Investigation of the funga of Surtsey 2008

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ABSTRACT

In August 2008 eighteen specimens of at least ten species of agarics (mushrooms) were collected on Surtsey. *Entoloma sericeum* was well established in grassland in the oldest part of the gull colony and at least seven ectomycorrhizal species, *Hebeloma collariatum, H. marginatulum, H. mesophaeum, H. vaccinum var. vaccinum, Inocybe lacera var. lacera, Laccaria laccata* and an unidentified *Cortinarius* species, were collected near their *Salix* hosts. One *Psilocybe* species, *P. inquilinus,* and one unidentified *Entoloma* species grew in *Leymus* dunes. Three collections identified to the genus *Entoloma* and three to the genus *Hebeloma* could represent two additional species. The findings in 2008 increase the total number of agarics from two to nine and of species of fungi on Surtsey from 26 to 33, counting only those which have been identified to species.

INTRODUCTION

The first mushroom on Surtsey was photographed in 1971 and collected several times in August 1975 growing with *Racomitrium* moss on lava. It was identified as *Arrhenia rustica* (Fr.) Redhead, Lutzoni, Moncalvo & Vilgalys s.l., but recently a *Botrydina*-type thallus was discovered at the base of the stem making it a basidiolichen of the genus *Lichenomphalia* (Kristinsson & Heidmarsson 2009). *A. rustica* s.l. is probably also present as a specimen referred to that species was collected in 1990 growing on soil in the gull colony (Table 1).

In middle of July 2005 *Entoloma sericeum* Quél., which is common species in grassland in Iceland, was collected growing amongst *Poa pratensis* and *Leymus arenarius* grass in the oldest part of the gull colony. During the same expedition mushrooms were observed near a willow, *Salix phylicifolia,* in the Surtungur crater. Based on photographs, one fruiting body could belong to a species of the genus *Hebeloma* and two to the genus *Laccaria*, thus confirming the presence of ectomycorrhizal fungi of the willows on Surtsey. Based on records of vascular plants on Surtsey 1965–2008 (Magnússon *et al.* 2009) and Gardes & Dahlberg (1996) for information on ectomycorrhizal plants, the three willow species were the only plants on Surtsey known to form ectomycorrhizae. Greipsson & El-Mayas (2000) found endomycorrhizal fungi in roots of *L. arenarius* grass from a 22 year old dune, the only plant species on Surtsey they investigated. They subsequently classified the early colonizing plants on Surtsey based on their dependency on arbuscular mycorrhizal (AM) fungi as: AMF non-dependent species, AMF facultative species, or AMF dependent species, using a list of the type of mycorrhizae formed by British plant species (Harley & Harley 1987).

In 1995 the first willow was discovered on Surtsey, two *S. herbacea* plants estimated to be two years of age. At present it is the most important ectomycorrhizal host with a few older plants and many young plants growing in the lava in the younger part of the gull colony. In 1998 the second willow species,

Table 1. Fungi on Surtsey island recorded prior to 2006, including species that were isolated from soil and grown in culture in the research laboratory. Based on Appendix 5 in Baldursson & Ingadóttir (2007). Fungi of each phylum are listed with a reference for each species but AMNH for specimens in the herbarium of the Icelandic Institute of Natural History in Akureyri.

