Colonization of lichens on Surtsey 1970–2006

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ABSTRACT

A list of lichen species from the volcanic island Surtsey is presented. A total of 87 species have been recorded since the first three species appeared in 1970. Notes on distribution and short description of the main lichen communities are given. Possible colonization routes to the island are discussed. Four of the species treated are new to Iceland, *Gyalidea fritzei* and *Psilolechia clavulifera* and two species, one *Lecanora* and one *Stereocaulon* which probably are new to science. Two further species belonging to *Lecanora*, provisionally determined as *L. albescens* and *L. semipallida*, are probably new to Iceland.

The primary colonization resembles what has been recorded on other lava fields in Iceland. Lichen species established very slowly on Surtsey with relatively few species found during the first two decades, in 1984 only 17 species had been recorded. That number almost doubled during the next six years, 31 species had been recorded on the island by 1990 and there has been a constant accumulation of species since then. The lichen colonization benefitted from the activity of gulls. Many species were probably dispersed by the trampling birds and colonized the naked lava rock around the breeding area. Later soil formation started in connection with the gull colony and the first colonizers were replaced by other species. The palagonite tuff has only recently been colonized by lichens and on the coastal rocks of the island only one lichenized species has been found so far.

INTRODUCTION

Surtsey (Fig. 1), formed by volcanic eruption in the years 1963–1967, has been carefully studied by scientists in order to monitor its colonization by organisms. Since 1965 the island has 15 times been visited for studies of the colonization and the development of lichen communities in different habitats. No traces of lichens were found in the first three visits, in 1965, 1967 and 1968 (Kristinsson 1970a). The first lichen species to be discovered on Surtsey was *Trapelia coarctata*, first seen in 1970 (Kristinsson 1972). It had by then already formed a more or less continuous cover of white to grey thalli with numerous ascospore-producing apothecia on steep lava rocks covering the outside wall of the Surtungur crater. The site of the lichen regularly received warm steam that kept the wall more or less constantly wet, depending on the wind direction.

In addition to this first mature colonizer, sterile initial stages of two other species were discovered in the Surtsey lava in 1970, *Placopsis gelida* and *Stereocaulon vesuvianum*. These two species together with *Stereocaulon capitellatum* increased greatly and later became the most successful colonizers everywhere in the lava fields throughout the island together with the mosses *Racomitrium ericoides* and *R. lanuginosum*. *Acarospora smaragdula* soon appeared on the elevated crater margin and outcrops in the lava fields. Light green patches widely distributed on overhanging rocks, in rifts and cave mouths, originally recorded as *Lepraria* and described in detail by Kristinsson (1974), turned later out to be *Psilolechia leprosa*.

Figure 1. Aerial photograph of Surtsey in 2007.

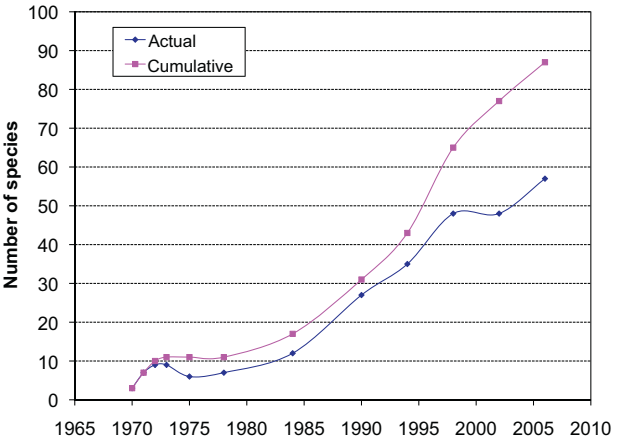


Figure 2. Number of lichen species found in Surtsey 1970–2006.

On the first visits the main emphasis was on a careful search for initial stages of lichens in all the different habitats found on the island. Later, when colonization had started, the distribution of the lichen species was recorded on the basis of a 100 x 100 m grid system.

The purpose of this paper is to give a preliminary list of all species identified from the island, together with notes on their frequency, distribution, and where feasible to consider possible colonization routes. Information on the colonization is compiled (Fig. 2) and the observed development of lichen communities in different habitats is described.

METHODS

During each visit to the island different habitats were carefully searched in order to record all visible lichen species. Common species were recorded on basis of the 100 x 100 m grid system that had been laid over the island for monitoring the distribution of vascular plants (Fridriksson *et al.* 1972). Distribution maps of common lichens based on that grid were already published (Kristinsson 1974). Samples were collected of new or unidentified species for microscopical identification in the laboratory. The chemical content of the specimens was studied using spot tests or thin layer chromatography. The nomenclature follows Santesson *et al.* (2004) for species listed there. All specimens are kept in the herbarium of the Icelandic Institute of Natural History, Akureyri Division (AMNH) and other data are kept in a digitalized database containing known distribution of Icelandic species of plants and fungi. All photos are taken by Hördur Kristinsson unless otherwise stated.

DEVELOPMENT OF LICHEN VEGETATION

Colonization of lichens in different habitats on Surtsey has followed a certain pattern, both regarding the habitat selection of different species and the time scale optimal for different communities. The development of the lichen vegetation often depends on weathering of the substrates, the erosive forces of the wind and sea together with the activity of other organisms colonizing the island.

The first lichen colonization took place around spots where steam condensed directly on the lava rock, a condition only present in the first years before the underlying lava cooled down. Next species to arrive were known primary colonizers in lava fields. However, unexpected they colonized first the youngest aa lava at the eastern side of the island that apparently was more favourable for the colonization than the oldest pahoehoe lava. Certain species preferred the peaks and outcrops in the lava, and others caves, rifts and overhanging rock. Unusual conditions were found in the sheltered area inside the Surtungur crater. The coastal rocks were broken down every year, thus marine lichens of the littoral zone like *Lichina confinis*, *Verrucaria maura* and *V. mucosa* were unsuccessful in colonizing. With the activity of the breeding gulls in the southern part of the island, new conditions were created on the rocks frequently visited by birds. They were colonized by crustose rock lichens probably carried around by the birds' feet, and by coprophilous lichens benefitting from nutrient enrichment by bird dung. Thin soil that slowly formed on these lava blocks created favourable conditions for many

terricolous and muscicolous lichens. The thicker soil and grassland that followed destroyed their habitat again, but offered still some conditions for fruticose and foliose lichens like *Cladonia* spp. and *Peltigera* spp. The erosive forces prevented lichen colonization on the palagonite tuff on the top of Austurbunki and Vesturbunki for a long time, but when they had stabilized enough after some 35 years, lichen colonization began. The steep slopes of the tuff cones are still too unstable for lichen colonization, except around the small lava outlets in the slopes (Bjallan, Strompur), where fulmars have nested. Finally, the manmade substrate concrete of the helicopter platform was colonized by lichens. Here, six different lichen habitats have been recognized on Surtsey, i.e. steam holes, lava fields, Surtur crater, seashore, the colony of breeding gulls and the palagonite tuff of Austurbunki. These different habitats will be described in more detail below.

The steam holes

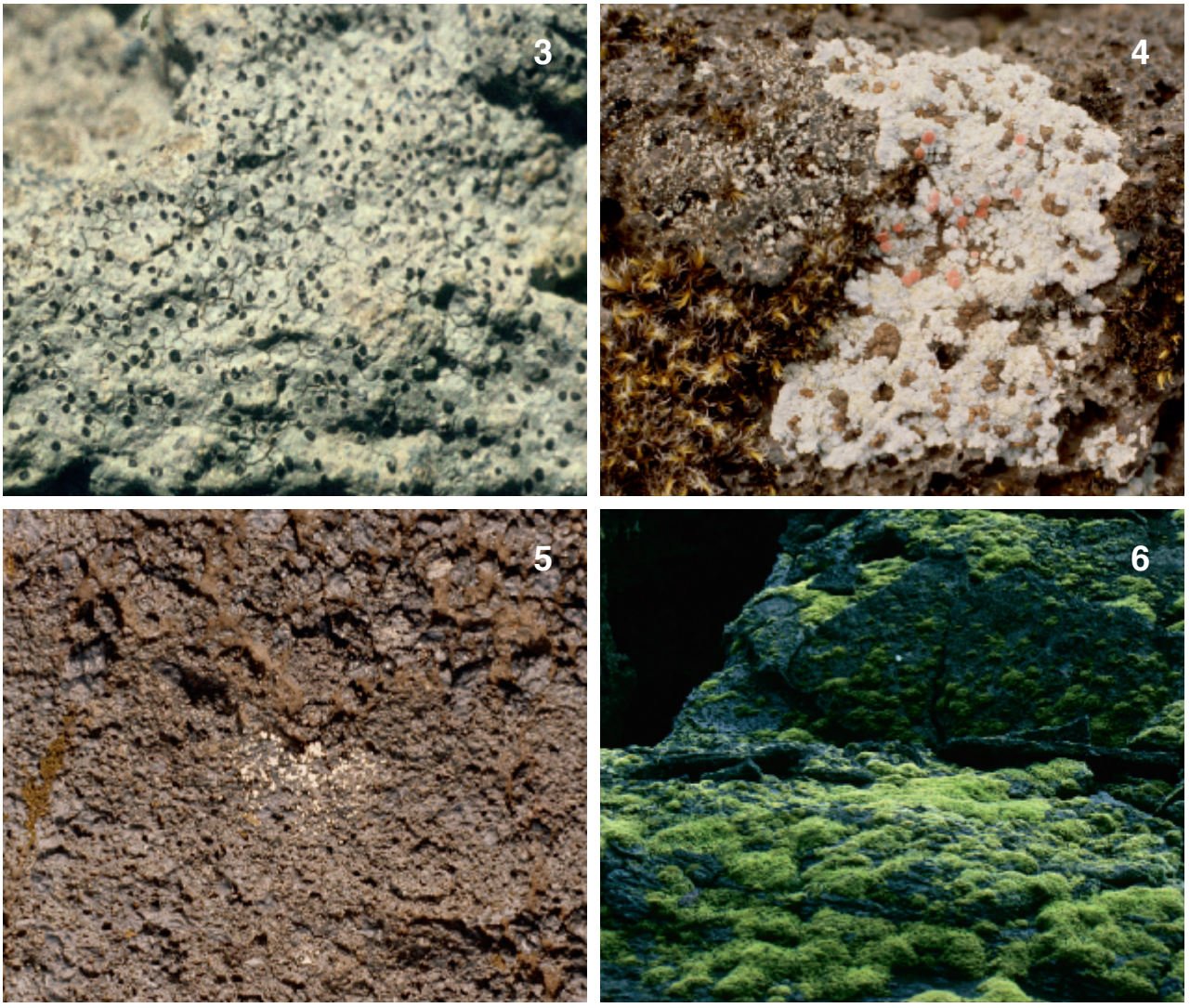
Thermal heat occurred widely in the first years after the Surtsey eruption, especially in the neighbourhood of the craters (Magnússon *et al.* 1970). Warm steam escaped through small openings in the lava surface. The steam was blown along the surface by the wind and maintained surrounding tephra and lava rock wet. The surface water stabilized the blowing tephra sand that became a suitable substrate for colonization of cyanobacteria and bryophytes (Behre & Schwabe 1970, Jóhannsson 1968) mainly *Anabaena variabilis*, *Bryum argenteum*, *Funaria hygrometrica* and *Schizothrix lardacea*. Lichens were not able to colonize these habitats except where the steam was blown over bare rock. Such habitats were mainly found near the Surtungur crater, especially on the outside of the western wall, but also in the surrounding lava fields. These habitats were mainly colonized by two species, *Trapelia coarctata* and *Psilolechia leprosa*. The former species was a very successful and rapid colonizer especially on the rather steep outside walls of Surtungur, facing northwest (Fig. 3). In 1970 and the following years these walls were more or less constantly kept moist by steam escaping through numerous steamholes. When first discovered, in 1970, *T. coarctata* had already formed an extensive cover of richly fertile thallus on these walls (Kristinsson 1972). Later it was also found in other localities under similar conditions. It was still present at number of sites throughout the island in 2006, long after the steam emission ceased, but much less abundant than in 1970. *Psilolechia leprosa* colonized the crater walls a little later and was very abundant in 1975 as minute, sterile thalli with granular surface. It was never seen fertile or covering large areas here as it was later on the overhanging walls in the rifts of the lava field. *Placopsis gelida* also colonized this habitat. As the years passed these habitats changed as they slowly cooled down and the steam disappeared. As those slopes dried out, *Trapelia coarctata* became less vigorous and *Psilolechia leprosa* almost disappeared, but *Placopsis gelida* survived like in the surrounding lava fields.

