ACTA BOT. ISL. 11: 17-88, 1992.

Hornstrandir — a Conspicuous Area of Vegetation-Shift in the Extreme Northwest of Iceland

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ABSTRACT: Water masses of different origins and hydrographic characteristics, which surround the Icelandic coast, have created a great variety of vegetation patterns. They are first of all characterised by low- eulittoral associations, which appear in the intermediate zone between fucoids and Laminarians, and secondly by tide pool associations. Distributional boundaries between these vegetation types are likely to be temperature-conditioned. The most pronounced area of vegetation-shift is around Hornbjarg, in the extreme northwest of Iceland, where a hydrographic discontinuity occurs. The benthic algal vegetation of the Hornstrandir coast viz. the open area south of Hornbjarg and outside the Húnaflói Bay is described in detail. Around Hornbjarg a sharp distributional boundary for typical Atlantic-water associations was found (of *Mastocarpus stellatus*, *Corallina officinalis* and *Callithamnion sepositum*) while the typical North Icelandic vegetation pattern is created gradually along the Hornstrandir coast (low-level associations of *Devaleraea ramentacea*, *Acrosiphonia* spp. and *Chordaria flagelliformis*). Enclaves of Atlantic vegetation features regarding tide pool associations were found farther south along Hornstrandir, in the sheltered areas of Ófeigsfjörður and Trékyllisvík.

Key words: Icelandic algal vegetation, zonations patterns, associations, hydrographic influences, vegetation changes, Hornstrandir from Hornbjarg to Reykjarfjörður

INTRODUCTION

The heterogenity of the Icelandic benthic algal vegetation has been of interest for many years (e.g. STRÖMFELT 1886, JÓNSSON 1910, 1912, ADEY 1968, MUNDA 1972a, 1972b, 1975, 1976a, 1976b, 1977a, 1978, 1980a, 1980b, 1981a, 1983, 1985, 1987).

Iceland has a central position in the North Atlantic on the Mid-Atlantic Ridge. Other submarine ridges devide the North Atlantic into basins and are decisive for the direction of the main ocean currents (the Reykjanes Ridge, Iceland-Greenland Ridge, Wyville-Thompson Ridge). Different currents surround the Icelandic coast. Warm, saline Atlantic water is conveyed along the

southern coast and farther northwestwards. Cold, low-salinity water streams southwards along the east Icelandic coast, conveyed by the East Icelandic Current. The north Icelandic shelf is a mixing area of different cold and warm as well as primary and secondary water masses (STEFÁNSSON 1962). These varying hydrographic conditions create widely different habitats and vegetation patterns around Iceland (MUNDA 1972a, 1975).

In the extreme northwest of Iceland, around Hornbjarg, a floristic and vegetation limit for benthic algae was found, reflecting the profound hydrographic changes in this particular area. These changes are mainly due to the diminished influx of Atlantic water off Hornbjarg with a simultaneous influence of drift ice and cold water masses from the East Greenland Current.

Entirely different zonation patterns and low-eulittoral algal associations were found around Hornbjarg and farther southwards along the Hornstrandir coast, if compared with the vegetation of the western side of the NW peninsula (e.g. Dýrafjörður, MUNDA 1978). Hence this area deserved special attention in a survey of the benthic algal vegetation of Iceland as a whole.

There are no previous algological data for this part of the Icelandic coast. Investigations were limited to July and August of the years 1964, 1972, 1973 and 1980. The Hornstrandir coast is unpopulated from Hornbjarg to Ófeigsfjörður. The first permanent human settlements are found in Ingólfsfjörður and in Trékyllisvík.

Field studies were carried out below Hornbjarg, in Látravík, several localities below the mountain of Axarfjall and in the bays of Hrolleifsvík, Smiðjuvík, Barðsvík and Bolungavík, ending in Furufjörður. These bays are situated between high mountains, which slope steeply into the sea. This part of the Hornstrandir coast is hence mostly inacessible and the landscape is wild and spectacular. Farther south from Bjarnarfjörður N over Drangar, Eyvindarfjörður, Ófeigsfjörður and Trékyllisvík, the coastal slopes are moderate and allow rather continuous algological observations. The southernmost point observed along Hornstrandir was in Reykjarfjörður.

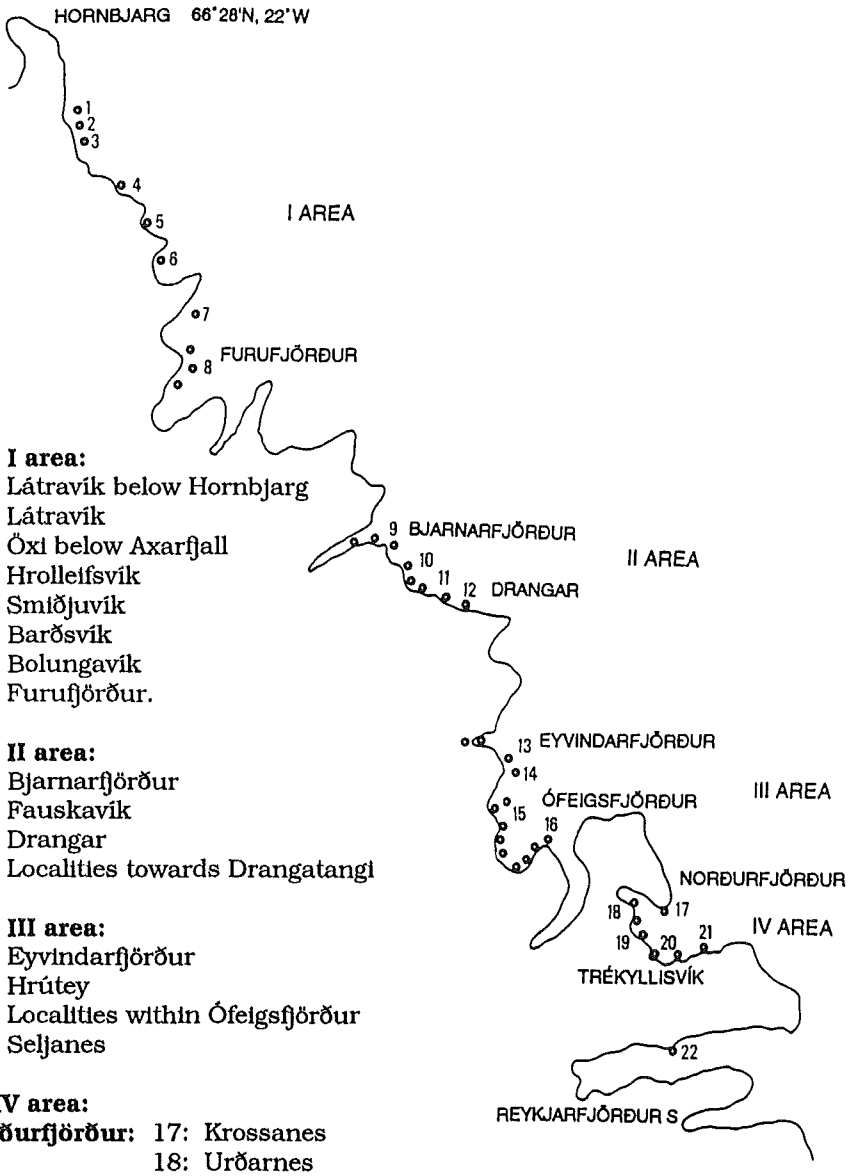
The aim of this study was to describe the benthic algal vegetation of a hydrographically discontinuous area and to follow the gradual formation of a typical north Icelandic vegetation along Hornstrandir. An abrupt vegetation-shift was, however, found in the vicinity of Hornbjarg, in the extreme Northwest.

INVESTIGATED AREA

Hornstrandir was investigated along the open coast-line outside the Bay of Húnaflói during several subsequent years. Four separate areas were studied here, differing in the configuration of the coastal habitats and vegetation patterns (see map, Fig. 1).

The first area extends from Hornbjarg to Furufjörður (Fig. 2). The Icelandic "Cap Nord" (Horn) extends 66°28'N as the northernmost point of western Iceland. The high and steep mountain of Hornbjarg (534 m) slopes almost vertically into the sea (Fig. 3).

Here the coast was accessible only from the sea by boat. There are high waterfalls in this area, which create enclaves of estuarine habitats on the steep rocky walls (Figs. 4, 5). The coast was accessible from the land in



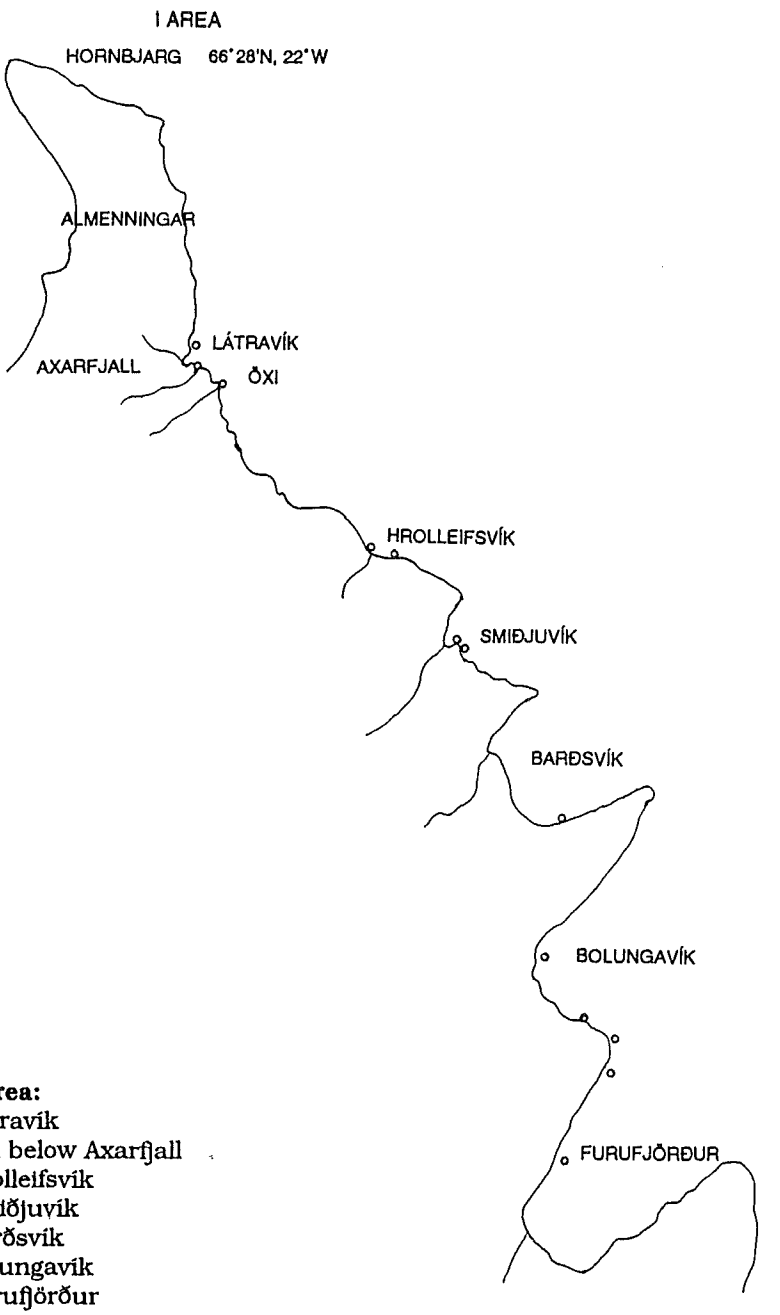
I area:
1: Látravík below Hornbjarg
2: Látravík
3: Öxl below Axarfjall
4: Hrolleifsvík
5: Smiðjuvík
6: Barðsvík
7: Bolungavík
8: Furufjörður.

