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TECHNICAL PROGRESS REPORT OF BIOLOGICAL RESEARCH ON THE VOLCANIC ISLAND SURTSEY AND ENVIRONMENT FOR THE YEAR 1974

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The study involves the terrestrial biological research on the volcanic island, Surtsey, off the coast of Iceland and the neighbouring islands and environs of the Westman Islands, which are situated on the Mid-Atlantic Ridge.

Principal Investigator: Dr. Sturla Fridriksson
Reykjavík,
Iceland.

MASTER

DISCLAIMER

DISCLAIMER

In 1974 research work was carried out on the islands of Surtsey and Heimaey during the summer-months June through August. Two students stayed on the islands and several scientific excursions were taken.

TOPOGRAPHY

Changes in the topography of Surtsey were quite noticeable. By comparing aerial photographs taken in 1974 with previous maps it is clear how the island is gradually being eroded on the south-western side, and how the rim of the Western-Bunki is being corroded down (see frontispiece).

MICROBIOLOGY

During excursions in July Dr. G. H. Schwabe, Max-Planck Institut für Limnologie, Plön, Germany, investigated the terrestrial algae. Lichen were studied by Hördur Kristinsson, Akureyri, Iceland. The lichens were noticed later than the moss but are now occupying higher levels of the lava. (Appendix I).

MOSS

The moss flora was investigated by Skúli Magnússon, who examined distribution and cover of the various species and measured the biomass in the fixed quadrats. The microclimate in the moss habitats has also been studied by Sögren as indicated in Appendix II.

VASCULAR PLANTS

The number of higher plants found on Surtsey in 1974 is shown in the accompanying table. Their location was mapped according to the same methods used in previous years (Appendix III).

The vascular flora on Heimaey was also investigated following the eruption that took place on the island in 1973.

ENTEMOLOGY

Recording of insects was continued by the group of Swedish entemologists led by Dr. Högni Bödvarsson of Stockholm University.

VERTEBRATES

The ornithological studies were carried out by Erling Olafsson. Of major interest in 1974 was the addition of the black backed gull to the breeding birds on Surtsey.

SOIL

Investigation of further changes in the substrate soil were continued by Sveinn Jakobsson, who has studied palagonitization of the tephra.

OTHER ACTIVITIES

A book on the terrestrial investigation has been written by the principal investigator Sturla Fridriksson and it is being published in 1975 by Butterworths, England.

The steering committee is preparing the next volume of the Surtsey Research Progress Report, i.e., volume VII. This will contain papers published in the period 1971 onwards.

On the accompanying list and chart of Surtsey are recorded vascular plant found on the island in 1974. In 1973 approximately 1273 palnts were recorded and of these approx. 537 have overwintered. They are marked on pages 1-3 on the plant list with 169 numbers. When several plants of a species, which were offsprings of an old plant, were found growing together they were given the same number and marked with the same stake. In addition to the overwintering planst on the list are 90 plants that were staked out as new in 1974. There were also 8 new Puccinellia maritima plants, offsprings of plant no. 72-90 in quadrat R-14. The mother plant of these eight seedlings disappeared during the summer and had apparently been uprooted and eaten by a bird. Many new Honckenya peploides plants colonized Surtsey during 1974 in addition to those listed. These were mostly found on the eastern and central parts of the island as well as on the northern ness. Many are offsprings of earlier colonizers. In one instance, in quadrat K-17, a Honckenya plant (No 68-56) had 50 offsprings, that formed a colony in the same quadrat and in the adjacent one, J-17. The map shows locations of various vascular plants in 1974 as well as the number of individuals.

Overwintering plants in Surtsey 1974.

Honckenya peploides	97
Elymus arenarius	13
Tripleurospermum	1
Festuca rubra	1
Mertensia maritima	1
Cystopteris fragilis	1
Cochlearia officinalis	3
Total	117

Plants from 1972 and older living 1974:

Honckenya peploides	37
Cochlearia officinalis	10
Tripleurospermum maritimum	1
Cystopteris fragilis	2 (3)
Carex maritima	1
Puccinellia maritima	1
Total	52

Total Old Plants in 1974	169
New seedlings of Cochlearia officinalis	360
New seedlings of Puccinellia maritima	8
GRAND TOTAL	537

LIST OF VASCULAR PLANTS
RECOVERED IN SURTSEY
1974

No 68-4 – 600 OVERWINTERING
FROM 1973

NO.	Species:	
68-4	Honckenya peploides	J-18
68-8	Honckenya peploides	J-18
68-21	Honckenya peploides	J-18
68-22	Honckenya peploides	J-18
68-23	Honckenya peploides	J-18
68-24	Honckenya peploides	J-17
68-56	Honckenya peploides	K-18
68-63	Honckenya peploides	I-18
68-64	Honckenya peploides	J-18
68-70	Honckenya peploides	J-18
68-83	" "	K-17
68-87	" "	J-18
69-62	" "	F-13
70-4	" "	J-18
70-20	" "	J-18
70-25	" "	J-17
70-31	" "	J-18
70-37	" "	D-12
70-39	" "	G-13
70-41	" "	F-13
70-54	" "	E-12
70-60	" "	F-13
70-64	" "	J-18
70-72	Carex maritima	H-11
70-74	Cochlearia officinalis	S-14
71-35	Honckenya peploides	I-4
71-43	" "	F-13
71-46	" "	F-13
71-46	" "	F-13
71-47	" "	F-13
71-54	Cochlearia Officinalis	S-14
71-57	" "	P-17
71-63	Honckenya peploides	J-13
71-68	" "	I-4
71-69	" "	N-10
71-70	Cochlearia officinalis	N-13
71-71	" "	P-10
71-72	Cystopteris fragilis	N-9
71-75	Cochlearia officinalis	R-11
72-30	Honckenya peploides	J-4
72-34	Cochlearia officinalis	S-14
72-37	" "	S-14
72-40	Tripleurospermum maritimum	S-14
72-41	Cochlearia officinalis	S-14
72-42	" "	S-14
72-45	" "	S-14
72-56	Honckenya peploides	K-5
72-53	Cochlearia officinalis	S-14

72-83
72-90 68-6 fannst after eftir
7
8
[illegible]
72-113
72-114

72-83	Honckenya peploides	F 14
72-90	Puccinellia sp.	R 14
72-99	Honckenya peploides	E 11
72-108	" "	H 10
72-109	" "	J 18
72-113	Cystopteris fragilis	I 8
72-114	Honckenya peploides	I 4
~~73-45~~		
73-4	" "	F 13
73-6	" "	F 13
73-7	" "	F 13
73-45	" "	I 17
73-46	" "	I 17
73-48	" "	I 17
73-50	" "	I 18
73-51	" "	I 18
73-53	" "	I 18
73-55	" "	I 18
73-57	Elymus arenarius	I 18
73-60	Honckenya peploides	I 18
73-65	" "	I 17
" -108	Elymus arenarius	I 17
" -115	Honckenya peploides	G 16
" -131	Elymus arenarius	F 13
" -145	" "	F 13
" -165	Honckenya peploides	G 13
" -166	" "	F 14
" -170	" "	F 14
" -183	" "	E 15
" -255	" "	K 16
" -265	" "	K 17
" -272	" "	K 17
" -275	" "	K 17
" -276	" "	K 17
" -278	" "	L 17
" -282	" "	L 17
" -285	" "	L 17
" -287	" "	K 17
" -289	" "	K 17
" -305	" "	J 17
" -317	" "	J 17
" -318	" "	J 17
" -320	" "	J 17
" -321	" "	J 17
" -322	" "	J 17
" -324	" "	J 17
" 344	" "	K 17
" 347	" "	K 17
" 348	" "	K 17
" 349	" "	K 17
" 351	" "	K 17
" 352	" "	K 17
" 353	" "	K 17
" 354	" "	K 17
" 355	" "	K 17
" 356	" "	K 17
" 357	" "	K 17
" 361	" "	K 17