Primary colonization in the lava fields

The primary colonization in the lava fields of Surtsey resembled other lava fields in Iceland. The first stages have been described in details by Kristinsson (1974). Five species played a main role in this colonization (Fig. 4): the lichens *Placopsis gelida*, *Stereocaulon capitellatum*, *S. vesuvianum* and the mosses *Racomitrium ericoides* and *R. lanuginosum*. These lichens contain cephalodia with cyanobacteria besides the green algae. They start growing within tiny cavities on the lava surface originally formed by air bubbles in the molten lava. These cavities accumulate dust and diaspores of organisms that are captured and settle down in the holes and they also retain some water for longer periods than the smooth lava surface (Kristinsson 1970b). They serve as suitable growth chambers for different kinds of diaspores, such as fungus spores, lichen soredia, cyanobacteria and green algal cells (Kristinsson 1974). Minute thalli of each of the three lichen species develop separately from many adjacent cavities forming a circular colony of 2–4 cm in diameter (Fig. 5), and later on coalescing to form one lichen thallus. In many of the cavities cephalodia containing cyanobacteria can be observed already at initial stages of the lichen growth. In the case of *Placopsis gelida*, this gives rise to a single white thallus with many small cephalodia as is characteristic for the Surtsey lava (Fig. 4), while in older habitats *Placopsis* thalli usually contains one large cephalodium in the center of the thallus.

From the beginning of the lichen colonization in the lava fields all members of the characteristic community were evenly distributed throughout the lava fields all over the island. This distribution pattern indicates wind dispersal. Since all remained sterile and without apothecia for many years, the diaspores must have been dispersed by long distance dispersal at least from the neighbouring islands or the mainland of Iceland.

Initially the growing conditions for lichens were best in depressions in the aa lava on the eastern side of the island, and inside the Surtungur crater. The growth was much slower at exposed sites and in the pahoehoe lava in the centre and on the western side of the island even though those lava flows are older. This was probably both due to the smooth surface structure and less favourable mois-



Figures 3–6. Fig. 3. *Trapelia coarctata* on the outside of the Surtungur crater in 1971. Fig. 4. Primary colonizers in the lava fields of Surtsey 1975. Center: The lichen *Placopsis gelida* with numerous, brown *Nostoc*-cephalodia and a few pink apothecia. Upper left: *Stereocaulon vesuvianum* with white pseudopodetia and black *Stigonema*-cephalodia. Lower left: the moss *Racomitrium lanuginosum*. Fig. 5. Initial stage of *Stereocaulon capitellatum* on lava surface in Surtsey. Typical group of separate thalli each developing from single small cavity on the surface, later coalescing to form one large thallus. Fig 6. *Racomitrium* carpet in the bottom of the Surtungur crater in 1978.

ture conditions, as well as infrequent but rather strong wind erosion occurring there.

Later three other species of *Stereocaulon* appeared in the lava fields, all with more limited distribution. *S. vanoyei* and *S.* sp. were relatively frequent in a limited area on the pahoehoe lava in the eastern part of the island, while *S. spathuliferum* established scattered populations in a few localities. A few *Porpidia* species appeared also quite early. *P.* cf. *crustulata* appeared first and had the widest distribution, and two sorediate species also became rather common, *P. melinodes* and *P. soredizodes*. *Lichenomphalia* cf. *velutina* was seen several times among the primary colonizers in the lava fields. It is a mushroom previously included in the genus *Omphalina* forming a green-algal thallus of *Botrydinia*-type around the base and growing directly on the rock already colonized by *Racomitrium*.

Protruding lava peaks, shady caves and rifts, offered some habitat diversity within the lava fields. The peaks were quite early colonized by *Acarospora smaragdula*. *Arthonia lapidicola*, *Catillaria chalybeia* and *Scoliciosporum umbrinum* also colonized similar habitats, but were less frequent. The overhanging rock in caves and rifts was mainly colonized by *Psilolechia leprosa*, a rapidly spreading species that was found in almost all suitable sites throughout the island, a fact that strongly suggests dispersal by wind.

During the first ten years of lichen establishment in the lava fields their distribution increased and the most favourable sites became mostly covered

by bryophytes and lichens, mainly the five species mentioned above. After this period, a deterioration was noticed, especially noticeable during the visit in 1984 and partly also in 1990. Apparently severe erosion had taken place, probably either caused by excessive drought or strong winds. The *Racomitrium* carpets were partly dead or worn away from the rock, some were partly filled with sand and the lichens had detoriated. Some of these sites recovered after 1990 and then some regions also experienced a new change due to the increasing activity of gulls.

The characteristic bryophyte and lichen communities of the lava fields are also severely affected by the closeness of the sea. They are poorly developed in the first 100–200 m from the edge of the seacliffs. In the same way, well developed lava communities that have been formed further inland, deteriorate again when the seacliffs are broken down and the ocean spray approached. *Stereocaulon* disappeared, both the *Racomitrium* species retreat or are replaced by yellowish brown bryophyte communities mainly dominated by *Schistidium maritimum*.

Sheltered habitats in the Surtungur crater

As mentioned earlier the community development in the lava fields was more pronounced in sheltered habitats. The most sheltered location on the whole island was inside the Surtungur crater, the bottom of which was surrounded by steep cliffs on all sides. It had been noticed, that the growth of lichens and bryophytes characteristic for the lava fields was most advanced here. This was the first locality where patches of closed carpets of *Racomitrium lanuginosum* were formed (Fig. 6). In addition to the primary colonizers several crustose lichens, including *Rhizocarpon lavatum*, *Porpidia* cf. *crustulata* (Fig. 7), *P. melinodes* and later *P. flavicunda*, appeared, first inside the crater but later in various locations in the surrounding lava fields. Apart from these rather common species, several very rare species appeared in this crater. Among these were *Gyalidea fritzei*, *Hymenelia arctica*, *Pilophorus cereolus*, *P. dovrensis*, *Psilolechia clavulifera* and *Stereocaulon* cf. *tornense*.

Several soil lichens were first found in the slope below the western wall inside the Surtungur crater, below some unsuccessful nesting attempts of a raven. Among these were *Collema tenax*, *Leptogium lichenoides*, *Peltigera didactyla*, *P. venosa* and *Solorina bispora*. An unidentified species probably belonging to the genus *Micarea* was found growing on rock in this locality.

The first closed moss carpets in the Surtungur crater also provided a substrate for the first specimens of *Peltigera canina* (Fig. 8), *Protopannaria pezizoides* and *Stereocaulon alpinum*.

The seashore

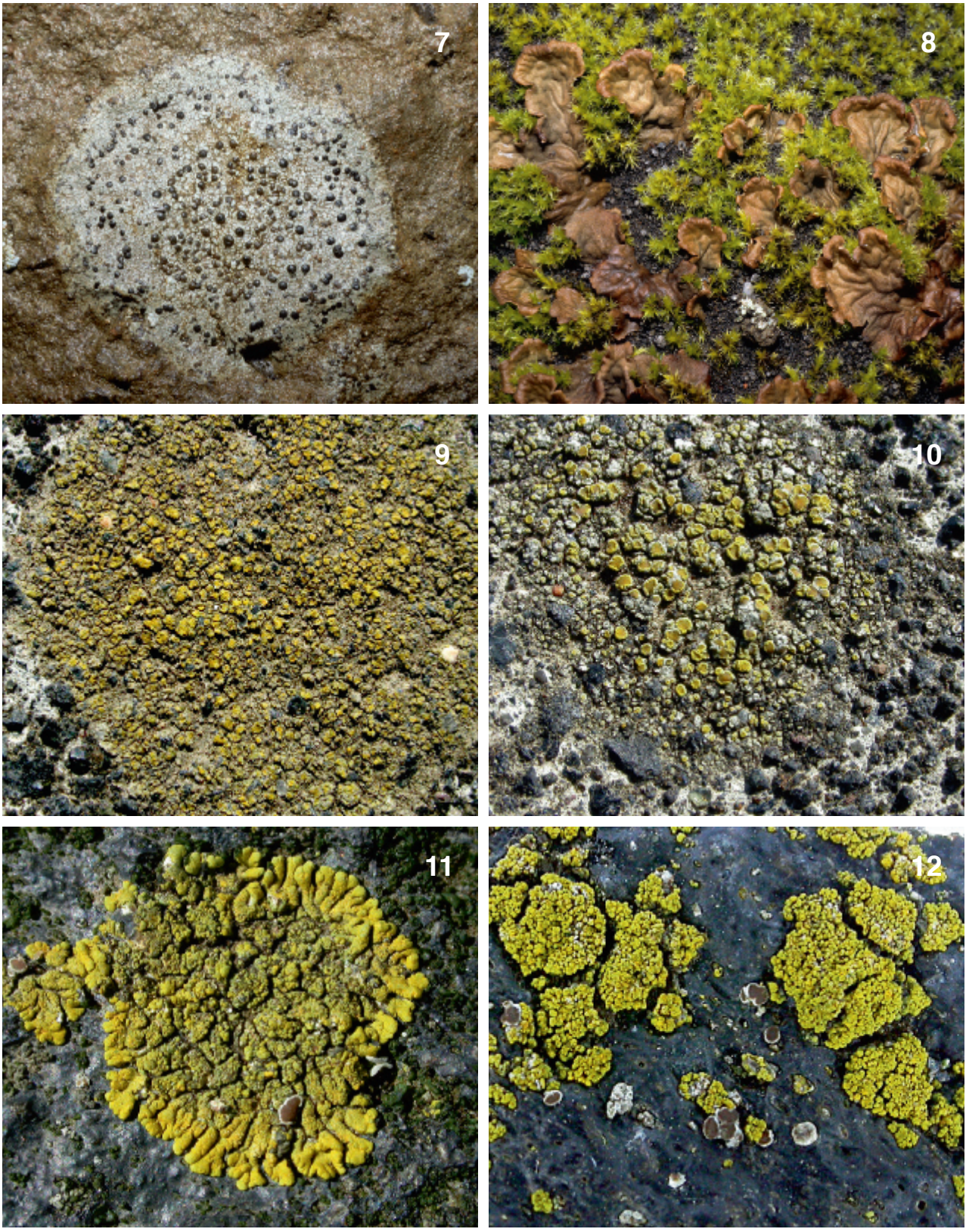
The coastline of Surtsey has changed much over the years due to sea erosion and the island has continued to decrease in size. The lava has been broken down to boulders and smaller particles and these have been rolled up and down the shore, successively getting more or less round. As a result of the sea currents a spit has formed on the northern side of the island. Because of the eroding sea-waves the coastal rocks around the island are very unstable habitats preventing the establishment of marine *Verrucaria* species, such as *V. maura* and *V. mucosa*, which are generally abundant on coastal rocks around Iceland. A similar tendency can be observed in the seaweed flora of the littoral zone which mainly consists of annuals (Jónsson & Gunnarsson 2000). The first, and so far the only, lichenized species growing directly on coastal cliffs was discovered in 2002. It was *Collemopsidium halodytes*, a species that can either grow on coastal rocks or on shells of *Balanus* spp.

Four species of seashore lichens growing above the *Verrucaria*-zone on coastal cliffs have been recorded on Surtsey, *Caloplaca verruculifera*, *Lecanora poliophaea*, *L. salina* and *Rinodina gennarii*. These species grow out of the reach of the ocean waves but they are more or less influenced by spray of seawater, especially during the winter storms.