II area:
9: Bjarnarfjörður
10: Fauskavík
11: Drangar
12: Localities towards Drangatangi

III area:
13: Eyvindarfjörður
14: Hrútey
15: Localities within Ófeigsfjörður
16: Seljanes

IV area:
Norðurfjörður: 17: Krossanes
18: Urðarnes
Trékyllisvík: 19: Árnesstapar
20: Vicinity of Árnesá
21: Oddi and Skarðsvík
Reykjarfjörður: 22: Naustavíkurhöfði

FIGURE 1. Map of Hornstrandir from Hornbjarg to Trékyllisvík (Drawn after map 1:250000)



I area:
Látravík
Öxi below Axarfjall
Hrolleifsvík
Smiðjuvík
Barðsvík
Bolungavík
Furufjörður

FIGURE 2. I area from Hornbjarg to Furufjörður (Drawn after map 1:50000)

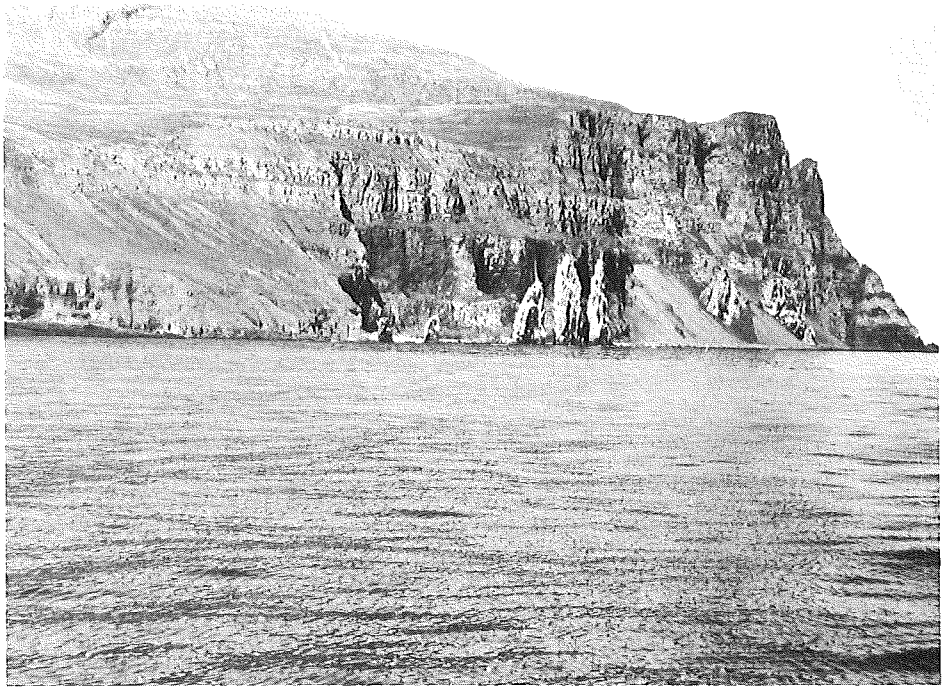


FIGURE 3. Hornbjarg.

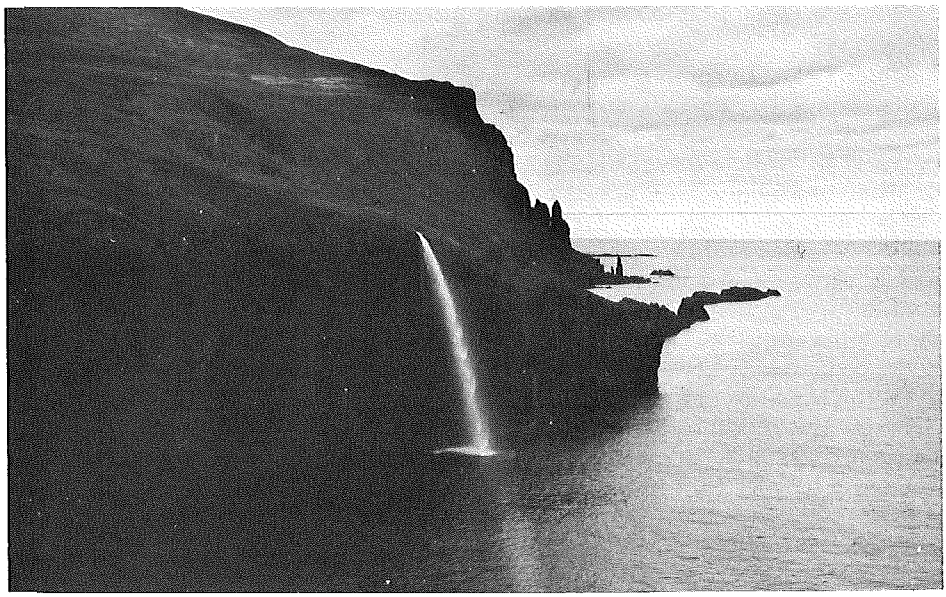


FIGURE 4. Waterfall below Hornbjarg.

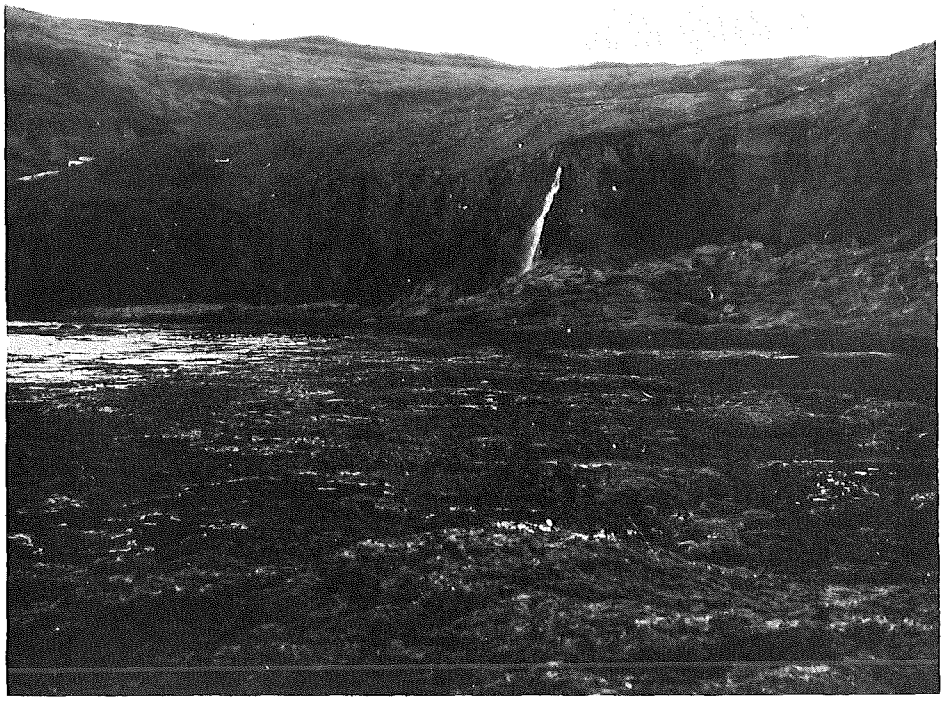


FIGURE 5. Waterfall in Látravík, horizontal rocky slopes eulittorally.

Látravík below Hornbjarg and around the rocky formations at Öxl below Axarfjall. Below the steep mountain walls follow almost horizontal rocky platforms, interrupted by numerous tide pools and lagoons (Fig. 6). From the edges of the wide eulittoral rocky surfaces, the coast slopes steeply to greater depths. Nearshore there are extenses covered by gravel and pebbles. Around Öxl a variegated shore configuration was observed with basaltic outcrops of various shapes and heights, which surround open basins (Fig. 7). There are widely different growth conditions within such basins and on the exposed seaward sides of the fringing rocks. Farther south, below Almenningar, steep mountains slope into the sea. Rocky outcrops perpendicular to the mainland make this area inaccessible. The mountains of Tertiary floodbasalts range up to 657 m over the sea. Field studies were only possible in the bays and fjords between the mountains, such as Hrolleifsvík (Fig. 8), Smiðjuvík, Barðsvík, Bolungavík and Furufjörður. In these bays and fjords glacial drift is followed seawards by Alluvial sand. In Barðsvík there are also nearshore aeolian deposits. Rocky slopes between Bolungavík and Furufjörður were accessible from the land. In these fjords (Fig. 9) there are moderate rocky slopes and boulders in the outer fjord area, followed by Alluvial deposits in the inner area. Glacial rivers originating from Drangajökull carry gravel and sand to the inner area of the Furufjörður.

