

Studies of the Colonization of Marine Benthic Algae at Surtsey in 1968

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Surveys on the marine algal settlement were undertaken on Surtsey in the course of the year 1968, in continuation of observations carried out since 1964 (1, 2, 3, 4). The period of investigation extended from June to November.

As previously, field work was done in the littoral and the sublittoral zone, the latter one being explored by SCUBA-diving techniques. In the intertidal zone, serious problems of access were encountered. The SW, SE and the greater part of the S coasts were quite inaccessible because of high vertical cliffs dropping into the sea. Heavy surf also made it impossible to approach this part of the rocky shore. On the other hand, the old NW coast, built up in 1964–1965, and the comparatively recent NE coast, resulting from the fan-shaped lava flow of 1966–1967, could be explored at low tides. These shores consist mainly of vertical walls bordered at their base by a narrow cover of huge blocks, boulders and, in some places, pillowlava-like outcrops. On the NE coast rock masses were locally surrounded by sand which exercised a severe scouring action on rock surfaces. Field collections in the intertidal zone were principally limited to these coastlines. The remaining part of the shore, i. e. the E coast and both sides of the sand ness, on the northern part of the island, were built up of a moving bench of boulders unsuitable for algal settlement. The outer lagoon, located on the sand ness was filled with sand and the inner one was considerably reduced by sand accumulation.

The bottom along the rocky shores down to about 20 m depth was found to be strewn with

boulders of different sizes surrounded with sand or some coarser material. Diving operations were limited to 12 localities including the submarine volcanos of Syrtlingur and Jólnir. They were made particularly difficult along the S coast and impracticable along the SW coast owing to continuous onshore wind and rough seas. The map, Fig. 1, indicates localities, which could finally be investigated and where samplings were made in the littoral and the sublittoral zones.

Material and data obtained were sorted and analysed partly in the Surtsey Biological Labora-

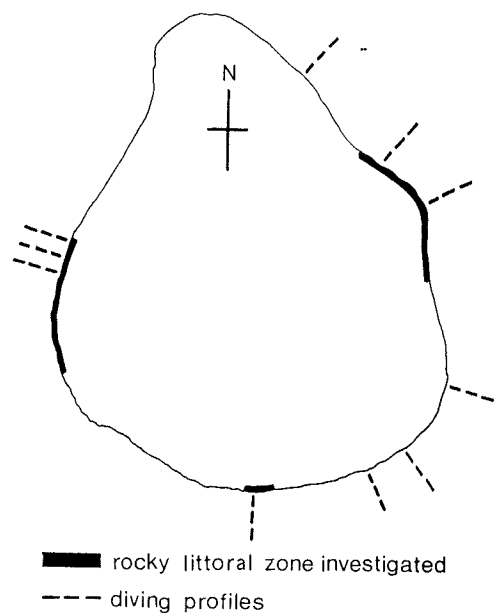


Fig. 1. Surtsey: Localities surveyed in 1968.

tory, Vestmannaeyjar, partly in the Marine Plant Biological Laboratory, Faculty of Sciences, Paris. Preparations of herbarium specimens for later reference were made and are to be preserved in the collections of the Surtsey Biological Laboratory.

1. Components of the marine algal flora, taxonomic notes

Following species were encountered on Surtsey and in surrounding waters during present investigations. With a few exceptions the nomenclature of Parke and Dixon (5) is adopted.

CHLOROPHYCEAE:

Ulothrix flacca (Dillw.) Thur. Fertile plants mixed with *Urospora* or forming pure stands on vertical rocks beneath bird droppings, were found on the NE and NW coasts (26/7, 9/8, 10/8).*

Previously recorded on Surtsey.

Ulothrix pseudoflacca Wille. Fructiferous plants in company with previous species grew on the NE and NW coasts and occasionally as undergrowth of *Petalonia zosterifolia* (26/7, 9/8, 10/8).*

Previously recorded on Surtsey.

Ulothrix consociata Wille. Some tufts, 0.5 cm high, occurred in supralittoral rock pools on the NW coast (10/8). The diameter of the filaments and the presence of one pyrenoid in each cell agree with characteristics given for this species by H. Jónsson (6,p.354). In other respects our specimens resemble *U. subflaccida* Wille.

New record for Surtsey.

Enteromorpha prolifera (O. F. Müller) J. Ag. Rather common on rocks and as epiphyte on *Petalonia fascia* on the NW and NE coasts, about 1.5–2 m above low tide level. Fertile or sterile specimens, 3–7 cm high and 0.5–2 mm broad, are with or without proliferations at the base of the stipe. Small cells, each with one big pyrenoid, are arranged in longitudinal and often in transversal series. The inner wall of the thallus is sometimes provided with trabeculae projecting into the thallus cavity as is the case in *E. prolifera* subsp. *radiata* (Bliding, 7, p. 59). This species was collected from June to November (26/6, 9/8, 10/8, 23/11).

