Lichen Colonization in Surtsey 1971—1973

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Lichens were first detected on Surtsey in the summer of 1970, when three species were found on the island, *Trapelia coarcata, Placopsis gelida,* and *Stereocaulon vesuvianum* (H. Kristinsson 1972). The present article deals with the results of three visits to Surtsey, in June 1971, July 1972 and in August 1973, when 2—3 days were spent there each year.

METHODS

Different habitats were searched for initial stages of lichens throughout the island by the aid of hand lens. Samples were collected of all species detected in the field. Final indentification was carried out in the laboratory by microscope and comparison with known samples from the mainland of Iceland, whenever such were available. In certain cases chemical analysis by thin layer chromatography was used to verify the identification. These methods have been described in detail by C. F. Culberson & H. Kristinsson (1970). All species found in Surtsey were numbered for convenience, so that even unidentified species could be referred to in this and eventually in subsequent papers.

The distribution of lichens in Surtsey was recorded by the aid of the local grid system of 100x100 m squares, already used for the distribution of vascular plants and mosses (S. Friðriksson et al. 1972). All squares were visited at least once, and the more common lichens were noted in the field, but all others collected for later identification.

LIST OF SPECIES

1. Trapelia coarctata (Sm. & Sow.) Choisy (Fig. 1A). First found in Surtsey in 1970 on the north facing rocky slope on the outside of the crater Surtur II. It is widely distributed around the craters Surtur II and Surtur I, and also found in the lava field south of Surtur II, where steam emission is still efficient, but nowhere else (distribution map, fig. 3). Under such conditions its growth rate is very rapid.

Trapelia coarctata forms in Surtsey light brown to whitish thallus of several cm in diameter. Apothecia are always present in great number, formed below the thallus surface, and braking through the cortex as they get mature. The apothecia are dark brown, 0.3-0.5 mm across, without exciple, but bordered by the ruptured cortex, until they get old. Epithecium and hypothecium brown, the hymenium 120-160 μ, the ascospores 12-20x7-11μ, colorless, subglobose to ellipsoid.

2. Placopsis gelida (L.) Linds. was first seen in 1970 in the same locality and habitat as *Trapelia coarctata.* Next year it was found in several localities in the most recent lava flow, which was formed in 1967. In contrast to *Trapelia coarctata* this species is now distributed throughout most of the lava flows independent of the steam emissions.

In the first stages of this lichen, scattered, white thalli are found distributed like dots through a patch of 2-10 cm^2 size (Fig. 1F). Their growth advances relatively fast, and soon small cephalodia are seen at the margin of many of the thallus dots. Through subsequent growth the thallus pieces finally coalesce and cover the rock surface to form an almost coherent thallus of the same diameter as the orginal patch (Fig. 1B). In that stage the thallus has lobed margin and is dotted with many, brown cephalodia. The largest thallus measured had a diameter of 6 cm. Soredia are soon formed in round soralia on the thallus surface, but no apothecia have been seen in Surtsey, and they are not frequent in Iceland either.

3. Stereocaulon vesuvianum Pers. appeared first on the lava fields north and northeast of Surtur II and in the northern outside slope of the same crater in 1970, both habitats influenced by warm steam. In the next year (1971) it was seen at several localities in the lava flows from 1967, where it now has a wide distribution independent of the steam holes. Its distribution extends now also to the lava of 1965 (Fig. 3), but it is still lacking in some parts of it.

Stereocaulon vesuvianum appears first as small, rounded warts (phyllocladia) scattered throughout the surface of the lava, either growing single out of small air bubbles, or frequently concentrated along delicate surface cracks of the rock. For that reason it grows frequently in long and narrow lines (Fig. 1D). The phyllocladia are not grouped into round plots, like is the case with *Placopsis gelida* and *Stereocaulon capitellatum* (Fig. 1E). As the growth advances, a dark, depressed spot appears in the center of the phyllocladia, a characteristic feature of the phyllocladia of *S. vesuvianum.* In general the development of this species is in Surtsey still at the stage of single phyllocladia. The growth is very slow, only at a few favorable sites had it in 1973 already formed about 4 mm long, erect pseudopodetia with many phyllocladia (Fig. 1C). Neither soredia nor apothecia were seen. Even cephalodia have not been noticed in the Surtsey specimens, but in Iceland the species generally bears cephalodia with either *Nostoc* or *Stigonema* as parasympiont, occasionally both occurring on the same plant.

