

Further settlement of marine benthic algae
on the rocky shore of Surtsey

by

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In a previous study it was reported that the first benthic marine colonization observed in Surtsey was carried out by Diatoms associated with Bacteria (1). This initial growth, very sparsely met with in 1964 on a 4 to 5 months old rocky shore, was followed about one year later, by a somewhat more conspicuous vegetation, represented by filamentous green algae found at high tide level, in few favored rocky sites on the open coast.

Further investigation was carried on in Surtsey in the course of the summer 1966, assisted by Örlygur Karlsson and Sigurdur V. Hallsson. Algological surveys for comparative purposes were also made along and off the coasts of Heimaey, the inhabited island of the archipelago, and in many of the smaller outer isles.

In Surtsey the entire island, except its intertidal region, was still covered by the loose cinder-cone material from adjacent satellite volcanos, one of which was in full activity during our stay. As to environmental changes in the rocky intertidal region it was of importance to note the absence of sand beaches, which the year before, stretched out from the base of the cliffs bordering the lava delta. These had now been replaced by rolling stones, projecting rocks and boulders, which already showed smooth surfaces due to active marine abrasion. The scouring action of waterborne sand had practically ceased along this coast.

The whole coastline was accessible during low tides and could be explored, except for a few localities on the southeast, the east and the southwest sides of the island, where lava-cliffs dropped abruptly into the sea from a height of about 20 m. After the new eruption in Surtsey, on August the 19th, 1966, the east and the northeast coast became again inaccessible. On both sides of the

lava front, advancing into the sea, sand beaches were formed and immediately the scouring action set in again.

Several days were spent in Surtsey in July and August, and extensive field collection made along the rocky shore. The study of the material has revealed many new species of algal colonizers. From their presence it is possible to make some estimations as to the evolutionary pattern of the benthic algal settlement in Surtsey.

1. List of species

The following species were found growing directly on the rocky shore of Surtsey in July and August 1966. Simultaneous records from the other isles of the archipelago, when available, are given for each species.

CHLOROPHYCEAE:

Urospora mirabilis Aresch (= U. penicilliformis (Roth) Aresch). This species grew very luxuriantly everywhere on the firm rocky substrate, about high tide level. Abundantly fertile, the specimens bear gametocysts and/or sporocysts. A few immature specimens of Codiolum gregarium, the unicellular sporophyte of this species, were also found above high water mark in a limited site of the northwest coast, associated with Urospora and Enteromorpha flexuosa.

Records from other isles: Very scattered growth on Heimaey, mixed with Ulothrix sp., Calothrix scopulorum, Bangia fusco-purpurea and Codiolum gregarium, the latter locally predominant (Skansinn, Eidid, below Dufthekja, on a promontory in Dal fjall, Klaufin).

Ulothrix flacca (Dillw. Thuret). Some fructiferous individuals mixed with Urospora.

Record from other isles: Bjarnarey.

Ulothrix pseudoflacca (Wille). A few fertile plants were found in company with Ulothrix flacca and Urospora. Young germlings were observed inside the zoidocysts.

Records from other isles: Heimaey (Klaufin, on the walls of a sea-grotto in Dal fjall).

Enteromorpha flexuosa (Wulfen ex Roth) Ag. Two fertile plants, 10 cm long, ramified but without secondary branching, were detected in the splash zone on the northwest coast. Our specimen shows angular cells arranged in longitudinal series, each with 1-2 pyrenoids. This species may be synonymous with some doubtful forms of *E. clathrata* gathered in the Vestmann Islands and described by H. Jónsson (2. p. 349).

Enteromorpha intestinalis (L.) Link. A few immature specimens, 5 to 20 cm long and 0.5 to 2,0 mm broad, occurred in high-lying rock pools on the northeast coast. The plants resemble somewhat the var. asexualis described by Bliding (3, p. 141). A small, but fertile specimen was also collected on the rocks on the northwest coast.

