Mushrooms in Spitsbergen
Leo M. Jalink and Marijke M. Nauta

Introduction
Even mycologists – scientists specializing in fungi – could hardly imagine that many mushrooms would occur in the Arctic region. Until the early 1980s very little attention had been focused on this region. It is now known that in Spitsbergen c. 300 species of macrofungi occur (Gulden & Torkelsen, 1996; Elvebakk et al., 1996) and that the densities (the number of specimens of a species per area) are often very high. It also turned out that fungi occur even in the most extreme parts of the area. In the 1980s, scientists from both the Netherlands and the Nordic countries carried out a considerable amount of mycological research in Spitsbergen. The results of this research – inasmuch as they are available – are summarized in this paper, which will also outline an overall picture of the occurrence and ecology of fungi in Arctic and subarctic regions.

In this study we have limited ourselves to the macrofungi, the larger (i.e., larger than c. 3 mm) fungi belonging to the morphological groups of the Agaricales (gilled mushrooms), ‘Gasteromycetes’ (puffballs), Ascomycetes and ‘Aphyllophorales’. The terms ‘mushrooms’ and ‘macrofungi’ are used indiscriminately.

To understand this paper properly, the reader needs to know that the generally short-lived mushroom is no more than the reproductive organ of a usually long-lived, invisible ‘plant’, the mycelium. The mycelium is usually in the soil, on or in rotting leaf litter, or in living plants if it is a parasite. In favourable conditions the visible fruitbodies are formed. It is in or on these fruitbodies that the spores which take care of the dispersal of the fungi are developed. The fruitbodies themselves are usually very sensitive to dry or freezing conditions, which occur frequently in Arctic regions. Due to its sheltered existence, the mycelium is less sensitive to such conditions.

Dutch research
The Dutch mycological research in Spitsbergen was a direct result of the presence of a well-equipped Dutch fieldwork station at Kapp Lee on Edgeøya which belonged to the Netherlands Foundation for Arctic Studies.
From 1969 onwards, Piet Oosterveld and a changing group of scientists worked from this station on a number of studies, with an emphasis on the relationship between reindeer (as primary consumers) and the vegetation (primary production). Tangible results of this research are an ecological landscape map of the whole island of Edgeøya, a typology of the vegetation (including mosses and lichens), a detailed vegetation map of part of the Rosenberg valley and the environment of the station, and a great deal of knowledge about the population dynamics and foraging behaviour of the reindeer. Another result was the determination of the surface biomass of thirteen vegetation types (Heinemeijer, 1979; Lebouille & De Nies, 1978).

To obtain a good understanding of the cycle of energy and nutrients, not only knowledge about production and consumption but also knowledge about the decomposition of organic material is essential. Although Oosterveld and his fellow researchers had often found fungi, nothing was known about the species in this region, although fungi play an important part in decomposition. At the invitation of Piet Oosterveld, in 1985 Barkman and Jalink set up a research, which was continued from 1986 onwards by Jalink and Nauta.

The type of research chosen was a mycocoenological study according to the methods of the Wijster school (Barkman, 1976 and 1987; Arnolds, 1986 and 1983). This method entails studying the macrofungi and vegetation, and the soil and other abiotic factors in permanent experimental plots. An important advantage of this method is the versatility of the results. On the one hand the research focuses on quantitative and qualitative description of the mycocoenoses (communities of fungi) in relation to vegetation and soil; on the other hand it also generates a large amount of knowledge about which species occur and the autecology of those species. Furthermore, the reproducible, quantified data thus obtained provide a good basis for comparisons with other areas and in particular for comparisons over time, for example to analyse the effects of air-pollution or the effect of global warming.

In addition to this research in semi-permanent experimental plots, forays were made to various accessible areas, collecting as many data as possible on the species of fungi occurring there and the biotopes in which they were found.
Fieldwork

In practice, the fieldwork consists of setting up a number of PQs (permanent quadrants) where the occurrence of macrofungi is studied over several years. This is necessary because not all of the mycelia present produce fruitbodies every year, and also because the numbers fluctuate per year depending on climatic conditions. In 1985, 34 plots each measuring 100 to 200 m² were set up in several selected vegetation types which were
considered representative, and investigated. In 1986 and in 1988 the plots were examined again. One plot which was difficult to reach could not be examined again after the first year because all attempts were frustrated by the presence of a polar bear in the vicinity.