14

73-363	Honckenya peploides	K 17
" -364	" "	K 17
" -365	" "	K 17
" -370	Festuca rubra	L 12
" -372	Honckenya peploides	L 11
" -373	" "	L 17
" 381	" "	K 17
" 385	" "	K 17
" 388	" "	L 17
" 390	" "	K 17
" 393	" "	L 17
" 394	Tripleurospermum maritimum	L 17
" 395	Honckenya peploides	L 17
" 412	Elymus arenarius	L 16
" 423	Honckenya peploides	L 16
" 429	Elymus arenarius	K 17
" 437	Honckenya peploides	L 17
" 440	" "	K 17
" 441	Elymus arenarius	K 17
" 444	Honckenya peploides	K 18
" 448	" "	J 18
" 449	" "	J 18
" 459	" "	J 17
" 463	" "	I 18
" 465	" "	I 18
" 466	" "	I 18
" 467	" "	I 18
" 468	" "	I 18
" 469	" "	I 18
" 470	" "	I 18
" 471	" "	I 18
" 472	" "	I 18
" 473	" "	I 18
" 474	" "	I 18
" 475	" "	I 18
" 477	Elymus arenarius	I 18
" 478	Honckenya peploides	I 18
" 479	" "	I 18
" 480	" "	I 18
" 484	" "	I 18
" 502	Elymus arenarius	I 18
" 503	Honckenya peploides	I 18
" 504	Elymus arenarius	I 18
" 507	Honckenya peploides	I 18
" 508	Elymus arenarius	I 18
" 509	Honckenya peploides	J 18
" 530	" "	I 18
" 531	Mertensia maritima	I 18
" 538	Honckenya peploides	K 18
" 543	" "	L 16
" 545	" "	K 17
" 567	Elymus arenarius	K 17
" 580	Honckenya peploides	L 16
" 586	" "	I 18
" 587	" "	K 17
" 588	" "	L 17
" 593	" "	L 16
" 594	Elymus arenarius	L 16
" 596	Cochlearia officinalis	R 11
" 597	" "	R 10
" 599	Cystopteris fragilis	O 13
" 600	Cochlearia officinalis	M 18

NEW PLANTS IN 1974

~~#-1 Festuca rubra~~

74-1	Elymus arenarius	I-18
" -2	Honckenya peploides	M-10
" -3	" "	M-10
" -4	" "	M-9
" -5	" "	M-9
" -6	" "	M-9
" -7	" "	M-10
" -8	" "	K-10
" -9	" "	K-10
" -10	" "	I-10
" -11	" "	I-10
" -12	" "	I-10
" -13	" "	J-10
" -14	" "	J-10
" -15	" "	J-10
" -16	" "	J-10
" -17	" "	J-10
" -18	" "	J-10
" -19	" "	J-10
" -20	" "	J-10
" -21	" "	J-10
" -22	" "	K-10
" -23	" "	K-10
" -24	" "	K-10
" -25	" "	J-9
" -26	" "	I-9
" -27	" "	I-10
" -28	Cochlearia officinalis	O-7
" -29	Honckenya peploides	M-8
" -30	" "	M-9
" -31	" "	M-7
" -32	" "	M-8
" -33	Mertensia maritima	E-12
" -34	Elymus arenarius	E-12
" -35	Mertensia maritima	E-12
" -36	" "	D-12
" -37	" "	D-12
" -38	" "	D-12
" -39	" "	D-12
40	Cakile edentula	D-12
41	" "	D-12
" -42	Elymus arenarius	C-13
" -43	" "	A-13
" -44	Mertensia maritima	D-14
" -45	Mertensia maritima	F-14
" -46	" "	E-12
" -47	Elymus arenarius	I-18
74-48	Mertensia maritima	K-18
" -49	Cochlearia officinalis	J-18
74-50	Elymus arenarius	K-18
" -51	" "	K-18
" -52	Mertensia maritima	K-17
" -53	" "	K-18
" -54	" "	K-17
" -55	Elymus arenarius	K-17
" -56	Mertensia maritima	J-17
" -57	" "	K-17
" -58	" "	K-17
" -59	Mertensia maritima	K-18
" -60	" "	K-18
" -61	Mertensia maritima	K-16
" -62	" "	L-17
" -63	" "	L-17
" -64	Mertensia maritima	L-17
" -65	" "	L-17
" -66	" "	L-17
" -67	" "	L-17
" -68	" "	L-17
" -69	Elymus arenarius	K-17
" -70	Mertensia maritima	K-17
" -71	unidentified sp	K-17
" -72	Mertensia maritima	K-17
" -73	Mertensia maritima	K-17
" -74	Elymus arenarius	K-17
" -75	Mertensia maritima	K-17
" -76	" "	K-17
" -77	Elymus arenarius	L-17
" -78	" "	
" -79	" "	L-16
" -80	Mertensia maritima	L-17
" -81	" "	
" -82	" "	K-18
" -83	" "	L-17
" -84	" "	G-13
" -85	" "	G-13
" -86	" "	L-17
" -87	" "	L-17
" -88	" "	L-17
" -89	unidentified sp	R-14
" -90	Elymus arenarius	
	Puccinellia maritima	R-14

8 afkvæmi 72-9

MOSS VEGETATION ON SURTSEY

Introduction. Moss was first found on Surtsey, in two locations,in the year 1967 (Jóhannsson, 1968). This situation prevailed during 1968, and it was not until 1969 that moss was found to any significant degree. (Bjarnason and Friðriksson, 1972). The distribution chart for that year showed that moss had been found in 29 of the island's quadrats. In 1970 the distribution was even greater (Fridriksson et al., 1970), at which time it was thus clear that moss had finally colonized on the island. Until this year, observations had been somewhat random and directed solely at collecting samples of moss for analysis and keeping track of general distribution.

From 1969 to 1970 the number of moss species more than doubled, increasing from 6 to 16. This fact, in addition to a great jump in distribution pointed to the need for more exact observation of the island's moss flora. It was therefore decided to organize a careful and systematic investigation of the island in 1971. A division of the island into quadrats (Friðriksson et al., 1968) formed the basis of this research, and each and every quadrate (100 x 100 m(was investigated separately. This method produced a picture not only of general distribution but also of species count and the spread of each individual species.

In 1972 it was decided to carry out the same kind of investigation of distribution but to include observation of the habitat choice of a species and their coverage in these habitats, and thereby attempt to discover which species were found together in communities and which species were typical for these communities.

Research Prodedures.

1971: A careful search for mosses was made in all quadrats of the lava. It was deemed unnecessary to make such a careful search on that part of the island consisting of volcanic ash and sand, since moss does not appear to thrive in such environments.

An exception, however, was made in those quadrats containing fumaroles (such as I-12 and H-13). It was customary to confine the search for mosses to one quadrat at a time, and to cover this area thoroughly. The distribution of species identified on the spot was recorded on a chart, whereas samples of other species were taken for laboratory identification. A drawback of the sampling procedure was the way in which all samples from the same quadrat were collected in one box, which prevented a means of ascertaining a species' frequency of occurrence in a particular quadrat. The prodecure established earlier (Fridriksson et al.,1970) was used to determine general distribution. An aerial photograph, with the quadrat boundaries drawn in, and a compass were used in determining location within a quadrat. In making up the map showing general distribution for each species, a species was assigned to one of three groups according to its frequency of occurrence in that quadrat. (See Table I.)

1972: The area in question was combed in the same manner as in 1972. Collection procedures, however, were modified so that each sample was kept in a special container designated by a catalogue number and a quadrat number. For each species that was found in a quadrat, the investigators noted the extent of coverage and the habitat at the first ten discovery sites in the quadrat. If the species was found in fewer than ten spots, then its coverage and habitat were noted at each location. Habitats were described as soon as they were observed, and were designated by a number that was used later for cataloguing purposes. The following categories were used:

1. Perpendicular lava cliffs in hollows and narrow crevices.
2. Moist sand in caverns shaded by a lava formation, from which water drips onto the sand.
3. A thin layer of tephra on a lava surface; fully exposed and unaffected by fumaroles.
4. Same as Habitat 3, but affected by fumaroles.
5. Naked, exposed lava surface without sand.
6. Hollows with sandy bottoms, moist and somewhat shaded.
7. Narrow cracks in lava, filled with sand.
8. Sand, shaded moist, and warm from fumaroles.
9. Sand-covered lava, fully exposed.
10. Sand on a lava slope, partly shaded, and moister than in Habitat 9.
11. Moist, naked, and shaded lava slopes.
12. Sand at the bottom of deep and narrow cracks in the lava; shaded.

Coverage was estimated as the average cover of the species in its habitat, which was determined with the use of a steel frame (25 x 25 cm) that contained a wire mesh with equal squares
Coverage was recorded in percentage, and the symbol + was used to designate coverage less than 1%. In calculating the average cover for each species in the quadrats, + was counted as o.2% coverage.