New record for Surtsey.

Enteromorpha linza (L.) J. Ag. Specimens, up to 10 cm high, grew on intertidal rocks in association with *Petalonia* on the NW and NE coasts (9/8, 10/8). They agree with the description of this species given by Bliding (7, p. 127).

Previously recorded on Surtsey.

Enteromorpha compressa (L.) Grev. One tuft, 0.7 cm high, was found, mixed with previous species on the NW coast (10/8). Each cell has one pyrenoid in apical position. In the lower part of thallus small daughter-cells are cut off by oblique walls.

New record for Surtsey.

Monostroma grevillei (Thur.) Wittrock. Three fructiferous, characteristic specimens were collected, one, 1.5 cm high, in the rocky littoral zone on the NW coast (26/6), and two, 5 cm high, off the S and the SE coast, on about 15–19 m depth (31/7, 6/8).

New record for Surtsey.

Urospora penicilliformis (Roth) Areschough. Very common everywhere on rock surfaces about high tide level in early summer, but becoming scanty in August, and being replaced by the sporophytic *Codiolum*-generations in November. This species was abundantly fructiferous.

Previously recorded on Surtsey.

Urospora wormskioldii (Mert.) Rosenv. Our specimens on account of the thickness of the filaments attaining 100 μ , can be referred, although with some hesitation, to this species. They grew on the NW coast mixed with previous species and *U. pseudoflacca* (26/6).

New record for Surtsey.

Acrosiphonia arcta (Dillw.) J. Ag. (= *A. albescens* Kjellm.). Six young and sterile tufts, sometimes provided with hooked branches, were met with in the intertidal zone on the NW and the NE coasts (26/6, 9/8, 10/8), and one tuft was picked up in the sublittoral zone, at about 5–10 m depth, off the NE coast (30/7).

Previously recorded on Surtsey.

PHAEOPHYCEAE:

Ectocarpus confervoides (Roth) Le Jolis. This species, forming 0.5–4.5 cm high tufts, was found to be common on rocks, in tide pools and as epiphyte on *Petalonia*, on the NW coast (26/6, 10/8), on the NE coast (9/8) and at 5–10 m depth off the NE coast (30/7). Only plurilocular zoidocysts were observed. Specimens,

*) Please note that the day is followed by the number of the month. Example: 10/8 is August 10th.

attached to the crampons of *Alaria esculenta* growing in the *Balanus*-zone of the NW coast resemble the var. *siliculosus* (Dillw.) Kjellm. as it has been described by Cardinal (8, p. 10). Previously recorded on Surtsey.

Giffordia hincksiae (Harvey) Hamel. A few characterising specimens bearing plurilocular zoidocysts were found in the *Balanus*-zone on a rock on the NW coast (26/6, 10/8) and at 5–10 m depth off the NE coast (27/7). Previously recorded on Surtsey.

Petalonia fascia (O. F. Müll.) Kuntze. This species was abundant on intertidal rocks on the NW coast (26/6, 10/8), but somewhat rare on the NE coast (9/8). Plurilocular zoidocysts. Previously recorded on Surtsey.

Petalonia zosterifolia (Reinke) Kuntze. Fertile specimens, bearing plurilocular zoidocysts, grew in company with previous species. Previously recorded on Surtsey.