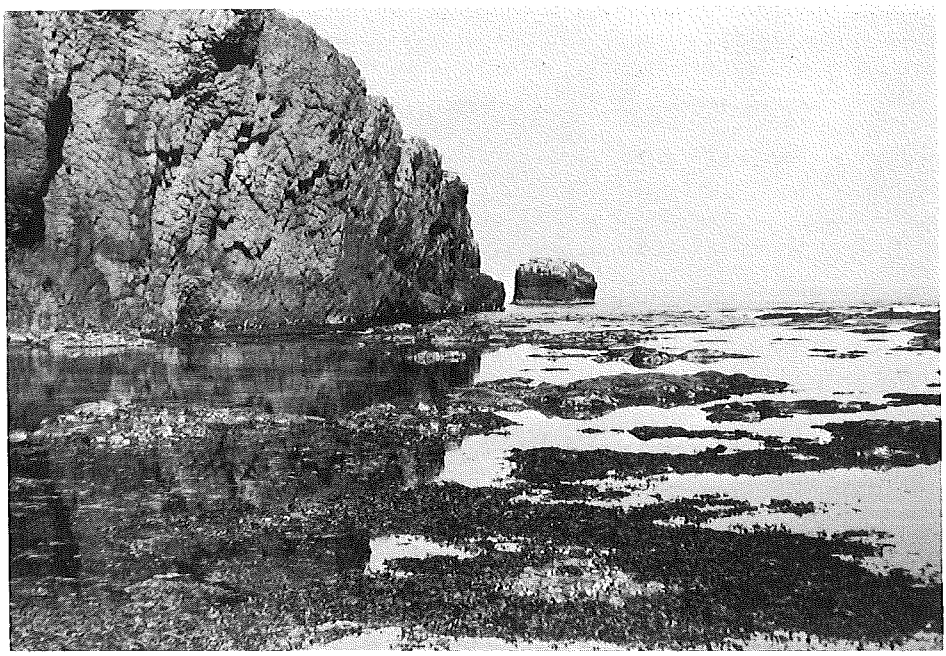


FIGURE 6. Horizontal rocky slopes with lagoons below Hornbjarg.

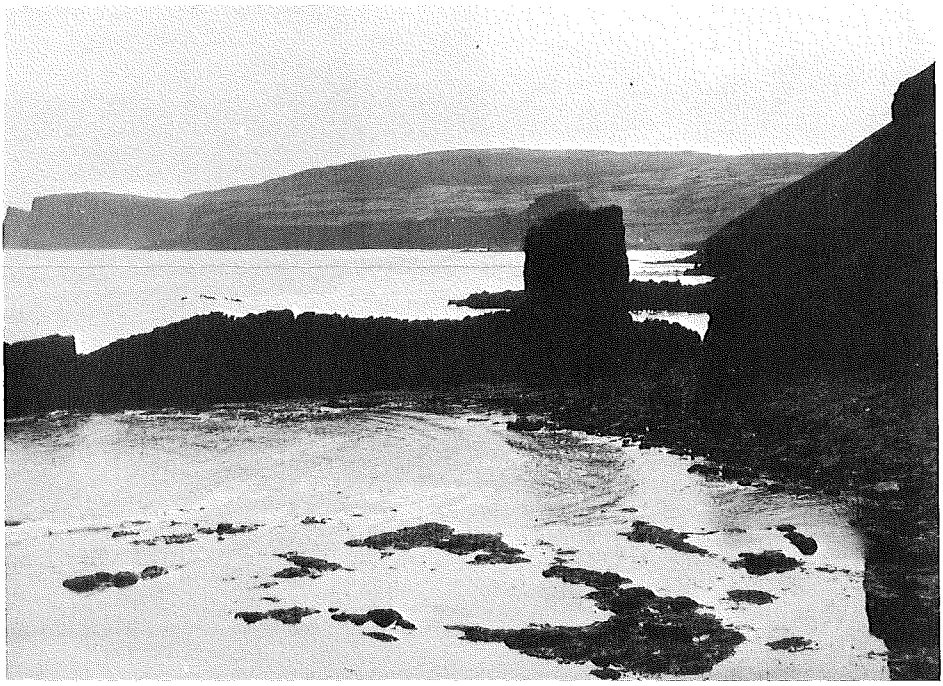
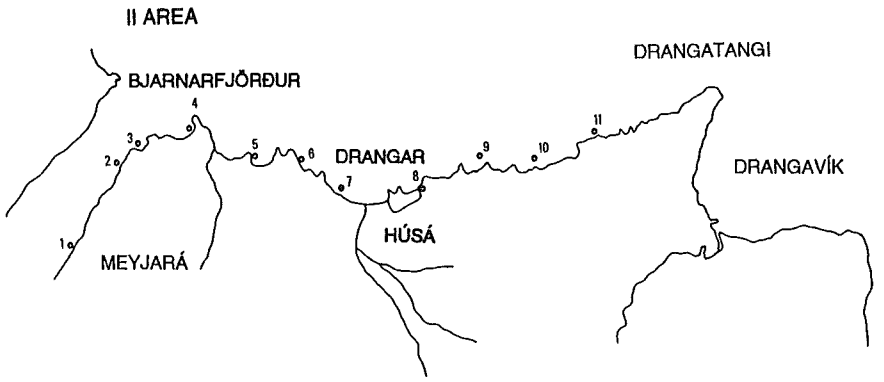


FIGURE 7. Öxl below Axarfjall.

FIGURE 8. Hrolleifsvík.

FIGURE 9. Furufjörður.



II area:

1-2:	Localities inside Bjarnarfjörður	6:	Vatnshöfði
3:	Drangakleifar	7:	Bæjarvík
4:	Meyjarnes	8:	Drangar
5:	Fauskavík	9-11:	Localities towards Drangatangi

FIGURE 10. II area from Bjarnarfjörður to Drangar (Drawn after map 1:50000)

FIGURE 11. Bjarnarfjörður.

FIGURE 12. Drangar.

III area. Eyvindarfjörður and Ófeigsfjörður:

1: Estuary of Eyvindarfjarðará
2: Álftabúðarhöfði
3-4: Básar
5: Hrúteyjarnes
6: Hrútey
7: Borg
8: Höfði
9: Strandatún
10: Hvalá
11: Melgraseyri
12: Öxl
13: Sandvík
14: Ófræðavík
15: Stapar near Húsá
16: Head of the Ófeigsfjörður
17: Sýrá
18: Hamrar
19: Helgaskjól
20: Seljanes

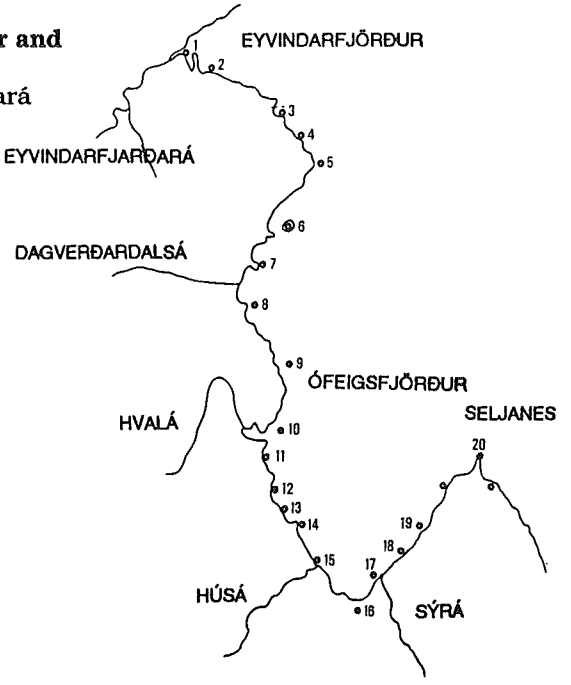


FIGURE 13. III area: Eyvindarfjörður and Ófeigsfjörður (Drawn after map, 1:50000).

Field studies proceeded in the second area (Fig. 10) between Bjarnarfjörður N and Drangavík. Bjarnarfjörður is a narrow fjord surrounded by high mountains (Fig. 11). In its outer area there are steep rocky formations followed by platforms and extenses covered by gravel and pebbles. Localitities called Drangakleifar and Meyjarnes were observed in this fjord. Farther southwards over Drangar to Drangatangi and Drangavík (Fig. 12) the rocky headland slopes gently and is easily accessible. The area between Bjarnarfjörður and Drangavík was transgressed by sea after the last glaciation. Along this coast-line estuaries of the rivers Meyjará and Húsá were investigated along with several rocky sites towards Drangatangi, such as Fauskavík, Vatnshöfði, Bæjarvík at Drangar, the island of Landeyjar and some spots along the rocky coast farther eastwards.

The third area investigated extends from Eyvindarfjörður over Ófeigsfjörður to Seljanes outside Ingólfsfjörður (Fig. 13). It was likewise transgressed by sea after the last glaciation. Most coastal sites are easily accessible. Nearshore the headland slopes gently with bogs and meadows as well as moderate rocky slopes. Contrary to the narrow Bjarnarfjörður, both Eyvindarfjörður and Ófeigsfjörður are open and rather exposed. In the first fjord the estuary of the river Eyvindarfjarðará, which is covered by fine-grained sand was observed, along with rocky sites of Álftabúðarhöfði and Básar farther out. Field studies continued around the peninsula of Hrúteyjarnes, the island of Hrútey and the flat rocky formations at Borg, Höfði and Strandatún. There are coastal shallows and extensive lagoons in this particular area.

Ófeigsfjörður extends from the estuary of the big river Hvalá to Seljanes. Rocky sites around Melgraseyri were observed south of the estuary. Around Öxl there are basaltic rocks which surround a land-locked lagoon. This lagoon, isolated from the surrounding sea, offers particular growth conditions. Even farther south, between Sandvík and Ófræðavík sandy and rocky slopes alternate. Next site studied within this fjord was at Stapar near the outlet of the Húsá river. Extensive and shallow tide pools are characteristic for this area. The head of the fjord is sandy. Along the peninsula which devides Ófeigsfjörður from Ingólfsfjörður the estuary of the river Sýrá was observed as well as rocky sites at Hamrar, Helgaskjól and Seljanes. Seljanes is, however, a heavily exposed promontory. There are gently sloping rocky surfaces with tide pools and lagoons and some partly land-locked basins, surrounded by basaltic outcrops. Around Hamrar and Helgaskjól the coastal rocks are steep and are interrupted by small sandy inlets.

