Microbiological Observations on Surtsey, 1970

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During the 1970 NASA expedition to Iceland and Surtsey I was able to continue my microbiological studies of Surtsey, following up on previous work done in 1965 and 1966. My previous two visits to Surtsey coincided with the Syrtlingur and Jólnir eruptions and most of the potential sites for biological development were being covered with volcanic ash. Now that eruptions have ceased and the habitats are more stable, biological studies can be carried out. The distribution of life seems closely associated with the availability of moisture, either as steam condensation from fumaroles or near the sea in lava crevices where higher humidities would be expected. Two kinds of microbiological studies were done: 1) Observations on the relative importance of blue-green algae versus higher plants (mosses and vascular plants) as primary colonizers; 2) The distribution of bacteria in terrestrial habitats. The conclusions from these studies can be simply stated: 1) Blue-green algae are *not* the primary colonizers of Surtsey, except in thermal areas where higher plants do not grow; and 2) Bacteria are found in terrestrial environments in the rhizosphere of plants, both mosses and vascular plants, and also on ash near blue-green algae and in fumaroles, but not in ash away from plants and fumaroles.

METHODS

The visit was made on 26 June 1970. Samples of soil, plants, and algae were taken in various parts of the island. For quantative study of relative importance of blue-green algae and higher plants, cores of green material were taken in a number of locations using a # 4 cork borer. Soil pH values were measured the same day using an Orion battery-operated pH meter after making a 1:1 mixture of soil and deionized water. Temperatures were measured with a Yellow Springs Instrument Co. thermistor. Preliminary microscopy was done the same day using a Carl Zeiss phase microscope and detailed microscopy was done 6 July 1970 using a Zeiss fluorescence microscope. With the latter, bacteria were sought upon soil particles and plant roots using acridine orange as a fluorochrome and a vertical illuminator, thus permitting examination of opaque surfaces. Algae were observed using the Zeiss phase contrast microscope.

RESULTS AND DISCUSSION

1. Are blue-green algae the primary colonizers of Surtsey?

In a number of areas on Surtsey, visibly green patches were taken and examined microscopically for the presence of blue-green algae and mosses. Such patches were mainly found where moisture levels were high, either in steam condensate from fumaroles or in crevices of lava rocks. In regions very near fumaroles, the temperature was high, 30—60°C, and in these areas blue-green algae were found. Thermal habitats of this type are rare on Surtsey, and studies of the algae present were carried out by R. W. Castenholz, University of Oregon, Eugene, Oregon, who reports (personal communication) that the cosmopolitan thermal alga *Mastigocladus laminosus* was present. Most habitats with green patches where condensing steam was present are not thermal, and temperatures around 25°C or less were measured. The present work concentrated on

these non-thermal areas, which were mainly around the newest crater of Surtur II in the southeast quadrant of the island. The data are presented in Table 1. The soil pH measured on several samples was 7.8—7.9, which is in an appropriate range for the growth of blue-green algae, yet no blue-green algae were found. I conclude, therefore, that blue-green algae are not the primary colonizers of non-thermal habitats on Surtsey. In the moister areas mosses were found and in drier habitats vascular plants were found. These observations suggest that vascular plants and mosses are the primary colonizers of non-thermal habitats, and only in thermal habitats are blue-green algae present.

Although these observations may seem at variance with those of Schwabe (G. H. Schwabe, 1970, On the algal settlement in craters on Surtsey during Summer 1968, *Surtsey Research Progress Report V*, 68—69; Schwabe, G. H., 1969, Pioniere der Besiedlung auf Surtsey, *Umschau in Wissenschaft un Technik* 2, 51—52; Schwabe, G. H. 1969, Ökogenese auf vulkanischem Subsrat, Intern. Symposium für Vegetationskunde,

TABLE 1

Search for blue-green algae in green patches in non-thermal areas where condensing steam was present