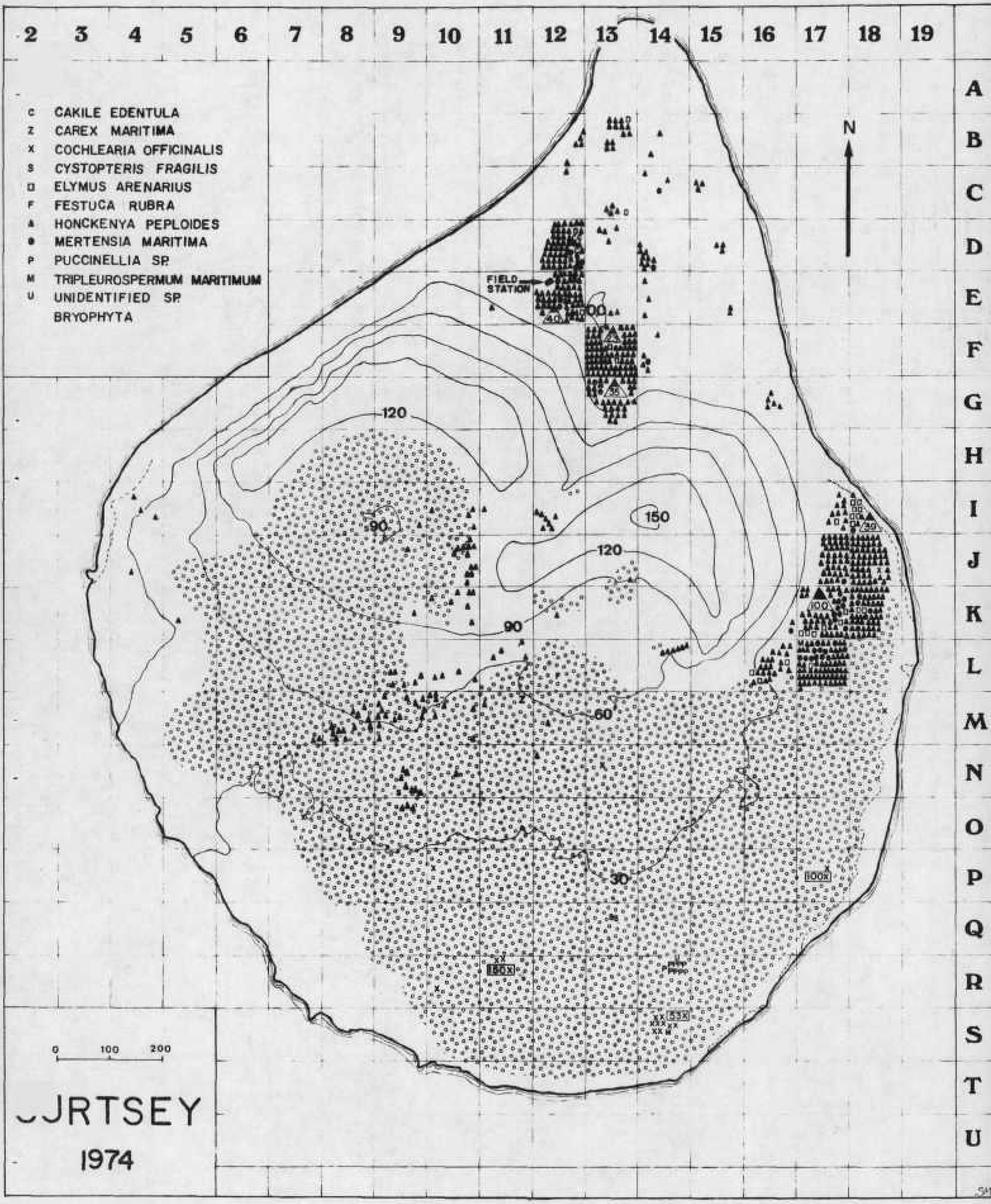
Information about a species' frequency of occurence in a quadrat was obtained later when the data was compiled. (Table I)

In addition to the above-mentioned details, investigators noted which species were found with capsules and gemma.

Table I

The following categories were used as criteria in determining the distribution symbols for each species in a quadrat:

Distribution Symbol	1971 Categories	1972 Categories
	Species found often	Species found in 10 or more locations
	Species found in several locations	Species found in 2-9 locations
	Species found once	Species found once



2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
A B C D E F G H I J K L M N O P Q R S T U
C CAKILE EDENTULA
Z CAREX MARITIMA
X COCHLEARIA OFFICINALIS
S CYSTOPTERIS FRAGILIS
□ ELYMUS ARENARIUS
F FESTUCA RUBRA
▲ HONCKENYA PEPLOIDES
● MERTENSIA MARITIMA
P PUCCINELLIA SP.
M TRIPLEUROSPERMUM MARITIMUM
U UNIDENTIFIED SP.
BRYOPHYTA
N
FIELD STATION
120
150
90
60
30
0 100 200
.JRTSEY
1974

Conclusions

General distribution: Between 1970 and 1971 the general distribution of mosses increased considerably on the island, but then decreased between 1971 and 1972. The clearest overview of these trends will be obtained by comparing the attached distribution maps with that from the year 1970 (Fridriksson et al.,1972).

The maps show that the main increase in the moss distribution occurred in the west, especially in 1971. Most of this area is on the southern slope of Surtsey II, that is, in quadrats J-6 and J 8-9, K 6-10, L 6-9, and M 6-9. In this area the lava is very rough, with 50% to 90% covered with volcanic ash (cf Fridriksson, Magnússon, and Sveinbjörnsson, 1972, p.62). The area is very dry, with caverns and small overhangings that provide good conditions for moss vegetation. The species Racomitrium canescens grew in this newly colonized area in very small and widely-scattered patches, and was responsible for the increase in distribution between 1971 and 1972 in quadrats J 5-6 and K 5-6. Mounds of volcanic ash limit the spread of moss to the north, since moss is not able to take hold there.

A minor concentration appears to have developed on the southeastern coast from 1971 to 1972, and is probably the result of coastline erosion and, as a consequence, increased proximity to the sea.

Although the rate of change in the distribution boundaries was slower in 1972 than in the previous year, this does not mean that propagation in moss areas came to a halt, since the general coverage of moss steadily increases from year to year.

List of Species

A great increase of species has occurred since 1970. In that year 16 species were known to exist on the island (cf Fridriksson et al., 1972). When samples from the summer of 1971 had been analyzed, the number of known species had risen to 37, that is, an increase of 20, or more than half the total number. All these new species were rare that year, except *Bryum stenotrichum*, which in all probability had arrived on the island earlier,but specimens of which had not been identified as a distinct species as the fruiting bodies had not developed until 1971. All specimens had, up to this point, been recorded as *Bryum spp.*

It is significant that the first liverwort species to be detected on Surtsey, *Marchantia polymorpha*, was among these new species. Two or three small individuals of this species were found on a rock in a moist hollow of a cavern in quadrat 0-17. After all the samples collected in the summer of 1972 had been classified, the number of species had risen to 72, or twice the number noted in 1971. Like the new species identified in 1971, the new species in 1972 were all rare, found only in a few places.

Three new liverworts were added to the list of known species, but it did not prove possible to assign them to a species with any certainty. They are species of the genera *Cephaloziella*, *Scapania*, and *Solenostoma*, all of which belong to the *Jungermanniales* family. The *Scapania* species is a member of either *S.scandica* or *S. curta*,whereas the *Solenostoma* species belongs either to *S. atrovirens* or *S. pumilum*.

Each species is designated with a letter in the alphabet, according to its frequency on the list, under the year column.

Reference to the accompanying list discloses that two species that were observed in 1970 and 1972 were not found in 1971. These are the species Aongstroemia Longipes and Brachythecium Salebrosum. Both were found in one place in 1970; in 1972 the former was found in two quadrats, the latter in eight. This indicates that both species were present, but went undetected. This is particularly true of the latter species.

In 1972 three species on the 1971 list, Fissidens adianthoides, Dicranella schreberiana, and Pholia annotina, were not rediscovered. There is reason to believe that F. adianthoides has died out on the island, in view of the fact that its precise location was known, that is, a small cave in L-12, where steam emission and optimum conditions were present. In 1972 the steam emission had ceased and a great deal of sand had blown in, so that the moss eventually dried up and perished for the most part.

The other two species are probably still subsisting, although there was no trace of them, but it is of course never possible, in terrain like that of Surtsey, to make a corroborative search. Thus, whatever rare species are found each year is largely a matter of coincidence. The species Bryum kingraeffii schimp., which was discovered in quadrat H8 in a tephra fumarole, had not previously been found in Iceland and is therefore new to the region.

Species Distribution

The accompanying charts show the distribution of only the most common species, since there is not adequate space for a chart comprising all the species in a short article like this one. This omission is justifiable, since only the most common species have real ecological significance in the formation of soil and vegetation cover on the island. When reviewing the charts it should be remembered that they show only what the moss search revealed, and, as mentioned earlier, it was often coincidence that determined what species were found in a quadrat and the frequency with which they were observed. The frequency of species not shown on the map may be found in the distribution groups in the list of species.

All the major species that were observed in 1971 spread greatly in 1972, not a surprising fact in view of the rapid increase that was apparent from 1969 to 1971. Unexpected, however, was the spread of the species Grimmia stricta and G. apocarpa in 1972, both which were found in 1971 in only two quadrats. By 1972 they had become common species and were often found with capsules.

Difficulties in classifying Bryum spp. made it necessary to represent their distribution combined on one chart. The Bryum species are among the island's most common, but it is not yet possible to state with any precision the role of each species in the general distribution. (Exceptions are B. argenteum and B. calophyllum.) It was possible to map the distribution of particular Bryum species as some specimens bore capsules and could be classified with certainty.