The fourth area investigated (Fig. 14) is ecologically different and relatively protected. It includes Norðurfjörður and Trékyllisvík, which are both surrounded by high mountains (Fig. 15). In Norðurfjörður observations were carried out at Krossnes and Urðarnes. In Trékyllisvík the area around Melar and Árnesstapar was studied. In the last named locality there are basaltic stacks, perpendicular to the coast (Figs. 16, 17) which provide a great variety of biotopes. They are surrounded by deep lagoons. Farther along the coast, the estuary of the river Árnesá (Fig. 18) was observed. Attention was paid to the gradual formations of an estuarine vegetation in the mixing area between freshwater and the sea. Sandy slopes around the estuary are followed farther out by wide rocky platforms (Fig. 19), which are interrupted by tide pools and

IV area. Norðurfjörður and Trékyllisvík:

1: Krossnes
2: Urðarnes
3: Melar
4: Hvalvík
5: Árnesstapar
6: Selsker
7: Krókur
8: Estuary of Árnesá
9: Oddi
10: Skarðsvík
11: Árnesey

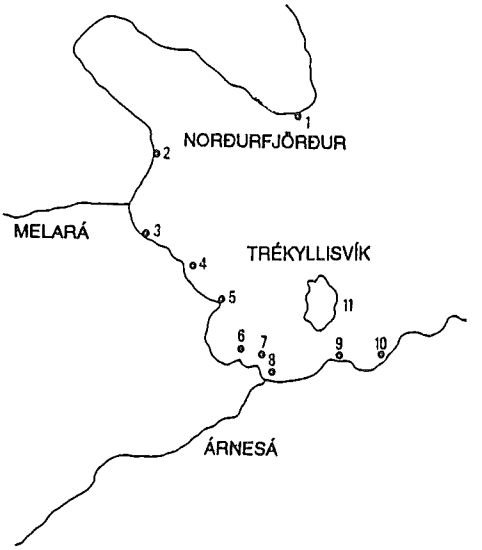


FIGURE 14. IV area: Norðurfjörður and Trékyllisvík (Drawn after map, 1:50000).

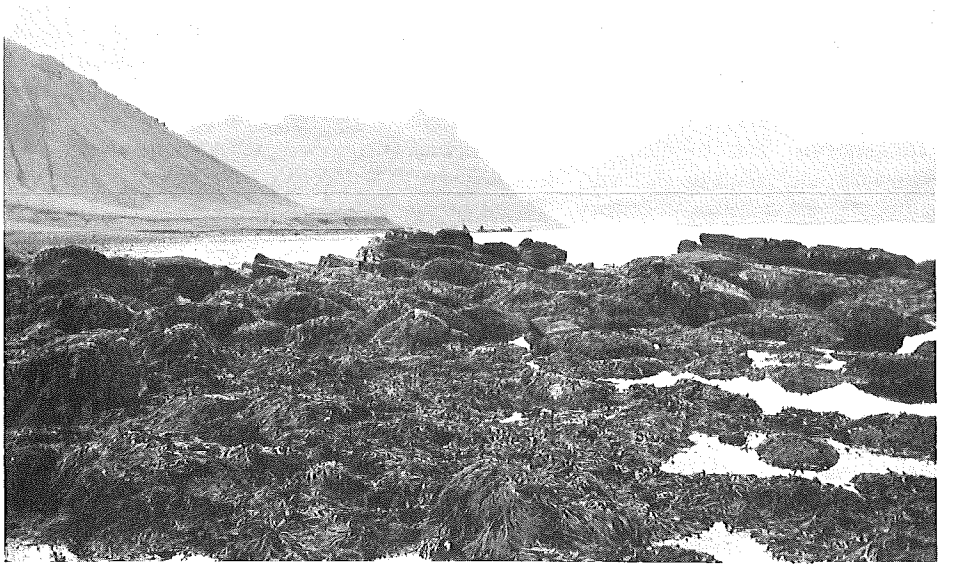


FIGURE 15. Trékyllisvík.

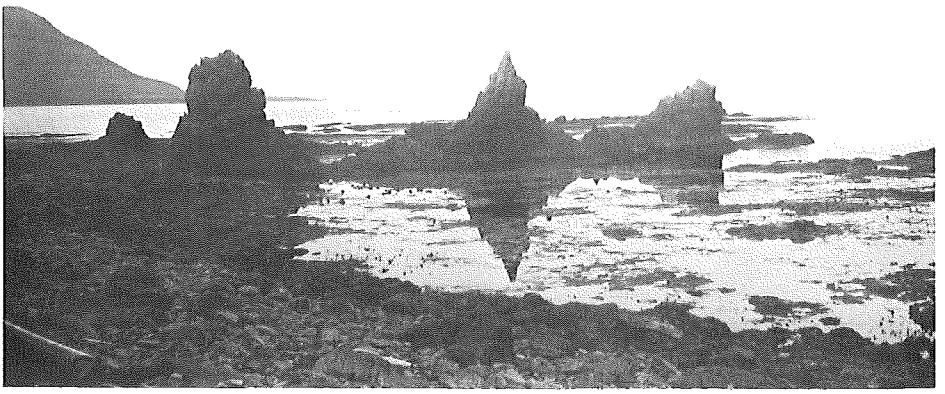


FIGURE 16. Árnesstapar in Trékyllisvík with lagoons.

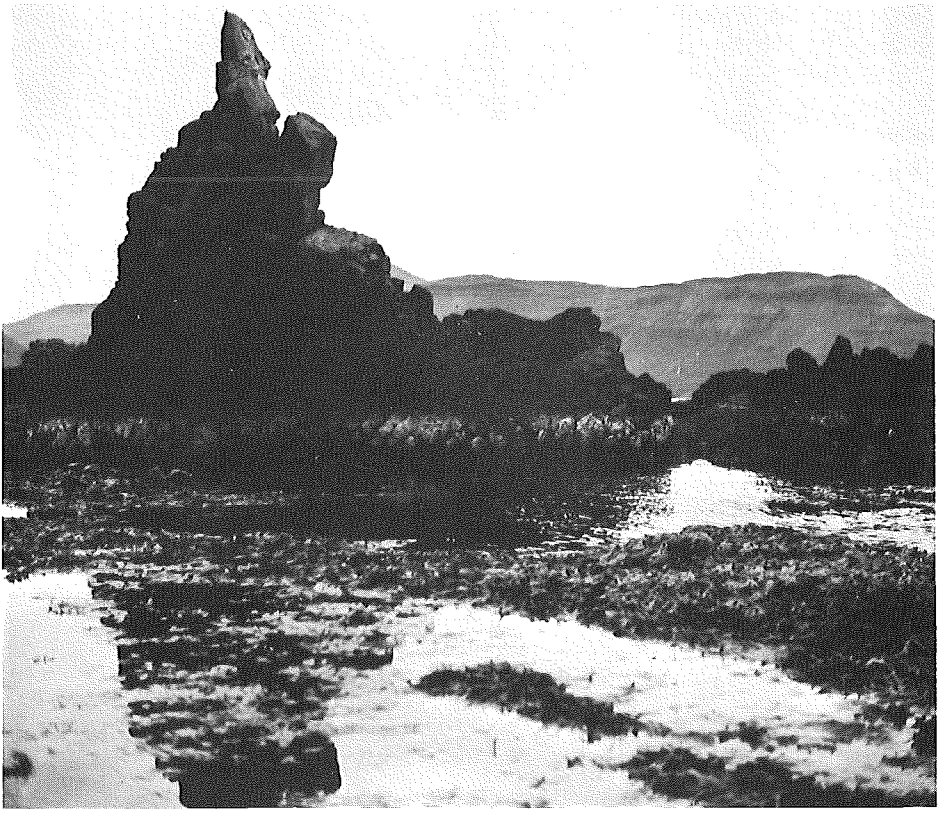


FIGURE 17. Detail from Árnesstapar.

lagoons. Around Árnes (Selsker, Krókur) there are bogs and meadows and some sandy stretches landwards, followed by almost horizontal rocky terraces seawards. There are wide shallow lagoons in between. Farther eastwards rocky slopes around Oddi and Skarðsvík were observed along with the island of Árnesey.

The neighbouring Reykjarfjörður was studied only in one spot, at Naustvíkurhöfði, close to a smal river outlet (Fig. 20).

FIGURE 18. Estuary of Árnesá.

FIGURE 19. Scattered estuarine vegetation near Árnesá.

FIGURE 20. Reykjarfjörður with Naustavíkurhöfði.

HYDROGRAPHIC CONDITIONS

The Irminger Current which conveys warm Atlantic water along the south and west Icelandic coast divides off Látrabjarg into an easterly and a westerly branch. One part of the Irminger Current follows the slopes of the north Icelandic shelf area eastwards and mixes with diverse primary and secondary water masses (STEFÁNSSON 1962).

There are wide seasonal and annual variations in the volume influx of Atlantic water in the northwest of Iceland, dependent mainly on climatic factors (EINARSSON 1949, STEFÁNSSON 1949, 1962). A complex hydrographic situation is met off Hornbjarg, due to the intermittent influx of Atlantic water into the North Icelandic coastal area. Changes in the ice boundary and distribution of drift ice are decisive for the hydrographic situation in the extreme northwest of Iceland. During heavy ice seasons the distribution of drift ice is the decisive factor (STEFÁNSSON 1969a). The cooling effect is most pronounced in May and June, at the time of the maximum ice extent (SIGTRYGGSSON 1972).

Temperature conditions in the extreme northwest of Iceland are hence the result of a complex interplay of various factors, both meteorological and oceanographical. Monthly isotherms (STEFÁNSSON 1954) show a southward bend from Hornbjarg towards Húnaflói. This course of the isotherms is due to the influence of drift ice north of Húnaflói. Loss of heat in the surface layers is connected with a greater vertical mixing in this area than farther eastwards.

TABLE I. Hydrographic data for the Hornstrandir coast.