Records from other isles: Very common everywhere in rock pools in the supralittoral spray zone of much exposed shores as those of Ofanleitishamrar on Heimaey.

PHAEOPHYCEAE:

Pylaiella littoralis (L.) Kjellm. A single tuft, 4 mm high, was found in a rocky crevice about high tide level on the northwest coast. Only few plurilocular sporocysts were observed.

Records from other isles: Heimaey (grotto of Klettshellir, in the Gigartina-belt of Ofanleitishamrar, as untergrowth in the Fucus spiralis - belt in Stórhöfði); Faxasker, Ellidaey.

Ectocarpus confervoides (Roth) Le Jolis. Some tufts, 1,5 cm high, were met with in high-lying rocky pools on the northeast and the east coast, in company with filamentous Diatoms. Plurilocular and some unilocular sporocysts occur on the same individuals. The specimens agree well with those described and figured by H. Jónsson (4, p. 155). By their habitat they, however, resemble the var. crouanii Thuret described by Cardinal (5, p. 21). Small swimming crustaceans were also

found in these rocky pools. These were the only intertidal animals met with on the coast.

Records from other isles: Geirfuglasker, Heimaey (epiphyte on Laminaria digitata in Urdir, and on the stipe of Alaria esculenta in Ofanleitishamrar).

Scytosiphon lomentarius (Lyngbye) Link. Three specimens, up to 10 cm long, grew solitary or in tuft in rock pools on the east and the west coast, in company with Petalonia zosterifolia, Enteromorpha intestinalis, Porphyra umbilicalis and filamentous Diatoms. The thalli, with or without constrictions, bear hairs and plurilocular sporocysts.

Record from other isles: Heimaey (Urdir).

Petalonia fascia (O.F. Müll.) Kuntze. Solitary typically sickle-shaped specimens, up to 13 cm high, were found in rocky pools in the upper littoral zone of the west coast. They bear plurilocular sporocysts (Determ. Dr. Bernadette Caram).

Records in the other isles: Not encountered by me, but occurs in the Vestmann Islands according to H. Jónsson (4, p. 168).

Petalonia zosterifolia (Reinke) Kuntze. Specimens, 5 to 20 cm high and 0,2 to 0,5 cm broad, grew gregariously in rock pools and in depressions in the rock in the upper littoral zone of the west and the east coast. These plants, of unusually great size, bear plurilocular sporocysts, except some very slender forms, 0,2 cm in diameter, which appear sterile (Determ. Dr. Bernadette Caram).

Records from other isles: Not found by me, but occurs in the archipelago according to H. Jónsson (4, p. 167).

Alaria esculenta (L.) Grev. One young, immature plant, only 1,5 cm high, detected by S.V. Hallsson, on the rock, covered with benthic Diatoms, near the limit of low tide, on the east coast.

Records from other isles: Grows very socially everywhere along the rocky shore.

RHODOPHYCEAE:

Porphyra umbilicalis (L.) Ag. This species was rather common on rocks and in rocky pools in the upper part of the littoral zone on the east and the west coasts. Specimens of great size, up to 5 cm in diameter, bear monospores. Young germlings of Urospora, intermingled with Licmophora, grew epiphytically on the fringe of the thallus.

Records from other isles: Very common on adjacent coasts exposed to excessive wave action, as, for example, in Geirfugla-sker, in Ofanleitishamrar on Heimaey, and on the regularly sloping south side of Sudurey.

DIATOMEAE:

The two following filamentous and mucilaginous species constituted the most conspicuous elements of the Diatoms-flora of Surtsey:

Navicula (Schizonema) mollis (W. Sm.) Cl. This species which was one of the two initially found in Surtsey in 1964, grew now very abundantly in pure populations on the rocks in the intertidal zone and apparently below it (Determ. Madame Marie-France Magne).

Other records: Ubiquitous species occurring on the coasts of Iceland according to Östrup.