Soil samples were taken in each plot; several abiotic parameters – such as depth of ice and humidity – were measured, and the extent of the presence of periglacial phenomena such as ice wedges, cryoturbation and gelification was determined. The vegetation was described in detail (including mosses and lichens) in each plot, using the Braun-Blanquet method.

Each year a mycological survey was made of each plot at least once. This survey entailed counting all the fungi, per species, in the plot and taking detailed notes about the habitat of the fruitbodies. Since many species could not be identified immediately and the chance of finding new, previously undescribed species in an area like Spitsbergen where hardly any research had been done was considerable, herbarium collections of all species were made. These collections served both as evidence of the species found and as a basis for taxonomic study. The collections were preserved by drying them at about 35 ºC, but before that could be done, the morphology of the fresh mushroom was described in detail and its dimensions and colours were accurately recorded, a job which can easily take half an hour per collection. A total of about 1800 collections were made (including the specimens found outside the plots). Moreover, about 600 colour slides were made of these species, preferably in their natural biotopes, but if the weather was too bad, indoors in artificial light.

As mentioned above, in addition to the research in the experimental plots, inventories were also made of species found elsewhere, on a number of locations on Edgeøya, Bjornøya, Barentsøya, Hopen and on the main island Vestspitsbergen. Figure 1 presents a survey of the areas visited.

Unexpectedly high numbers
The first extensive mycological research in Arctic regions took place in Greenland (Lange, 1948, 1955, 1957). Up until 1968, except for a few publications about ‘incidental finds’ of various expeditions (Karsten, 1872, Dobbs, 1942, Skirgiello, 1961 and 1968), nothing was known about the macrofungi of Spitsbergen. In that year the first survey by Kobayasi et al. (1968) appeared, listing 31 species of macrofungi. Soon after a more detailed study by the Finnish mycologist Ohenoja appeared (1971), with about 60 species. In the meantime arctic-alpine mycology had expanded
enormously, as is shown for example by the fact that an international symposium on the subject was held in Alaska in 1980: ‘The First International Symposium on Arcto-Alpine Mycology’ (ISAM I, Laursen & Ammirati, 1982).

In the literature up until 1984, a total of about 80 species had been recorded as occurring in Spitsbergen. Although there is still a lot of work to be done before all the results of the Dutch expeditions in 1985, 1986 and 1988 is published, and although some species have not yet been identified, the number of species we found is about 200, of which almost 150 on Edgeoya. Several of them are undoubtedly new to science.

In the same period, mycologists from Scandinavia, Finland and Denmark made inventories of fungi on Vestspitsbergen. There they found partly the same and partly different species, so that the total number of species found in Spitsbergen is now approaching 300. Part of this research has been published (Gulden et al., 1985; Gulden, 1987 & 1988; Gulden & Jenssen, 1988; Huhtinen, 1987; Lange, 1987; Gulden & Torkelsen, 1996; Elvebakk et al., 1996).

A further increase in this number can be expected. In 1988 the third international symposium on Arcto-alpine mycology (ISAM III) was held on Spitsbergen; both authors of the present paper participated. In addition to the presentations, much time was available for excursions in the surrounding areas of Ny-Ålesund, Gipsvika and Longyearbyen. Many species were found
on these forays, often species which could not be immediately identified. The results have yet to be published, but it is expected that many species can be added to the list for Spitsbergen.

As well as this unexpectedly high number of species, there was also a very high number of fruitbodies. Except in the very dry valleys and steep gravel slopes, it does not take long to find mushrooms in Spitsbergen. Usually several species can be found quite easily, some of them in enormous numbers. In 1985 and 1986 the number of fruitbodies of Agaricales per 100 m² in the experimental plots varied from 200 to 600, with extremes from 0 to 22,000, in other words as many as 220 mushrooms per m². In Spitsbergen most mushrooms can be found from about 10 July to well into mid-August.