4. Stereocaulon capitellatum Magn. In 1971 small, more or less erect, light grey lichen lobes were found in different places of the lava field of 1967. The single lobes were 1-2 mm in diameter but growing scattered in patches of 1-3 cm diameter. (Fig. 1E). The lobes were partly with recurved margins, on which the underside or the margin broke up to form soredia. Thin layer chromatography of such lobes showed that they produced the same combination of compounds as found in *Stereocaulon capitellatum* and *S. farinaceum* (lobaric acid, anziaic acid and perlatolic acid). In 1972 and 1973 the recurved lobes started erect growth at favorable sites, to form pseudopodetia with spherical soredial heads, typical morphological feature of these same species. At the same time cephalodia with Nostoc were found interspersed between the pseudopodetia of well developed specimens. At present this species has almost as wide distribution in the lava fields as *S. vesuvianum* and *Placopsis gelida.* It is not obvious to which of the two species these young plants belong, but the substrate would rather indicate *S. capitellatum,* since *S. farinaceum* generally grows on soil.

5. Lepraria incana (L.) Ach. *(L. aeruginosa* (Sm.) Wigg.) In the summer of 1971 attention was paid to light green patches interspersed with dark green algal coats on overhanging rocks and cave mouths throughout the lava fields. The light green thallus consists of one-celled green alga of *Trebouxia* type, enveloped by fungal hyphae. The surface of the thallus is at first crustose, granulose-verruculose, but soon the total surface breaks out into soredia. Apothecia are never produced on this thallus.

Lepraria incana is very common in Iceland on overhanging rocks or soil banks and in cave mouths, and was by some earlier authors called *Lepraria latebrarum.*

6. Acarospora. In one sample collected on the north slope of Surtur II in 1971 there were some sterile thallus lobes, which on better samples from 1972 could be identified as *Acarospora.* In 1973 this same species was found in several other localities. It is fairly frequent on the margin top of Surtur II and in the slope below the top, and it also occurs on bird-manured lava outcrops.

The thallus consists of small squamules, about 1 or maximal 2 mm across, pale grey-brown to straw-colored, single or more often crowded together, each with the lobe margin slightly recurved. On older squamules there are one to several, brown, immersed apothecia. In section the hymenium measures 120-150 μ, the ascospores are many hundreds per ascus, 2.5-3x1.2 μ. This species has not been identified yet, but could well be either *A. fuscata* or *A. smaragdula.* The specimens are still too small to obtain distinct chemical reactions indispensible for their identification.

7. Bacidia. One species of *Bacidia* was found 1972 in the western outside margin of Surtur II, growing among *Trapelia coarctata* and *Acarospora* 6. Only small sample was available of this species, and it has not been finally identified (fig. 2A). The thallus is areolate-verrucose, light-colored, pycnidia abundant, apothecia dark

