condition and assessment of wood deterioration taking place. ICOMOS International Polar heritage Committee, pp. 30-37.

Blanchette R, Held BW, Jurgens JA, McNew DL, Harrington TC, Duncan SM, Farrell RL, 2004. Wood-Destroying Soft Rot Fungi in the Historic Expedition Huts of Antarctica. Applied and Environmental Microbiology 70(3), 1328-1335.

Cockcroft R, 1979. Some Wood-Destroying Basidiomycetes, Vol. 1 of a collection of monographs. The international Research Group on Wood Preservation. Papua New Guinea.

Dahle K, Bjerck HB, Prestvold K, 2000. Kulturminneplan for Svalbard 2000-2010. Sysselmannens rapportserie 2/2000. Sysselmannen på Svalbard.

Domsch KH, Gams W, Anderson T, 1980. Compendium of soil fungi. Academic press, London.

Eriksson J, Ryvarden L, 1976. The Corticiaceae of North Europe Vol. 4, 812-830.

Friesvad, J C, 2008. Fungi in Cold Ecosystems. pp. 137-156. In R. Margesin et al (eds.): Psychrophiles: from Biodiversity to Biotechnology. Springer-Verlag Berlin Heidelberg 2008.

Gobakken L, Mattsson J, Alfredsen G, 2008. In-service performance of wood depends upon the critical in-situ conditions. Case studies. International Research Group on Wood Protection, IRG/WP 08-20382.

Gulden G, Torkelsen AE, 1996. A catalogue of Svalbard plants, fungi, algae and cyanobacteria part 3. Fungi I. Agaricales, Gastromycetales, Aphyllophorales, Exobasidiales, Dacrymycetales and Tremellales. University of Oslo.

Hallenberg N, Eriksson J, 1985. The Lachnocladiaceae and Coniophoraceae of North Europe. Fungiflora.

Harmsen L, 1982. Trænedrydende svampe i ganvtræ. Svampe 5:11-58.

Held BW, Jurgens JA, Duncan SM, Farrell RL, Blanchette RA, 2005. Assessment of fungal diversity and deterioration in a wooden structure at New Harbour, Antarctica. Polar Biology 2005.

Index Fungorum, 2010, CABI Bioscience, CBS and Landcare Research, http://www.indexfungorum.org/Names/Names.asp. Cited March 8 2010.

Kosonen T, Huhtinen S, 2008. Wood-rotting basidiomycetes of Svalbard (Norway). Karstenia Vo. 48 no.1, 2008. Helsinke.

Mattsson J, 1995. Råte- og insektskader. Tilstandsanalyse og utbedringstiltak. FOK-programmets skriftserie nr. 23. Norges Forskningsråd.

Mattsson J, Flyen A-C, 2008. Biodeterioration in buildings in Svalbard (Spitsbergen). ICOMOS International Polar heritage Committee, p. 23-29. 2008.

Parmasto E, 1967. Corticiaceae U.R.S.S. IV. Descriptiones taxorum novarum. Combinationes novae. Eesti NSV Tead. Akad. Toim. Biol. 16, 385.

Rayner ADM, Boddy L, 1988. Fungal decomposition of wood. Its biology and ecology. John Wiley & sons, Chichester.

Ryvarden L, Høiland K, 2009. Some higher Basidiomycota from Jan Mayen, Norway. Agarica 2009, vol. 28. Norges sopp- og nyttevekstforbund.

The Svalbard Environmental Protection Act, 2002. Act of 15 June 2001 No.79 Relating to the Protection of the Environment in Svalbard. The Norwegian Ministry of Environment.