**Distribution of species**

Not every species occurs throughout the whole archipelago. This is probably partly a result of climate differences: the west coast of the island of Vestspitsbergen is more humid and slightly warmer than Edgeøya. Edgeøya is regarded as the high Arctic, whereas the areas visited on Vestspitsbergen (except for Hornsund) are regarded as part of the mid-Arctic zone (Brattbakk, year unknown). Another difference is the soil, which on Edgeøya consists mainly of Triassic calcareous sediments and on Vestspitsbergen of the same but also volcanic rock. The climate and soil differences affect the

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**Figure 3. Distribution of Galerina pseudo-mycenopsis.**

- •: own observations;
- ▲: addition from Ohenoja (1971);
- ○: addition from Gulden (1987)

(map: Leo M. Jalink and Marijke M. Nauta).
fungi directly, but also indirectly, through the vegetation. An example of the latter is a certain species of bolete, *Leccinum rotundifolium*, which occurs only on the dwarf birch *Betula nana*, with which it lives in symbiosis. The dwarf birch is found only in the innermost parts of the western fjords and the same is true of *Leccinum rotundifolium*.

With respect to other species the cause of the distribution pattern found is less clear. It was striking that on the west coast of Vestspitsbergen many more species of genera such as *Mycena*, *Hygrocybe* and *Helvella* occur, that species such as *Lactarius pseudouvidus*, *Russula delica* and *Thelephora caryophyllea* are more numerous and that the species *Dermocybe polaris* is restricted to this area (see fig. 2). There do not seem to be any species which are found only on Edgeoya, although *Fayodia arctica*, for example, is much more common there than on the main island. Many species, including *Omphalina ericetorum*, *Omphalina alpina* (= *O. luteovitellina*), *Arrhenia lobata* and *Galerina pseudomycenopsis* (= *G. moelleri*, see fig. 3 and fig. 9) are distributed across the whole archipelago.

For mushrooms, which due to their light spores can be disseminated relatively easily by the wind, the biological law that ‘everything is everywhere and the environment selects’ seems to hold quite well. Many species appear to have an arctic-alpine distribution, i.e. some of the same species are found both high in the Central European mountains and in the lower mountains in Scandinavia, and again at sea level in Arctic regions. The further north these
species are found, the lower the elevation above sea level. This counts also
for mosses and a number of vascular plants (for example moss campion,
Silene acaulis). Very frequently species which were first described in the
Alps, where J. Favre, the pioneer of alpine mycology, was active as early as
the 1950s, were found in Spitsbergen or in the mountains of Scandinavia,
but also in Greenland and Alaska. This illustrates a second feature of the
distribution of mushrooms: many species have a circumpolar distribution. A
good example of a species with a circumpolar arctic-alpine distribution is the
webcap Cortinarius favrei, which lives in symbiosis with various dwarf
willows. This species occurs not only in Spitsbergen (see fig. 4), but also,
according to the literature, in alpine areas in continental Europe (including
the Alps and Tatra), Scotland, Arctic regions in the Nova Zembla-Kola area,
Greenland, Canada and Alaska (Ohenoja, 1971), and in alpine areas in the
United States (Rocky Mountains, Mooser & McKnight, 1987). Arrhenia
auriscalpium has a similar distribution (fig. 5); this species occurs mainly in
sparse pioneer vegetations or on bare soil (in Spitsbergen it usually occurs
on bare cryoturbation boulders; for its distribution in Spitsbergen see fig. 6).
Unfortunately, to date few data are available on the northern parts of the former USSR. There are a number of species with an arctic-alpine distribution pattern which have not – yet – been found in North America, although they have been observed in Greenland, for example *Clitocybe lateritia* and *Russula norvegica* (for distribution in Spitsbergen see fig. 7).

Some of the species found in Spitsbergen also occur in the ‘lowlands’ of Europe; they are limited mainly to ‘cold-climate’ regions. Sometimes they are also found in the Netherlands, for example the oysterling *Arrhenia lobata*, the heath navel *Omphalina ericetorum* and *Galerina pseudomycenopsis*. From the first reports about the Antarctic, where we are still at the ‘incidental finds’ stage, it seems that some species also occur in Antarctic and sub-Antarctic areas. These species include *Omphalina ericetorum*, *Galerina pseudomycenopsis*, *Coprinus martinii* (Horak, 1982) and *Arrhenia lobata* (Gulden & Jenssen, 1988).