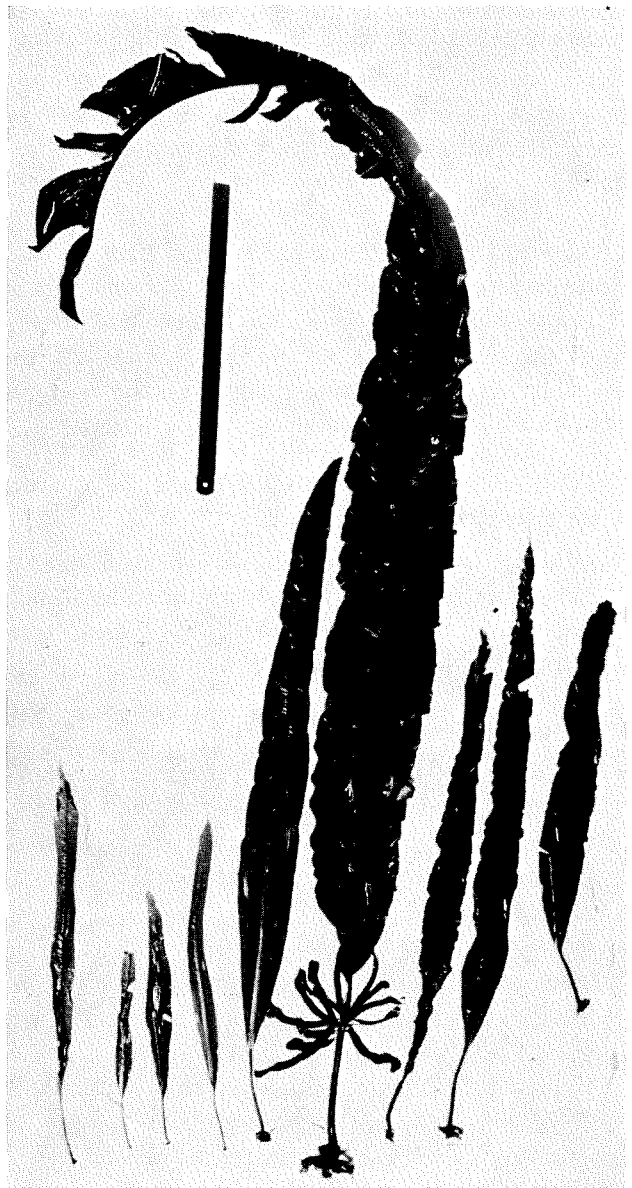
Scytosiphon lomentaria (Lyngbye) Link. A solitary tuft, 3.5 cm high, was collected on the NE coast (9/8). The plant is sterile, without constrictions and paraphyses, but furnished with hairs. Previously recorded on Surtsey.

Desmarestia aculeata (L.) Lamour. Three specimens, 35 cm high, were collected, one very young entirely clothed with hairs, the others somewhat older bearing hairs and/or spinules. These plants were sterile and without epiphytes. They occurred on rocks on 3–5–20 m depth off the NW coast (27/7, 4/8). New record for Surtsey.

Desmarestia viridis (O. F. Müll.) Lamour. Scattered individuals, 30–38 cm high, without hairs, but bearing unilocular zoidocysts, were found growing on 15–20 m depth off the NW (27/7), the S (6/8) and the SE (31/7) coasts. Previously recorded on Surtsey.

Desmarestia ligulata (Lightf.) Lamour. Confined to 13–20 m depth, this species was rather common on rocks off the NE (30/7, 31/7) and the S coast (6/8). Young plants, 7–20 cm high, consisting of a simple thallus were found among adult plants attaining 83 cm high. This growth was sterile. New record for Surtsey.

Laminaria hyperborea (Gunn.) Fosl. Two sterile specimens, one 28 cm, the other 58 cm high, were collected on the rocky bottom on about



Phot. 1 Growth variations in the *Alaria esculenta*-population of Surtsey in August 1968. Scale: 20 cm.

15 m depth off the NW (27/7) and the NE (30/7) coasts. One of the specimens has a lamina covered with hydrozoa. New record for Surtsey.

Alaria esculenta (L.) Grev. This species grew socially everywhere on rocky surfaces in the sublittoral zone at 18–19 m depth, and occasionally in the lower part of the littoral zone on the NW coast. Individual growth in the *Alaria*-populations was found to be very variable (Phot.1). Mature plants, reaching a length of 1.60 m bore fertile sporophylls. Colonies of hydrozoa and mussels were sometimes attached to these algae. Previously recorded on Surtsey.

RHODOPHYCEAE:

Phorphyra umbilicalis (L.) J. Ag. Fertile individuals were common, but not abundant, on the NW (26/6, 10/8) and the NE coasts (9/8). Previously recorded on Surtsey.

Porphyra purpurea (Roth) C. Ag. A solitary plant, 13 cm long and 3 cm broad, was collected on the landward side of a rock in the *Balanus*-zone on the NW coast (10/8). This specimen, attached to the substrate by a short basal holdfast, is in agreement with descriptions given for this species by Conway (9). However, it proved to be sterile.

New record for Surtsey (and Iceland).

Porphyra miniata (C. Ag.) C. Ag. Five characteristic specimens, reaching 25 cm length and 13 cm breadth, were found at 13 m depth of the NE coast (30/7) and the SE coast (31/7). Some of them were fructiferous.

New record for Surtsey.

Lomentaria orcadensis (Harv.) Coll. ex Taylor (= *L. rosea*). A unique specimen, 4 cm high, containing numerous tetrasporangia in the pinnae, were found growing on a rock at 19 m depth off the S coast (6/8).

New record for Surtsey.

Antithamnion floccosum (O. F. Müll.) Kleen.

Ten tufts of sterile plants, attaining 4.5 cm high, were collected at 5–15 m depth off the NE (30/7) and the NW coasts (4/8) in association with mussels, hydrozoa and *Fragilaria*-diatoms. They also occurred in the *Balanus*-zone, on the lee side of a rock on the NW coast (10/8). Principal filaments are 65–80–100 μ thick, the cell length being 160–300 μ . Our specimens agree fairly well with illustrations given for this species by Zinova (10, Fig. 135) and Jaasund (11, Fig. 37).