Sample	Moss	Blue-green algae
Near Surtur II		
878	Present	Absent
933	Present	Absent
869	Present	Absent
930	Present	Absent
916	Present	Absent
963	Present	Absent
971	Present	Absent
964	Present	Absent
924	Present	Absent
936	Present	Absent
960	Present	Absent
954	Present	Absent
Near Surtur I		
863	Present	Absent
912	Present	Absent

TABLE 2

Bacteria associated with volcanic ash and plants

Sample	Material	Observations
22-1	Ash 6 cm from *Minuartia peploides* pH 6.4	No bacteria
23-1	Ash attached to *M. peploides* pH 6.85	Many small rods, few actinomycete hyphae
23-1	Root hairs of *M. peploides*	Few small rods
23-3	Ash in fumarole with alga *Mastigcladus laminosus*, 60°C, pH 7.8	Many small rods, some in microcolonies
24-1	Ash in fumarole with *M. laminosus* 40—50°C, pH 7.8	Many small rods, some in microcolonies
24-2	Ash in fumarole no algae, 90°C, pH 7.9	Frequent small rods, some in microcolonies
24-4	Ash in fumarole, no algae, 55°C, pH 5.1	No bacteria
24-6	Ash in fumarole, no algae, 39°C, pH 5.1	No bacteria
25-1	Ash in condensing steam near Surtur II, 25°C, pH 7.9	Many small rods, many in microcolonies
26-1	Ash in fumarole, 95°C, pH 7.5	Frequent small rods
26-2	Ash in fumarole, 74°C, pH 7.9	Frequent small rods
26-3	Ash in tufa cliff away from fumaroles, air temperature, pH 7.3	Frequent small rods, some in microcolonies
26-4	Moss rhizoids	Many actinomycete hyphae
26-4	Ash near moss rhizoids	No bacteria
26-5	Roots of *Minuartia peploides*	Many small bacteria
26-5	Ash near *M. peploides* roots	No bacteria
27-2	Ash from tufa cliff near hut, air temperature, pH 6.65	No bacteria

Assessment based on fluorescence microscopy after acridine orange staining.

Rinteln; Schwabe, G. H., Blue-green algae as pioneers on post volcanic substrate (Surtsey/Iceland), unpublished manuscript, Plön, January 1970), examination of Schwabe's papers shows that he assessed blue-green algal development by enrichment culture techniques, which are excellent for floristic surveys aimed at detecting organisms present even in small amounts, but do not provide any estimate of quantitative abundance. Direct microscopy, used in the present study, will miss rare organisms but will give a good estimate of the quantitative importance of dominants. Thus the fact that I have not detected blue-green algae in my cores does not mean that they are not present, but only that they are rare. Blue-green algae are hence probably not of any great ecological significance in contributing organic matter for soil formation and for the development of heterotrophic microorganisms and higher levels in food chains, whereas mosses and vascular plants clearly are.

2. Bacteria in terrestrial habitats on Surtsey.

The use of the fluorescence microscope with acridine orange staining permits a direct examination for the presence of bacteria on opaque surfaces. Samples of volcanic ash, mosses, and vascular plants were studied. Some samples of ash were collected from around plant roots and others were collected at sites quite distant from plant roots. The results, given in Table 2, show that bacteria are widely but not universally distributed in terrestrial environments on Surtsey. Virtually every plant root or rhizoid examined had a high bacterical population, as would be expected since it is well know that roots and rhizoids excrete organic materials upon which bacteria can grow. Bacteria were also found in large numbers in ash near fumaroles, even ones of quite high temperature (90–95°C), although not in ones where the ash is acidic. Some samples of ash collected near to but not attached to roots or rhizoids were devoid of bacteria. Thus it seems that bacteria develop in large numbers where appropriate energy sources are available (probably organic materials in plant rhizospheres and inorganic reduced compounds in fumaroles). Although the sources of bacterical inocula are unknown, it seems reasonable that those bacteria associated with plants were brought to Surtsey attached to the plant disseminules. Those bacteria associated with fumaroles were probably dispersed through the air, either free or attached to particles.

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