Navicula ramosissima (Ag.) Cl. The species was common on the rocks in the intertidal zone, but did not form a pure population. Licmophora gracilis (Ehr.) Grun var. anglica (Kütz.) Per. grew epiphytically (Determ. Mme. Marie-France Magne).

Other records: On the coasts of Iceland.

2. The marine algal vegetation

Three kinds of vegetation could be distinguished in Surtsey according to the abundance of the species encountered and their distribution.

a) Green belt of *Urospora mirabilis*. The most extensive developed populations were represented by this species, which exhibited nearly pure stands, 2 to 3 cm high, on the rock surfaces along the shore bordering the lava delta. On gigantic boulders on the northeast coast, this belt was particularly conspicuous, attaining 8,30 m width, and extending downwards from about the high water line or a little above it. On the vertical basaltic cliffs this belt becomes much narrower, being approximately 0,50 to 1,0 m large. Closely associated to this growth were *Ulothrix flacca*, *Ulothrix pseudoflacca* and *Enteromorpha flexuosa*. However, they did not play any part in the general physiognomy of this vegetation. The same is true for *Porphyra umbilicalis* occurring immediately below the green *Urospora*-belt.

b) Brown belt of filamentous Diatoms. This growth formed a very striking contrast with the green belt above. Mainly composed of *Navicula (Schizonema) mollis*, it offered a dense slippery coating, about 10 mm high, everywhere on the rock surfaces, and extended downwards as far as could be seen. A same kind of growth also occurred in some high-lying rock pools. The only macroscopic vegetation observed in the brown belt was the young plant of *Alaria esculenta* growing in the lowest part of the intertidal region.

c) Tide pools vegetation. Confined to the rock pools of the upper littoral zone, this growth was dominated by *Petalonia zosterifolia*, while the other species encountered, *Pylaiella littoralis*, *Ectocarpus confervoides*, *Petalonia fascia*, *Scytosiphon lomentarius* and *Enteromorpha intestinalis*, were only represented by scattered individuals. It should be noted that this biotope showed the greatest diversity of species. Tide pools did not occur on the south coast of the island. They were limited to the west, east and the northeast coast.

No indigenous algal growth was found on the sand beach and on the rolling stones on the north side of the island.

3. Remarks on the marine algal colonization

As shown in table I the rate of algal colonization on the rocky shore of Surtsey has increased constantly since 1964, when only Bacteria and Diatoms were observed. The first macroscopic element of the benthic flora, Urospora mirabilis, was detected in 1965. During the following year the number of indigenous species raised considerably, as 11 new species were met with, Diatoms not included.

TABLE I Rate of colonization of marine benthic algae in Surtsey until 1966.

	1963	1964	1965	1966
Supralittoral			[Urosp.]	[Urosp.]
Eu-littoral		[Bact. + Diat.]	[+ Diat.]	[+ Uloth. Enterom. Porphyra Diat.] [Rock pool veget.] [Alaria]
Sub-littoral				[?]

It should be noted that during the same time the ecological conditions prevailing along the rocky shore, improved, due to regressive sand scouring action of the sea. In this connection it is also noteworthy that after the onset of the scouring action following the formation of new sand beaches in August 1966, the algal growth was locally wiped away or buried under the sand. This factor evidently has a very unfavourable influence on the algal settlement.

A striking fact is the extensive development of Urospora mirabilis all over the upper part of the rocky shore, whereas this species was just of local occurrence during the same time in adjacent floral areas. This expansion points to a remarkable capacity of this species for rapid initial population of a virgin substrate. This has without doubt been favoured by the asexual reproduction abundantly shown by these algae. This is in some respects similar to the proliferation exhibited in some cases by animal species recently introduced in vacant habitats.