August 1964:	T (°C)	S (‰)
Látravík below Hornbjarg	8.1	34.61
vicinity of waterfall	9.5	29.03
Öxi	7.8	34.52
below Almenningar	7.6	34.63
July/August 1972:		
Eyvindarfjörður and Ófeigsfjörður:		
Eyvindarfjarðará -river	6.7	0.50
Eyvindarfjarðará -estuary	8.0	0.80
Álftabúðarhöfði	8.0	33.03
Básar	8.3	34.80
Hrúteyjarnes	8.7	32.03
Hrúteyjarnes -bay	8.9	31.80
Hrútey	8.2	34.75
Borg	8.6	32.22
Höfði	7.8	32.64
Hvalá	9.0	0.50
Öxi -lagoon	14.5	22.56
Öxi -tide pool	9.0	25.13
Stapar	8.5	17.87
Húsá -river	8.2	0.50
Húsá -estuary		0.90
head of the Ófeigsfjörður	8.2	11.87
Sýrá	11.0	0.50
Hamrar	8.2	34.09
Helgaskjól	8.3	33.82
Seljanes	7.9	34.64
tide pools near Stapar:		
uppermost- Enteromorpha spp.	14.5	16.50
mid-eulittoral- Dictyosiphon spp.	14.0	26.60
tide pools at Seljanes:		
uppermost-Enteromorpha spp.	9.0	24.68
mid-eulittoral-Corallina officinalis	9.6	30.06
Trékyllisvík and Norðurfjörður		
Krossnes	8.1	33.75
Urðarnes	8.3	33.41
Árnesstapar	8.3	33.75
Árnesstapar-lagoon	9.0	33.82
Árnesá-river	10.5	0.05
Árnesá-estuary	10.2	0.50
Árnesá-estuary-first Enteromorpha	10.0	1.00
Selsker	8.3	33.83
Skarðsvík	8.4	33.75
Skarðsvík-lagoon	12.0	32.71
Reykjarfjörður		
Naustavíkurhöfði	8.3	34.13

Thermographic records in Icelandic waters revealed a decline in the yearly temperature averages on the line from Látrabjarg over Rit to Hornbjarg from 5.5°C over 5.0°C to 4.5°C. The seasonal course of the surface water temperatures in the three named areas was similar during winter and spring, while notable differences were obvious between June and October (STEFÁNSSON 1969b).

Temperature and salinity measurements were carried out during algological studies in 1964 and 1972. Results are presented in Table I. Water temperatures recorded around Hornbjarg were lower than in the outer area of the Dýrafjörður, which was investigated during the same summer (1964). Further measurements were carried out in 1972 in Eyvindarfjörður, Ófeigsfjörður and Trékyllisvík. During July/August a temperature average of 8.3°C was found for the entire area. Measurements in tide pools, lagoons, estuaries and river outlets were treated separately. In such sites temperatures were elevated and salinities low, depending on the distance from the freshwater outlets. For Eyvindarfjörður and Ófeigsfjörður an average salinity of 33.47‰ was found and of 33.78‰ for Trékyllisvík.

Referring to previous measurements around Hornbjarg lower temperatures and higher salinities were found along this exposed area than farther southwards along Hornstrandir. In general, elevated salinities (over 34 ‰) were recorded in exposed, open sites, such as Básar, Hrútey, Hamrar and Seljanes. Also in the Dýrafjörður in western Iceland, salinity values over 34‰ were found along open exposed sites and in areas between the western fjords.

Because of difficult field conditions we lack hydrographic measurements for the area between Látravík and Furufjörður as well as for Bjarnarfjörður and Drangar.

The benthic algal vegetation

I. AREA: HORNBJARG TO FURUFJÖRÐUR

The benthic algal vegetation of Látravík below Hornbjarg was limited to vertical rocky slopes in the upper eulittoral and to flat rocky terraces of a considerable width in the mid- and lower eulittoral (Figs. 21 and 22). On vertical walls, belts of *Ulothrix* spp. with *Urospora penicilliformis* were followed lower down the eulittoral by *Bangia atropurpurea* and *Porpyra umbilicalis* in a reduced, surf-adapted growth form. Mats of *Pilayella littoralis* were interimposed between the *Porphyra* belt and the fucoids in most sites (Fig. 21b). *Fucus distichus* ssp. *anceps* and *F. distichus* ssp. *edentatus* were common in this area. Only in the shelter of protruding rocks *Fucus spiralis* and *F. vesiculosus* were found, while *Ascophyllum nodosum* was absent from the vegetation.

Below the fucoids extensive meadows of diverse *Acrosiphonia* species (Fig. 22) were found on flat rocky surfaces. Separate surfaces on the rocks were covered by mats of *Monostroma grevillei* and the two populations did not mingle. *Enteromorpha linza* was prolific and belt-forming below the fucoid populations. In the upper eulittoral levels, the algal zonation was still similar to the one found in the western fjords, as e.g. in the Dýrafjörður (MUNDA

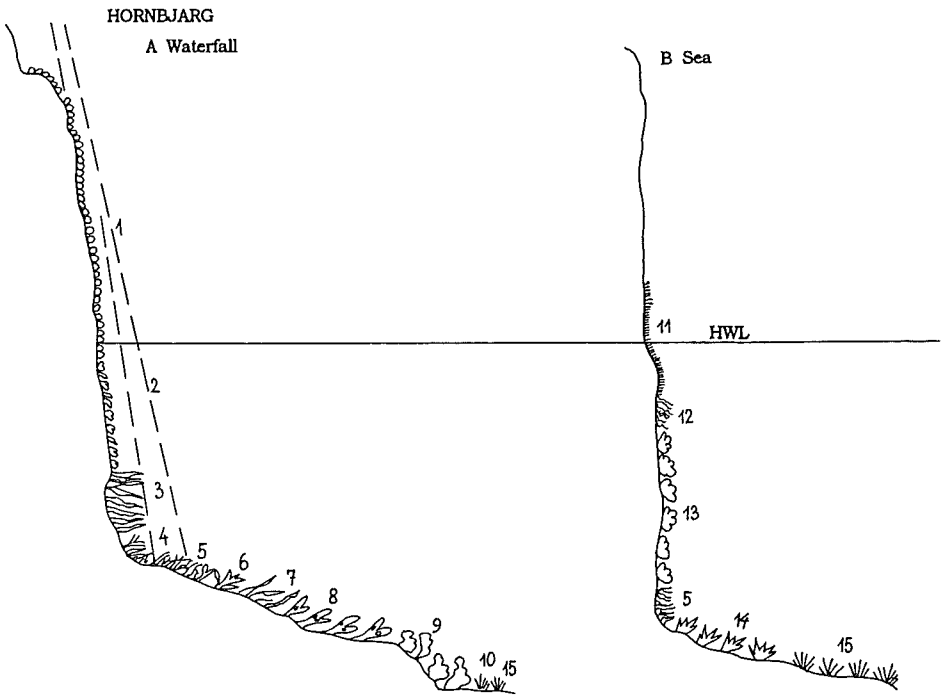


FIGURE 21. Hornbjarg: a) waterfall and b) sea.

Species list for Figures 21 to 29.

1. Blidingia minima
2. Blidingia chadefaudii
3. Enteromorpha intestinalis
4. Cyanobacteria
5. Pilayella littoralis
6. Palmaria palmata f. sarniensis
7. Enteromorpha linza
8. Fucus vesiculosus
9. Monostroma grevillei
10. Ulva lactuca
11. Ulothrix spp. - Urospora penicilliformis
12. Bangia atropurpurea
13. Porphyra umbilicalis
14. Fucus distichus ssp. anceps
15. Acrosiphonia spp.
16. Fucus spiralis
17. Fucus distichus ssp. edentatus
18. Palmaria palmata
19. Antithamnionella floccosa - Polysiphonia urceolata
20. Scytosiphon lomentaria
21. Alaria esculenta
22. Chordaria flagelliformis and other filamentous brown algae (Chorda filum, Dictyosiphon foeniculaceus, Eudesme virescens, Ectocarpus siliculosus)
23. Corallina officinalis
24. fields of crustose corallines (Lithothamnion spp., Clathromorphum circumscriptum)
25. Laminaria saccharina
26. Chaetomorpha melagonium
27. Prasiola stipitata
28. Devaleraea ramentacea
29. Rhodomela lycopodioides
30. Laminaria digitata
31. Cladophora oblitterata
32. Petalonia spp.
33. Fucus distichus ssp. distichus
34. Cladophora rupestris
35. Mastocarpus stellatus
36. Ascophyllum nodosum
37. Saccorhiza dermatodea
38. Punctaria latifolia
39. Ceramium spp.
40. Porphyra abyssicola

1978). Differences in the sequence of algal belts and leading associations became obvious in the mid- and lower eulittoral. In the lower eulittoral crustose corallines covered extensive rocky surfaces (*Clathromorphum circumscriptum, Lithothamnion* spp.). Such *Lithothamnion* fields were interrupted by deep lagoons in which *Laminaria saccharina* dominated. Small, shallow pools in between were covered by *Corallina officinalis* (Fig. 22). Only sporadically some species were found attached to the crustose corallines: *Chordaria flagelliformis, Devaleraea ramentacea, Palmaria palmata, Dictyosiphon foeniculaceus, Scytosiphon lomentaria, Cladophora rupestris, Cl. oblitterata* and crusts of *Ralfsia fungiformis*. On the edges of the *Lithothamnion* fields prolific but narrow belts of *Palmaria palmata* were locally found. On the outermost edges of the eulittoral rocks, belts of codominant *Polysiphonia urceolata* and *Antithamnionella floccosa* were characteristic for this particular area. The dominant species were usually attached to small *Mytilus edulis* shells and were accompanied by single specimens of *Scytosiphon lomentaria* (Fig. 22). In some sites extensive *Acrosiphonia* spp. meadows dominated the entire eulittoral slopes and were fringed at their lowed edges by belts, mentioned above. Sublittorally *Alaria esculenta* belts were found all over the area. *Alaria* was usually found in its long, narrow growth form.