Fungi	References
Oomycota	
Aphanomycopsis bacillariacearum Scherff.	Johnson & Cavaliere 1968
Zygomycota	
Absidia corymbifera (Cohn) Sacc. & Trotter	Henriksson & Henriksson 1974
Mucor hiemalis Wehmer	Henriksson & Henriksson 1974
Glomeromycota	
Glomus hoi Berch & Trappe	Greipsson *et al.* 2002
Scutellospora dipurpurascens Morton & Koske	Greipsson *et al.* 2002
Ascomycota	
Ceriosporopsis halima Linder	Johnson & Cavaliere 1968
Kirschsteiniothelia maritima (Linder) D. Hawksw.	Johnson & Cavaliere 1968
Lamprospora crouanii (Cooke) Seaver	AMNH
Lulworthia medusa (Ellis & Everh.) Cribb & J.W. Cribb	Johnson & Cavaliere 1968
Octospora axillaris (Nees) M.M. Moser	AMNH
Onygena corvina Alb. & Schwein.	AMNH
Peziza varia (Hedw.) Fr.	AMNH
Anamorphic fungi	
Cadophora fastigiata Lagerb. & Melin	Henriksson & Henriksson 1974
Cadophora malorum (Kidd & Beaumont) W. Gams	Henriksson & Henriksson 1974
Cladosporium macrocarpum Preuss	Henriksson & Henriksson 1974
Dinemasporium marinum Sv. Nilsson	Johnson & Cavaliere 1968
Epicoccum nigrum Link	Henriksson & Henriksson 1974
Lecanicillium psalliotae (Treschew) Zare & W. Gams	Schwabe 1970
Penicillium citrinum Thom	Schwabe 1970
Penicillium palitans Westling	Henriksson & Henriksson 1974
Phoma putaminum Speg.	Schwabe 1970
Trichoderma harzianum Rifai	Henriksson & Henriksson 1974
Trichoderma viride Pers.: Fr.	Henriksson & Henriksson 1974
Ulocladium botrytis Preuss	Henriksson & Henriksson 1974
Basidiomycota	
Arrhenia rustica (Fr.) Redhead, Lutzoni, Moncalvo & Vilgalys	AMNH
Entoloma sericeum (Bull.) Quél.	AMNH
Lichenomphalia sp. (misapplied name *A. rustica*) (lichen)	AMNH

S. phylicifolia, was found and the third, *S. lanata,* in 1999. Each of the three plants of *S. phylicifolia* has formed a low bush of several stems while the four plants of *S. lanata* are smaller. As the willows form ectomycorrhizae with many different fungi (Nara, Nakaya & Hogetsu 2003, Mühlmann & Peintner 2008) some of which would produce their fruiting bodies in the vicinity of their host's roots, an effort was made to locate these plants in the search for fungi. However, willows also form arbuscular mycorrhizae (Allen *et al.* 2005, Trowbridge & Jumpponen 2004) and only some of their ectomycorrhizal fungi produce fruiting bodies around the plants as research using molecular methods on the ectomycorrhizal roots has shown, species of ascomycetes, anamorphic fungi and basidiomycetes which form inconspicuous, resupinate or fan-shaped fruiting bodies, were more common on the roots than were the agarics commonly associated with willows (Mühlmann & Peintner 2008, Nara *et al.* 2003).

Driftwood on the northern shore was another habitat where marine microfungi and some wood decay fungi could be present. The only dung of herbivores which is suitable substrate for coprophilic fungi is goose dung while keratinophilic fungi could grow on remains of dead birds and feathers such as in regurgitated bird pellets.

Over the years a few mushrooms belonging to five species have been found on Surtsey some of which were collected and kept as dried specimens in the herbarium of the Icelandic Institute of Natural History in Akureyri (AMNH). In 2006, in a document prepared for the nomination of Surtsey for the UNESCO World Heritage List (Baldursson & Ingadóttir 2007), a brief outline of the research on fungi prior to 2006 and a list of 24 species of fungi, two of which were agarics, was compiled based on articles (Johnson & Cavaliere 1968, Schwabe 1970; Henriksson & Henriksson 1974) and herbarium specimens. Specimens identified to the genus level

were excluded from that list (Table 1). Since the identity of the *Lichenomphalia* species has not been confirmed it was not assigned to a species here but earlier it was included in the species *A. rustica* s.l. (misapplied name). Since it is a lichen it is counted with the other lichens (see Kristinsson & Heidmarsson 2009) but as it belongs in the order Agaricales of the phylum Basidiomycota with numerous other agarics it is also treated here. Missing from the list were two species of arbuscular mycorrhizal (AM) fungi *Glomus hoi* Berch & Trappe and *Scutellospora dipurpurascens* Morton & Koske of the phylum Glomeromycota isolated from a 22 year old *Leymus arenarius* sand dune using the trap culture method. Younger dunes, five or ten years old, yielded no AM fungi (Greipsson *et al.* 2002).