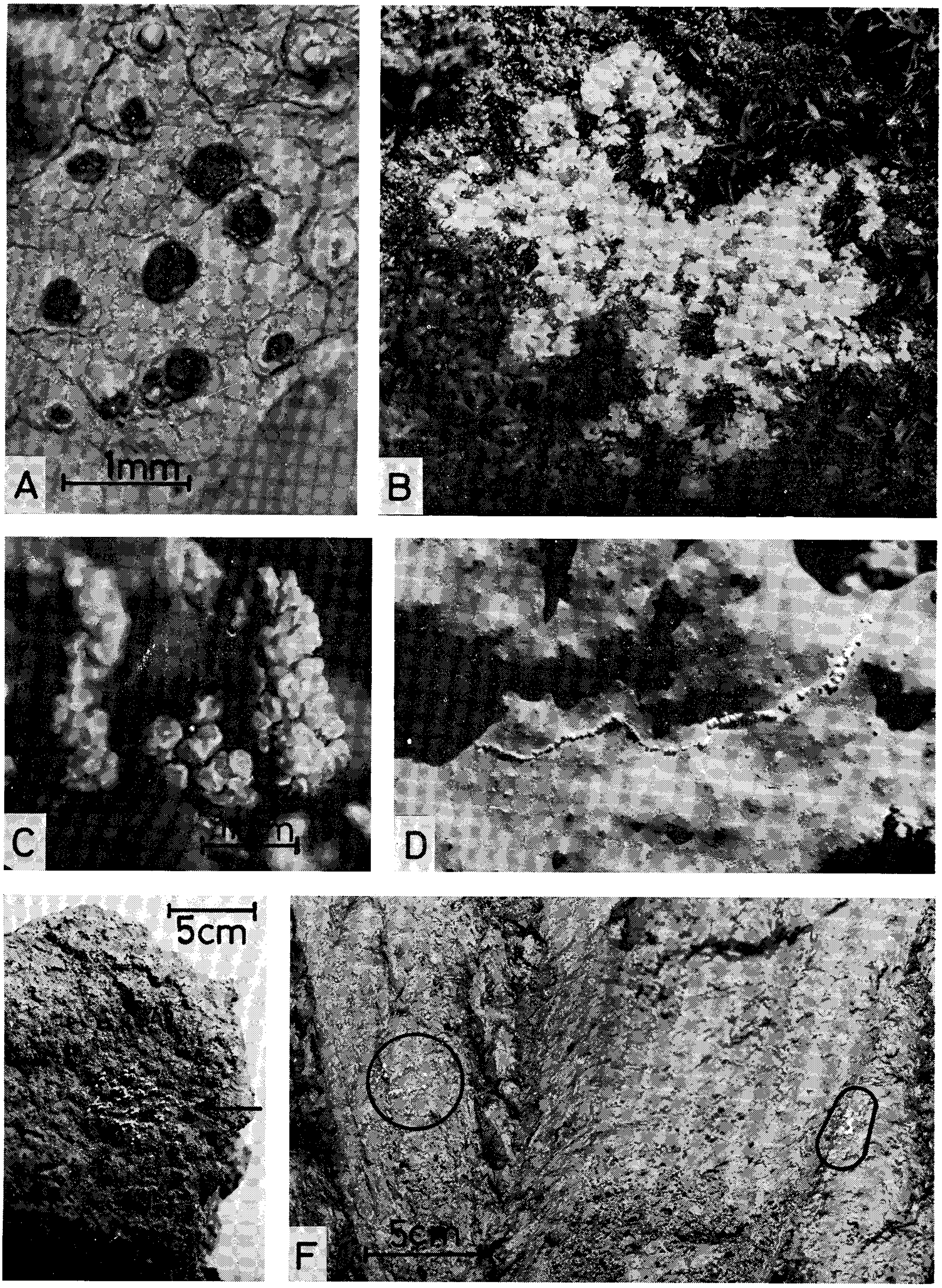

Fig. 1. A) *Trapelia coarctata* from Surtsey 1972. Thallus with apothecia. B) *Placopsis gelida,* a specimen collected in Surtsey in 1972 in a sheltered habitat in the Aa-lava from 1967. C) *Stereocaulon vesuvianum,* pseudopodetia from a sheltered habitat in the Aa-lava from 1967 (1973). D) *Stereocaulon vesuvianum* growing along a crack in lava block (1972). E) A circular plot of *Stereocaulon capitellatum* on lava block. No thallus lobes are found outside the plot (1973). F) Two plots of *Placopsis gelida* (encircled), separated by a distance of 20 cm devoid of any thallus lobes (1973).

brown to blackish, short stalked, concave. The hymenium measures 50-60μ, colorless, the epithecium brown, the hypothecium colorless, paraphysae simple, with brown head at top, the spores hyaline, 4-celled, 20-30μ long.