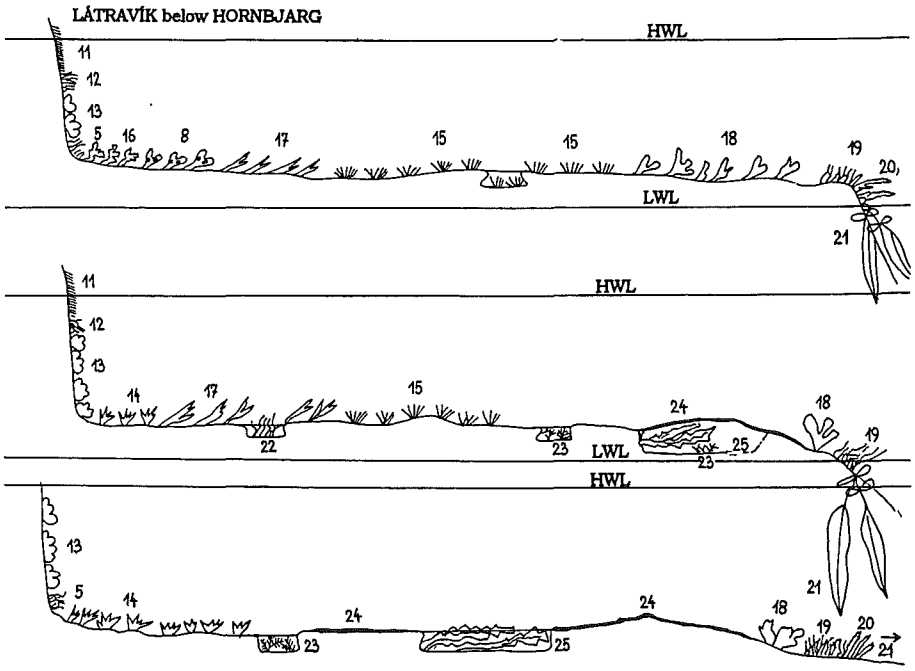


FIGURE 22. Látravík below Hornbjarg.

A certain zonation was likewise found in the tide pool vegetation. The uppermost pools were coated with *Hildenbrandia rubra* and *Phymatolithon lenormandii* and populated by *Punctaria plantaginea, Stictyosiphon tortilis, Dictyosiphon chordaria* and *Ralfsia fungiformis*. In some of the pools a prolific vegetation of green-algae was found, represented by *Cladophora oblitterata, Enteromorpha linza* and *Monostroma* species (*Monostroma grevillei, M. undulatum*). In mid-eulittoral pools *Sphacelaria radicans*, attached to *Clathromorphum circumscriptum* and *Lithothamnion* sp., was common in the undergrowth. In such pools the dominant species were either *Corallina officinalis* or *Acrosiphonia* spp. *Corallina* was also common as undergrowth in deep lagoons, covered by *Laminaria saccharina*.

Around Látravík below Hornbjarg there are numerous high waterfalls. An uplift of the eulittoral vegetation was observed on freshwater-washed rocky walls (Fig. 21a). *Blidingia minima* and *B. chadefaudii* covered vertical slopes up to several meters over the HWL. They were followed lower down by *Enteromorpha intestinalis* and mats of filamentous Cyanobacteria. Below the vertical slopes followed usually *Pilayella littoralis*. An enclave of estuarine vegetation was hence found around such waterfalls. Dwarf *Palmaria palmata* f. *sarniensis, Enteromorpha linza* and *Fucus vesiculosus* belts followed on moderate slopes below the waterfalls. Farther down the eulittoral followed belts of *Monostroma* species, *Ulva lactuca* and *Acrosiphonia* spp. meadows.

In a certain distance from the waterfalls the usual upper-eulittoral zonation was again observed (belts of *Ulothrix* spp. - *Bangia atropurpurea* - *Por-*

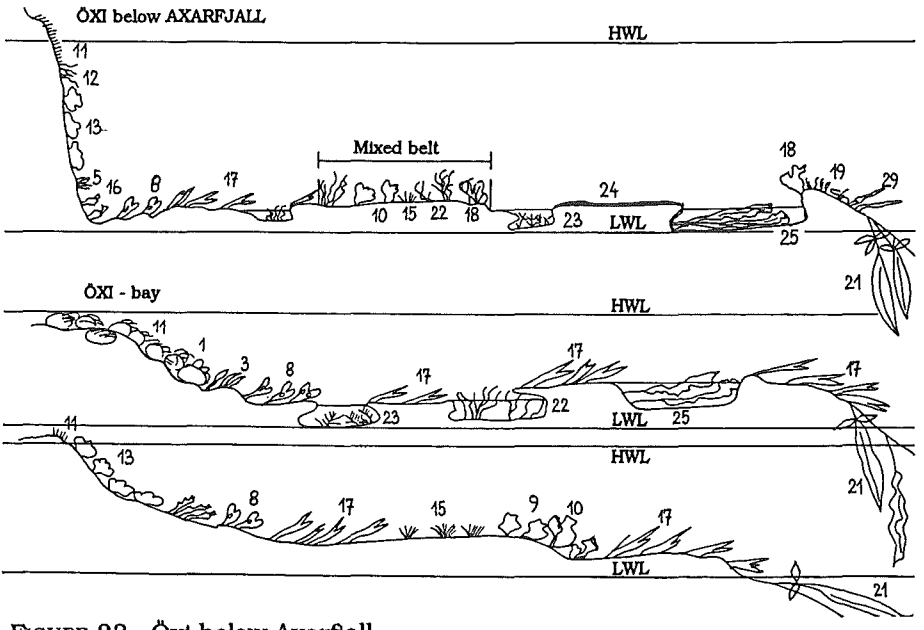


FIGURE 23. Öxi below Axarfjall.

phyra umbilicalis). At Öxi below Axarfjall (Figs. 23 and 24) a great variety of zonation patterns was observed, due to the variegated configuration of the coastal rocks. In some sites there were pebbles in the upper eulittoral, covered by *Urospora wormskioldii*, and flat rocky surfaces with *Porphyra umbilicalis* and *Fucus distichus* ssp. *edentatus* lower down. A prolific vegetation of green-algae was found at different eulittoral levels, represented by *Ulva lactuca, Monostroma* species, *Enteromorpha linza, E. compressa, E. intestinalis* and *Cladophora oblitterata*. On flat open slopes a variety of zonation patterns was found in the mid- and lower eulittoral, and more uniformity in the upper levels. *Fucus distichus* ssp. *anceps* was in most sites the only fucoid present. Below its belt mixed populations of diverse green algae could follow (*Enteromorpha linza, Monostroma grevillei, M. undulatum, Ulva lactuca*) and lower down *Acrosiphonia* spp. meadows, which were fringed by *Palmaria palmata*. Patches of foliose green algae were found in between the *Acrosiphonia* meadows at different levels. *Fucus distichus* ssp. *edentatus* was usual on flat rocky surfaces and could touch the *Alaria esculenta* belt without any intermediate zones. A further zonation-variant were mixed algal belts (*Chordaria flagelliformis, Palmaria palmata, Ulva lactuca*) below the fucoids, and fields of crustose corallines lower down the eulittoral. Such fields, which could locally occupy the entire eulittoral, were fringed at their lower edges by *Palmaria palmata* and the above mentioned belts of *Antithamnionella floccosa - Polysiphonia urceolata*, in which some *Scytosiphon lomentaria* was intermingled. The tide pools were overgrown by *Corallina officinalis*, by *Chordaria flagelli-*

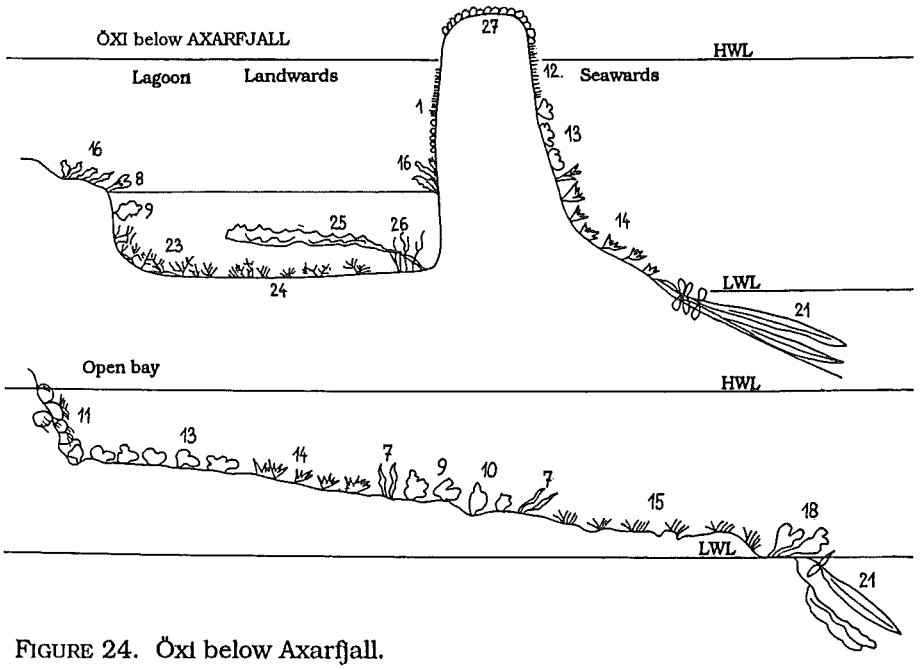


FIGURE 24. Öxi below Axarfjall.

formis or by *Acrosiphonia* species. In the lagoons *Laminaria saccharina* dominated (Fig. 23).