New record for Surtsey.

Phycodrys rubens (L.) Batt. Five typical, but sterile specimens, about 8 cm high, were gathered at 13–20 m depth off the NE coast (30/7). Some of them were covered with various species of bryozoa.

New record for Surtsey.

Polysiphonia urceolata (Lightf. ex Dillw.) Grev.

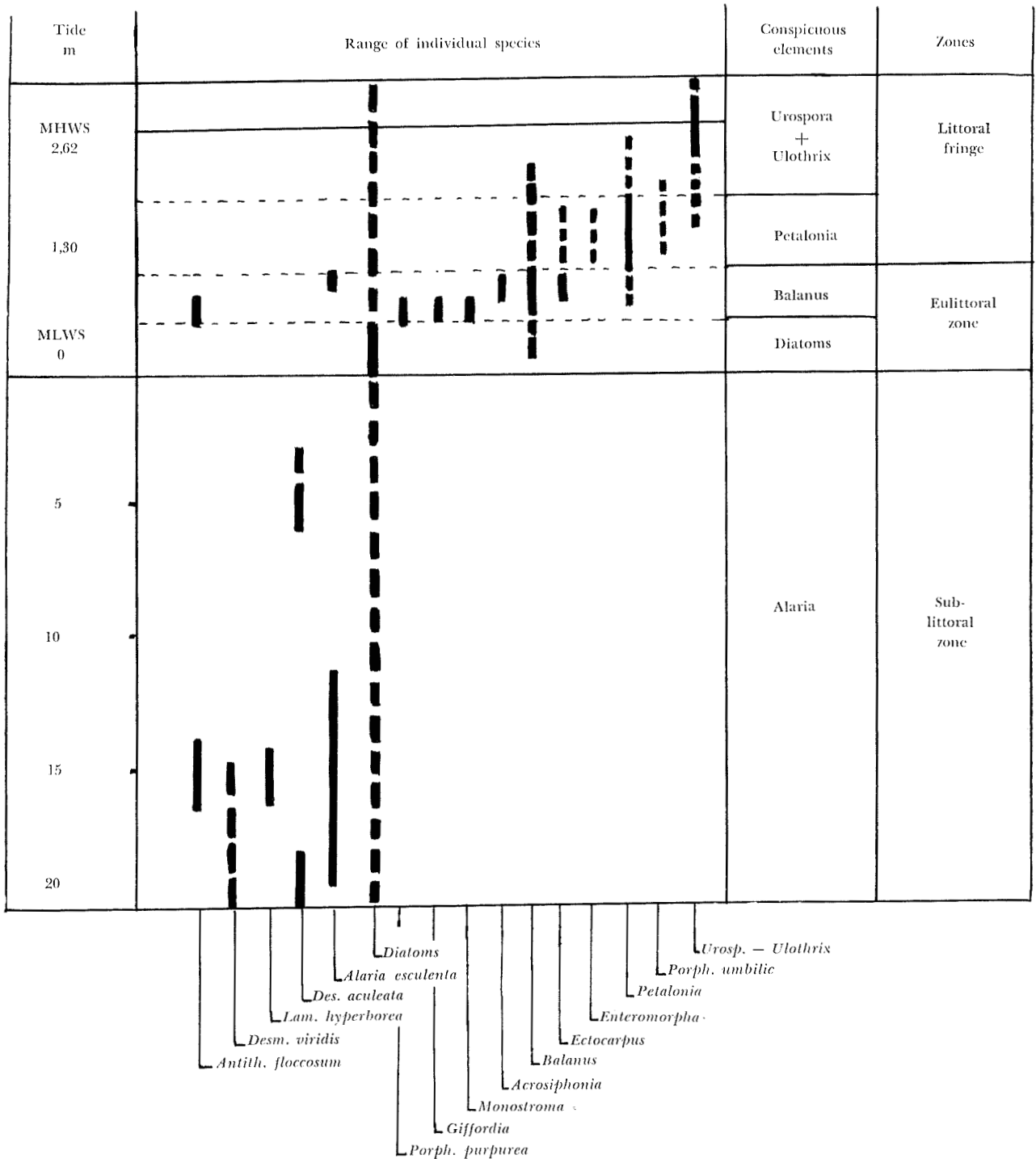
Seven tufts of plants, 5–7 cm high, were found on 5–10 m depth off the NE coast (30/7), sometimes attached to mussel byssus. Some of them are tetrasporiferous, others are bearing urn-shaped cystocarps. *Licmophora*-diatoms were found as epiphytes.

New record for Surtsey.