After the establishment of Urospora mirabilis as pioneer species in Surtsey it was assumed (1, p. 40) that the other components of the filiform algal community to which this species belongs would soon colonize the island. It was therefore not quite surprising to find Ulothrix flacca, Ulothrix pseudoflacca and Porphyra umbilicalis among the new colonizers in 1966. Until now representatives of all the algal associations composing this community on adjacent coasts have been found in Surtsey, except *Bangia fuscopurpurea*, rare during the high summer, as well as some Blue-green algae, such as Calothrix scopulorum. This community has not yet reached its climax-stage, and it will be of great interest to follow its development.

The occurrence of the brown belt of filamentous Diatoms indicates that the algal colonization has now begun in the other part of the intertidal zone. Of particular interest is to note that the precursors of this settlement are also the benthic Diatoms. This fact is similar to that observed by Delepine et al. in Antarctic waters where the repopulation of rocky substrate, periodically denuded by floating ice, always begins with these algae. In Surtsey the next step of the algal colonization appears to be that of Alaria esculenta. After the occupation of the intertidal zone by Diatoms, the macroscopic settlement seems therefore to proceed from two starting points, one situated at high water mark, the other at low water mark.

It should be noted that all the algal species found in Surtsey have also been met with in the other isles of the archipelago. This means that Surtsey belongs to the floral district of this

region, and that the colonization will, presumably, take place from adjacent floral areas.

As to the means of dispersal of the marine algae to Surtsey it is noteworthy that almost all the species settled on the coast have also been washed ashore as driftweeds. It is therefore possible that immigrants arrive by this way to the island. The dissemination of microscopic spores by means of sea-currents, which are very strong between the isles, should, however, not be minimized.

It is obvious that all the species reaching the island do not necessary colonize it. This is the case of Ascophyllum nodosum, the most common driftweed found in Surtsey. This species grows in semi-exposed sites at Heimaey, and it is doubtful if, under the present conditions, it will settle on the very exposed shores of Surtsey. This applies also to other species found in similar habitats in the archipelago, such as Pelvetia canaliculata, Catenella repens (new record for Iceland, found in Heimaey in Sept. 4, 1966), Chondrus crispus, Ahnfeltia plicata, Fucus vesiculosus, Fucus serratus and Laminaria saccharina. The special environmental conditions caused by the heavy surf prevailing along the coast of Surtsey, surely act as a selective filtering for the species. Only those adapted to surf-habitats may be expected to pass through, as, for instance, Laminaria digitata var. stenophylla, Gigartina stellata, Callithamnion arbuscula, Rhodymenia palmata, Corallina officinalis, Acrosiphonia albescens, Ceramium rubrum, Polysiphonia urceolata, Phymatolithon polymorphum, Fucus distichus, Fucus spiralis, in addition to species already established. However, exceptions to this might be found in tide pools and ecological niches. As to the deep-water flora it can be assumed that it will not differ fundamentally from that of fairly uniform feature, observed around the other isles. This is characterized by species which frequently come up in dredgings, such as Desmarestia ligulata, Desmarestia viridis, Desmarestia aculeata, Membranoptera alata, Phycodrys rubens, Ptilota plumosa, Plocamium vulgare, Lomentaria clavellosa, Lomentaria orcadensis, Euthora cristata and Laminaria hyperborea. None of these species have been found off Surtsey.

It is interesting to compare the marine algal colonization of Surtsey with that studies by Dawson in 1953, on new and denuded substrates following the volcanic eruption of the Isla San Benedicto, off the Pacific Coast of Mexico. About nine months after the ceasing of the lava flow, 9 algal species were discovered on the new substrate, seven of which, surprisingly, were not found in the surviving flora on the other side of the island. Among these were the two dominating elements of the growth. In this area the settlement is initiated by other species that in Surtsey, because of a different composition of the flora. But in both islands the first visible growth is represented by species, which at the same period of the year are rare or temporarily absent in the nearby populations. Further development of the marine algal colonization will show if this fact is due to competition between species in two dissimilar habitats.

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