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Beggiatoas as pioneers in volcanic soils of Surtsey, Iceland

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ABSTRACT: *Beggiatoa* species commonly occur on Surtsey at locations where also mosses and blue-green algae are found. The species recorded were *B. alba*, *B. leptomitoformis*, and *B. minima*. The occurrence is discussed with respect to the environmental conditions.

Beggiatoa species are filamentous gliding bacteria, also called "colourless algae". They are cosmopolitan and often found in polluted water and in sediments. The *Beggiatoas* have demonstrated an ability to release energy both from organic substances and by oxidizing H_2S (KOWALLIK and PRINGSHEIM 1966). They have no resting spores and, as far as is known, can not endure dry conditions.

The island of Surtsey (in the Vestmannaeyjar Islands, Iceland) was formed by a series of eruptions in the Atlantic during 1963-1968. Nowadays it has an area of 2.4 km^2 and there are two main craters, Surtur I (150 m above sea-level) and Surtur II. Lava blocks have formed various sized structures on the island, and there are vents (fumaroles) among the blocks from which steam emerges frequently, specially during the early years. In 1972, when we first visited Surtsey, an odour of H_2S was generally detectable around the craters and the steam vents. Later on this characteristic smell has decreased. The island is covered with layers of lava sand or tephra.

Ever since Surtsey was formed, it has been defended as far as possible from injury and pollution by man, being a national protected area under supervision of the Surtsey Research Society. Therefore Surtsey has given remarkable opportunities for studies of the colonization of microorganisms and higher plants into virgin soils, at the beginning practically free from organic substances and available bound nitrogen (PONNAMPERUMA *et al.* 1967, HENRIKSSON & HENRIKSSON 1974b). In 1972 it was still possible to gather soil samples without detecting any microbial life (HEN-

RIKSSON & HENRIKSSON 1974a).

As a result of field-work on Surtsey in 1974 and 1976, frequent occurrence of *Beggiatoa* could be recorded, and it was reported that *Beggiatoas* belonged to the first immigrants to Surtsey (HENRIKSSON & HENRIKSSON 1978). More samples were collected on our next expedition to Surtsey in 1978 in order to confirm their continued occurrence and to identify the species present.

This communication presents our results and gives some physiological and ecological aspects on the occurrence of *Beggiatoa* on Surtsey.

MATERIAL AND METHODS

a. Soil sampling. The soil samples studied were mainly gathered around the crater rim of Surtur I and in the vicinity of and in the cave, "The Bell", a formation of big lava blocks and steam vents. The soil samples from the surface of each locality were aseptically deposited in small sterilized plastic capsules (Cerbo, Sweden, No. 18014) of 20 ml volume with a sample spoon attached inside each screw-cap.

b. Enrichment cultures. For the enrichment cultures of *Beggiatoa* the medium recommended by AARONSON (1970) was used and was prepared as follows: Dried hay was extracted 3 times at 100° C in large volumes of water. The extracted hay was then drained and dried at 37°C. Dried hay (0.2 g) and water (25 ml) in 50 ml Erlenmayer-flasks were autoclaved together and after cooling inoculated with 1-2 g of the aseptically gathered soil. Incubation was at 21°C. In the presence of *Beggiatoa* a white film appeared on the surface of the medium after a few weeks and this film was studied microscopically. By adding H_2S to the cultures an enrichment of the sulphur granules in the *Beggiatoa* cells could be detected.

c. Identification. The identification of the *Beggiatoa* species present was made according to LEADBETTER (1974) and FJERDINGSTAD (1979). The identifications are based upon the width of the filaments.

RESULTS AND DISCUSSION

The following *Beggiatoas* were recorded in the enrichment cultures, obtained from the soil samples gathered.

Beggiatoa alba (Vaucher) Trevisan	(2.5-5.0 µm width)
Beggiatoa leptomitoformis (Meneghini) Trevisan	(1-2 µm width)
Beggiatoa minima (Winogradsky)	(1 µm or less width)

Members of the family Thiobacillaceae were also present in the cultures. These organisms, like the *Beggiatoas*, are able to metabolize sulphur and sulphur compounds. *Thiobacillus denitrificans* was recorded from Surtsey in an earlier communication (HENRIKSSON and RODGERS 1978).

The first blue-green algae and the moss *Funaria hygrometrica* Hedv. were also reported from the same *Beggiatoa* locations (SCHWABE 1972). Schwabe followed the colonization of algae at Surtsey, and

found that the first oases of growth occurred at the steam vents, and that the algae were associated with bacteria.

Several strains of *Beggiatoa* are known to be able to grow chemo-autotrophically (KOWALLIK and PRINGSHEIM 1966, PRINGSHEIM 1967), but all strains grow better in the presence of low levels of certain organic substances. It is also known that the *Beggiatoas* are stimulated by association with other organisms, for instance with pink-pigmented cocci (BURTON and MORITA 1964) and with rice (JOSHI and HOLLIS 1977). It seems plausible that the *Beggiatoas* are colonizing Surtsey in association with other early immigrants.

Thus *Beggiatoas* are commonly found in rich sediments but also in the native meagre soils of Surtsey. However, it should be remembered that blue-green algae grow in fertilized soils or polluted waters and also as pioneers on Surtsey. Recently it has been shown that the moss *Funaria hygrometrica*, and other mosses, grew together with *Beggiatoas* in water flumes containing silage juice in such a high concentration as 1:1000 (BRINK 1978). The same mosses as in the flume-investigations of Brink are growing together with *Beggiatoas* in the Surtsey soils.

It has also been reported that *Funaria* and blue-green algae stimulate each other when growing together in the Surtsey soils (RODGERS and HENRIKSSON 1976).

The problem arises how the *Beggiatoas* are able to invade the craters of Surtsey. The indications are that winds and frequently occurring rains in the area can transfer these bacteria from the other Vestmannaeyjar Islands, formed about 5000 years ago, and from the southern coast of Iceland to the high levels of Surtsey. The possibilities to be dispersed to Surtsey are generally easier than to survive and develop under the environmental conditions present on Surtsey. A characteristic feature of the first immigrants is their ability to utilize low levels of available nutrients.

BROCK (1972, 1973) suggested that blue-green algae were of less importance as primary colonizers on Surtsey than could be supposed by studying enrichment cultures of the algae, since they probably were not adaptable to the environment by severe conditions in the Surtsey soils. However, our results on the nitrogen-fixing activity of blue-green algae in field experiments indicated that blue-green algae are vital for the biological development on Surtsey (HENRIKSSON and HENRIKSSON 1974b, HENRIKSSON and RODGERS 1978). Generally they can not be observed by the naked eye but can be detected only after enrichment culturing (HENRIKSSON and HENRIKSSON 1974b, SCHWABE 1974). This seems also to be the case with the *Beggiatoas* reported in the Surtsey soils.

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