Phot. 2. An aspect of the *Alaria esculenta*-population growing on rock at about 20 m depth off the S coast (23/6, 1968). Note a dense cover of diatoms (and hydrozoa?) between the *Alaria*-plants. Photogr. Dr Thorbjörn Alexandersson.

TABLE I
VERTICAL DISTRIBUTION OF SPECIES ON AND OFF THE NW COAST



It appears from the above that 27 algal species were recorded in the coastal waters of Surtsey in 1968. To this must be added benthic diatom-species, the most common of which were the filamentous forms of *Navicula* (*Schizonema*) *mollis* (W. Sm) Cl. and *Navicula ramosissima* (Ag.) Cl. previously found on Surtsey.

2. General features of the marine algal vegetation

The distributional range of individual species and the dominating elements of the vegetation are diagrammatically represented in Tables I, II, III. Tidal data, not yet available for Surtsey, is that known for Heimaey, situated about 10 nautical miles from Surtsey.

TABLE II
VERTICAL DISTRIBUTION OF SPECIES ON AND OFF THE NE COAST

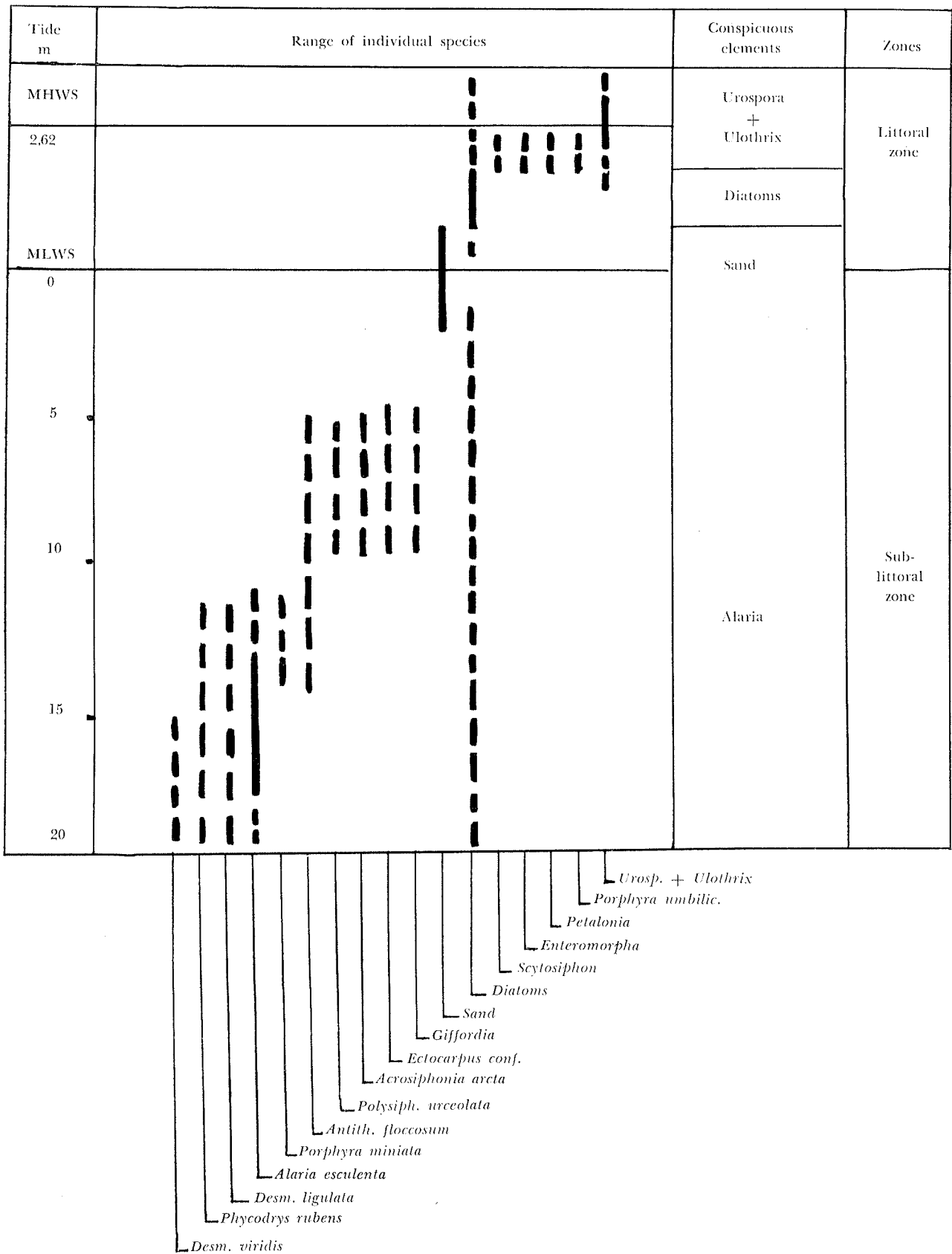
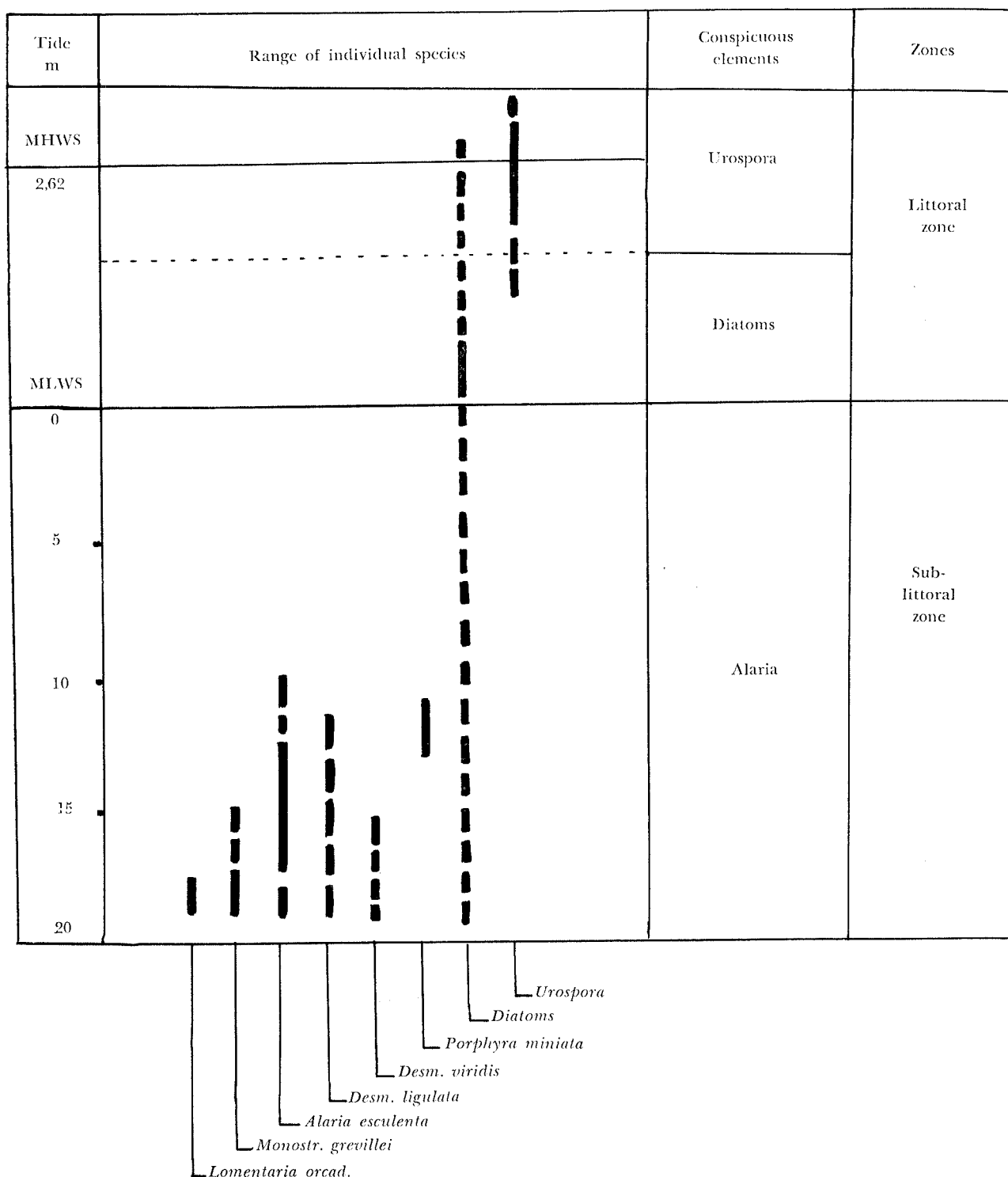


TABLE III
VERTICAL DISTRIBUTION OF SPECIES ON AND OFF THE S AND SE COASTS



It can be seen that only a small number of species played a significant role in the general aspect of the marine vegetation.