The colony of the breeding gulls

In 1986 the first lesser black-backed gulls (*Larus fuscus*) were observed nesting on Surtsey. In the following years three other gull species started nesting, viz. herring gull (*L. argentatus*), glaucous gull (*L. hyperboreus*) and great black-backed gull (*L. marinus*). These gulls have formed a relatively dense colony on the island and the nutrient enrichment caused by the faeces of the gulls has triggered a vegetation succession and soil formation within the colony differing from the rest of the island (Magnússon & Magnússon 2000). This succession and subsequent soil formation have formed a habitat for several lichen species which could not grow on Surtsey earlier, such as some *Cladonia* and *Peltigera* species. We can distinguish between two different types of lichen habitat created by the gulls:

1. Blocks of naked lava frequently traversed by the birds. These are colonized by crustose and foliose lichens that are probably brought in and dispersed mainly by the birds themselves. The main species belonging here are *Lecania subfuscula* and an unnamed *Lecanora* sp. which cover most of the blocks. Furthermore, *Lecanora salina*, *Lecanora poliophaea* and *Rinodina gennarii* are frequently found in this habitat, and more sparsely *Candelariella coralliza*. Following these are the bright yellow *Caloplaca verruculi-*



Figures 7–12. Fig. 7. The crustose lichen, *Porpidia* cf. *crustulata*, in the Surtungur crater 1994. Fig. 8. The lichen *Peltigera canina* growing in a carpet of *Racomitrium ericoides* in the bottom of the Surtungur crater in 1990. Fig. 9. *Caloplaca citrina* on palagonite tuff on top of Austurbunki in 2006. Fig. 10. *Candelariella aurella* on the helicopter platform in 2006. Fig 11. *Caloplaca verruculifera* on lava rock near the gull colony in 2006. In the lower part the lichen has grown around a brown apothecium of *Lecanora* sp. Fig. 12. *Candelariella coralliza* on lava rock in the gull colony in 2006. Brown apothecia with white margin belong to *Lecanora* sp.

fera, *Xanthoria candelaria* and *X. parietina*, and the gray-coloured *Phaeophyscia orbicularis*, *Physcia caesia* and *Physcia tenella*. As the succession proceeds and the flat lava blocks get covered by soil and grassland, this community survives only on lava peaks protruding out of the vegetation.

2. Blocks with thin soil formation, first colonized by the vascular plants *Poa annua, Sagina procumbens, Stellaria media* and the agaric *Omphalina rustica* leading later to thicker soil dominated by grasses. The first stages of the soil formation are favourable for many lichens including *Baeomyces rufus*, *Cladonia chlorophaea*, *C. furcata*, *C. macroceras*, *C. pocillum*, *C. symphycarpia*, *Collema tenax* and *Leptogium lichenoides*. Some of these, especially the *Cladonia* species, also survive partly in the third stage of the succession, characterized by thick soil and grassland dominated by dense stands of grasses and other vascular plants. Lichens are not prominent in the grassland, apart from *Cladonia* species and some species of *Peltigera*, especially *P. canina* and *P. neckeri*.

The palagonite tuff of Austurbunki

For many years the volcanic cones, Vesturbunki and Austurbunki, made of loose tephra, were unfavourable for lichen colonization. They were not firm enough and eroded too quickly. First in 2002 it was noticed, that lichen colonization had started on the top of Austurbunki and a little later on the little lower southeast shoulder of the same mountain. The first species seen on this substrate were *Caloplaca citrina* (Fig. 9), *Lecanora* cf. *albescens* and *Lecanora* cf. *semipallida*. In 2006, *Caloplaca crenularia* and *Verrucaria muralis* were also recorded there.

Man-made substrate, concrete

In 1993 a helicopter platform made of concrete was built. In 2006 three lichen species had established on the platform, viz. *Candelariella aurella* (Fig. 10), *Lecanora* cf. *albescens* and *Lecanora* cf. *semipallida*.

ANNOTATED LIST OF SPECIES

All species of lichenized and lichenicolous fungi recorded on Surtsey are presented below in alphabetical order. Their occurrences on Surtsey and in other parts of Iceland are described. Lichenicolous species are marked with an asterisk (*). Figure 2 shows the number of species found 1970–2006, together with the accumulated number of species recorded over the same period. In Table 1 the species are listed in the order they were discovered on Surtsey.

Acarospora smaragdula *(Wahlenb.) A.Massal.*

Common in the more oceanic parts of Iceland, in the South and along the western and eastern coasts. It is characterized by light brown or gray-green, very pale, rather dispersed thallus lobes of 0.5–2 mm diameter. The apothecia are immersed, light to dark brown, one to several on each thallus lobe. In the more continental regions of the North and Northeast of Iceland it is more or less replaced by *Acarospora veronensis*.

On Surtsey *A. smaragdula* was first seen in 1971 and again 1972 on the elevated margin of the Surtungur crater. In 1973 it was seen in several localities, mainly on peaks in the lava fields (Kristinsson 1974, as *Acarospora*). In 1978 the species was already very widely distributed on lava surfaces but also on vertical rock faces and shelves. Even though *A. smaragdula* requires an oceanic climate, it obviously tolerates drier habitats than most other lichens on Surtsey. Most other lichens on Surtsey express more vigorous growth in the lower sites between the peaks where moisture conditions are more favourable.

A few *Acarospora* specimens on Surtsey deviate from the typical *A. smaragdula* by having more or less continuous, areolate thallus and larger apothecia with more raised margin. The colour of the thallus has often an orange tint. These specimens were collected on the lava fields around the gull colony in 1994 and 1998, and might belong to *A. amphibola*.

****Arthonia gelidae*** *R.Sant.*

A lichenicolous fungus growing on *Placopsis*. Collected on Surtsey in 1998, growing on *Placopsis* beneath a bird's nest on the inside wall of the Surtungur crater. This species has only been recorded once before in Iceland by Berger (2000) who found it growing on *Placopsis gelida* at Landmannalaugar in the southern part of the Central Highlands of Iceland.

Arthonia lapidicola *(Taylor) Branth & Rostr.*

Very small and inconspicuous species, rarely collected. The thallus is very thin and concoloured with the rock, the apothecia black and only 0.2 mm diameter, barely visible to the naked eye. In Iceland it is usually found on small pebbles lying on the ground, especially on moderately moist gravel flats or old river beds.

This species was first found on Surtsey 1973 growing on a lava outcrop below a top with *Acarospora* (mentioned in Kristinsson 1974 as *Arthonia*). Later it was also found in a sample of *Hymenelia arctica* collected 1998 on basalt on the bottom of the Surtungur crater. It is probably more common on Surtsey than these two records suggest.

Table 1. Lichen species found on Surtsey during the years 1970–2006. Filled squares indicate that the species was seen that year.

Species	1970	1971	1972	1973	1975	1978	1984	1990	1994	1998	2002	2006
Placopsis gelida	■	■	■	■	■	■	■	■	■	■	■	■
Stereocaulon vesuvianum	■	■	■	■	■	■	■	■	■	■	■	■
Trapelia coarctata	■	■	■	■	■	■		■	■	■	■	■
Acarospora smaragdula		■	■	■	■	■	■	■	■	■	■	■
Lichenomphalia cf. *velutina*		■			■	■						
Psilolechia leprosa		■	■	■	■	■	■	■	■	■	■	■
Stereocaulon capitellatum		■	■	■	■	■	■	■	■	■	■	■
Lecania subfuscula			■	■			■	■	■	■	■	■
Porpidia cf. *crustulata*			■				■	■	■	■	■	■
Xanthoria candelaria			■	■				■	■	■	■	■
Arthonia lapidicola				■								
Porpidia soredizodes							■	■	■	■	■	■
Rhizocarpon lavatum							■	■	■	■	■	■
Stereocaulon alpinum							■		■	■	■	■
Stereocaulon glareosum							■				■	
Stereocaulon spathuliferum							■					
Caloplaca verruculifera								■	■	■	■	■
Cladonia furcata								■	■	■	■	■
Cladonia macroceras								■		■	■	■
Cladonia symphicarpia								■	■			
Gyalidea fritzei								■				■
Gyalidea sp.								■	■	■	■	
Hymenelia arctica								■	■			■
Lecanora sp.								■		■	■	■
Lecidea lapicida var. *pantherina*								■	■	■	■	■
Micarea sp.								■	■	■	■	■
Peltigera canina								■				■
Porpidia melinodes								■			■	■
Porpidia tuberculosa								■		■		
Rhizocarpon expallescens								■				■
Rhizocarpon petraeum								■				
Scoliciosporum umbrinum								■				■
Stereocaulon cf. *tornense*								■		■	■	
Stereocaulon sp.								■				■
Xanthoria parietina								■	■			■
Cladonia chlorophaea									■	■	■	■
Collema tenax									■			■
Lecanora salina									■	■		
Leptogium lichenoides									■			■
Peltigera didactyla									■			■
Pertusaria sp.									■			
Protopannaria pezizoides									■	■		
Rhizocarpon reductum									■			
Stereocaulon arcticum									■			■
Stereocaulon rivulorum									■			
Stereocaulon vanoyei									■	■		■
Trapelia involuta									■	■		■
Arthonia gelidae												
Baeomyces rufus												■
Calvitimela armeniaca												
Candelariella coralliza												■
Catillaria chalybeia												■
Cladonia pocillum												■
Cladonia rangiformis												■
Lecanora poliophaeae												■
Lecidea sp.												
Peltigera venosa												
Pilophorus cereolus												
Placopsis lambii												
Polyblastia sp.												
Porpidia flavicunda												■
Solorina bispora												
Stereocaulon tomentosum												■
Verrucaria aquatilis												■
Verrucaria muralis												■
Caloplaca citrina											■	■
Cladonia islandica											■	
Collemopsidium halodytes											■	■
Lecanora cf. *albescens*											■	■
Lecanora cf. *semipallida*											■	■
Peltigera neckeri											■	■
Peltigera praetextata											■	
Pilophorus dovrensis											■	
Psilolechia clavulifera											■	
Pyrenidium hyalosporum											■	
Rinodina gennari											■	■
Verrucaria sp.											■	■
Arthonia phaeobaea												■
Caloplaca crenularia												■
Candelariella aurella												■
Endococcus fusiger												■
Peltigera rufescens												■
Phaeophyscia orbicularis												■
Physcia caesia												■
Physcia dubia												■
Physcia tenella var. *marina*												■
Porpidia speirea												■

Arthonia phaeobaea *(Norman) Norman*

Considered common all around Iceland on coastal rocks. Sigrídur Baldursdóttir (1985) studied marine and maritime lichens in six localities from Hvalfjördur in the southwest to Hornafjördur in the southeast and found *A. phaeobaea* in all localities.

It was first discovered on Surtsey in 2006, growing on the lava surface. The thalli of the specimens are richly fertile and contain a great number of pycnidia.

Baeomyces rufus *(Huds.) Rebent.*

Very common in all parts of Iceland, usually growing on bare soil and peat. First found on Surtsey in a few localities on thin soil around the gull colony in the southern part of the island in 1998. Fertile samples, growing directly on weathered lava rock, were collected 2006 inside the Surtungur crater.

Caloplaca citrina *(Hoffm.) Th.Fr.*

Common on and around bird cliffs along the southern coast of Iceland. It has a sorediate surface, with particles that will easily attach to and be carried around by birds' feet.

First seen and collected on Surtsey in 2002 on palagonite tuff on top of Austurbunki, which is the highest top of the island. It was accompanied by a species of *Verrucaria*. In 2006 it was seen again on the southeastern ridge of Austurbunki, growing on the same substrate (Fig. 9). It is one of very few species that have managed to colonize the secondary rock formed by consolidation of the tephra.

Caloplaca crenularia *(With.) J.R.Laundon*

Rather frequent on rock along the western and southern coasts of Iceland, but not in other regions. It was first discovered on Surtsey in 2006, growing together with *Caloplaca citrina* (see above) on palagonitized tephra on top of the southeastern ridge of Austurbunki. It has a white thallus with orange to rusty brown apothecia. So far it is known only from this single locality on Surtsey.

Caloplaca verruculifera *(Vain.) Zahlbr.*

Common on coastal rocks all around Iceland except on the sandy southern coast. First seen on Surtsey in 1990 within the gull colony, like *Xanthoria candelaria* mainly growing on lava peaks and blocks visited by birds (Fig. 11). There is little doubt that *Caloplaca verruculifera* has been transported to the island by the birds like *Xanthoria candelaria*. Both produce soredia, which are easily attached to the bird's feet, and both are only found in the regions with the highest activity of the seabirds. However, in the central part where the colonization started, their habitat is deteriorating because of the rapid thickening of the soil and expansion of the grassland. However, their distribution extends towards the margins where new areas are colonized by birds.

Calvitimela armeniaca *(DC.) Hafellner*

Only seen on a sample collected in 1998 in a depression in the lava flow east of the hut, Pálsbaer. Four separate, sterile thallus areolae on a sample of *Porpidia soredizodes* had the characteristic colour of this species, with very pronounced, black hypothallus around them. Spot tests also showed the characteristic red reaction by K and KC generally found by *C. armeniaca*. Since this species is absent from the whole southern part of Iceland and common only in the North and the Central Highlands, this record from Surtsey should be treated with caution.

Candelariella aurella *(Hoffm.) Zahlbr.*

Probably very common in all regions of Iceland on various substrates. It is, however, rarely collected since it mainly grows on man-made substrates like monuments, concrete walls and pavements, and it is not easily distinguished from *C. vitellina*. It was found on Surtsey in 2006 growing on the concrete of the helicopter platform (Fig. 10).