Around Öxi there are also land-locked lagoons. A different zonation was found on the seaward- and landward sides of rocky stacks (Fig. 24). On the tops of basaltic columns *Prasiola stipitata* was usual. Below it followed seawards *Ulothrix* spp., *Porphyra umbilicalis*, *Fucus distichus* ssp. *anceps* and *Alaria esculenta*. Landwards, *Blidingia minima* and *Fucus spiralis* followed below the relatively narrow *Ulothrix* spp. belt. The deep land-locked lagoons

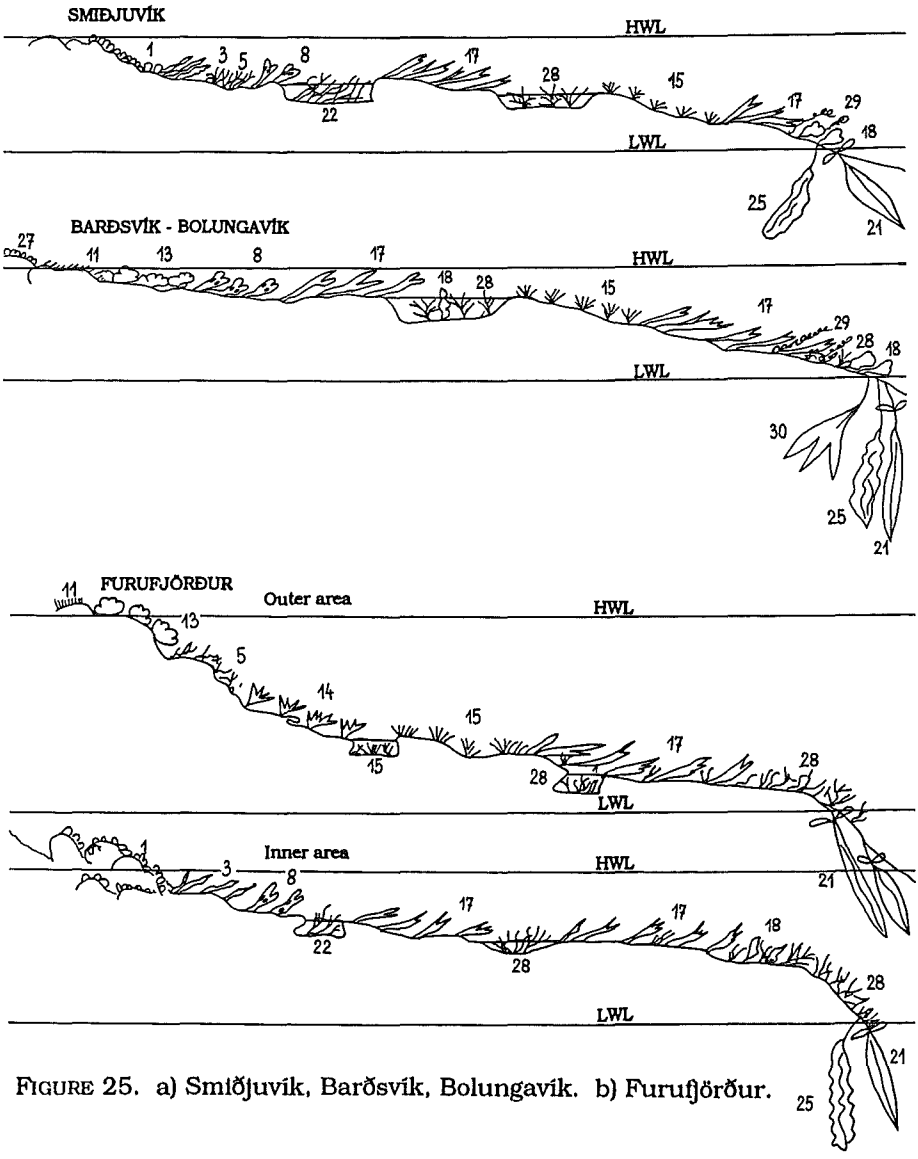


FIGURE 25. a) Smiðjuvík, Barðsvík, Bolungavík. b) Furufjörður.

at Öxi were covered by *Corallina officinalis*, *Laminaria saccharina*, *Chaetomorpha melagonium*, *Ulva lactuca* and *Monostroma* species and were fringed by *Fucus spiralis* and *F. vesiculosus*.

The immediate surroundings of Hornbjarg, Látravík and Öxi, exhibit, however, a vegetation which is different from the one observed in the outer areas of western fjords and open coast-lines between them. Differences centre first of all to the low-eulittoral vegetation. Belts of *Mastocarpus* stellatus and meadows of *Corallina officinalis* were absent here. Typical algal associations found in northern Iceland were, on the other hand, not yet formed in this area. Typical for the surroundings of Hornbjarg were wide and extensive *Acrosiphonia* spp. meadows, which replaced *Corallina officinalis* meadows, characteristic for Atlantic-water regions of Iceland. *Acrosiphonia* populations were only found in patches in western Iceland and did not influence the vegetation pattern. Around Hornbjarg *Corallina officinalis* was prolific in tide pools and lagoons, while *Mastocarpus stellatus* was not association-forming and appeared only in single, scattered specimens. A further characteristic feature of the surroundings of Hornbjarg were wide meadows, covered by crustose corallines, belts of *Palmaria palmata* at their lower edges and mixed belts of *Antithamnionella floccosa- Polysiphonia urceolata* lowermost, touching *Alaria esculenta* belts. The benthic algal vegetation of this northernmost area in western Iceland could be further characterised by a prolific green algae vegetation of different foliose species. The absence of intermediate low-eulittoral belts was also characteristic for some sites in this area (Fig. 23).

It is noteworthy that during a repetition of fields observations in the same area in 1973 the vegetation around Hornbjarg was changed. *Corallina officinalis* was less prolific in tide pools and lagoons, while *Mastocarpus stellatus* and *Leathesia difformis* were not found. These changes, which centre on a diminished Atlantic character of the vegetation, might obviously relate to the severe ice seasons, which occurred between the two periods of field studies in this area. They were likewise realised in an increase of *Devaleraea ramentacea* in the tide pools and on the eulittoral slopes. Extremely wide *Porphyra umbilicalis* belts were noticed during the last obvervation period (up to 3 m in width). *Ascophyllum nodosum* was absent from the vegetation during both observation periods and occurred only locally in single, scattered specimens.

Farther southwards along Hornstrandir, below Almenningar, field observations were only possible in the bays of Hrolleifsvík, Smiðjuvík, Barðsvík and Bolungavík (Fig. 25a). There are sandy slopes around river outlets in these bays. Farther out towards the sea the eulittoral is formed of flat rocky surfaces. In these bays, which are freshwater-influenced, the vegetation was non-typical. Belts of *Blidingia minima*, *Enteromorpha intestinalis*, *Pilayella littoralis*, *Fucus vesiculosus* and *F. distichus* ssp. *edentatus* followed in a vertical sequence along the slopes. *F. distichus* ssp. *edentatus* belts were interrupted by wide meadows of diverse *Acrosiphonia* species.

Near the sea the estuarine upper-eulittoral belts were replaced by *Ulothrix* spp. and *Porphyra umbilicalis*. In the lowermost eulittoral an association of *Rhodomela lycopodiodes* with *Palmaria palmata* was common, while the

upper sublittoral was occupied by mixed belts of *Alaria esculenta* and *Laminaria* species (*L. digitata, L. saccharina*). The quantity of *Devaleraea ramentacea* was increased in these bays, if compared with the vegetation around Hornbjarg. This was especially true for the Fucacean undergrowth. On vertical, isolated cliffs fucoids were represented only by *Fucus distichus* ssp. *anceps*, whereas on moderate rocky slopes *Fucus vesiculosus* and *F. distichus* ssp. *edentatus* were usual. In tide pools near the sea *Corallina officinalis* and *Devaleraea ramentacea* associations alternated. In the bays of Smiðjuvík and Barðsvík only the inner part of the bays was accessible, whereas continuous observations were possible between Bolungavík and Furufjörður. In the lowermost eulittoral inconspicuous belts of codominant *Rhodomela lycopodioides-Palmaria palmata-Devaleraea ramentacea* were still found.

Inside Furufjörður (Fig. 25b) the coast slopes gently and fucoids dominate in the eulittoral. Different zonation patterns were found in the upper eulittoral of this fjord: *Blidingia minima, Enteromorpha intestinalis* with *E. prolifera* and *Fucus vesiculosus* on moderate slopes and *Ulothrix* spp.-*Porphyra umbilicalis-Pilayella littoralis-Fucus distichus* ssp. *anceps* on steep rocks. Fields of *Fucus distichus* ssp. *edentatus* dominated, however, the eulittoral slopes, while *Ascophyllum nodosum* was still absent as association. *Acrosiphonia* spp. meadows were interimposed between fucoid belts. The tide pools in Furufjörður were dominated by *Acrosiphonia* species, by filamentous brown algae (*Chordaria flagelliformis, Dictyosiphon foeniculaceus, Stictyosiphon tortilis, Eudesme virescens*) or by *Devaleraea ramentacea. Corallina officinalis* pools were likely to decrease in frequency in this area. The most characteristic feature of the vegetation in Furufjörður was the formation of a low-eulittoral *Devaleraea ramentacea* belt, which was still narrow and inconspicuous. It appeared as a downwards extension of the Fucacean undergrowth, and reached to the Laminarian zone (*Laminaria saccharina, Alaria esculenta*). In this belt, the dominant species was found in a pure growth (Fig. 30), whereas the *Devaleraea ramentacea* association in tide pools was floristically rich, with numerous companion species and epiphytes, such as *Chordaria flagelliformis, Dictyosiphon foeniculaceus, Eudesme virescens, Ectocarpus siliculosus, Scytosiphon lomentaria, Acrosiphonia grandis, Spongomorpha aeruginosa, Palmaria palmata, Rhodomela lycopodioides, Petalonia fascia, Ulva lactuca, Ceramium rubrum, C. areschougii, Cladophora rupestris.* In the undergrowth *Clathromorphum circumscriptum, Lithothamnion* sp., *Ralfsia fungiformis* and *Hildenbrandia rubra* were usual.

Field observations along the northernmost area of Hornstrandir have revealed that a transition between a non-typical vegetation around Hornbjarg and the typical North Icelandic vegetation takes place gradually along the coast-line between Almenningar and Furufjörður. The low-level *Devaleraea ramentacea* belt, which is the main characteristic feature of the North Icelandic vegetation type, appears first as a dense undergrowth in the lower levels of fucoid belts. In Furufjörður, however, the first narrow *Devaleraea ramentacea* belt was observed (Fig. 30).

II AREA: BJARNARFJÖRÐUR N AND DRANGAR

The coast-line between Bjarnarfjörður N and Drangaskörð was investigated in several spots (see map, Fig. 10).

In the outer area of the Bjarnarfjörður different zonation patterns were found, dependent on the varying shore configuration (Fig. 11). The North Icelandic vegetation type was more pronounced along this area than in Furufjörður. *Devaleraea ramentacea* was outstanding in the vegetation both in tide pools and on low-eulittoral slopes (Figs. 26, 31).