In the littoral zone, *Urospora penicilliformis*, often associated with *Ulothrix-species*, was found everywhere, at least in the beginning of the sur-

vey, towards the high tide level of the shore forming a conspicuous belt variable in width according to the inclination of the substrate. On the NW coast luxuriant *Petalonia*-populations occurred below the *Urospora*-belt, especially during midsummer, when *Urospora* was declining. *En-*

teromorpha-species, *Ectocarpus confervoides* and *Porphyra umbilicalis* were mainly bound to the same level as *Petalonia*, representing the subsidiary growth of the *Petalonia*-belt. In a selected locality of the NW coast, on the sheltered side of a rock, near the northern point of the lava front, barnacles reached their maximal development immediately below the *Petalonia*-belt, their upper limit in quantity being at about 1.30 m above low water mark. Scattered individuals of *Antithamnion floccosum*, *Porphyra purpurea*, *Alaria esculenta* and *Giffordia hincksiae* grew in this part of the intertidal zone. In other places barnacles were scanty and randomly distributed. The lowest part of the littoral zone supported pure stands of filamentous diatoms. Were *Petalonia* and barnacles were poorly represented, as was the case on the NE and S coast, the diatom growth constituted an independent belt immediately below the *Urospora*-belt. On the southern part of the NW coast pillowlava-like rock masses, occupying the greater part of the littoral zone, proved to be entirely covered with diatoms. Isolated patches of diatoms and *Urospora* could also be observed on rocks of the boulders bench shores, which, because of their mobility, were otherwise devoid of algae. No vegetation at all was found growing on the sand beach on the north part of the island. This applies also to tide pools, frequently occupied by rolling stones.

In the sublittoral zone, *Alaria esculenta* represented the salient feature of the vegetation growing luxuriantly on rock surfaces at a depth range varying from 3 to 19 meters (Phot. 2). Its average degree of covering was estimated at about 80 individuals per m², at 12 m depth. Generally rock surfaces between *Alaria* plants were inhabited by filamentous diatoms, hydrozoa, tube worms or other animals. However, on the S coast, at 19 m depth, *Alaria* was found on a rock occupied at the same time by *Desmarestia ligulata*, *Desmarestia viridis*, *Lomentaria orcadensis* and *Monostroma grevillei*. In localities where stones were more or less buried in sand, only diatoms occurred on rock surfaces. This was observed out from the boulder bench shore off the E coast and the NNE coast as well as on the submarine craters of Jólnir and Syrtlingur, at about 28 m depth. A special aspect of the deep-water vegetation was offered by scattered populations of red algae (*Porphyra miniata*, *Antithamnion floccosum*, *Phycodryx rubens* and *Polysiphonia urceolata*). As with *Alaria*, this growth was confined to rocks, except for *Polysiphonia*, also found growing in company with mussels. This growth was mainly

located off the NE coast. Species such as *Desmarestia ligulata*, *Desmarestia viridis* and *Ectocarpus confervoides* were also quite frequent in these waters. The remaining components of the submarine vegetation, *Laminaria hyperborea*, *Desmarestia aculeata* and *Giffordia hincksiae* played a rather subordinated role, being represented by isolated individuals.

The lower limit of the algal growth, diatoms growth not included, appeared approximately to coincide with the 20 m depth-line.

3. Remarks on the marine algal colonization

Algal species invading the marine environment of Surtsey since the beginning of the settlement as well as their order of arrival are listed below:

| Species (diatoms not included) | 1964 | 1965 | 1966 | 1967 | 1968 |
|-----------------------------------|------|------|------|------|------|
| <i>Urosp. penicillif.</i> | | — | — | — | — |
| <i>Uloth. flacca</i> | | | — | — | — |
| <i>Uloth. pseudofl.</i> | | | — | — | — |
| <i>Ent. flexuosa</i> | | | — | | |
| <i>Ent. intestinalis</i> | | | — | | |
| <i>Pyl. littoralis</i> | | | — | | |
| <i>Ectoc. confervoid.</i> | | | — | — | — |
| <i>Scyto. lomentaria</i> | | | — | — | — |
| <i>Pet. fascia</i> | | | — | — | — |
| <i>Pet. zosterifolia</i> | | | — | — | — |
| <i>Alaria esculenta</i> | | | — | — | — |
| <i>Porph. umbilicalis</i> | | | — | — | — |
| <i>Ent. linza</i> | | | | — | — |
| <i>Ent. compressa</i> | | | | — | — |
| <i>Acrosiph. arcta</i> | | | | — | — |
| <i>Giff. hincksiae</i> | | | | — | — |
| <i>Desm. viridis</i> | | | | — | — |
| <i>Uloth. consoc.</i> | | | | | — |
| <i>Urosp. wormsk.</i> | | | | | — |
| <i>Ent. prolifera</i> | | | | | — |
| <i>Monostr. grev.</i> | | | | | — |
| <i>Lam. hyperborea</i> | | | | | — |
| <i>Desm. ligulata</i> | | | | | — |
| <i>Desm. aculeata</i> | | | | | — |
| <i>Porph. purpurea</i> | | | | | — |
| <i>Porph. miniata</i> | | | | | — |
| <i>Lom. orcadensis</i> | | | | | — |
| <i>Antith. floccosum</i> | | | | | — |
| <i>Phycodryx rubens</i> | | | | | — |
| <i>Polysiph. urceolata</i> | | | | | — |
| TOTAL | 0 | 1 | 12 | 14 | 27 |