8. Lecidea. At the same locality as *Bacida* 7, a species of *Lecidea* was also collected in 1972 (fig. 2B). The thallus is thin, light colored, slightly areolate, the apothecia sessile, black, first concave, then plane, with elevated margin. The hymenium measures 100-120μ, colorless, the epithecum is dark brown to black, the hypothecium dark brown, the excipulum blackish near the outside, the ascospores colorless, one-celled, 12-15x7-9μ.

9. Lecidea. Another species of *Lecidea* was detected in a sample from the western slope of Surtur II collected in 1972. The thallus is sorediate, ochraceous, the soralia are erumpent, blue-grey, round and clearly delimited, about 0.1-0.3 mm across. No apothecia vere present. An identification must await for better samples, and better knowledge of the Icelandic species of the genus *Lecidea,* than we now have.

10. Xanthoria candelaria (L.) Th. Fr. This species was seen in one locality both in 1972 and 1973. Several plants were found in an area of 1-2m² around a spot where an artificial plastic pool had been set up as a trap for fresh water organisms (Maguire 1968). This species is foliose, but the thallus lobes are narrow and more or less erect, of bright orange-yellow color. It is very common throughout Iceland on places where birds rest, on top of boulders, rock outcrops and fence posts.

11. Arthonia. A specimen provisionally referred to the genus *Arthonia* was collected in 1973 on exposed rock around a lava peak in the lava flow from 1967. *Acarospora* was found on the top of this same outcrop, but the rock below the top was overgrown with *Arthonia.* Besides growing directly on rock, its thallus also extends over hardened accumulations of volcanic ash in the air bubbles on the rock surface. The thallus is very thin, hardly visible, the apothecia are black, tiny, 0.05-0.2 mm in diameter, plane to slightly convex. The hymenium is 40-50μ high, the epithecium greenish black, the hypothecium 8-11x 4μ, inequal twocelled. These specimens belong probably to *A. lapidicola* (Tayl.) Zahlbr., but the identification needs to be checked.

12. Lecanora. A fertile specimen belonging to the genus *Lecanora* was collected in 1973 by Skúli Magnússon, growing on bone and dead straw. The specimen has not been identified, but probably belongs into the relationship of *L. varia* and *L. conizaeoides.*

HABITATS

The lichens presently known from Surtsey grow in four different habitats:

1. Rock affected by warm steam. This habitat is found all around the craters Surtur I and II. The steam emanates from small holes which open out through the elevated crater margin or in the surrounding lava field. The condensation water from the steam keeps the surrounding lava surface wet. The steam is blown by the wind, so that some areas are only periodically exposed to the steam, but others seem to be constantly moistened by steam from the surrounding steam holes at any wind direction.

The steady supply of water provided by the steam is of primary significance to the lichen growth in this habitat. Even though lichens in general can survive long periods without water, they stop growth as soon as they get dry, because they are unable to maintain water in the thallus at dry air conditions. The speed of growth is therefore directly related to the length of time they are kept moist.

The raised temperature caused by the steam is probably only of secondary importance. At a certain distance from the hole lichen growth may possibly be promoted by the raised temperature, but around the opening their development is prevented by the heat.

The most successful colonizer of these steam habitats is *Trapelia coarctata,* which apparently grows and distributes very rapidly under these conditions. It has not been found in any other habitats in Surtsey. When originally found in 1970, it had already thousands of mature apothecia, so that local dissemination probably had taken place for some time in Surtsey. Some indications were seen for distribution by rain water running down the slope.

Another member of this community is *Placopsis gelida,* which developes well under these conditions, but is not dependent on the steam water.

Bacidia 7, *Lecidea* 8, and *Lecidea* 9, all only found in one sample, were collected in this same habitat. Other lichens, like *Stereocaulon vesuvianum* and *Acarospora,* which actually belong to other habitats, as will be pointed out later,