Candelariella coralliza *(Nyl.) H.Magn.*

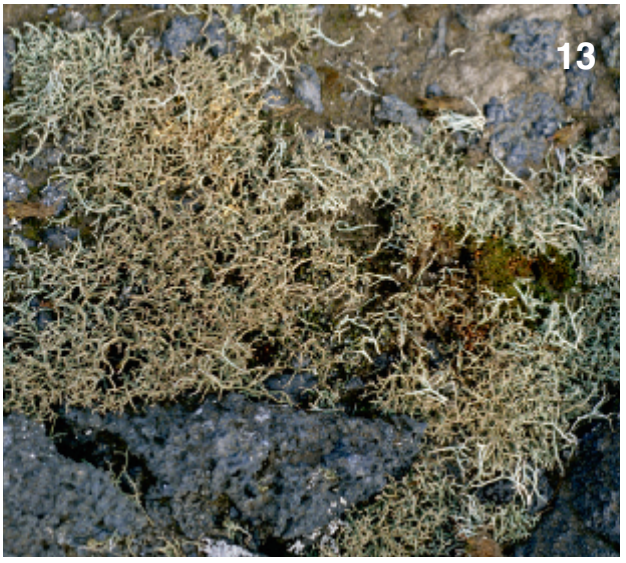
Common in Iceland growing on rock as well as on soil, peat and mosses. First seen on Surtsey 1998 on lava rocks in the gull colony, growing together with *Acarospora smaragdula*, *Lecanora* sp., *Psilolechia leprosa* and *Stereocaulon vesuvianum*. It is still rare there, but was seen again in 2006 growing directly on lava rock (Fig. 12).

Catillaria chalybeia *(Borrer) A.Massal.*

Widely distributed along the western, southern and eastern coast of Iceland. It forms thin, blackish, areolate crusts with small, black apothecia. It was found on Surtsey in 1998 on lava blocks frequently visited by birds east of the Pálsbaer. In 2002 and 2006 it was collected in a few other localities, at the western margin of the Surtungur crater and in the lava fields. It is probably rather widely distributed on the island but easily overlooked because of its dark colour.

Cladonia chlorophaea *(Flörke ex Sommerf.) Spreng.*

Very common all over Iceland. Well developed and typical specimens with podetia were first recorded on Surtsey in the year 1994. They were found growing on soil in the gull colony. Primary squamules of *Cladonia* containing fumarprotocetraric acid that was found as early as 1990 might well belong to this species but it has not been possible to identify them with certainty. Since the spe-



Figures 13–15. Fig. 13. *Cladonia furcata* on thin soil over lava rock near the gull colony in Surtsey in 1998. Fig. 14. *Cladonia macroceras* over mosses in the gull colony in 1994. Plants of *Sagina procumbens*, a rapid colonizer in the early soil formation, are seen at the upper margin. Fig. 15. *Cladonia rangiformis* in Surtsey in 2005 (Photo: Sigurdur H. Magnússon).

cies generally grows on soil it had no suitable habitat on Surtsey until soil had been formed in the gull colony.

Cladonia furcata *(Huds.) Schrad.*

Very common in all parts of Iceland. On Surtsey it was one of the first lichens to colonize the thin soil formed around the gull colony together with *Cladonia macroceras*. First seen in 1990 in a depression in the lava field very close to the first plants of *Alchemilla filicaulis*. The thalli of this first sample are more slender than usually, a growth form frequently found in the southeastern part of Iceland. It has been seen frequently in recent years and can now be regarded as very common in the area affected by the gulls (Fig. 13).

Cladonia islandica *Kristinsson & Ahti*

Widely distributed in Iceland, although not very common. Although known for many years, it was first recently formally described (Kristinsson & Ahti 2009). It is related to *Cladonia subulata* and has fumarprotocetraric acid as the sole secondary lichen compound. It differs from that species in having podetia that are densely squamulose in the lower part and usually more or less decorticated in the upper part, without soredia.

This species is probably rare on Surtsey and has been collected only once in 2002, when it was found growing on soil in a lava channel on the northwest side of the gull colony.

Cladonia macroceras *(Delise) Hav.*

Rather common in all regions of Iceland and seems to prefer tops of cairns or hills or rather fertile heathland. Like *Cladonia furcata* this species was first found on Surtsey in 1990 when the soil formation around the gull colonies had started. It is more frequent than *C. furcata*, and has been recorded on every visit since it was first discovered. Already in 1994 it had a wide distribution and formed well developed, rather large specimens (Fig. 14). *Cladonia furcata* and *C. macroceras* are the most common fruticose lichens on Surtsey. According to our observations *C. macroceras* is more coprophilic and more attracted by the bird colonies than *C. furcata*.

Cladonia pocillum *(Ach.) Grognot*

This is one of the most common *Cladonia* species in Iceland. Generally it is a primary colonizer of disturbed sites, growing on soil or peat, but it is not always easily identified, least of all in its younger stages. Some unidentified specimens collected or seen on Surtsey already in 1978 may belong to this species. There were, however, no suitable habitats until 1990 and later when some soil had been formed in the gull colony. Good samples were col-

lected in 1998, both under the western cliffs inside the Surtungur crater and also in the gull colony in the southern part of the island, where it was widely distributed and common in 2002.

The specimens here referred to as *Cladonia pocillum* differ somewhat from the typical *C. pocillum* as it appears in Iceland. The podetia are low, rarely exceeding 5 mm in height, with broad cups up to 7 mm in diameter. The particles covering the surface inside the cups vary from corticated, bullate granules up to 0.5 mm diameter to fine grained soredia. The primary squamules are neither as thick nor as coalescent as in typical specimens, but rather erect, concave and partly with a shiny surface. The specimens collected on Surtsey are very uniform in this respect. Most of these deviating characters agree with those of *Cladonia monomorpha* Aptroot, Sipman & van Herk. (Aptroot *et al.* 2001), except that many of the cups have sorediate inside.

Cladonia rangiformis *Hoffm.*

Relatively common in coastal districts all around Iceland. Rare on Surtsey, first detected 1998 growing on the soil formed in the gull colony, and again seen both in 2005 (Fig. 15) and 2006. Morphologically rather similar to *Cladonia furcata* but contains atranorin. Some of the Surtsey specimens are more prostrate and less branched than normal *C. rangiformis*, belonging to a morphotype frequently found in exposed habitats in Vestmannaeyjar Islands and some other localities along the southern coast.

Cladonia symphycarpia *(Flörke) Fr.*

Fairly common in Iceland, but overlooked since it only forms primary squamules without podetia. It was already among the primary colonizers in the gull colony in 1990 and collected again 2006. The samples contain atranorin and trace of norstictic acid. The psoromic acid strain (*Cladonia dahliana* Kristinsson), which is characteristic for snow rich habitats in Iceland, has not been found on Surtsey.

Collema tenax *(Sw.) Ach. em. Degel.*

Common in Iceland, growing on soil and over mosses. First discovered on Surtsey 1994 on a rocky slope on the inside of the Surtungur crater below a raven's nest. It was growing over mosses on rocks. The same year it was also seen over mosses on a vertical wall of a lava channel in the gull colony, as well as directly over the thin soil already formed in the colony. Since 1998 it has been found to be common and widely distributed around and in the colony forming well developed specimens and some even with apothecia.

Collemopsidium halodytes *(Nyl.) Grube & B.D.Ryan*

Probably common on the Icelandic coasts although rarely collected. First discovered on Surtsey in 2002, on coastal rocks on the eastern coast of the island. Seen again in the same area 2006. This is the first lichen limited to coastal cliffs found on Surtsey. *Verrucaria maura* and *V. mucosa* which are very common around the Icelandic coast have not yet been seen on Surtsey, mainly because most of the coastal rocks are constantly being broken down by the ocean every winter so these lichens do not have sufficient time to become established.

****Endococcus fusiger*** *Th.Fr. & Almq.*

A rare lichenicolous fungus which was found growing on *Rhizocarpon lavatum* on Surtsey in 2006. The species has previously been found at one locality in northern Iceland (Svane & Alstrup 2004).

Gyalidea fritzei *(Stein) Vězda*

First collected on Surtsey in 1990 and again in 1994 in the bottom of the Surtungur crater. It was apparently rather widely distributed within the crater, on sloping faces of basalt rock and also on vertical walls in a rift in the crater bottom. In 1998 and 2006 the species was also collected in lava fields outside the crater (Fig. 16). It is a very inconspicuous species, with a thallus concolorous with the basalt and the dark apothecia very small, 0.2–0.4 mm in diameter. The species has not been recorded from Iceland before but is probably overlooked. We have seen one further specimen collected by Svanhildur Svane in 1992 in Streitishvarf, East Iceland.

Gyalidea sp.

Another species of *Gyalidea* was collected in the Surtungur crater 1990, and again in the aa lava about 100 m south of Pálsbaer. This species has a white apothecial margin. None of these samples had mature asci or ascospores. Some *Gyalidea* species have whitish apothecia, like for instance *Gyalidea praetermissa* Foucard & G.Thor.

Hymenelia arctica *(Lynge) Lutzoni*

Rather rare species found in different regions of Iceland but appears to be especially common in the southern part of the Central Highlands. A well developed specimen of this species was collected in 1998 in the bottom of the Surtungur Crater, on basalt rock. It was richly fertile with orange, shining apothecia. A sample collected 1990 on the western edge of the eastern crater (Surtur I) probably also belongs to this species but it is poorly fertile and not as characteristic.

Lecania subfuscula *(Nyl.) S.Ekman*

In the herbaria there are only a few collections of this species from Iceland. These records suggest, however, that it might be common in some specialized habitats, like near bird cliffs. In one case it has been collected growing directly on the excrements of geese.

On Surtsey it was first discovered in 1972, growing on a rock on the outside of the elevated margin of the Surtungur Crater together with *Acarospora smaragdula* and *Trapelia coarctata*. This sample was recorded and illustrated in a previous paper (Kristinsson 1974), as nr. 7, *Bacidia*, occurring very sparsely. It has not been seen again in that locality.

In 1984 it was found again in two other localities on Surtsey, one at the side of white-painted square used as landmark for air photography, and the other in a place where activity of birds had triggered soil formation. The white square attracted birds just as the water tubs did before, and the lichen was growing on the surrounding rocks that were trampled and defecated by birds, probably mainly gulls.

After 1990 this species has become the main colonizer of all rock faces within and around the gull colony. It covers more or less the whole territory inhabited by the gulls along with the *Lecanora* sp. mentioned below, occurring on various substrates, directly on lava rock, on soil or over mosses.

Lecanora *cf.* ***albescens*** *(Hoffm.) Branth & Rostr.*

The first lichens growing directly on palagonitized tephra were collected 2002 and again 2006 on the top of Austurbunki. Among them was a species of the *Lecanora dispersa*-group which seems to belong to *L. albescens*. If correctly identified, this is a new record for Iceland. Similar thalli were found growing directly on the concrete basis of the helicopter platform in 2006 (Fig. 17). In both cases the species was growing together with the following species, *L.* cf. *semipallida*.

Lecanora poliophaea *(Wahlenb.) Ach.*

Common on maritime rocks around Iceland, usually growing together with *Lecania aipospila*, *Lecanora helicopis* and other species just above the *Verrucaria maura* zone. Characteristic for the species is very pronounced, areolate, grey thallus, the areolae with warted surface. The apothecia are brown with whitish margin.

On Surtsey it was first found in 1998, growing very sparsely on lava rock in the gull colony. It was more widely distributed in 2006 but still only within the gull colony (Fig. 18).

Lecanora salina *H.Magn.*

Very small and inconspicuous with apothecia in small groups, 0.3–0.6 (–0.8) mm in diameter, light yellowish brown with lighter margin, and concolourous, hardly visible thallus.

Only detected in few samples from Surtsey, the first ones collected in the western slope of the Surtungur Crater in 2002 and in Strompur, a small lava outlet on the inside of Austurbunki. Later on it was also detected in an older sample from 1994 collected in the lava fields around the gull colony (Fig. 19). This species has been recorded only once from Iceland before (Kristinsson 1999) and is probably overlooked because of its small size and obscure colour.