In Spitsbergen itself elevation is also important. Most species are found at elevations between sea level and about 100 metres. On Edgeøya only three species were found above 300 metres: *Galerina pseudomycenopsis*, *Galerina arctica* and *Arrhenia lobata*; all three are moss inhabitants. The polar willow cannot tolerate this elevation either. Of course there is still a great deal to learn about the distribution patterns of mushrooms in the Arctic; at this stage it is impossible to present a detailed survey.
Many symbiotic associations

Fungi can be divided into a number of categories according to the way they obtain their nutrients: the parasites (usually on living plants), saprotrophs (which break down dead organic material such as humus, wood, dung, etc.) and symbionts, in this case the so-called ectomycorrhizal symbionts. Part of the mycelium of these species surrounds the roots of vascular plants, creating a contact zone in which the fungus exchanges all sorts of nutrient elements it extracts from the soil for sugars produced by the higher plant; in other words, this is a form of collaboration. However, it is not clear whether both parties benefit to an equal extent from the association. One of the most surprising results of the research on Edgeøya is the extremely high percentage of fruitbodies belonging to ectomycorrhizal species, which is about 80% (plot data from 1985 and 1986). From the data recorded by Senn-Irlet (1987), who carried out a similar study in the Swiss Alps, it can be deduced that in that region this percentage is only 35%. The high percentage on Edgeøya is even more remarkable in view of the fact that on Edgeøya only three species of higher plants occur which are able to collaborate with fungi in this way: the Polar Willow *Salix polaris*, a knotweed *Polygonum viviparum*, and Mountain Avens *Dryas octopetala*. On the west coast of Vestspitsbergen another two species occur: the dwarf birch *Betula nana* and the Reticulate willow *Salix reticulata*. Probably a total of more than
a hundred different species of fungus act as mycorrhizal partners for the polar willow. These fungi are species belonging to very commonly occurring genera such as *Lactarius* (Milkcaps), *Russula* (Brittlegill), *Laccaria* (Deceivers), *Cortinarius* (Webcaps), *Inocybe* (Fibrecaps) and *Hebeloma* (Poisonpies).

About 1% of the fruitbodies belong to a very special group, the basidiolichens. These are gilled mushrooms which live in symbiosis with green algae. The term basidiolichens is used to distinguish them from ‘true’ lichens, which consist of an ascomycete and a green alga or a cyanophyte. The basidiolichens include the commonly occurring species *Omphalina ericetorum* (*Lichenomphalia umbellifera*), *Omphalina alpina* (*Lichenomphalia alpina*) and *Omphalina velutina* (*Lichenomphalia velutina*). These lichenized *Omphalinae* are now regarded as a separate genus, *Lichenomphalia* (Redhead et al., 2002).
True parasites among the fungus species found are very rare and the remaining 20% are nearly all saprotrophs and weakly parasitic species. The vast majority of this group live on mosses. It is difficult to determine whether these fungi are harmful to the mosses on which they are found or not. Among the many moss-inhabiting species are the moss bells (*Galerina*, many species), the navels (*Omphalina*, especially the non-lichenized species) and the oysterlings (*Arrhenia*, three of the four species). The saprotrophs also include: on wood, one indigenous agaric (*Marasmius epidryas* on dead branches of *Dryas octopetala*) and a number of species of small ascomycetes from genera such as *Dasyscyphus, Hymenoscyphus* and *Mollisia*; on dung a considerable number of ascomycetes and a few species of inkcap (*Coprinus*); on litter and humus a very large number of species, including some belonging to the genera *Clitocybe* (Funnel) and *Lepista* (Blewit).

A true parasite which causes moss to die back is *Bryoglossum gracile*, a species which occurs on very wet moss tundra.
Of course, there is much more to be said about the ecology of the various species, but a detailed discussion of this subject falls outside the scope of this paper. Examples of species with very specific habitat demands are *Lepista multiforme*, which was nearly always found on the steep slopes of ice wedges, *Arrhenia salina*, which was always found in mosses in the salty spray zone near the sea, and *Coprinus martinii* (fig. 8), which always grew attached to the dead remains of grass, usually *Dupontia psilosantha*, in the soaking wet moss tundra. The species *Fayodia arctica* usually occurs in thick, not very humid moss carpets. At first it seemed likely to be a saprotroph, but when it was observed more closely it turned out that near the base of its stem dying pieces of lichens of the genus *Peltigera* could always be found. On one occasion *Fayodia arctica* was even attached to the lichen. It now seems more probable that it is a parasite.

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**Notes**

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