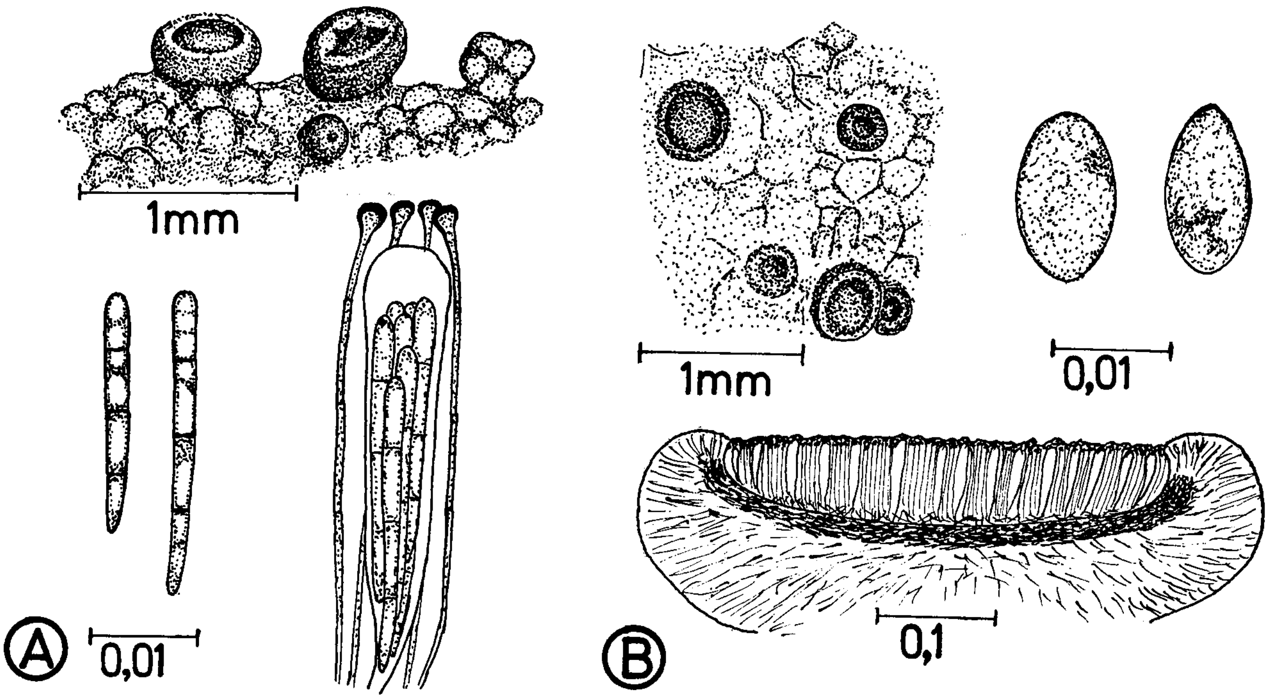

Fig. 2. A) *Bacidia* 7, a portion of thallus with apothecia and a pycnidium; ascospores, paraphysae and an ascus. B) *Lecidea* 8, thallus with apothecia, ascospores, and a section through an apothecium.

were also first found at the crater margin, simply because their growth was faster here than elsewhere.

2. Bird manured rocks. There are numerous lava outcrops in Surtsey frequently visited by birds, which both can act as dispersal agents and also as providers of nitrogen. Most of these outcrops, however, are still devoid of vegetation, primarily because water is too scarce. The first colonizer of these habitats in Surtsey is *Acarospora* 6. It is found in several localities on lava peaks and on the margin tops of Surtur I and Surtur II. It developes faster where it is subjected to the moisture of a warm steam. It is presumed, that the extreme dryness of most exposed lava peaks is probably the reason why the development of this community advances slowly and only in relatively few places.

Other colonizer of a similar habitat is *Xanthoria candelaria* which only occurred in one locality, around a plastic fresh water basin, which was set up 1967 and later removed again. This is a species, which in Iceland generally grows on bird manured outcrops like the *Acarospora*. In Surtsey, however, it either did not happen to be carried to such places, or they are too dry for it. The fresh water basin acted as an attraction for seabirds, and this was stationed on a less exposed spot than most of the bird manured lava peaks, and therefore offering better water conditions. The propagules of *Xanthoria candelaria* were probably brought in by birds, which washed them off in the water, and then splashed them around. This idea is supported by the single occurrence at this one locality, and by its frequency within the splashing distance from the water basin.