It appears that 30 species of benthic algae, diatoms not included, have been identified on Surtsey so far. Of these only 3 species seem to have disappeared, at least temporarily, as they have not been found again since 1966. It can also be noted that the number of colonizing species has been steadily increasing since 1965, when the first macroscopic element settled on the island. During the period of 1967 to 1968, 13 new invaders were discovered. A striking fact is that species found in 1967 were all rediscovered in 1968. This suggests that these species have maintained themselves on Surtsey during this period. However, it must be remembered that most of these species are annual forms which might be of casual occurrence in Surtsey. Moreover, neocolonization of certain species is not to be excluded. Presumably, this is the case with *Scytosiphon lomentaria*, initially found on the NW coast and then rediscovered only on the NE coast.

Among the 13 new colonizers observed in 1968 10 are subtidal species, which settled in the sublittoral zone. At present the submarine colonization is therefore progressing faster than the littoral colonization which appears to be more or less stabilized. However, this does not mean that the algal settlement in the littoral zone has reached its final stage. The shifting from littoral to sublittoral settlement might rather indicate temporarily changes in the sequences of the algal colonization.

An important event in the history of the benthic settlement of the littoral zone of Surtsey is represented by the occurrence of a barnacles zone in a single locality of the NW coast. In taking barnacles as biological indicator, according to the definition of Lewis (12), we can now subdivide the littoral zone into an eulittoral zone, extending from the upper limit of the *Alaria*-growth to the upper limit of barnacles in quantity, and a littoral fringe above, extending from the barnacles zone and upwards. This may be regarded as an early zonation of the coast. It can be noted that the *Urospora*-belt and the *Petalonia*-belt are at present mainly confined to the littoral fringe, while diatoms are dominating in the eulittoral zone. However, it should be noted that both zones are actually not clearly defined, as many benthic organisms characterizing them are lacking. Thus, littorinids, marine lichens and myxophyceae have not been found to occur in the littoral fringe.

As other algal species previously settled in Surtsey, the new colonizers all occur in the Vestmannaeyjar-archipelago, except for the single

specimen of *Porphyra purpurea*, which has not been recorded in Icelandic waters before. Other species have been met with during our studies concurrently carried out on the marine flora of the area, with the exception of *Antithamnion floccosum*, recorded by H. Jónsson (13). This reinforces the presumption that the marine flora of Surtsey will not differ from adjacent floral areas.

It was assumed (4), on the basis of life-cycles generally exhibited by *Alaria esculenta* and *Desmarestia viridis*, that these species grew up from eggs which settled on the slopes of the island. As the *Desmarestia*-species, now found on Surtsey, as well as *Laminaria hyperborea* are known to have similar life-cycles, it is possible that the same applies to them. Sexual reproduction and egg formation seem to take place in these species during the wintermonths. It therefore appears that this growth was not more than 4–7 months old. This gives some idea about the growth rate of the species involved. Thus, *Desmarestia ligulata* and *Desmarestia aculeata*, being represented by adult plants, measuring respectively 83 and 85 cm, seem to be capable of a rapid growth, whereas *Laminaria hyperborea*, represented only by small plants, grows somewhat more slowly. As to *Alaria esculenta*, settled in 1967 and now represented for the first time by adult sporophyll-bearing plants, its complete development seems to be brought about in one year. Young immature individuals of this species occurring among the adult plants might be either the second generation or neo-colonizers. The growth rate of the recently invading red algae is seemingly very rapid, as all of them represent full grown individuals, frequently provided with reproductive organs.

A special mention must be devoted to the occurrence on Surtsey of *Monostroma grevillei*, *Acrosiphonia arcta* and *Patalonia fascia*. The first two mentioned species normally have an heteromorphic alternation of generations between morphologically differentiated gametophytes and monocellular sporophytes (14, 15). The sporophytes of *Monostroma* are known to inhabit mollusc tests, as those of *Acrosiphonia* live as endophytes in the crust of some red algae, especially *Petrocelis hennedyi*, found to occur in the area, but not on Surtsey. As neither of these sporophytes have been met with in Surtsey, the question is raised as to how these species maintain themselves. In absence of culture experiments, it may be assumed that the gametophytes are capable of independent reproduction: *Monostroma*

by direct development of gametes and *Acrosiphonia* by pseudozygotes, as has been shown to be the case for some populations in European waters (16). As to *Petalonia fascia*, it is believed (17) to have a *Ralfsia*-stage in its life history. This stage has not been found on Surtsey, so far, suggesting that the species might achieve its life-cycle in some other way.

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