There is no doubt, however, that *Bryum stenotrichum* is the most common *Bryum* species on Surtsey, since by far the greatest number of capsulated specimens that have been found are of this species.

The *Philonotis spp.* chart shows the general distribution of all *Philonotis* species on the island, that is to say, if there are any other species than *P. fontana*. It has been possible to assign only a few specimens to a species, and they are all of *P. fontana*, so it is likely that most of the *Philonotis* samples belong to this species. These classification difficulties stem from the immaturity of the specimens.

Sporing

The following table shows which species were found with spores in 1971 and 1972 their location:

When a species reaches the stage of forming spores and capsules, its chances for spreading on the island are no doubt increased all the more. But in general it is not known exactly to what extent propagation by spore contributes to the increase of each distinct species. In addition to sexual reproduction, asexual reproduction by means of gemma and other plant parts is very common.

Gemma (asexual reproduction) have been found on the following species:

- _Marchantia polymorpha_
- _Bryum Klimgraeffii_
- _Bryum pallens_
- _Pohlia proligera_
- _Pohlia annotina var. decipiens_
- _Pohlia schweicheri_

Although asexual reproductive organs have been found only on those species mentioned above, it is certain that other species have propagated asexually on the island, that is, with plant bodies, such as leaves and stalks, which break off the parent plant and are carried to a new location where they form new colonies.

Habitats

As indicated earlier, investigators recorded the various habitats for each species observed in the different quadrats on Surtsey.

The following table represents the conclusion of these observations for 23 of the most common species on the island. They are arranged according to distribution, with the most common listed first, and so forth.

This arrangement, however, does not apply to the Bryum species,except B. argenteum, which is easily identifiable with the naked eye. The others were recorded as Bryum spp.

The frequency figures indicate how often species were recorded in the various habitat categories. Thus, for example, the species R.canescens was recorded at a total of 966 locations, being in the habitat category No. 5 in 954 instances. The highest frequency figures for each species are underlined in the table, thus showing the most common habitats of the species.

According to the number of samples, category No. 5 is the most common habitat on the island. It is favored by various species, such as Racomitrium canescens and R. lanuginosum, Grimmia stricta and G. apocarpa, all of which can be said to be characteristic for this habitat.

These four species seem to thrive well on the island but have not yet undergone the competition that will show which one will eventually dominate this community in the future. Several other species were found growing in this habitat, but they are so far only associate species in this primary succession. An example of these is Bratramia ithyphylla, a species which also grows under various other conditions.

An other common habitat on Surtsey in the category No. 6. It is favored by many species, such as various Bryum species like B. stenotrichum, as well as Funaria hygrometrica, which are still the most dominant species. Associate species are

Pohlia cruda, Philonotis sp., Ceratodon purpureus, Bartramia ithyphylla, and others.

The other habitats can be examined in the same way as these two.

This classification is based on 4.593 observations. Classical sociological measurements could not be applied because the moss colonies are still rather scattered.

Cover

The total cover of mosses on Surtsey is still rather small, and exact measurements of their coverage are therefore very difficult to obtain. The roughness of the lava surface also adds to these difficulties.

As mentioned above, the cover of each species in its habitats was recorded in each quadrat. The accompanying cover maps show the mean cover value in each quadrat for the six most common species.

The maps reveal that although Racomitirum canescens is the most common species on the island, it ranks only third in coverage, the patches being usually much smaller than those of Bryum spp. (mostly B. stenotrichum) and Funaria hygrometrica, which show the highest cover values. Other species have much less average cover per quadrat.

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Lichen Colonization in Surtsey 1971-1973.

Skýrsla til Surtseyjarfélagsins í janúar 1974.
(ekki ætlað óbreytt til prentunar)

Lichens were first detected on Surtsey in the summer of 1970, when three species were found on the island, Trapelia coarctata, 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 inital stages of lichens throughout the island by the aid of hand lens. Samples were collected of all species detected in the field. Final identification was carried out in the laboratory by microscopical work 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 100 x 100 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. First found in Surtsey 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 emmission is still efficient, but nowhere else. Under such conditions its growth rate is very rapid.

Trapelia coarctata forms in Surtsey light brown to whitish thallus of several cm diameter. Apothecia are always present in great number, formed below the thallus surface, and brake 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 120-160μ, the ascospores 12-20 x 7-11μ, colorless, subglobose to ellipsoid.

2. Placopsis gelida (L.) Linds. was first seen 1970 in the same locality and habitat as Trapelia coarctata. Next year it was found in several localities in the most recent lava field which came up 1967. In contrast to Trapelia coarctata this species is now distributed throughout most of the lava fields 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 diameter. 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 a coherent thallus of the same diameter as the original patch. 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 fields from 1967, where it now has a wide distribution independent of the steam holes. Its distribution extends also to the lava of 1965, 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. The phyllocladia are not grouped into round plots, like Placopsis gelida and Stereocaulon capitellatum. 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 pseodopodetia with many phyllocladia. 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 parasymbiont, 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. 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 favourable 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. 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, which is classified to the genus Lepraria.

The species found in Surtsey is very common in Iceland on overhanging rocks and in cave mouths, and was by earlier authors called Lepraria latebrarum. I have seen specimens of this same lichen collected by Lynge and identified as L. aeruginosa. According to P.W. James (1970) the correct name for. L. aeruginosa is L. incana (L.) Ach. But otherwise the identity of this species must be considered uncertain. The taxonomy of this genus is rather incomplete because of lack of good morphological criteria.

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 recurved. On older squamules there are one to several brown, immersed apothecia. In section the hymenium measures 120-150μ, the ascospores are many hunderds per ascus, 2.5-3 x 1.2μ. This species has not been identified yet.

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.

The thallus is areolate-verrucose, lightcolored, pycnidia abundant, apothecia dark 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 Bacidia 7, a species of Lecidea was also collected in 1972. 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 epithecium is dark brown to black, the hypothecium dark brown, the excipulum blackish near the outside, the ascospores colorless, one celled, 12-15 x 7-9μ.

9. Lecidea. Another species of Lecidea was detected in a sample from the western slpe 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 were present. An identification must await for better samples, and better knowledge of the Icelandic species of the genus Lecidea, than we have now.

10. Xanthoria candelaria (L.) Th.Fr. This species was seen in one locality both 1972 and 1973. Several plants were found in an area of 1-2 m^2 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 1973 on exposed rock around a lava peak in the lava field 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 colorless, the exciple darkened. The ascospores are colorless, 8-11 x 4μ, inequal two-celled.

HABITATS

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

1. Rocks influenced by warm steam. This habitat is found all around the craters Surtur I and II. The steam comes out of 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, but others seem to be constantly moistened by the steam from surrounding damp 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 have no way to maintain water in the thallus by 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 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 develops 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, were also first found at the crater margin, simply because their growth was faster here than elsewhere.

2. Bird manured rocks. There are plenty of lava outcrops in Surtsey, which are characterized by frequent visits of 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 at several localities on lava peaks and on the margin tops of Surtur I and Surtur II. It developes faster where it enjoys 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 onlynin relatively few places.

Other colonizer of a similar habitat is Xanthoria candelaria, which only occurred in one locality, around a plastic fresh water basin, set up 1967 and later removed again. This is a species, which 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 habitat, which is charachterized by its shade, and moist, stagnant air. Besides the lichen, a species of a 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 is the growth in this habitat 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 keep the drying effects of the wind away 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. canescens. 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.

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 has been more successful in this part of the new lava, than elsewhere in the lava fields. But even in those parts of the new lava, which have a very hard, glassy surface, 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 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 ABOUT LICHEN TRANSPORT TO SURTSEY.

There are no direct observations available on how the 11 lichen species were brought to Surtsey. No success was made by searching for lichen propagules on the feet and plumage of birds caught in Surtsey and made available through Dr. Sturla Friðriksson 1969 and 1970, although some other plant material was found, like green and bluegreen 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 atttempts 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) arrived by air to Surtsey, and that one species (Xanthoria candelaria) was born there by birds. For the 6 species left, no conclusion has been made.

The four species supposed to come by air, 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 an 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 components 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 air 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 get there. We do however not know for sure, whether free living Nostoc cells can be captured by the fungus to form cephalodia in Stereocaulon or Placopsis, even though this has been suggested for Peltigera aphthosa (Hale 1967), or whether some special physiological adaptation is needed for the lifein 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 arrived by birds, was until 1973 only found at one locality, but many plants were within 1,5 meter distance from the spot, where one of the fresh water basins 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 six species about which no conclusion was made concerning their transport to Surtsey, five 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 tranpport and dispersal capacity of the wind, the role of birds is in my opinion negligible for species with effective wind distribution. 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 surroundings and is frequently visited by birds.