The funga of Surtsey was further studied in 2008, when a mycologist joined the biological expedition in early July and the geological expedition in middle of August. In July microfungi on overwintered plant material and some parasitic fungi on living plants were collected and in August more microfungi on various substrates were added. However, in August it was the search for and collection of mushrooms, the fruiting bodies of agarics, a major group of the basidiomycetes, that was the focus of the investigation.

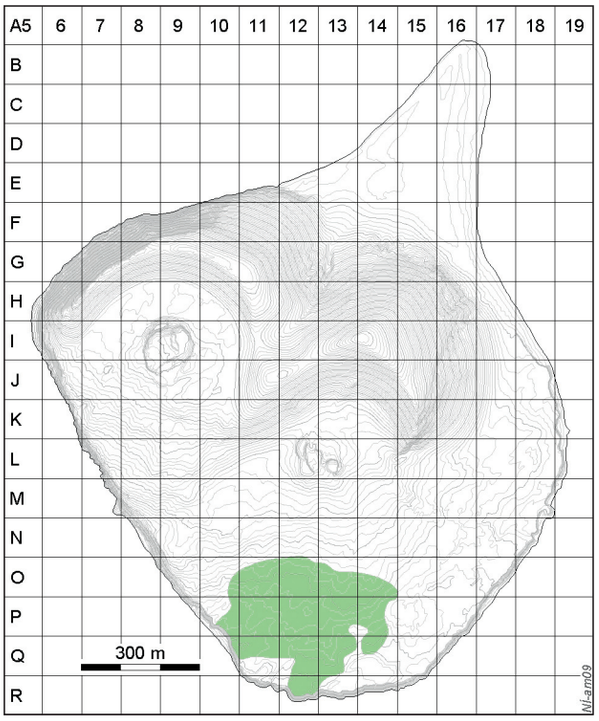

Fig. 1. Surtsey in 2007 with the area of dense vegetation shown in green and the 100 x 100 m grid system for mapping distribution of plants on Surtsey. The names of quadrats of the grid where agarics were collected were used as localities, e.g. plot I9 or plot L17.

METHODS

In 2008 fungi were collected during the periods July 7 to 10 and August 11 to 14. In July microfungi parasitic on living plants or saprophytic on overwintered, dead plant material and on driftwood were collected but no agarics were found at that time. In August more microfungi on dead plant material and other substrates were collected and the search for agarics was successful as fruiting bodies of several species were found. For each site the coordinates were recorded using a GPS unit and later placed in the 100 x 100 m grid system for Surtsey (Fig. 1). Samples of greylag goose (*Anser anser*) dung were collected and sent to Scotland to a specialist in coprophilic fungi for incubation in moist chambers. Three small soil samples were also collected and sent to a mycologist in Canada who will attempt to isolate microfungi of the genus *Leohumicola* from the soil.

Fruiting bodies were photographed and their macroscopic characteristics recorded before each collection was dried in warm air. Microscopic characteristics of the larger basidiomycetes have been examined and each collection identified to a genus, assigned a collection number (FA-number), and recorded in the AMNH herbarium database. Specimens were identified using keys (Knudsen & Vesterholt 2008) and monographs, e.g. Vesterholt (2005) for *Hebeloma*, Noordeloos (1992, 2004) for *Entoloma*, and Brandrud *et al.* (1998) for the genus *Cortinarius*. Presently, the identification to the species level is tentative for many of the collections and the names assigned may change. In the coming years the current name for each collection can be accessed through the GBIF data portal www.gbif.net by its FA-number in the AMNH herbarium.

RESULTS AND DISCUSSION

Fungi on driftwood and microfungi collected on Surtsey have not been examined and those results will be reported later. Most of the driftwood on the northern shore was in good condition and relatively few boles showed signs of decay.