Lecanora *cf.* ***semipallida*** *H.Magn.*

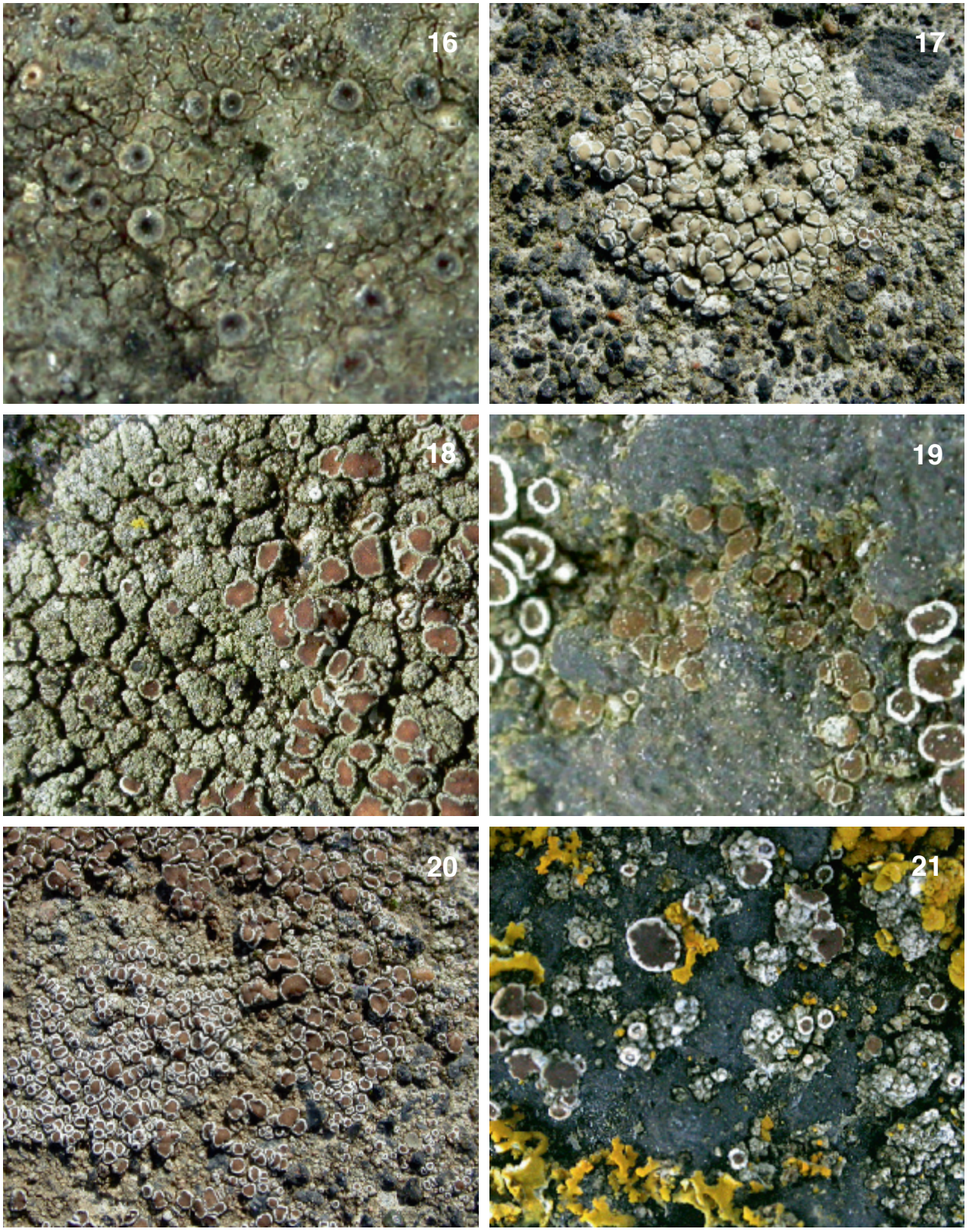
Collected on the top of Austurbunki 2002 and on the helicopter platform in 2006 (Fig. 20). At the first locality it was growing directly on palagonite tuff together with *Caloplaca citrina* and *Lecanora* cf. *albescens*. In the second locality it was associated with *Candelariella aurella* and *Lecanora* cf. *albescens*. This species was recently redelimited by Śliwa (2007a, 2007b). The specimens from Surtsey fit well her description except that the apothecial margin shows negative reactions to K and C. The identification needs to be confirmed when more material becomes available.

Neither *L. albescens* nor *L. semipallida* have been recorded from Iceland before even though they must certainly be rather common on concrete. They are probably included in older records under the names *Lecanora dispersa* or *L. hagenii* but the *L. dispersa* group in Iceland has not yet been revised.

Lecanora sp.

One of the two most successful colonizers on the lava rock around the gull colony was a *Lecanora* species which has not yet been identified. The other equally successful colonizer of this habitat was *Lecania subfuscula*. These two species almost fully covered the rock faces regularly tramped by the gulls. They retreated as soil and dense grass vegetation developed. They retained their habitat only on single peaks of lava rocks protruding through the vegetation cover.

This *Lecanora* mainly consists of a great number of apothecia, often without a visible thallus. When present the thallus is white, with verrucose surface, partly formed by primordial stages of apothecia (Fig. 21). Mature apothecia are brown to dark brown with rather thick, white thalline margin, relatively large, 0.5–2.5 mm in diameter, constricted at the base and often incised, more or less flexuose with age. The apothecia are similar to those of *Lecanora poliophaea*. The species differs from *L. poliophaea* by lacking the characteristic dark grey, ver-



Figures 16–21. Fig. 16. *Gyalidea fritzei* in Surtsey in 1994. Fig. 17. *Lecanora* cf. *albescens* on the helicopter platform in 2006. Fig. 18. *Lecanora poliophaea* on lava rock in the gull colony in 2006. Fig. 19. *Lecanora salina* (small apothecia in the center) on lava rock in the gull colony. *Lecanora* sp. is seen on the left and the right side with white margin. Fig. 20. *Lecanora* cf. *semipallida* on the helicopter platform in 2006. Fig. 21. *Lecanora* sp. (white thallus with dark brown apothecia) between thalli of *Xanthoria candelaria* (lower left) and *Caloplaca verruculifera* (upper right).

rucose thallus of that species. If present, the thallus is white rather than grey.

A specimen of this *Lecanora* was sent to Ulf Arup in Lund, Sweden for further investigation and DNA-analysis. His results indicate that this is a new species with the closest relationship to *Lecanora beringii* Nyl., an arctic species known from the Beringian Islands, the Canadian Arctic and Greenland.

Lecidea lapicida *(Ach.) Ach. var.* ***pantherina*** *Ach.*

One of the most common species on basaltic rocks in Iceland. Rarely seen on Surtsey, first observed inside the Surtungur Crater in 1990 and again 1998. It has also been found on the aa lava near the eastern coast.

Lecidea sp.

An unidentified species of *Lecidea* was collected on basalt rock on Surtsey 1998. It has a white, relatively thick thallus with a glossy surface, and black apothecia with a dark brown hypothecium. All thallus reactions are negative, including the I-reaction of the medulla.

Leptogium lichenoides *(L.) Zahlbr.*

This is the most common species of the genus *Leptogium* found all over Iceland. It grows over mosses on soil and cliffs. It is a foliose lichen with very small, crowded, brown, incised lobes, c. 0.5 mm broad.

It was first found on Surtsey in the inside slopes of the Surtungur Crater below the raven's nest site in 1994. In the same year the first specimens were also detected near the gull colony, on soil frequently trampled by birds, growing together with *Bryum argenteum*. Since then this species has been seen frequently as primary colonizer over the mosses following the soil formation in the gull colony. Like the mosses it retreats again as the succession continues and their habitat gets converted into grassland.

Lichenomphalia *cf.* ***velutina*** *(Quél.) Redhead et al.*

In 1971 the first mushrooms were discovered on Surtsey apparently growing directly out from the lava rock, often accompanied by mosses mainly of the genus *Racomitrium* (Fig. 22). Several collections of the species are from 1975 and 1978. On closer observation a *Botrydina*-type thallus was observed around its base, so this mushroom turned out to be lichenized *Omphalina*, now usually referred to the genus *Lichenomphalia*. This species has been found now and then in the following years growing in the lava fields, often accompanied by the usual colonizers like *Racomitrium lanuginosum* and *Stereocaulon vesuvianum*. Rarely seen in the later years, but the darker brown mushroom *Omphalina rustica* is very common on soil in the gull colony.

Micarea *sp.*

An unidentified specimen probably belonging to the genus *Micarea* was collected on rock below the nesting site of a raven in the inside slope of the Surtunger crater in the year 1990. It has not been seen again.

Peltigera canina *(L.) Willd.*

One of the most common species of this genus in all regions of Iceland. It was also the first species of *Peltigera* found on Surtsey, on the bottom of the crater Surtungur in 1990 (Fig. 8), growing on a continuous carpet of *Racomitrium ericoides*. The lichen had already reached considerable size so it must have been growing there for some years although it was not found in 1984. In 1994 and thereafter the species has also been found in depressions and rifts in the lava fields in the southern part of the island. Since 1998 it has been considerable common on soil inside the gull colony.

Peltigera didactyla *(With.) J.R.Laundon*

Frequent colonizer on soil in relatively moist, disturbed areas in Iceland. It was found in several locations inside the Surtungur crater in 1994 and again in the same localities 1998 and 2002. It was most frequent on the western slopes under the inside cliffs, and also in rifts on the bottom of the crater.

Peltigera neckeri *Hepp. ex Müll.Arg.*

This is the most common species of the *Peltigera polydactyla*-group in Iceland and the first to be seen on Surtsey. A large specimen was found in the northwestern part of the gull colony in 2002. Four years later, in 2006, well developed thalli appeared to be rather widely distributed in the gull colony.

Peltigera praetextata *(Flörke ex Sommerf.) Zopf*

Rather widely distributed throughout Iceland, but more common in the South than in other parts of the country. Two young specimens of this species were collected on Surtsey in 2002. They were first thought to be *Peltigera canina* since the main characters distinguishing *P. praetextata*, the isidia on the margin and along cracks on the surface were hardly visible. But the venation on the lower side and the appearance of the upper surface strongly suggest that these specimens belong to *P. praetextata*. Both locations were within the gull colony.

Peltigera rufescens *(Weiss) Humb.*

Very common in all regions of Iceland, especially abundant at higher elevations and in the North. Not seen on Surtsey until 2006 when a very charac-

teristic and well developed specimen was collected growing on mossy soil in a lava channel south of the Pálsbaer.

Peltigera venosa *(L.) Hoffm.*

Common in all regions of Iceland, especially found under soil banks or on steep or overhanging cliffs. Very young specimens were first discovered on Surtsey 1998, and were again seen 2002 in the same locality as *Peltigera didactyla* below the cliffs in the Surtungur Crater. Only small, infertile lobes were seen.

Pertusaria sp.

Samples of a sterile, crustose species with white thallus growing on rock were collected in 1994 and 1998 on the bottom of the Surtungur Crater. The thallus is thin and has coarsely granular soralia. Neither the thallus nor the soralia react with Pd, K or C. The specimens resemble *Pertusaria aspergilla* morphologically but that species is Pd+ orange-red. Another possibility would be *P. albescens* but that species is usually more or less dark grey, not fitting the Surtsey specimens.

Phaeophyscia orbicularis *(Neck.) Moberg*

Rather common along the western and southern coasts of Iceland near sea bird cliffs, rare elsewhere. First found on Surtsey 2006 on lava rock in the eastern part of the gull colony. The specimen was small but had well developed lobes with soralia.

Physcia caesia *(Hoffm.) Fürnr.*

Distributed all over Iceland and the second most common *Physcia* after *P. dubia*. A quite well developed specimen, about 3 cm across and with abundant soralia was found on Surtsey in 2006, growing in the eastern part of the island on lava peaks north of the gull colony.

Physcia dubia *(Hoffm.) Lettau*

Very common all over Iceland, growing in a similar habitat to *Xanthoria candelaria*, i.e. on rock outcrops, fence posts and other sites frequently visited by birds. First seen on Surtsey 2006 on lava outcrops near the gull colony.

Physcia tenella *(Scop.) DC. var.* ***marina*** *(E.Nyl.) Lynge*

This species is common in the coastal districts of Iceland but rare further inland. It was not found on Surtsey until 2006 (Fig. 23), very close to the locality of *Physcia caesia*. The small samples have the characteristic marginal cilia distinguishing it from the other *Physcia* species. Moberg (2002) considers this variety to be merely a habitat-induced modification.

Pilophorus cereolus *(Ach.) Th.Fr.*

Rare in Iceland, most records from the southwestern region. First collected in 1998 on Surtsey on light reddish brown rock southeast of the Surtungur Crater. The specimen has a crustose, K+ yellow thallus with black cephalodia and some sorediate warts and is apparently a young, immature thallus of *Pilophorus cereolus*. Two specimens were found in new localities in 2002. One of them was well developed and typical with mature pseudopodetia, growing on the western inside slope of Surtungur crater. The other one was at a similar early stage as the one from 1998, found on the mountainside of Austurbunki above Strompur, growing on palagonite tuff.