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~~Schwabe;~~

Temperatures, steam emission and moss cover in the thermal areas of the island of Surtsey, Iceland

By

ERIK A. SJÖGREN

Institute of Ecological Botany, Uppsala University, Sweden

INTRODUCTION

In August 1972, four days were spent on Surtsey, 12-15/8. In the years after 1968, colonization by mosses on the island has been followed in detail (cf. Bjarnason - Fridriksson, 1972; Fridriksson - Bjarnason - Sveinbjörnsson, 1972; Fridriksson- Sveinbjörnsson - Magnusson, 1972). The largest patches of dense moss cover are found in the thermal area of the island (cf. Magnusson- Sveinbjörnsson - Fridriksson, 1972). This does not mean, however, that the largest number of recorded localities with primary colonization by bryophytes are to be found within the thermal area.

At the beginning of 1972, I received the generous invitation of the Surtsey Research Society to come to Surtsey. My intention put forward at that time was to study microclimatic conditions in the thermal area in places where moss cover was present. Tha main questions to be studied were the influence of heat, steam and windtransported material (accumulation and erosion) on colonization by mosses.

A "Grant multipoint temperature recorder, model D, was used for the temperature recordings. With this instrument, it is possible to record temperatures from 28 thermistor probes within 3 minutes, i.e., almost simultanously. The recordings are made automatically at intervals of one hour. Reading the recorded values, and calibration of the instrument, including the necessary use of a conversion chart, allows the measurement of temperatures to $\pm$ 0,2°.

The probes used during the measuring series were equipped with radiation shelters of aluminium foil. The full capacity of the instrument could not be used, as there were difficult problems with short circuit because of the permanent steam in the measuring areas.

Meteorological measurements in August on Surtsey (cf. Sigtruggsson, 1970 p. 119) indicate a mean temperature of 10.7^{o}, wind velocity at 2 m above ground level of 3,9 m/sec. (13 days) and precipitation of 25,4 mm (13 days).

MEASURING AREAS

A. A total of 13 probes were scattered within and in the vicinity of the so-called "Bell", which is a cave formed by tephra and accumulated sand. It has a W-facing entrance and a hole in the roof. The "Bell" is situated in the section J 13 (110 m above mean sea level) to the NE of the so-called Surtur I crater (cf. below). It is situated on a S-facing slope with an inclination of about 30%. In the area are numerous steam-emitting holes. Steam comes out continuously from places in and close to the cave. Moss cover is concentrated in the vicinity of the steam holes, in the interior of the cave and at the top of the cave where the sand is permanently moist. In this locality, sand covers 90-100% of the new lava (cf. Fridriksson - Magnusson - Sveinbjörnsson, 1972).

B. A total of 21 probes were placed in the northern part of the crater "Surtur I" (local names cf. Thórarinsson, 1968 p. 143-148) in the section L 12. This part of the crater has very many steam fissures and holes. There is continuous condensation of water in the area, and the accumulation of sand is considerable 17 probes were placed within the crater; 2 probes on the northern rim, and 2 in a place with no steam emission, E of the rim. Moss cover is frequently present close to places of steam emission. The degree of cover within sample plots of the size 1/4 m^2 exceeds 50% in several places.

RECORDINGS

A. Locality: "The Bell".

Time period: 12/8 14.00 - 14/8. 13.00 (1972).

Weather: 12/8 14.00, 100% cloud cover, winds from SE about 10 m/sec. In the night 12-13/8, strong winds and scattered rain showers. 13/8 12.00, generally 100% cloud cover, winds from W-SW, about 15 m/sec , scattered rain showers. 14/8 after 07.00, about 75% cloud cover, winds from S-W, 5-10 m/sec.

All measuring points (fig. 1: 1-5): Temperatures measured at intervals of one hour have been connected in the diagrams. Values from 13 probes will be discussed below. Mean, maximum and minimum temperatures refer to the whole measuring period of 48 hours. Probe numbers followed by (a) indicate that the position was below the soil surface, if followed by (b) the position was at the soil surface.

Probes 1a and 2b (fig. 1-1).

Position: Inside "the Bell". (1a ----) at the base of the northern wall, 1 cm below the soil surface in moist loose sand; (2b . . .) same locality, at the surface.

1a.	max.	19.0°	min.	8.7°	mean temp	13.8°
2b.	"	14.8°	"	5.6°	"	10.5°

Steam is blown into the cave from the steam hole (at short intervals) to the W and it is also emitted from the bottom of the cave. The steam keeps the sand permanently warmer than the air at the sand surface where steam is frequently removed by the winds blowing through "the Bell". Condensation of water is especially abundant on the N vertical wall in the cave, where the moss cover has the highest degree of cover. - Bryophytes: Atrichum undulatum, Leptobryum pyriforme

Probes 3a and 4b (fig. 1:2).

Position: Inside "the Bell". (3a ———) at the S wall, 1 m above the bottom of the cave, 1 cm below the surface in densely packed moist sand; (4b ......) same locality, sand surface.

3a.	max.	26.0°	min.	14.5°	mean temp.	20.9°
4b.	"	22.5°	"	4.2°	"	12.9°

The sand is kept permanently warm by the penetrating steam. Air temperatures are much less, because of the rapid air circulation in the cave.

Probes 5b, 6b and 7b (fig. 1:3).

Position: 1 m to the W of the entrance to "the Bell". (5b -·-·-·-) 5 dm S of a steam hole; (6b ·····) 8 dm S of the steam hole, (7b -·-·-) 10 dm S of the same steam hole. All the probes at the surface, hard surface with very little loose windblown sand.

5b.	max.	26.2°	min.	9.4°	mean temp.	15.3°
6b.	"	20.4°	"	7.4°	"	11.0°
7b.	"	23.1°	"	8.0°	"	11.7°

Size of the oval steam hole at the opening, 15-20 cm in diameter. Hot steam is continuously blown out, generally in a southward direction down the slope. The steam moves continuously over a narrow field from the opening of the hole to 5 dm to the S of it. The field between 5-8 dm is less in contact with the steam and is wetted by the condensation of water from the cooled steam. During windy weather the steam is frequently forced down by the winds on to a small area to the S of 6b, which explains the higher maximum and minimum and mean temperatures at probe 7b than at 6b. There was less wind after 07.00 14/8 and the steam could not then reach probe 7b so easily. - There is moss cover in a narrow band from 5-8 dm to the S of the steam hole.

Bryophytes: Bryum argenteum, Funaria hygrometrica.

Probes 8a, 9a, 10b and 11b (fig. 1:4).

Position: To the N of the opening in the roof of the cave. (8a ——) in densely packed sand 5 cm below the surface, 2 dm to the N of the edge of the opening in the roof of the cave, (9b · · · · ·) same locality but at the surface, (10a - - - - -) in densely packed sand 5 cm below the surface, 8 dm to the N of the edge of the opening in the roof of the cave, (11b -·-·-·-) same locality but at the surface.

8a.	max.	44.6°	min.	33.4°	mean temp.	39.0°
9b.	"	27.2°	"	7.8°	"	18.0°
10a.	"	39.0°	"	30.0°	"	34.3°
11b.	"	31.2°	"	8.8°	"	17.4°

Steam permanently warms the sand of the roof of the cave. The air at the surface is, however, cooled down by the permanent turbulence round the cave. Slightly higher maximum and minimum temperatures at 11b than at 9b might be explained by random downward movement of the steam by the winds. There is moss cover between 9b and 11b where moisture is provided by the cooled steam. - Bryophytes: Funaria hygrometrica, Dicranella crispa.

Probes 12a and 13b (fig. 1:5).

Position: 5 m SW of "the Bell", between small steam holes. (12a ——) 5 cm below the surface in densely packed sand; (13b · · · · ·) same locality at the surface.

12a.	max.	50.8°	min.	41.1°	mean temp.	46.1°
13b.	"	28.8°	"	12.1°	"	18.2°

These were the highest maximum, minimum and mean temperatures recorded with soil thermistors within the area. Turbulence in the air strata close to the ground is most efficient in the locality, but the high soil temperatures mean that 13b recorded the highest minimum temperatures of the air thermistors in the area.

- Bryophytes: Bryum argenteum, Pohlia albicans.

Comments: Temperatures in the thermal area in and around "the Bell" are already comparatively high at a depth of 5 cm in loose sand or/tephra They are charecterized by rather small diurnal amplitudes. Low air temperatures at night seem to have only a small effect on the ground temperatures, which are regulated by the hot steam penetrating from below. The diurnal temperature amplitudes are thus much larger at the soil surface, as shown especially clearly by the probes of fig. 1:4. In the temperature gradients indicated by Johanesson (1972, p. 129 ff.), there is no information about temperátures between 0-20(30) cm depth. His curve of point 11 ("the Bell") indicates temperatures of only 35^0 at a depth of 30 cm, which seems to be much too low for this area (cf. also Jakobsson 1972, p. 122).

B.

Northern part of "Surtur I" (70-72 m above sea level).