Fruiting bodies of several different agarics were found on Surtsey in August (Table 2). Since most of the time fungi are practically invisible as delicate mycelia in soil or other substrates, only those producing fruiting bodies at this particular time were investigated. The maritime climate, lack of water, sandy soil and the lack of ectomycorrhizal hosts other than the three *Salix* species, limit the funga of Surtsey to species adapted to such habitats. Fruiting bodies of one or more ectomycorrhizal species were found near six *Salix* plants, two *S. herbacea* plants, one *S. lanata* plant, and three *S. phylicifolia* plants.

At least four ectomycorrhizal species were found with the older *S. herbacea* plants, while no fruiting

Table 2. Agarics collected on Surtsey 2008, their lifestyle and location (grid plot) in the 100 x 100 m grid for Surtsey (Fig. 1). (Lifestyle: ectomycorrhizal (EM), and saprophytic (S). One unidentified species of a genus is indicated by an sp. after the genus name or spp. when there are more than one species. When (?) is in front of a grid plot name the identification of collections from that site needs confirmation.)

Species	New on Surtsey	Life-style	Host plant or substrate	Grid plots
Cortinarius sp. (subgen. *Telamonia*)	x	EM	*S. herbacea*	O12
Entoloma sericeum Quél.		S		O11, P11, P12
Entoloma spp. (at least two species)	x	S		O12, O13, O14, L17
Hebeloma collariatum Bruchet	x	EM	*S. herbacea*	O12
Hebeloma marginatulum (J. Favre) Bruchet	x	EM	*S. phylicifolia*	I9
Hebeloma mesophaeum (Pers.) Quél.	x	EM	*S. phylicifolia*	?I8, O13
Hebeloma vaccinum Romagn. var. *vaccinum*	x	EM	*S. phylicifolia*	O13
Hebeloma spp.	x	EM	*S. herbacea* *S. lanata*	I8, O14
Inocybe lacera (Fr.: Fr.) P. Kumm. var. *lacera*	x	EM	*S. phylicifolia*	O13
Laccaria laccata (Scop.: Fr.) Berk. & Broome	x	EM	*S. herbacea*	O12
Psilocybe inquilinus (Fr.: Fr.) Bres.	x	S	*L. arenarius*	M12, M13

bodies were found near the younger plants. The fifth species, an unidentified *Entoloma* sp. (Table 2), could either be mycorrhizal or saprophytic as some members of the genus form mycorrhizae with plants while many are saprophytic (Knudsen & Vesterholt 2008). When the young *S. herbacea* plants grow and form approximately 30 cm wide mats their mycorrhizal partners should be able to produce fruiting bodies if conditions are right. Nara, Nakaya & Hogetsu (2003) who investigated fungi associated with *Salix reinii* growing on tephra on Mount Fuji in Japan found that the biomass of fruiting bodies increased with host size as did species diversity of the associated fungi which produced fruiting bodies. Since numerous fungi are able to form ectomycorrhizae with *S. herbacea* it will be interesting to document the establishment of its funga as the plants grow older.

Agarics associated with willows

In the following section the specimens collected in 2008 at different localities are listed. Localities are named with a letter and a number, e.g. I8, which refers to the 100 x 100 m grid for Surtsey (Fig. 1). Most of the fruiting bodies found close to the willow plants were less than 2 m from the plants often at the base of lava ridges or inside small lava cavities and apart from one species (*Entoloma* sp.) are known to form ectomycorrhizae with *Salix* spp.

Plot I8. *Hebeloma* spp., seven fruiting bodies (Fig. 2), five brownish (FA-19519) and two which were greyish in color and could represent a different *Hebeloma* species (FA-19518). Both specimens appear to belong to species in the section *Hebeloma,* perhaps *H. mesophaeum* (Pers.) Quél. Both collected 12.8.2008 close to *S. herbacea* (plant 1) in the Surtungur crater in a sandy patch on lava partly covered by *Racomitrium* moss.

Fig. 2. Brown fruiting bodies (FA-19519) above, and grayish (FA-19518) below, of unidentified *Hebeloma* species mycorrhizal with *Salix herbacea* in the crater Surtungur (I8). Photo GGE.