Pilophorus dovrensis *(Nyl.) Timdal, Hertel & Rambold*

Can be regarded as common in the neighbourhood of the glaciers in the Central Highlands and in high mountain areas in the northern Iceland, but rather rare in other regions. First recorded from Surtsey in 2002, growing on a rock in the southern part of the Surtungur crater. Richly fertile.

Placopsis gelida *(L.) Linds.*

Very common in the more oceanic parts of Iceland. In the more continental regions it is rare except at higher elevations, where it apparently enjoys higher moisture than in the lowlands. It is one of the main colonizers of lava fields in Iceland along with *Stereocaulon capitellatum, S. vesuvianum*, *Racomitrium ericoides* and *R. lanuginosum*.. It was one of the three lichen species first observed on Surtsey in 1970, in the lava fields north of Surtungur where some steam kept the surface moist. In the following years it was found everywhere in the lava fields and in the Surtungur crater. This simultaneous appearance almost everywhere in the lava fields can be seen as evidence of dispersal by air currents. In the Surtungur crater, in sheltered, moist habitats, it was often richly fertile with large, pink apothecia.

Placopsis lambii *Hertel & V.Wirth*

This species, described by Hertel and Wirth in 1987 (Wirth 1987), was overlooked in the Nordic countries, until Moberg and Carlin (1996) clarified its status in those countries. Morphologically *P. lambii* and *P. gelida* are not easily distinguished, although typical specimens can be recognized in the field. The safest way of recognizing *P. lambii* is by TLC, as the species differs from *P. gelida* in having 5–0-methylhiascic acid. Only four specimens of *P. lambii* have been collected on Surtsey, the first in 1998, but it is possible that some of the field observations of *P. gelida* refer to *P. lambii*.

***Polyblastia** sp.*

The lichen genus *Polyblastia* has been circumscribed as having muriform spores, either hyaline or brown. The genus has recently been revised by Savić *et al.* (2008) who showed that *Polyblastia* as traditionally circumscribed is polyphyletic. The specimen from Surtsey was collected in 1998 on basalt and belongs to *Polyblastia* s.str. as delimited by Savić et al (2008).

***Porpidia** cf **crustulata** (Ach.) Hertel & Knoph*

This is by far the most common species of the genus *Porpidia* on Surtsey (Fig. 7). The identification has been very problematic and we must still look at this as a species group which we have not been able to separate in a reasonable way. Most of the specimens have epilithic, moderately thick, white thallus, thicker than is usual for *P. crustulata*. For this reason it was first identified by morphology alone as *Porpidia cinereoatra* but since it either contains stictic acid as the main substance or lacks substances, this possibility was excluded. Of the *Porpidia* species containing stictic acid, *P. crustulata*, *P. macrocarpa* and related species seem to fit most of the specimens best. The separation of these two species has long been very problematic, the main characters separating them being the spore size and the size of apothecia. *P. crustulata* should have apothecia less than 1.5 mm in diameter, and ascospores 12–16 µm long, while in *P. macrocarpa* the apothecia are up to 2–3 mm in diameter, and the ascospores 16–23 µm long. In the material from Surtsey both the size of the apothecia and the ascospores is very variable (the ascospores 12–22.5 µm and the apothecia 1–2.5 mm). Most probably both *P. crustulata* and *P. macrocarpa* are present in the material, but it would seem rather arbitrary to try to separate them solely on the basis of these characters, especially since they are inconsistent.

Some of the specimens have pruinose apothecia which might indicate that *Porpidia platycarpoides* is also involved. That species has not been recorded in Iceland but Friday (2005) lists it both from the British Isles and North America. The recently described *Porpidia islandica* (Fryday 2005) might also be included in the collected material. In our opinion it is hardly possible to separate the Surtsey material of this group sufficiently without a revision of the large Icelandic collection of the whole group at the same time.

The species complex described above was first seen on Surtsey 1972, recorded as No. 8 *Lecidea* in Kristinsson 1974. It was seen again in 1975 and after that in increasing number at each visit. Today it is common in the lava fields and in the craters of Surtsey.

***Porpidia flavicunda** (Ach.) Gowan*

Very common in Iceland. It is generally characterized by a dark orange thallus without soredia, much darker than *Porpidia melinodes*. Specimens assigned to this species in Iceland have recently been separated into two species, *P. flavicunda* and *P. flavocruenta* (Fryday 2005) but the relationship between the two species has not yet been clarified in Iceland.

Porpidia flavicunda s. lat. was first noticed on Surtsey in 1998 at four different localities, growing on lava rock. The Surtsey specimens have not quite as dark colour as is usually seen in Icelandic material of this species.

***Porpidia melinodes** (Körb.) Gowan & Ahti*

Equally common in Iceland as *P. flavicunda*, occurring from the lowlands to the alpine zone. It is lighter in colour, always with dark grey soredia, sometimes also fertile. On Surtsey it has mainly been recorded since 1990 in both of the craters and elsewhere on lava blocks (Fig. 24). A sample collected already in 1972 on the outside wall of Surtungur crater, a site that was long supplied by warm steam, is probably also *P. melinodes*. It was mentioned in Kristinsson 1974 as No. 9 *Lecidea*. At present it is widely distributed throughout the lava fields in favourable sites.

***Porpidia soredizodes** (Lamy ex Nyl.) J.R.Laundon*

Sterile and sorediate species with a non-amyloid (I–) medulla. It is widely distributed in Iceland and rather common on blocks in the lava fields of Surtsey and in the craters. It was first identified in a sample from 1984.

***Porpidia speirea** (Ach.) Kremp.*

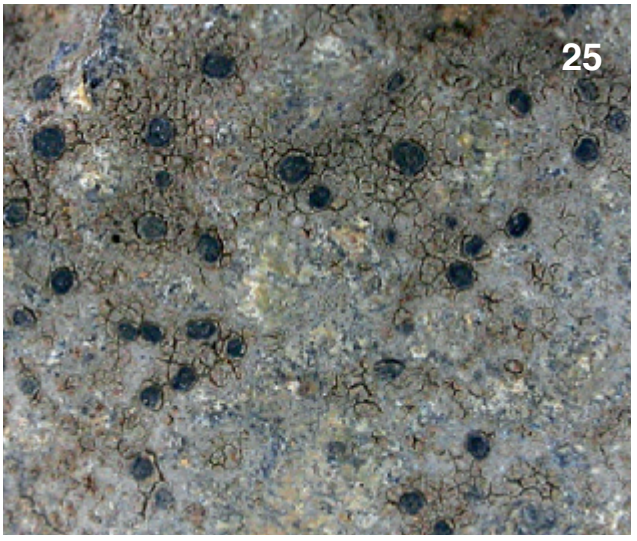
Rather common on rocks in Iceland, preferable shaded side. Easily recognized by the pronounced white thallus and the black, more or less immersed, often pruinose apothecia. Rare on Surtsey, first collected in 2006 on rock in the lava field.

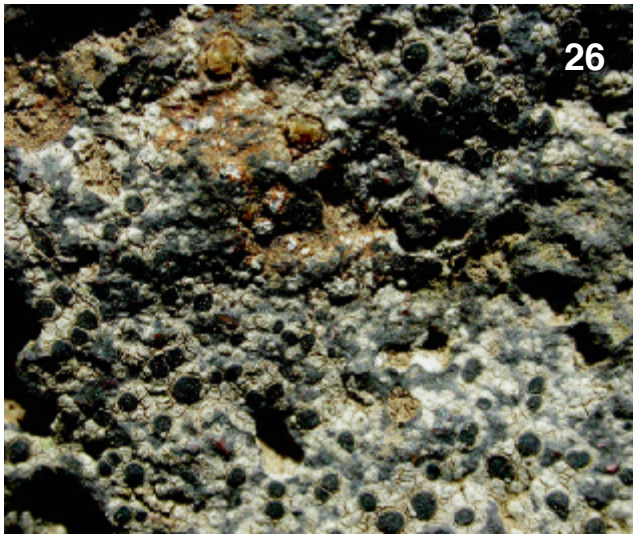
***Porpidia tuberculosa** (Sm.) Hertel & Knoph*

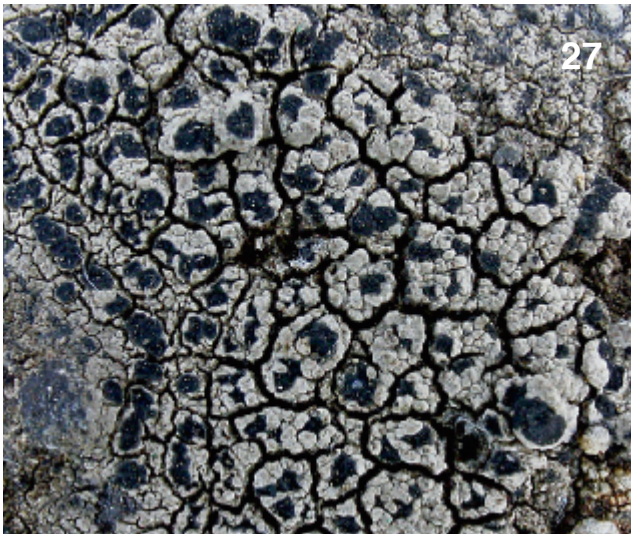
Sterile and sorediate species with an amyloid (I+) medulla. Widely distributed in Iceland, but probably less frequent than *P. soredizodes*. Rare species on Surtsey, found only in a few places in the lava fields, first collected 1990.

***Protopannaria pezizoides** (Weber) P.M.Jørg. & S.Ekman*

Very common growing on soil all around Iceland. Very rare on Surtsey, only seen once in 1994 in a cleft of the lava field in the bottom of the Surtungur crater. It has not been seen again.







Figures 22–27. Fig. 22. *Lichenomphalia* cf. *velutina* among young *Racomitrium* plants in the Surtsey lava in 1971. (Photo: Erling Ólafsson) Fig. 23. The first specimen of *Physcia tenella* seen in Surtsey in 2006. Fig. 24. *Porpidia melinodes* on the lava fields in Surtsey in 2006. Fig. 25. *Rhizocarpon expallescens* in the Surtungur crater in 1990. Fig. 26. *Rhizocarpon lavatum* in the lava fields of Surtsey in 2006. Fig. 27. *Rhizocarpon petraeum* in Surtsey in 1998.

Psilolechia clavulifera *(Nyl.) Coppins*

Very rare, only found once in the Surtungur crater in 2002. Apothecia barely visible as black dots, only 0.2 mm in diameter on colourless thallus growing on bare rock. Found in a sample of *Placopsis* and *Rhizocarpon lavatum*. This is the first record of the species in Iceland.

Psilolechia leprosa *Coppins & Purvis*

Very few records from Iceland, but locally apparently quite common, e.g. in the lava fields around Laki in the southern part of the Central Highlands.

On Surtsey this species was one of the very early, successful colonizers in the lava fields, occurring mainly in rifts, caves and other shady places and in the craters. It was first discovered in 1971, found in sites where warm steam kept the rocks constantly wet, as on the western outside wall of the Surtungur crater, where also *Trapelia coarctata* was first found. Very soon *P. leprosa* had colonized crevices and caves throughout the island. Thus, it was most likely dispersed to the island by wind. In the beginning it formed a sterile, sorediate crust, but after a few years abundant, pale brown or pinkish, globose apothecia developed. The thallus is white, at first with a warted, cauliflower-like surface, but soon becoming sorediate-leprose.

In Kristinsson (1974) it was recorded as *Lepraria incana* since it resembled a *Lepraria* when lacking apothecia. True *Lepraria* spp. have not yet been verified in samples from Surtsey.

****Pyrenidium hyalosporum***
Alstrup, D.Hawksw. & R.Sant.

First recorded in Iceland by Svane & Alstrup (2004), growing on *Placopsis gelida* collected in Mýrdalur, South Iceland. It was found on Surtsey in two localities in 2002, also growing on *Placopsis*.

Rhizocarpon expallescens *Th.Fr.*

Small, crustose species with thin, grey to whitish thallus and black apothecia, ascospores one-septate, colourless. Probably widely distributed in Iceland but rarely collected because of its small size. First collected on Surtsey 1984 from the lava fields near the east coast. Most of the samples collected later are from within and on the outside walls of the Surtungur crater (Fig. 25).