Time period: 14/8 14.00 - 15/8 13.00 (1972).

Weather: 14/8, 14.00 to 18.00, 75-100% cloud cover, winds 5-10 m/sec.

15/8, after 04.00, winds below 5 m/sec. and 75-100% cloud cover.

All measuring points (fig. 2:1-9): Temperatures measured at intervals of one hour have been connected in the diagrams. Values from 21 probes will be discussed below. Probes with numbers followed by (a) are situated below the soil surface and those by (b) at the surface.

Probes 1a and 2b (fig. 2:1).

Position: 2 dm above vertical oval opening with steam emission. Diameter of the hole is 10-15 cm. (1a ——) 1 cm below the surface in loosely accumulated moist sand; (2b ·····) same place at the surface.

1a.	max	25.6°	min.	7.1°	mean. temp.	17.1°
2b.	"	24.3°	"	9.1°	"	19.9°

Steam emission in the vicinity of the hole during the morning hours with rather light winds clearly increases the temperatures in the air close to the ground surface above the temperatures in the sand. Between 14.00 - 24.00. the winds blow the steam downwards in a SW direction from the hole (cf. probes 12a and 14b).

Probes 3a and 4b (fig. 2:2).

Position: 3 m SW of the same steam hole as above. (3a ——) 1 cm below surface in moist, fine, densely packed sand; (4b ·····) same place at the surface of the sand.

3a.	max.	19.2°	min.	12.2°	mean temp	14.5°
4b.	"	18.7°	"	8.9°	"	12.4°

The winds do not continuously blow the steam as far as 3 m from the hole Sand temperatures are thus almost continuously higher than air temperatures. Values should be compared with the lower values recorded at 15a and 17b, at the same distance from the steam hole but in a place with loose sand where the percentage content of fine grain material is small and penetration of steam is apparently easier.

Probes 5a and 6b (fig. 2:3).

Position: 5 m E of rim of the crater, on slope facing E. (5a ——) 1 cm below the surface in dry loose sand; (6b · · · · ·) same place, at the surface.

5a.	max.	17.9°	min.	8.7°	mean	temp.	11.3°
6b.	"	18.5°	"	7.9°		"	10.1°

Lowest minimum and maximum air temperatures recorded within the area. Comparatively low minimum temperatures and the lowest maximum temperatures recorded at a depth of 1 cm in the area. The lowest mean temperatures were at these probes.

Probes 7a and 8b (fig. 2:4).

Position: Rim of crater, 1 m to the E of steam hole mentioned above and 5 m W of position of 5a and 6b. (7a ——) 1 cm below the surface in moist sand; (8b · · · · ·) same place, at the surface.

7a.	max.	18.5°	min.	10.7°	mean temp.	13.0°
8b.	"	19.7°	"	9.6°	"	13.0°

During morning hours with light winds, only slight influence of steam at probe 8b, much weaker than at 2b. Comparatively low minimum and maximum values at both probes. – Bryophytes: Dicranella crispa, Leptobryum pyriforme.

Probes 9a, 10a and 11b (fig. 2:5).

Position: 3 dm W of steam hole (same as above). (9a ——) 1 cm below the surface in moist sand; (10a - - - -) same place 5 cm depth; (11b · · · · ·) same place, at the surface.

9a.	max.	27.2^{o}	min.	11.1^{o}	mean temp.	18.9^{o}
10a.	"	32.2^{o}	"	21.3^{o}	"	26.4^{o}
11b.	"	27.6^{o}	"	8.3^{o}	"	16.7^{o}

There is a steep rise in temperature from the surface to a depth of 5 cm in the sand. - Bryophyte: Pohlia nutans.

Probes 12a, 13a and 14b (fig. 2:6).

Position: 1 m W of the steam hole. (12a ———) 1 cm below the surface in moist sand; (13a - - - -) same place, 5 cm depth; 14b · · · · ·) same place, at the surface.

12a.	max.	20.8^{o}	min.	12.6^{o}	mean temp.	15.7^{o}
13a.	"	26.7^{o}	"	18.8^{o}	"	21.0^{o}
14b.	"	24.4^{o}	"	9.1^{o}	"	15.8^{o}

The three probes measured series of temperatures of special importance to the understanding of conditions close to steam emission holes. The increase of temperatures with depth of only 5 cm is very marked. The air temperatures at the surface are influenced by steam blowing down from the hole in the first half of the time period; during the second half the influence decreases as the wind decreases. A comparison of air temperatures at a distance of 3 dm and 1 m from the hole shows that the steam emerges from the hole in a steep upward direction and then is carried down by winds to the ground further away. These conditions were also observed at probes 6b and 7b outside "the Bell" (fig. 1:3).

Temperatures very close to a steam hole are evidently subject to larger and more frequent changes (cf. probes 9a, 10a, 11b) than at a longer distance from it. - Bryophyte: Bryum argenteum.

Probes 15a, 16a and 17b (fig. 2:7).

Position: 3 m to the W of the steam hole (2 m W of 12a, 13a, 14b). (15a ——) 1 cm below the surface in moist loose sand deposits; (16a - - - - -) same place, at a depth of 5 cm; (17b · · · · ·) same place, at the surface.

15a.	max.	24.8°	min.	16.9°	mean temp.	19.4°
16a.	"	33.7°	"	27.5°	"	30.6°
17b.	"	21.1°	"	9.8°	"	14.8°

The heat provided from below to the accumulated sand and to the air above in this thermal area also depends on the depth of the deposited sand layer. There was a much thinner sand layer above the lava here than at a distance of 3 dm or 1 m from the steam hole.

Probes 18a and 19b (fig. 2:8).

Position: At a distance of 1 m W of the large steam hole, 10 cm from the opening of a small round steam hole with horizontal opening 3 cm in diameter. (18a ——) 1 cm below the surface in moist loose sand; (19b · · · · ·) same place, at the surface.

18a.	max.	60.3°	min.	25.2°	mean temp.	40.3°
19b.	"	49.4°	"	20.1°	"	35.2°

Largest temperature ranges recorded within the area both in air and sand. The very large increase in temperatures between 03.00 – 05.00 can not be correlated with similar changes in conditions at the other probes. Temperatures very close to steam holes change rapidly and frequently (cf. 20a, 21b).

Probes 20a and 21b (fig. 2:9).

Position: At a distance of 1 m W of the big steam hole, 3 cm from 2 dm long narrow fissure in the sand. (20a ——) 1 cm below the surface in moist loose sand; (21b ·····) same place, at the surface.

20a.	max.	47.6°	min.	39.1°	mean temp.	43.1°
21b.	"	55.4°	"	31.3°	"	46.6°

Highest maximum air temperature recorded. Highest mean temperatures both in air and sand.

- Bryophytes: Pohlia albicans, Bryum argenteum.

Comments: The series of records have shown the same conditions as within the first described area: generally lower temperatures at the soil surface than at a depth of 1 cm in sand or tephra. The further increase in temperatures until the depth of 5 cm appears to be very steep. Strength and direction of winds influence air temperatures, in relation to the contribution of hot steam in localities close to steam emission holes. Depth of accumulated sand probably has an influence on amounts of heat penetrating up to the surface but not on the frequency and time of change in temperatures.

Steam from holes and fissures is apparently carried by the wind in a curve from the opening down to areas around, unless the winds are very week. Amounts of steam emitted depend on the size of the holes; the direction of the steam depends on the inclination of the holes and the exposure of the situation to the wind

DISCUSSION

Thermal areas on Surtsey locally provide suitable conditions for colonization by mosses. Such localities are situated in the vicinity of steam emission holes and fissures. In these places there are now coherent moss carpets with fairly large degrees of cover. The colonized areas are frequently distinctly limited, with few specimens growing outside the dense carpets.

The steam provides heat and condensed water to areas close to the emission holes. It was supposed by Bjarnason & Fridriksson (1972, p. 10) that water condensed from the steam is a more probable explanation of the development of bryophyte diaspores than the heat. The stabilizing effect of the steam on the sand was also mentioned. This supposition can be further verified.

The large amount of heat with no steam emission provided to several places in the thermal area where mosses are absent supports this idea. There is an increase in heat towards the opening of big steam holes, but often a sharp limit of moss cover at some distance from them. However, high temperatures are tolerated round small emitting holes. The high temperatures, often reaching 60°C, are thus not likely to be able to support or to hinder the moss colonization.

Condensation of water takes place round the steam holes, up to a certain distance not generally reached by the steam. The steam is carried further from the holes during windy weather. The transport of steam from the holes with inclined openings seems to be always in one direction, even if winds are blowing towards the opening of the hole. For example, this was the case at the large steam hole at a distance of 1 m W of "the Bell" on 13/8, when strong SW winds were blowing. Steam was then first carried from the S-facing opening in a first southwards direction, to nearly exactly the far limit of the moss cover situated to the S of the hole.