3. Overhanging rock walls and caves. Only one lichen species, *Lepraria incana,* is found in this type of habitat, which is charcterized by its shade, and moist, stagnant air. Besides the lichen, a species of green alga of *Chlorococcus* type is also widely distributed in this same habitat.

4. The lava fields. The dry rock surface of the lava fields represents the most widely distributed habitat of all, but it raises higher demands to the water deficiency tolerance of its inhabitants, than habitat 1 and 3. Consequently the growth in this habitant is generally slow, and there is a marked difference between the exposed lava peaks, which quickly dry out, and the deeper depressions and hollows, where the moisture is longer preserved. The water supply is evidently the factor, that limites the speed of growth here. The initial development of this vegetation starts in small air bubbles on the rock surface; these serve to accumulate diaspores and dust brought by the wind, as well as to reduce the drying effects of the wind and preserve the moisture longer than is possible on the smooth rock surface. Small cracks or fissures on the rock surface also serve similar purpose.

These dry lava fields are colonized chiefly by three species of lichens: *Stereocaulon vesuvianum, S. capitellatum* and *Placopsis gelida.* Several mosses belong to the same community, mainly *Rhacomitrium lanuginosum* and *R. canesens.* Especially *Placopsis gelida* grows much more rapidly in the depressions, and the same applies to *Rhacomitrium. Stereocaulon vesuvianum* seems to have the highest tolerance for water deficiency, it is a slow growing species, and relatively indifferent to the position of its habitat.

EARLY STAGES IN LICHENIZATION

Some facts about the early stages in development of *Placopsis gelida* and *Stereocaulon capitellatum* are worth special consideration, since they can serve as a basis for experimental work on the reproduction of these lichens. The new lava fields offer good opportunities to study the individual development of the young lichen thalli, because the presence of older thalli can be completely eliminated.

Both *Placopsis gelida* and *Stereocaulon capitellatum* start growth as single lobes in each of many adjacent, tiny surface cavities, formed as air bubbles in the molten lava. In the surface cavities outside these lobe groups no lichenization is found, but other lichenized plots are usually present at some distance (Fig. 1E,F). It is inconceivable, that the propagules arriving from the mainland, whether soredia or ascospores, would only settle in such regular, round plots, leaving the extensive spaces in between uncolonized. On the contrary, they would rather be expected to distribute more or less at random throughout the whole rock surface. In fact the colonized plots themselves seem to be distributed at random and not the single lobes.

This supports the conclusion, that the whole plot of adjacent lobes must derive from one diaspore, and that the lichen fungus must be able to reach the adjacent air bubbles through hyphal growth from its original center, either before or soon after the first lichenization starts.

Later on the single lobules of *Placopsis gelida* coalesce through growth and the colonized plot becomes what appears to be single lichen thallus, of as much as 4-5 cm diameter in only 5 years (Fig. 1B), containing several cephalodia.

Further observations and experimental work are needed to decide on the number and nature of propagules which initiate a plot of the type described above.

The development of *Stereocaulon vesuvianum* differs from the species mentioned above. It appears to grow out from every suitable cavity or surface crack in the area colonized, not forming round plots.

DISTRIBUTION

During my first search for lichens in the lava fields of Surtsey (1968, 1970), primary attention was paid to the oldest lava from 1965, since vegetation development was expected to start there. Nevertheless, the colonization of lichens and mosses started in the new lava flow from the last effusive phase of the eruption in 1967. In 1971 both the *Stereocaulon, Placopsis* and *Rhacomitrium* were widely distributed there, but could hardly anywhere be encountered in the lava from 1965. Still in 1973 the vegetation of this lava was extremely scarce, and large areas of it were completely devoid of vegetation.

In an effort to find the explanation of this difference, it was noticed, that the surface structure in certain parts of the new lava (the Aa lava) is more porous than the old lava, which probably means improved water retaining capacity. The colonization is much further advanced than in the older lava of 1965. Consequently the surface structure can not explain the more advanced colonization there.

The presence of a trace of some toxic substances has also been suggested as possible reason, but no support for that hypothesis has been obtained from chemical analysis made by the geologists.