Rhizocarpon lavatum *(Fr.) Hazsl.*

Similar to *Rhizocarpon expallescens* but with larger apothecia with a thicker margin and containing muriform, hyaline spores later becoming dark. Common in Iceland, more collected in the southern part than in the North.

First seen in the eastern part of Surtsey in 1984, later found to be rather common, especially in the Surtungur crater but also widespread in the lava fields (Fig. 26). These two species of *Rhizocarpon* are now very common on Surtsey, but none of the yellow species of *Rhizocarpon*, most frequent in Iceland, have yet been found on the island.

Rhizocarpon petraeum *(Wulfen) A.Massal.*

Considered common on rock all over Iceland (Ihlen 2004). First detected on Surtsey in a sample from 1990 on the western outside wall of the Surtungur crater. It was found in numerous places in the lava fields in 1994 and 1998 (Fig. 27). The Surtsey specimens have characteristically rather thick, areolate thallus with innate apothecia. The thallus shows very slow Pd+ orange reaction, indicating the presence of stictic acid.

Rhizocarpon reductum *Th. Fr.*

Common in Iceland according to Ihlen (2004). First found in a Surtsey sample from 1994 from the margins of both the large craters, Surtungur and Surtur. In 1998 and 2002 it was also collected in the lava fields on the eastern side of the island. The specimens are morphologically rather variable but contain stictic acid and have shorter ascospores than *R. petraeum* (20–30) µm versus (26–38 µm).

Rinodina gennarii *Bagl.*

Common in Iceland, especially along the coast. Not seen on Surtsey until 2002 when it was discovered on the western outside walls of Surtungur and also sparsely in the gull colony. It was already rather common and abundant on rock in the lava fields around the gull colony in the next visit in 2006. It appears from this, that it arrived late on Surtsey but once there, it rapidly colonized the gull colony.

Scoliciosporum umbrinum *(Ach.) Arnold*

Common in Iceland, but not yet recorded in the Vestfirdir region. It has usually been found growing on rock but also on other substrates.

First collected 1990 on Surtsey, growing on fish bone in the lava field apparently carried by birds, either from the coast or from outside the island. It was collected again in several localities in 1998 and 2002, generally growing directly on basalt on the top of lava peaks or on the elevated crater margins.

Solorina bispora *Nyl.*

Common on soil all over Iceland. Found on Surtsey 1998 in the slope under the raven's nest on the inside wall of the Surtungur crater. That was also the first locality of several other soil lichens on Surtsey like *Collema tenax*, *Leptogium lichenoides*, *Peltigera didactyla* and *P. venosa*. The species has not been seen on Surtsey again.

Stereocaulon alpinum *Laurer*

One of the most common *Stereocaulon* species in the heath vegetation of Iceland. First collected on Surtsey in 1984, growing in a carpet of *Racomitrium lanuginosum* in the Surtungur crater. It is rare on Surtsey, not seen with certainty outside the crater (Fig. 28). Samples which morphologically resemble this species elsewhere in the lava fields have turned out to contain stictic acid and have subsequently been referred to *S. tomentosum* as *S. alpinum* contains lobaric acid.

Stereocaulon arcticum *Lynge*

Common in Iceland, both as primary colonizer on bare soil and river flats, where it often is found together with *Stereocaulon glareosum*, and also forming cheese–like cushions on volcanic gravel deserts in the Central Highlands. On Surtsey it was first seen in 1994 as primary colonizer on the soil formed around the gull colonies. In 2002, it was widely distributed at the margin of that area. At that time it was also found in a shady cleft in the Surtungur crater.

Stereocaulon capitellatum *H.Magn.*

Rather rare in Iceland, but scattered throughout the country. On Surtsey it was a very active primary colonizer, appearing almost everywhere in the lava fields together with *Placopsis gelida* and *Stereocaulon vesuvianum* from 1971. The first stages consisted of circular colonies of separate, erect lobes arising from air bubbles on the lava surface (Fig. 5). The marginal tip of these primary phyllocladia formed soredia. First a few years later the lobes gradually formed pseudopodetia with capitate soralia as characteristic for the species, and brown cephalodia with *Nostoc* (Kristinsson 1974, Fig. 29). From the beginning these small thalli could be identified as *S. capitellatum* because of the characteristic lichen substances, perlatolic, anziaic and miriquidic acids. In the later years this species has gradually retreated from the lava fields and currently only found in scattered but well developed colonies.

Stereocaulon glareosum *(L.I.Savicz) H.Magn.*

Common in Iceland as primary colonizer on river flats and on open soil. It forms a crust of white, cylindrical isidia with brown tips, interspersed with large, pinkish brown cephalodia. On Surtsey it was first discovered in 1984 on tephra between lava ropes, but later it became rather common on the soil formed in the gull colony. Apart from its first locality, it has only been found in regions where some soil formation has taken place.

Stereocaulon rivulorum *H.Magn.*

Common all over Iceland, usually growing on gravel and in screes. First seen on Surtsey in several localities in 1994, growing on volcanic slag or sand in the lava fields and in the Surtungur crater.

Stereocaulon spathuliferum *Vain.*

Relatively rare in Iceland, but found scattered throughout the country, more frequent at higher elevations than in the lowland. It was first discovered on Surtsey in 1984 growing on a rock in the lava field on the eastern side of the island. Later, similar specimens were found west of the Surtungur crater but the specimens collected there were not so typical and may belong to other species. It is still a rare species on Surtsey, found mainly in two areas.

Stereocaulon tomentosum *Fr.*

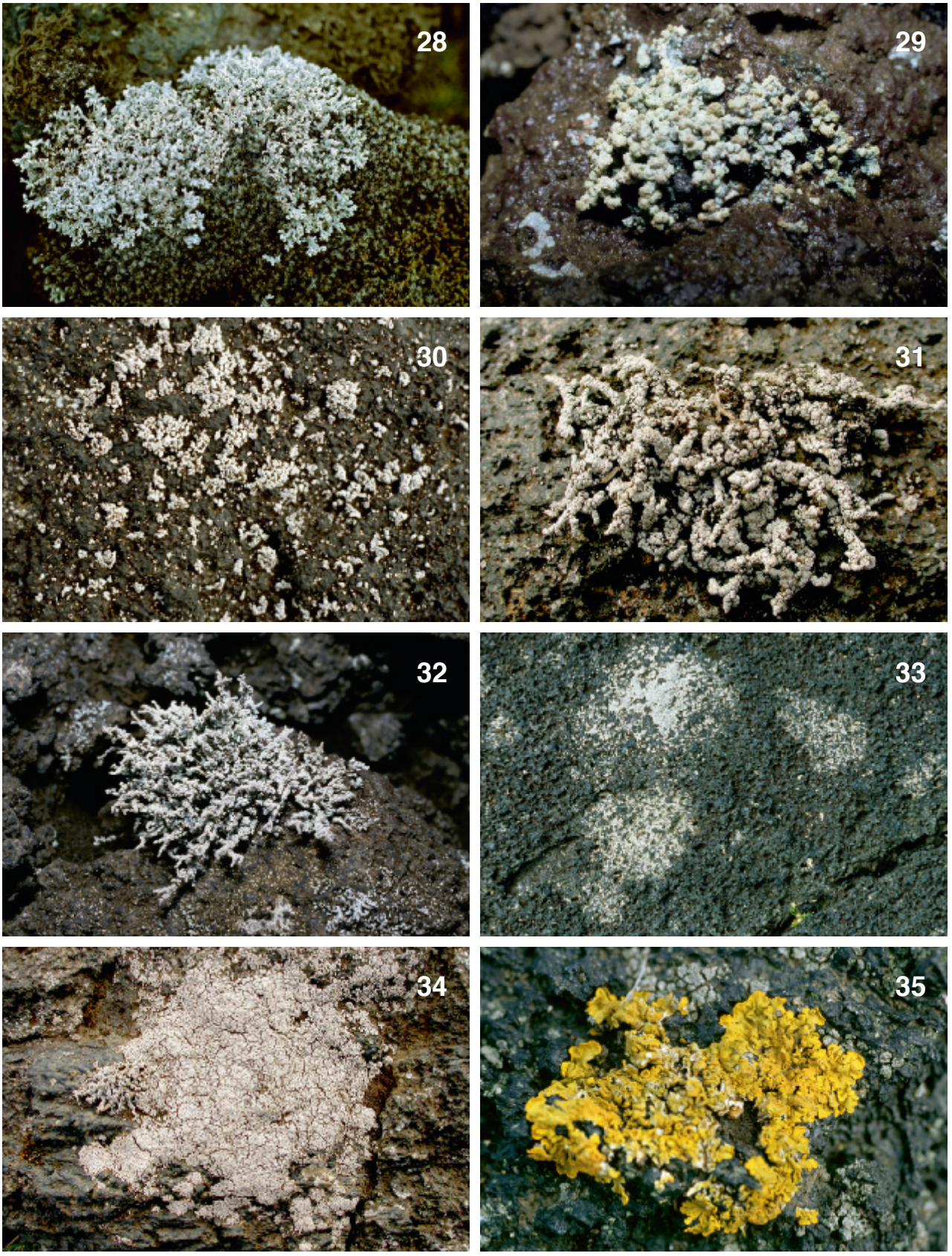
Typical, fertile specimens of *S. tomentosum*, characterized by many, small apothecia, were first collected in 1998, and again in 2002 and 2006. Some of the older samples from 1984 and 1990 might also possibly be young, infertile specimens of this species. It usually grows on mossy soil or in carpets of *Racomitrium lanuginosum*. Most sterile specimens with the appearance of *Stereocaulon alpinum* on Surtsey contain stictic and norstictic acids and should therefore rather be referred to *S. tomentosum*, which appears to be more common on Surtsey than *Stereocaulon alpinum*. These two species are morphologically similar and can hardly be distinguished from each other in sterile condition. *Stereocaulon tomentosum* differs mainly in having crowds of lateral, small apothecia, and reacting slowly orange by Pd because of its content of stictic acid.

Stereocaulon *cf.* ***tornense*** *(H.Magn.) P.James & Purvis*

Rare and scattered in different parts of Iceland, but locally common, especially in the southern part of the Central Highlands. In 1990 and again in 1994 a crustose lichen was collected in a crevice in the Surtungur crater. It had not fully developed apothecia and has therefore not been securely identified, but the phyllocladia resemble those of *Stereocaulon tornense* in habit and the chemical reaction fits that species. As in *S. tornense*, cephalodia with cyanobacteria are prominent between the phyllocladia.

Stereocaulon vanoyei *Duv.*

This species was originally described from Krýsuvík, Iceland by Duvigneaud (1941) in his account of an expedition which Prof. P. van Oye made to Iceland in 1938. It is now known from about eight localities in Southwest and South Iceland, all on rocks in recent lava flows. It is related to, but morphologically distinct from, *Stereocaulon vesuvianum*, differing by having large and inflated or bullate phyllocladia, usually without the dark, concave



Figures 28–35. Fig. 28. *Stereocaulon alpinum* in a carpet of *Racomitrium lanuginosum* in the Surtsey lava field in 1998. Fig. 29. *Stereocaulon capitellatum* with capitate soralia and pinkish brown cephalodia in the Surtungur crater in 1994. Fig. 30. Young stage of *Stereocaulon vanoyei* on lava rock in 1994. Fig. 31. *Stereocaulon vanoyei* with mature pseudopodetia in 2006. Fig. 32. *Stereocaulon vesuvianum* on the Surtsey lava. Fig. 33. *Stereocaulon* sp., rather young stage in the lava field east of Pálsbaer in 1994. Fig. 34. Mature *Stereocaulon* sp. forming flat, compact surface in the lava field east of Pálsbaer in 2006. On its left side is rather small specimen of *Stereocaulon vesuvianum* with elongated pseudopodetia. Fig. 35. *Xanthoria parietina* on lava rock near the gull colony in 1998.

central part characteristic for *S. vesuvianum* and *S. arcticum*.

It was first discovered on Surtsey in 1994. It has been found in two localities, in the lava fields on the eastern side of the island (Figs. 30, 31) and within the Surtungur crater. It grows directly on the lava rock.