It was then carried by the wind in a curve towards the N. The emission of steam from the holes during very windy conditions takes place in a curved direction in a way probably providing less steam and heat to places very close to the holes and more to a more distant area. These conditions have been illustrated by the temperature series both from "the Bell" and from "Surtur I".

The correlation between position of moss cover and contribution of steam - condensation of water - seems to be well-established. However, the reason for the absence of mosses in areas closest to big steam holes remains to be discussed. In that connection, the stabilization of sand and finer material by the condensed water chould be stressed. In the vicinity of the steam holes, there is often a building up of cones of accumulated material. The accumulation decreases away from the holes and drops rather abruptly to small amounts at the far limit of the general range of the steam. Just around the holes there is probably an accumulation of wind-transported material which is too rapid to allow diaspores of mosses to develop. Within the range of moss colonization, the water supply is certainly essential but also the stabilization of the substrate, with accumulation not rapid enough to lead to oversanding of the growing diaspores. ~~supplied~~ Differences in accumulation of wind-blown material might be explained by a more permanent moistening of the zone nearest to the holes than in places further away, in the usual direction of movement of the steam emitted, where moss cover is present.

Outside the area reached by the steam, there is a lack of moisture and also frequent change between accumulation and erosion of deposited material. Such conditions are here unfavourable to the attachment and further development of moss diaspores.

The sizes of the steam emission holes and fissures regulate the amounts of steam provided to the surroundings. The accumulation of wind-blown material close to the holes and the building up of cones often means that the openings are inclined, situated on the slopes of the small cones. The emission of heat and steam then takes place in one general direction. The development of a moss cover then depends quantitatively on the amounts of steam emitted; and its situation depends on the direction of the steam outflow. A concentric coherent moss zone round steam holes is therefore rare. Moss cover is often observed within a narrow segment extending away from the holes.

Temperature records: One of the general features of the temperature sequences within the two measuring areas is the sharp increase in temperature from the surface down to a depth of 5 cm. There are also distinctly higher temperatures at 1 cm depth than at the surface. 5 m SW of "the Bell", the mean temperature at a depth of 5 cm in the tephra was within the temperature range (40-60^{o}), earlier recorded in 1970 at a depth of 20 cm (cf. Magnússon - Steinbjörnsson - Fridriksson 1972, p. 83). Temperatures recorded at a depth of 5 cm in "Surtur I" were also within the range of 20-40^{o}, indicated from a depth of 20 cm for that area (op. cit.) The further very steep rise in temperature down to 60 cm was recorded by Jakobsson (1972, p. 122). His values seem to be more probable than those showing a much less steep gradient, obtained by Johannesson (1972, p. 135, point 11).

Weakening turbulence may for a short time increase the surface air temperatures close to steam holes above those measured at a depth of 1 cm in the sand, especially if the accumulated sand layer is deep. Diurnal temperature ranges at the surface are larger than within the sand or tephra. The ranges at 5 cm depth would in a larger number of series of records show comparatively very small diurnal ranges with changes not always correlated with day or night. The supply of heat to the air nearest the ground close to steam holes is parallel to the supply of steam - condensed water.

To sum up, moss cover on Surtsey is not favoured by heat supply. Localities are now numerous outside thermal areas. Mosses do not seem to be hindered from colonising habitats where there are continuously high temperatures. Lack of water is certainly limiting factor. Too much supply of water is, however, probably also unfavourable, because of the secondary effect of too rapid an accumulation of wind-transported material. A moderate water supply is required, with a favourable balance between accumulation and wind-erosion of supplied sand of finer material.

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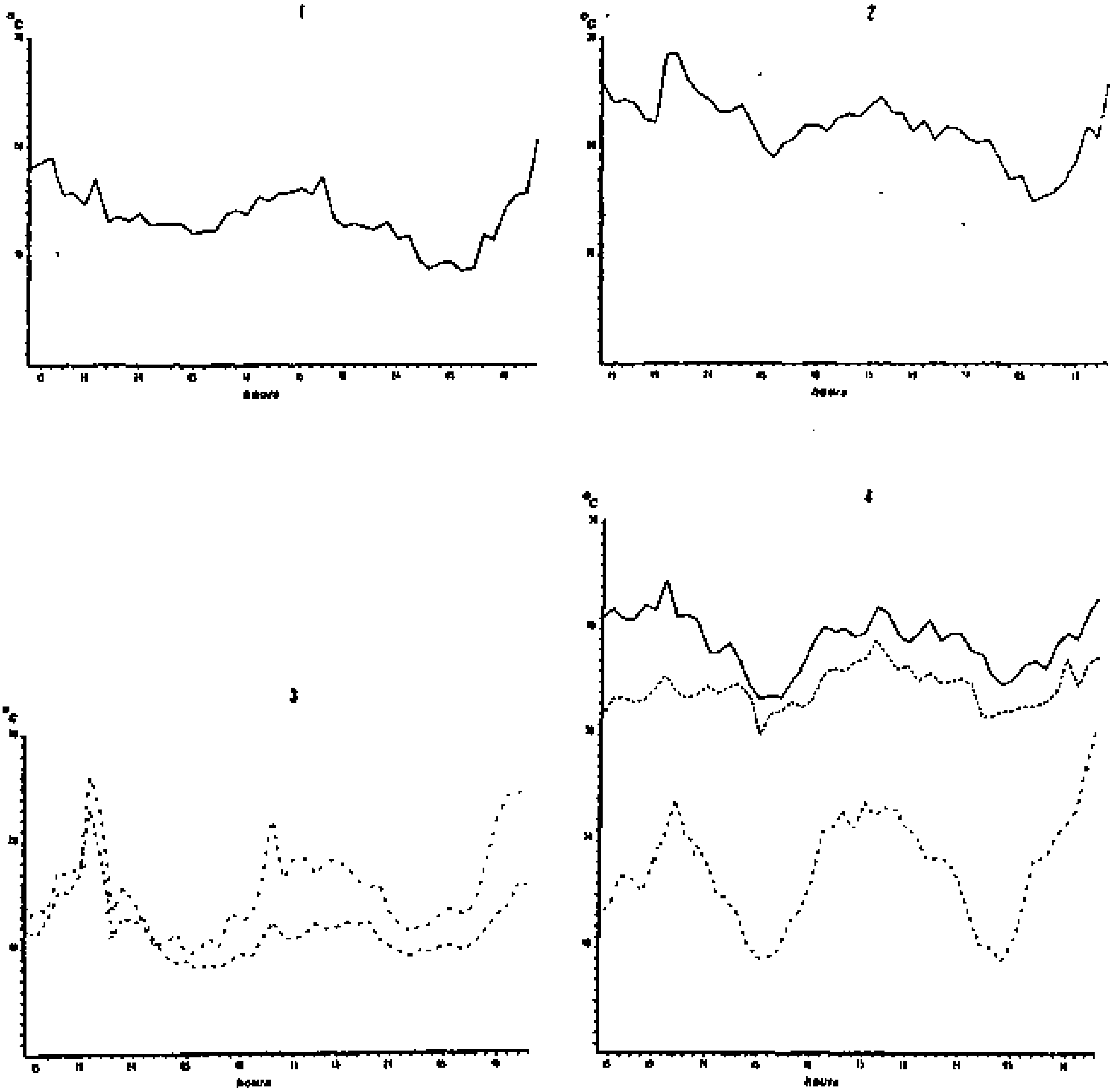

Fig. 1:1-4.

Surtsey

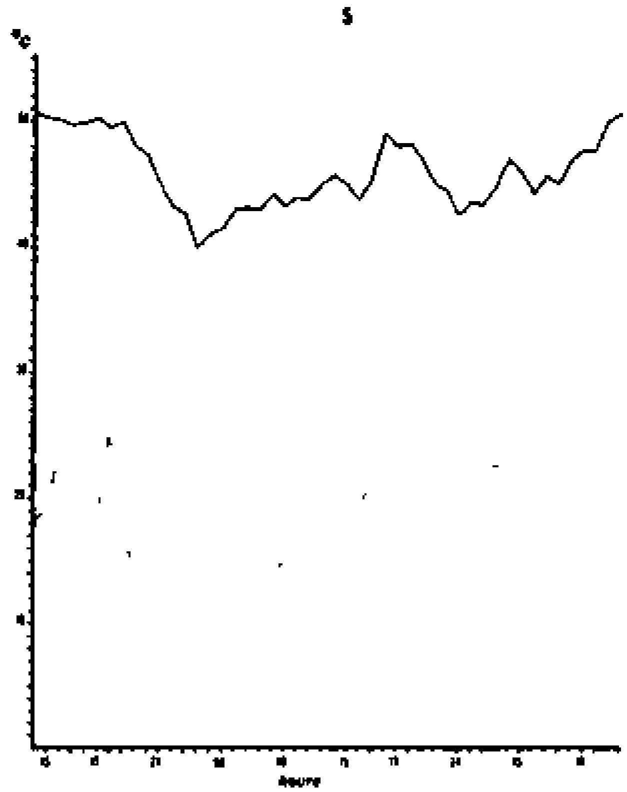

Fig. 1:5.