Another and perhaps a more satisfying explanation of the different success in colonization of the old and the new lava suggests that the retarded growth in the old lava is due to lack of water, caused by heat emission, which dries out the rock surface more quickly than in the new lava, where apparently no heat emission occurs. Although not perceptible in the field during summer, this heat emission has been demonstrated by air photos taken in the winter. While thin snow layer covered the lava from 1967, large parts of the old lava remained free of snow.

No lichens at all have been found anywhere in the northern part of the island, neither along the shore nor in the palagonite area.

CONCLUSIONS REGARDING LICHEN DISPERSAL TO SURTSEY

There are no direct observations available on how the 12 lichen species dispersed to Surtsey. Without success lichen propagules were searched for on the feet and plumage of birds caught in

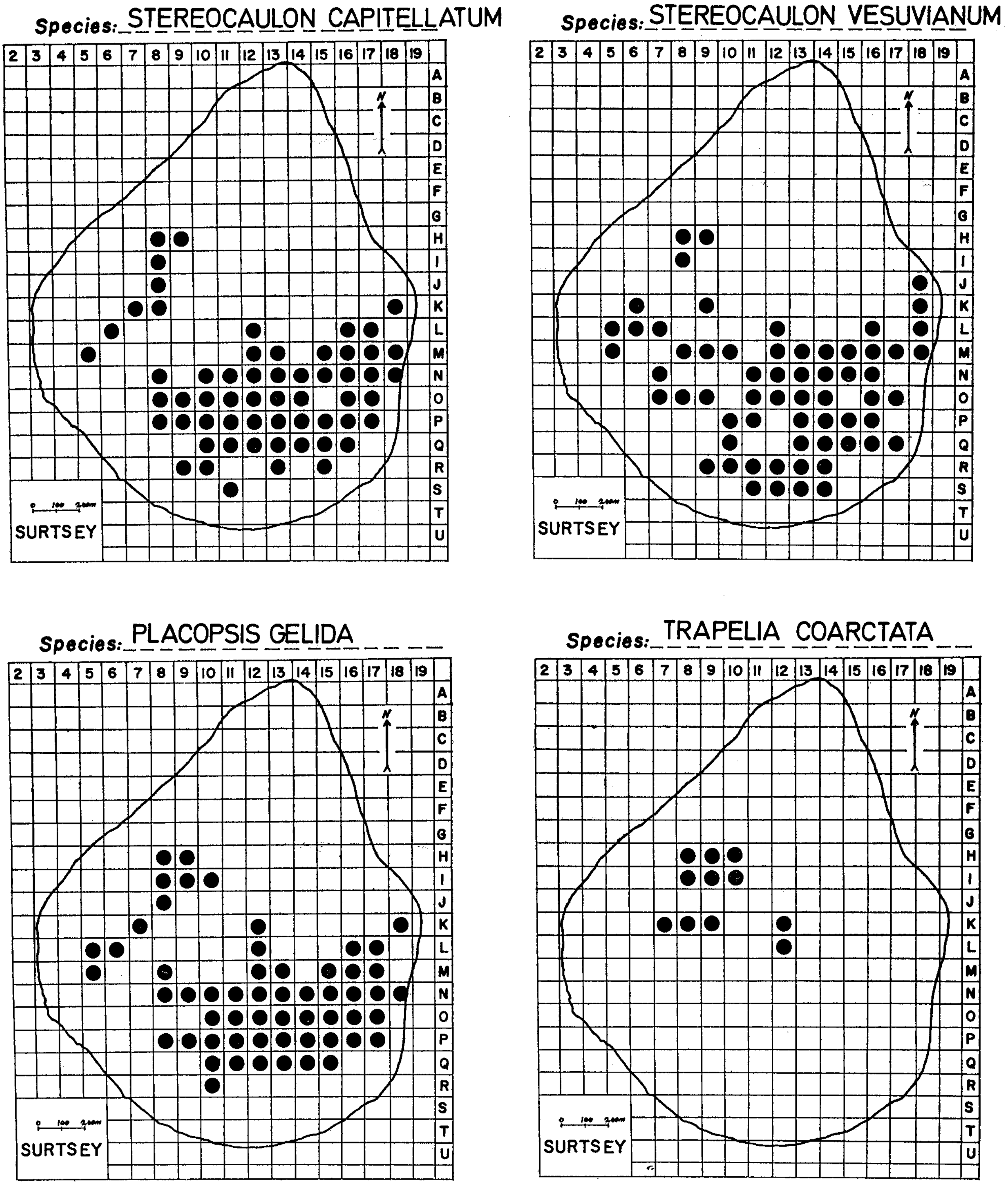

Fig. 3. The distribution of *Stereocaulon capitellatum, S. vesuvianum, Placopsis gelida* and *Trapelia coarctata* in Surtsey in 1973.

Surtsey and made available through Dr. Sturla Friðriksson in 1969 and 1970. Some other plant material was, however, found like green and blue-green algae, moss parts, fern sporangia, and tissue fragments of vascular plants. It would have been of interest to have samples taken of the air plankton around Surtsey, to investigate its content of lichen and moss diaspores, but no attempts have been made in that direction.

Through indirect observations it seems reasonable to conclude, that at least 4 species *(Stereocaulon vesuvianum, S. capitellatum, Placopsis gelida* and *Lepraria)* were dispersed to Surtsey by wind, and that one species *(Xanthoria candelaria)* was born there by birds. For the 7 species left, no conclusion has been drawn.

The four species supposed to have come by wind, were all evenly distributed throughout the island, wherever the appropriate conditions for their growth were present, before any local dissemination could be accomplished. No dispersal agents other than the wind could possibly ensure for such and even distribution into every small corner in the lava fields in these few years. All of these four species do form soredia which can be air born, and simultaneously carry the green algal component and the fungus. Three of the species have cephalodia with blue green algae *(Nostoc)* and these appear later than the mycobiont and the green algal symbiont. I presume, that they distribute separately by wind and are captured by the fungus. Free *Nostoc* colonies have been isolated from the lava