Stereocaulon vesuvianum *Pers.*

This species was one of the first three species to be discovered on Surtsey in 1970. In that year it was only found on lava blocks kept wet by steam from nearby steam holes, close to the Surtungur crater. In the following years it was widely distributed in lava fields all over the island. Its wide and rapid distribution throughout the entire lava fields at the same time is support for effective wind dispersal from the mainland. The growth is on the other hand very slow, starting with a single, small, sphaerical phyllocladia growing out from every bubble hole in a colony of a few cm in diameter. A dark depression in the center of each phyllocladium confirms that this is *S. vesuvianum*. These dispersed, round phyllocladia develop slowly over a period of several years (Fig. 4) and finally unite to form a colony of short, elongate branches interspersed with black cephalodia (Fig. 32). This process is especially slow in the drier parts of the lava field, but faster in moist habitats protected against the drying effects of the wind, for instance within Surtungur crater or in depressions in the lava fields.

Stereocaulon sp.

In 1990 a new *Stereocaulon* was noticed in the lava fields in the eastern part of the island, differing clearly from *Stereocaulon vesuvianum*. It forms very compact, low cushions directly on the lava surface, with very small (0.1–0.2 mm) granular phyllocladia without the dark center characteristic for those of *S. vesuvianum* (Fig. 33). The pseudopodetia are richly branched in the upper part with dichotomous branching, resulting in the relatively smooth and compact surface of the colony (Fig. 34).

Morphologically it is similar to *Stereocaulon depressum* but differs by containing stictic and norstictic acids besides atranorin. This secondary chemistry leaves only a few possibilities apart from *S. vesuvianum*, which is morphologically different (Fig. 33). Two species treated in Lamb's Conspectus deserve special attention (Lamb 1977): *S. lavicola* H.Magn. and *S. vulcani* (Bory) Ach. The former is known only from Hawaii. The morphological description of the lectotype given by Lamb fits the *Stereocaulon* from Surtsey rather well. The latter, *S. vulcani*, is known from Hawaii, the Azores and the Canary Islands. It is morphologically variable, but forma *maunae-loae* (H.Magn.) Lamb, which Magnusson originally described as a separate species, *Stereocaulon maunae-loae*, represents a compact, pulvinate form very similar to the specimens from Surtsey. Further study is needed to find out whether the Surtsey specimens may belong to either of these species or represent a new undescribed species.

We have seen a few other specimens from the mainland of Iceland, which appear to belong to this species, containing either atranorin, stictic and norstictic acids, or atranorin alone. Also one specimen from Faroe Islands identified as *Stereocaulon evolutum* but containing atranorin, stictic and norstictic acids seems to belong to the same species.

Trapelia coarctata *(Sm.) M.Choisy*

This was the first species discovered on Surtsey in 1970. At that time it was limited to steep lava rocks on the outside of the Surtungur crater (Kristinsson 1972), in a site constantly kept wet by steam from nearby steam holes (Fig. 3). Already in 1970 it was very abundant in this habitat, covering wide areas with richly fruiting thalli. Judging from its appearance, it must already have been present in this locality in 1969 but lichens were not investigated that year. In the following years it was found in several other localities also influenced by steam holes, and later it was seen in other damp or relatively dry but sheltered localities, such as in the craters or other depressions in the lava fields. It is still present in many localities but not abundant.

Trapelia involuta *(Taylor) Hertel*

Very rare in Iceland, only two localities outside Surtsey known: Vidvík in the North (Branth 1903, as *Lecanora coarctata* var. *ornata*) and Thórsmörk in the South (collected by Svanhildur Svane 1972, kept in C).

On Surtsey it is apparently also rare, collected in 1994 and again in 2006. In both cases it was growing on rock near the activity of birds.

Verrucaria aquatilis *Mudd*

First collected on Surtsey 1998 and discovered on several locations on the island since then, although easily overlooked because of the small perithecia. *Verrucaria aquatilis* has only been found in a few localities in Iceland, but it is probably overlooked. On Surtsey it grows on the lava although it is an aquatic species that usually is found growing along rivers or creeks, even inundated in some places.

Verrucaria muralis *Ach.*

Discovered on Surtsey in 2006 growing on palagonite tuff on Austurbunki in a moist habitat close to steam holes. The species was first recorded in Iceland by Branth (1903), based on material collected by Ólafur Davídsson in northern Iceland

and determined as *Verrucaria rupestris*. Alan Orange collected the species on two localities in the North and East in 2007 with the specimens kept in Cardiff. Specimen from Surtsey was determined by Alan Orange in Cardiff, Wales. A specimen collected in 1998 also seems to belong to this species. It was collected close to the locality where it was found 2006.

***Verrucaria** sp.*

There are three *Verrucaria* specimens collected in 2002 and 2006 which have not yet been identified. They might belong to more than one taxon. Two of them have brown thalli while the thallus of the third one is rather indistinct. The sporelength is ranging from 15 to 26 µm and an involucrellum is present. At least one of the specimens has a black prothallus. These specimens might belong to *Verrucaria aethiobola* and/or *V. nigrescens*.

***Xanthoria candelaria** (L.) Th.Fr.*

Very common in Iceland growing on wood, trees and rocks frequently visited by birds. It was first detected on Surtsey in 1972, in connection with experiments carried out by hydrobiologists by placing fresh water tubs in the lava field in order to study colonization of fresh water life (Kristinsson 1974). One of these tubs attracted some gulls that used it for bathing. Within the splashing zone of the tub very small thalli of *Xanthoria candelaria* were seen in 1972 and 1973, but already deteriorating in 1975, and not seen in the years thereafter. Apparently the diaspores of the lichen had been transported by the gulls, washed out in the water and splashed around onto the lava rock. But since this is an extremely coprophilous lichen, it apparently did not get the necessary nourishment after the tub had been removed, and died off.

It was not found again until 1990 after the permanent colonization of the gulls had taken place. Then it colonized the lava rocks most frequently trampled by the gulls along with *Caloplaca verruculifera* and *Xanthoria parietina* and has been seen in each visit after that.

***Xanthoria parietina** (L.) Th.Fr.*

Common in the more oceanic regions of Iceland, absent in the northeastern inland areas where it is replaced by *Xanthoria elegans*. Often gives the cliffs of the sea birds bright yellow colour.

On Surtsey the first small thalli of *X. parietina* were seen on lava rocks in the gull colonies in 1990. From 1998 it was found in several localities in the area affected by the gulls (Fig. 35). It is often accompanied by *Caloplaca verruculifera*, and has, like that species, probably been transported on feet of gulls to Surtsey.

DISCUSSION

Surtsey has given unique opportunity for the study of primary lichen colonization on a pristine island. Although several volcanic islands can be found throughout the world, Surtsey is the only one where lichen succession has been monitored since it appearance. The island Krakatau has some similarity to Surtsey but its location in the tropics makes all comparison difficult.

How were the lichens transported to the island?

For most of the 87 lichen species recorded on Surtsey the travel route to the island is unknown, especially those with very local or scattered distribution. However, the data obtained from the 40 years monitoring allows some speculations on the topic for a number of species. It is most likely that the most successful colonizers in the lava fields were transported by air currents. It is the only way that can explain the simultaneous appearance of their initial stages almost all over the lava fields where suitable conditions were present. This applies to *Placopsis gelida*, *Psilolechia leprosa*, *Stereocaulon capitellatum* and *S vesuvianum*. (see distribution maps in Kristinsson 1974). Local spread after their first appearance can be excluded for at least two of the species (*Placopsis gelida* and *Stereocaulon vesuvianum*) because they were sterile and without soralia for several of the first years eliminating that possibility.

Dispersal by air currents probably also applied to *Trapelia coarctata*, which early colonized rocks in close vicinity of the steam holes. The limited distribution seen on distribution maps from 1973 (Kristinsson 1974) reflected mainly the limited occurrence of steam condensating on bare rock, the most suitable habitat for that lichen. Another lichen that hypothetically could have been dispersed by air currents is *Acarospora smaragdula*. Its distribution throughout the island rather early supports this. However, the species preferred the elevated margin of the craters, and protruding lava peaks and that may suggest an alternative, i.e. the role of small birds that tend to rest on these tops in the lichen's dispersal.

Several species have most likely been dispersed to Surtsey by birds. The best evidence is provided by the colonization history of *Xanthoria candelaria*, the lichen which had its first colonization in the splashing zone of the experimental water tubs that the gulls used for bathing (see under that species, and also Kristinsson 1974). For most of the other species colonizing only the rocks in the gull colony, transport by gulls seems to be the most acceptable dispersal route. Certainly wind dispersal is also possible, but since few of these species have been seen in the isolated nesting places of fulmars found in small lava outlets in the slopes of the large crater

cones, is seems to be less important than dispersal by gulls for these species. This could apply to *Lecania subfuscula*, *Lecanora* sp., *Xanthoria parietina* and probably also *Phaeophyscia orbicularis*, *Physcia caesia* and *Physcia tenella*. Three further species (*Caloplaca verruculifera*, *Lecanora poliophaea*, *Rinodina gennarii*) are in Iceland like elsewhere confined to coastal cliffs. This suggests two possible dispersal routes but it cannot be distinguished between them, e.g. by birds and by sea water that can be sprayed far up from the shore on Surtsey during winter storms.

Species considered rare in Iceland

It is remarkable that many of the lichen species known from Surtsey are considered extremely rare, or even not present in Iceland, but still have found their way to Surtsey. Examples of such species are *Arthonia lapidicola*, *Gyalidea fritzei*, *Gyalidea* sp., *Hymenelia arctica*, *Lecania subfuscula*, *Micarea* sp., *Pilophorus cereolus*, *P. dovrensis*, *Psilolechia clavulifera* and *Trapelia involuta*. Many of these species are, however, very small and inconspicuous, sometimes even just visible to the naked eye. They may therefore be more frequent in Iceland than the few records indicate for owing to the extensive monitoring of the lichen colonization on Surtsey.

Some of the species colonizing Surtsey appear to be ecological opportunists, they reproduce very quickly when managing to colonize empty niches, like on Surtsey, but retreat again as their habitat gets colonized by stronger competitors. Such species are likely to be rare on the mainland, except in very special habitats, or only at times when similar empty niches are created locally by volcanic eruptions. Such examples are *Trapelia coarctata*, which spread very rapidly in the beginning where steam escaped out from the lava, and *Stereocaulon capitellatum* which was very widely distributed throughout the lava fields in the beginning but has become rather rare during the last years. Still other examples are *Lecania subfuscula* and the presumably new species of *Lecanora*, both of which very rapidly colonized all rock faces in and around the gull colony, sites that were more or less constantly traversed by the gulls. All these species have relatively few records in the mainland of Iceland.

Common species that have not arrived on Surtsey

Many of the most common rock lichens in Iceland, species that one would expect on Surtsey sooner or later, have still not arrived there. Among those are species like *Aspicilia cinerea, Lecanora intricata*, *L. polytropa*, *Rhizocarpon geographicum* and *Tremolecia atrata*, which can be found on almost every piece of rock in Iceland. The rocks on Surtsey should provide them with plenty of suitable sites. Even though some initial time might be needed before they can colonize fresh volcanic rock, 45 years is a long time. All five species mentioned had already colonized the Hekla lava flows within 20 years of the 1947 eruption (Kristinsson unpublished data from 1967 and 1968). This fact suggests that the distance over the sea from the mainland of Iceland to Surtsey presents a barrier for their dispersal. The fungal or the algal part, or both, might have difficulties in getting to the island to establish the symbiosis.

Furthermore, not a single *Umbilicaria* species has been seen on Surtsey, whilst in the Hekla lava four *Umbilicaria* species had established within 20 years from the eruption in 1947. These were *Umbilicaria cylindrica*, *U. torrefacta*, *U. proboscidea* and *U. hyperborea*, each represented by very small thalli. The first three of these species are very common in the Icelandic lowlands and should be expected on Surtsey. Apart from these exceptions, the main colonizing species around Hekla were the same as on Surtsey, *Placopsis gelida*, *Stereocaulon capitellatum* and *S. vesuvianum* as well as the bryophytes *Racomitrium lanuginosum* and *R. ericoides*. As on Surtsey *Acarospora smaragdula* was equally frequent on top of lava peaks (Kristinsson, unpublished data).

CONCLUSIONS

High proportion of the primary lichen colonizers on Surtsey were cephaloid. The simultaneous lichenization in a group of adjacent cavities on the lava surface is characteristic for the three most successful colonists. With soil formation in the gull colony habitat for lichens dependent on soil as species of the genera *Cladonia* and *Peltigera* appeared in the island which partly explains the increased rate of lichen colonization after 1986. Sea erosion has prevented most common sea-shore species from establishing on Surtsey. The great success of the two genera, *Stereocaulon* and *Porpidia*, on Surtsey is apparent, as 75% of all *Stereocaulon* and 50% or more of all *Porpidias* in Iceland have already arrived there, while some other large genera are absent or represented only by one or two species.

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