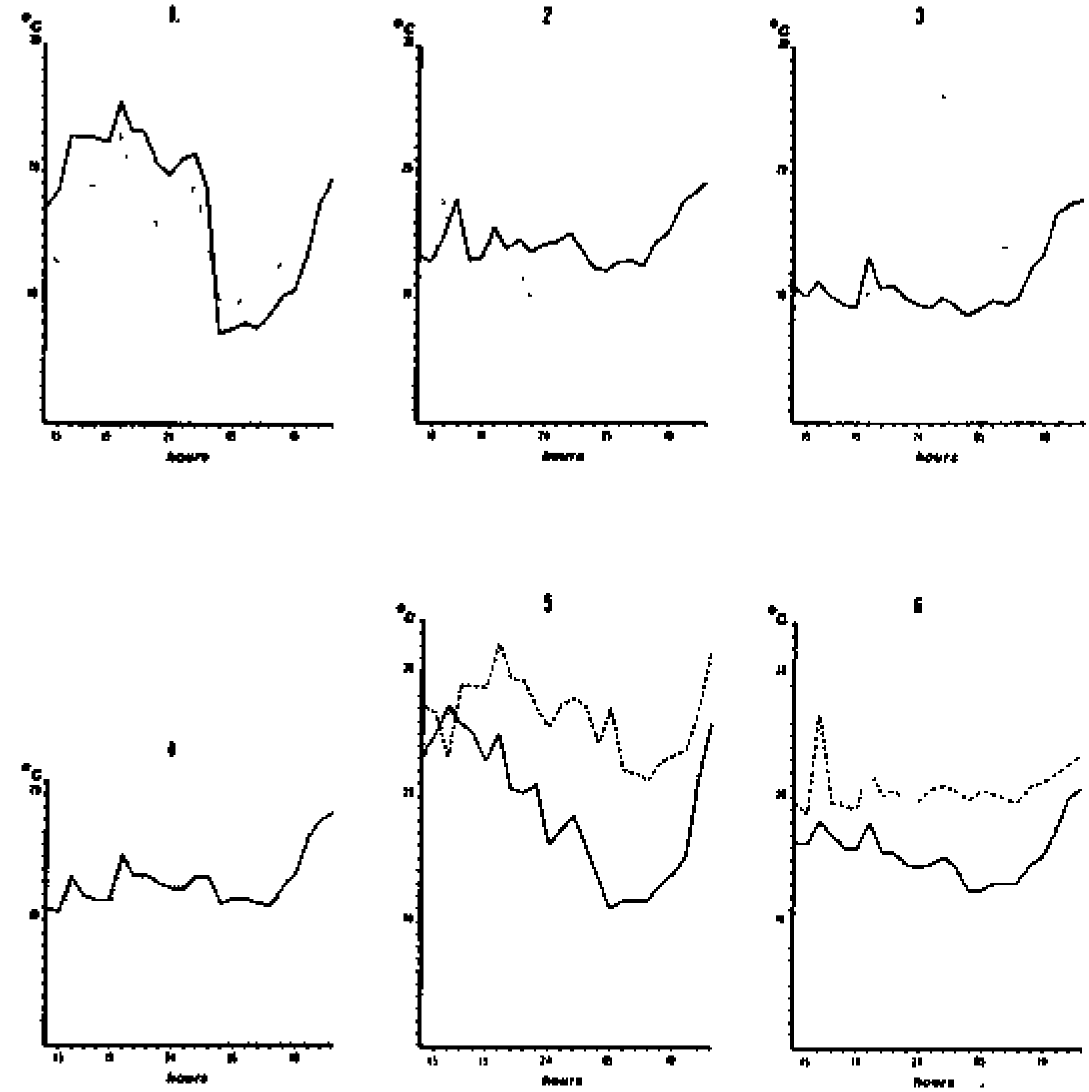

Fig. 2: 1-6.

Surtsey

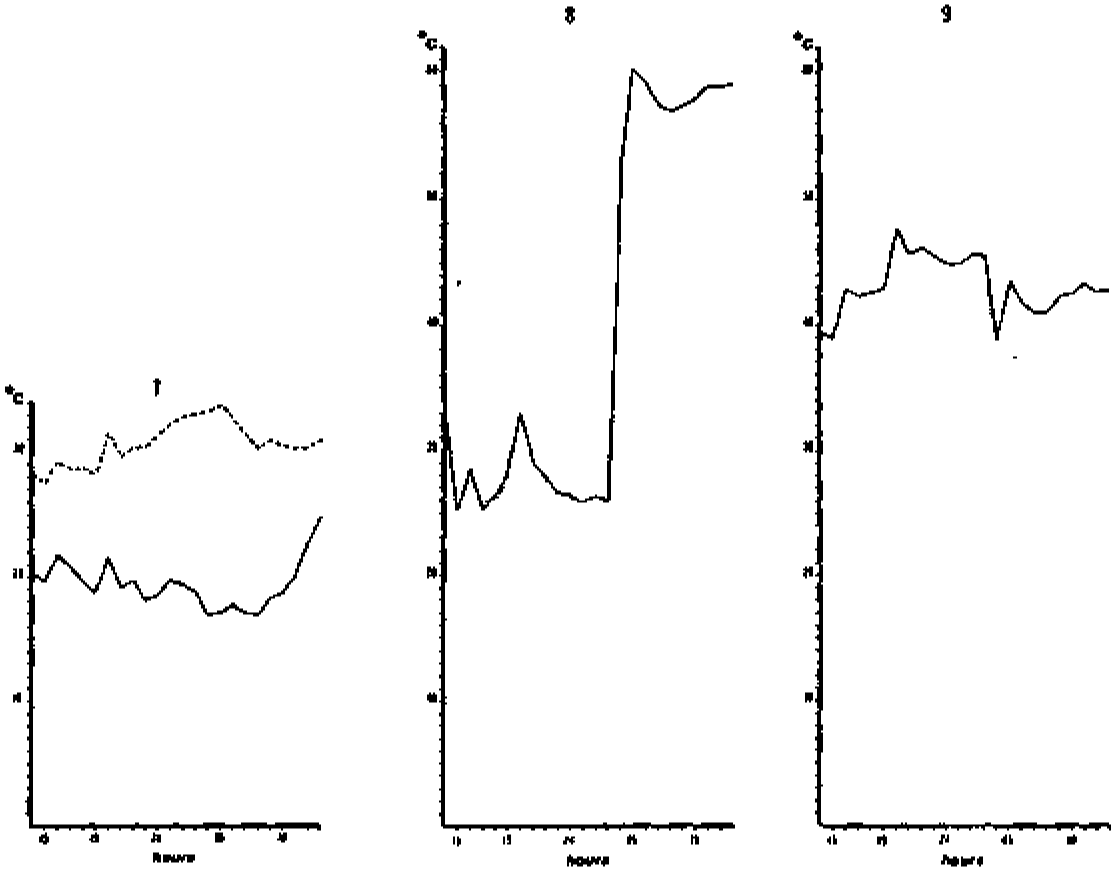

Fig. 2 : 7-9.

Surtsey

(fig. texts)

Fig. 1:1-5. Temperatures recorded with 13 thermistor probes at intervals of 1 hour, inside and close to "the Bell", section J 13 in the thermal area. (The position of the probes is described in the text.)

Fig. 2:1-9. Temperatures recorded with 19 thermistor probes in the N part of "Surtur I" and with 2 probes outside the crater, section L 12 in the thermal area. (The position of the probes is described in the text.)

Fig. 3. "The Bell", situated on the S facing slope to the N of the crater "Surtur I". Steam emission from several places in the area. - 14.8.1972. E. Sjn.

Fig. 4. "The Bell" seen from S (cf. temperature diagrams fig. 1: 1-5). In the foreground, probes 12a and 13b (fig. 1:5). To the left, probes 5b, 6b and 7b (fig. 1:3), located 1 m W of the entrance to the cave and to the S of the steam hole. - 14.8.1972. E. Sjn.

Fig. 5. Northernmost part of "Surtur I" with temperature recording instrument (cf. fig. 2: 1-9). To the left, probes 18a, 19b, 20a and 21b (fig. 2: 8, 9). To the right, rim of crater, position of probes 7a and 8b (fig. 2:4). Behind the instrument, which was protected by a plastic envelope, are probes 1a, 2b, 9a, 10a and 11b (fig. 2:1, 5). - 15.8.1972. E. Sjn.

Fig. 6. "Surtur I" seen from the N from the slope just below "the Bell". The location of the temperature recording instrument is visible. Steam emission from the area is strong. - 15.8.1972. E. Sjn.

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