Fig. 3. *Hebeloma collariatum* (FA-19523) mycorrhizal with *Salix herbacea* in the oldest part of the gull colony (O12). Photo GGE.

Plot O12. *Hebeloma collariatum* Bruchet, six fruiting bodies (FA-19523) (Fig. 3). This is the second record of the species in Iceland. One fruiting body of *Laccaria laccata* (Scop.: Fr.) Berk. & Broome (FA-19524) and a group of seven small, brown fruiting bodies of an unidentified *Cortinarius* sp. of the subgen. *Telamonia* (FA-19526) (Fig. 4). One fruiting body of an unidentified, small *Entoloma* sp. (FA-19525), a species which may or may not be mycorrhizal (Fig. 4). Collected 13.8.2008 close to *S. herbacea* (plant 2) in the oldest part of the gull colony growing in a depression between lava ridges with *Honckenya peploides* and *Poa pratensis*.

Plot O14. *Hebeloma* sp., three fruiting bodies (FA-19527), collected 13.8.2008. This collection appears to belong to one of the species in the section *Hebeloma,* its spores somewhat larger than is typical for *H. mesophaeum*. It was close to a *S. lanata* (plant 1) in the younger part of the gull colony in a deep depression in lava with *Honckenya peploides, Cerastium fontanum* and *Sagina procumbens*. This was the only agaric found near a *S. lanata* plant as no fruiting bodies were found near the other plant located in this survey (plant 2 in plot O12).

Plot O13. *Hebeloma mesophaeum* (Pers.) Quél., two fruiting bodies (FA-19517), collected 11.8.2008 (Fig. 5), and *Hebeloma vaccinum* Romagn. var. *vaccinum,* three fruiting bodies (FA-19521) (Fig. 6) and five fruiting bodies of the larger *Inocybe lacera* (Fr.: Fr.) P. Kumm. var. *lacera* (FA-19522) grew amongst the smaller *H. vaccinum* (Fig. 6). Collected 13.8.2008. If the identification of *H. vaccinum* is correct then this is the second record of the species in Iceland. *H. mesophaeum* grew with *S. phylicifolia* (plant 1) in the younger part of the gull colony, sheltered at the bottom of a lava channel, while the other two grew by *S. phylicifolia* (plant 3) also in the younger part of the gull colony amongst grasses in a slight depression between low lava ridges.

Plot I9. *Hebeloma marginatulum* (J. Favre) Bruchet, five fruiting bodies (FA-19520) (Fig. 7). Collected 12.8.2008 close to *S. phylicifolia* (plant 2) in the slope of Surtungur crater in gravelly patches on lava.

Each of the three *S. phylicifolia* plants currently growing on Surtsey was associated with one or more ectomycorrhizal fungi producing fruiting bodies.

Agarics in grassland, sand dunes, or sandy soil

With the exception of one species of the genus *Psilocybe* all the fungi saprophytic in grassland on sandy soil, in *Leymus arenarius* dunes, or sparse vegetation, belong to the genus *Entoloma*. The number of species is at least two, perhaps more, with *Entoloma sericeum* being common in grassland in the oldest part of the gull colony. Identification of *Entoloma* species is difficult and all the collections from

Fig. 4. A group of *Cortinarius* sp. subgen. *Telamonia* fruiting bodies (FA-19526) mycorrhizal with *Salix herbacea* in the oldest part of the gull colony (O12) and one small fruiting body of an *Entoloma* species (FA-19525) (bottom central). Photo GGE.

Fig. 5. *Hebeloma mesophaeum* (FA-19517) mycorrhizal with *Salix phylicifolia* in the younger part of the gull colony (O13). Photo GGE.

Fig. 6. *Hebeloma vaccinum* var. *vaccinum* (FA-19521) three smaller fruiting bodies below central and four larger *Inocybe lacera* var. *lacera* fruiting bodies (FA-19522) above, mycorrhizal with *Salix phylicifolia* in the younger part of the gull colony (O13). Photo GGE.