fields of Surtsey (Schwabe, personal communication) so we know that they do easily reach the island. We do however not know for sure, whether free living *Nostoc* cells can be captured by the fungus to form cephalodia in *Stereocaulon* and *Placopsis,* as is know for several other lichens, or whether some special physiological adaptation is needed for the life in the cephalodia. Three of the four species do form ascospores in Iceland, but sparcely compared to the soredia.

Xanthoria candelaria, which is supposed to have been dispersed by birds, was until 1973 only found in one locality, but many plants were within 1,5 meter distance from the spot, where one of the fresh water basin was stationed few years before. It probably was born by birds into the basin, then washed off in the water and splashed around.

This species does sometimes form ascospores in Iceland, but distribution by air born ascospores to Surtsey would hardly result in several plants in a plot of ca 2 m^2 size, with all other parts of the island uncolonized. Soredia are not formed by *X. candelaria,* but the finely branched, erect lobes do very easily fragment, and have a suitable shape to get attached to birds. The probability of being carried by birds increases through its habitat, since it is coprophil and specializes in the resting places of birds.

Of the seven species about which no conclusion was made concerning their transport to Surtsey, six appear to reproduce by ascospores, and one, *Lecidea* 9, by soredia. Most of them were first found on the elevated crater margin of Surtur II. They could easily be air born, and the reason that they first appear at this locality may be simply because the conditions for their growth are best there, due to the condensation water from the steam emissions. If that is the case, they would be expected to turn up in other places later. Consequently we do not need birds to explain their presence there. Because of the tremendous transport and dispersal capacity of the wind, the role of birds is in my opinion negligible for species with effective wind dispersal. Only in cases, where wind distribution fails for some reason, occasional bird transport becomes important. On the other hand, the crater margin of Surtur II projects several meters above its surrounding and is frequently visited by birds.

ACKNOWLEDGEMENTS

These studies have been financed by the Surtsey Research Society, Reykjavík. I thank Dr. H. Hertel, Botanische Staatssammlung, München, and Dr. P. W. James, British Museum, for their valuable efforts to identify specimens from Surtsey.

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