Fig. 7. *Hebeloma marginatulum* (FA-19520) mycorrhizal with *Salix phylicifolia* in the crater Surtungur (I9). Photo GGE.

Fig. 8. *Entoloma sericeum* (FA-19512) fruiting bodies picked from a 3 m long line in grassland in the oldest part of the gull colony (P12). Photo GGE.

Surtsey had isodiametric spores of approximately the same size range. Collections with cheilocystidia remain unidentified while those without were tentatively identified as *E. sericeum.*

Plots O11, P11, P12. *Entoloma sericeum* Quél. was relatively common in grassland on sandy soil in the oldest part of the gull colony. Ten fruiting bodies in a 3 m long line (P12) (FA-19512) (Fig. 8), in (O11) a small cluster (FA-19513), in (P11) (FA-19514). Three collections 11.8.2008. These and additional fruiting bodies (not collected) in clusters and forming short lines in the oldest part of the gull colony indicate that this species has become well established and must have been growing in this area for many years. Fruiting bodies usually form near the growing edge of a mycelium, in a young mycelium sometimes forming a circle but as the fungus grows and forms a wider circle, parts of which may die, thus producing fruiting bodies in short, nearly straight lines.

Plot O13. *Entoloma* sp., five fruiting bodies in a cluster (FA-19516). Collected 13.8.2008 in grass in the younger part of the gull colony in a slight depression between low lava ridges.

Plots L17, M16, M17. *Psilocybe inquilinus* (Fr.: Fr.) Bres. and *Entoloma* sp. The *P. inquilinus,* thirty fruiting bodies (FA-19528) (Fig. 9), was collected 12.8.2008 in a sheltered *Leymus arenarius* dune in lava east of the research hut Pálsbaer (M16–M17) at the entrance of a lava cave on dead stems and leaves of the plant. Most of the fruiting bodies were attached to decaying fragments of *L. arenarius* grass buried in sand in this relatively moist dune. This fungus had low conical cap which became plane as it matured with only slightly moist surface and very limited, if any, fragments of veil. *P. inquilinus* has viscid cap and is thinner than the largest fruiting bodies of this collection but they share the same habitat and produce spores which are 7–8 µm long with a distinct and large germ pore, are rather thick-walled, and ovoid to rhomboid in front view

Fig. 9. *Psilocybe inquilinus* (FA-19528) growing on fragments of *Leymus arenarius* in a dune at the opening of a lava cave (M16 – M17). Photo GGE.

(Knudsen & Vesterholt 2008). Thus although the collection deviates somewhat from the species concept of *P. inquilinus* it is tentatively identified as that species. The *Entoloma* sp. (FA-19511) was collected 12.8.2008 in an exposed *Leymus arenarius* dune in lava east of the research hut Pálsbaer (L17). It was found as three solitary fruiting bodies each in a different part of the dune. The fruiting bodies were smaller than those of *E. sericeum* from the oldest part of the gull colony and cheilocystidia were present.

Plot O14. *Entoloma* sp., a single fruiting body (FA-19515). Collected 13.8.2008 in sand within a *Honckenya peploides* plant in lava at the northern edge of the gull colony.

General conclusions

In total, at least ten species of agarics were collected in the 2008, eight of which have been identified to a species and seven were new for Surtsey (Table 2). The findings in 2008 increase the total

number of fungi identified to a species on Surtsey to 33 thereof the number of agarics to nine (Tables 1 and 2).

The presence of fruiting bodies of several different agarics in middle of August 2008 shows that conditions have been right for reproduction of these fungi while other species, reproducing earlier or later in the year or not at all, may also be present. The willows are still young, the oldest plants have been growing on Surtsey for 15 years while most of the plants are less than ten years of age. Thus their ectomycorrhizal funga may change as the plants mature. The maritime climate, sandy soil, *L. arenarius* dunes, and *S. herbacea* as the primary ectomycorrhizal host species, are some of the parameters influencing the development of the funga of Surtsey.

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