On pebbles in the upper eulittoral *Ulothrix* spp.-*Urospora* spp. belts were usual. They were followed lower down the eulittoral by belts of *Enteromorpha intestinalis, Fucus vesiculosus, F. distichus* ssp. *edentatus*, and by *Acrosiphonia* spp. meadows. Within Bjarnarfjörður an association of codominant *Acrosiphonia* spp.-*Pilayella littoralis* followed the coast almost continuously, whereas the lowermost eulittoral was occupied by wide and prolific *Devaleraea ramentacea* belts. In some sites the just mentioned belt was interrupted, and replaced by an association of codominant *Palmaria palmata-Rhodomela lycopodioides*. In the upper sublittoral *Laminaria saccharina* f. *linearis* and *Alaria esculenta* were usual inside the fjord, up to Drangakleifar. Outside the fjord, already at Meyjará, the sublittoral was occupied solely by *Alaria esculenta*.

There were numerous tide pools and lagoons throughout the eulittoral

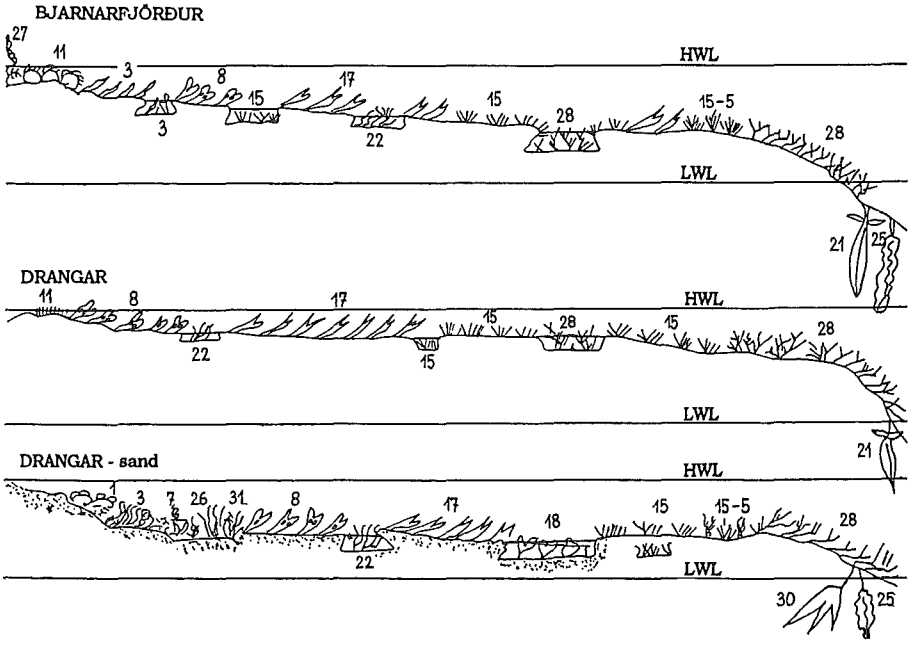


FIGURE 26. Bjarnarfjörður, Drangar.

slopes in this fjord. In tide pools of the upper eulittoral level *Enteromorpha intestinalis* and *Acrosiphonia sonderi* were usual. The latter species was also outstanding in *Acrosiphonia* meadows, which were found in between the Fucacean fields (Fig.32). In some high-level tide pools *Stictyosiphon tortilis* and *Dictyosiphon foeniculaceus* were found. In the low eulittoral pools *Devaleraea ramentacea* dominated. It was covered by *Elachista fucicola*. Numerous companion species were noticed in such pools, as e.g. *Palmaria palmata, Rhodomela lycopodioides, Ceramium* spp., *Ulva lactuca, Scytosiphon lomentaria, Chordaria flagelliformis, Ectocarpus siliculosus, Pilayella littoralis*; while *Ralfsia fungiformis, Clathromorphum circumscriptum, Lithothamnion* spp. and *Sphacelaria radicans* were usual in the undergrowth. In deep lagoons, *Laminaria saccharina* and *Alaria esculenta* dominated, with *Devaleraea ramentacea* in their undergrowth.

Fucoids were represented by *Fucus vesiculosus* and *F. distichus* ssp. *edentatus*. It is noteworthy, however, that an enclave of fruiting *Ascophyllum nodosum* was found in the middle area of this fjord. This species was absent from the vegetation along the northern area of Hornstrandir. *Corallina officinalis, Cystoclonium purpureum, Ceramium* species, *Punctaria plantaginea* and *Petalonia* species were, on the other hand, extremely rare in this fjord. Tide pools dominated by *Corallina officinalis* were absent. *Devalerea ramentacea* covered, however, most of the pools.

In Bjarnarfjörður N a characteristic North Icelandic vegetation was thus observed, with extensive *Acrosiphonia* spp. meadows and prolific *Devaleraea ramentacea* belts.

Along the cost-line from Bjarnarfjörður N to Drangatangi, the benthic algal vegetation exhibited typical North Icelandic features. Several spots were investigated along this coast-line. The vegetation was, in general, similar to the one just described for Bjarnarfjörður N (Fig. 26). A wide variation in the distribution of the upper-eulittoral algal belts was noticed, dependent on the substrate-configuration. On rocky slopes the *Ulothrix* spp.-*Urospora* spp. belts were narrow and discontinuous. In many sites the eulittoral vegetation started immediately with *Fucus vesiculosus*. On steep rocks and boulders the upper-eulittoral zones were represented by *Porphyra umbilicalis* and *Fucus distichus* ssp. *anceps*. Flat rocky surfaces, covered by a sandy layer were common in the area around Drangar. On such sand-covered rocks, especially in the vicinity of river outlets (Húsá, Meyjará) belts of *Blidingia minima* and *Enteromorpha intestinalis* were usual in the upper eulittoral. *Enteromorpha, linza, Chaetomorpha melagonium*, and *Cladophora oblitterata* occupied upper-eulittoral sandy pools. In rocky pools at this level *Enteromorpha clathrata, Stictyosiphon tortilis* and *Ectocarpus siliculosus* were represented on an undergrowth of *Hildenbrandia rubra*.

The mid-eulittoral was occupied by extensive meadows of *Fucus vesiculosus* and *F. distichus* ssp. *edentatus*. Their undergrowth was poorly developed since the flat rocky surfaces were covered by a sandy layer. In the mid- and lower eulittoral extensive *Acrosiphonia* spp. meadows were usual. They interrupted locally the Fucacean vegetation. *Acrosiphonia* species, first of all *A.*

sonderi, occupied also tide pools at these levels. Pools occupied by *Fucus distichus* ssp. *distichus* and by diverse filamentous brown algae (*Eudesme virescens*, *Dictyosiphon foeniculaceus*, *Chordaria flagelliformis*, *Ectocarpus siliculosus*) were frequently found. The most common low-eulittoral tide pool association was that of *Devaleraea ramentacea*, which exhibited a high floristic diversity. The dominant species was densely covered by *Elachista fucicola*, *Ectocarpus fasciculatus*, *Chordaria flagelliformis*, *Dictyosiphon foeniculaceus*, *Porphyra miniata*, dwarf *Ulva lactuca*, *Monostroma* sp., *Ceramium rubrum*, *Spongomorpha aeruginosa*. Some of these epiphytes were likewise found as companion species beside *Palmaria palmata*, *Rhodomela lycopodioides*, *Scytosiphon lomentaria*, *Petalonia fascia* and *Stictosiphon tortilis*.

All along this area, but in particular around Vatnshöfði and Bæjarvík, extensive shallow lagoons were usual. They were covered by different algal populations. In one type of such lagoons *Devaleraea ramentacea* dominated. The floristic composition was somewhat different from the one found in the tide pool association of this species. The epiphytic cover was less prolific and as companion species *Fucus distichus* ssp. *distichus*, *Laminaria saccharina*, *Chordaria flagelliformis*, *Dictyosiphon foeniculaceus*, *Scytosiphon lomentaria*, *Ceramium rubrum* and *Palmaria palmata* were usual. In other lagoons *Palmaria palmata* (yellow plants) dominated with the same companion species, as mentioned above. In a third type of lagoons filamentous brown algae occurred (*Chorda filum*, *Chordaria flagelliformis*, *Dictyosiphon foeniculaceus*).

Also around Drangar extensive *Acrosiphonia* spp. meadows occupied moderately sloping rocky surfaces in the lower eulittoral. They were fringed by a *Pilayella littoralis-Acrosiphonia* spp. belt, which is characteristic of semi-exposed sites. Locally, pure *Pilayella* belts were found, as e.g. in Fauskavík and Bæjarvík. Below the named associations pure and prolific *Devaleraea ramentacea* belts followed the entire coastal area (Fig. 31). This low-eulittoral association had a considerable vertical extension, reaching locally into the upper sublittoral. The dominant species appeared mainly as f. *robusta* and was bare of epiphytes. Only a few companion species were found in this belt, such as *Palmaria palmata*, *Rhodomela lycopodioides*, *Scytosiphon lomentaria*. *Ralfsia fungiformis* and crustose corallines occurred in the undergrowth. The upper sublittoral was occupied by *Alaria esculenta* along the open coast-lines and by *Laminaria* species (*L. digitata*, *L. saccharina*) in inlets.

In the vicinity of the two big rivers, Húsá and Meyjará, an estuarine association of *Fucus ceranoides*, *Pilayella littoralis* and *Enteromorpha intestinalis* was found on pebbles and rocks. In the vicinity of these rivers there are extensive sandy slopes touching the eulittoral lower down than the level of fucoids. The level of the eulittoral / sublittoral junction was covered by a belt of diverse *Enteromorpha* species (*E. intestinalis*, *E. prolifera*, *E. compressa*, *E. ahlneriana*), joined by *Pilayella littoralis* and *Palmaria palmata*, while the sublittoral was devoid of benthic algae.

The benthic algal vegetation investigated along the area from Bjarnarfjörður to Drangatangi exhibits, however, a typical North Icelandic character. Its most characteristic features are extensive *Acrosiphonia* ssp. meadows and

Devaleraea ramentacea belts in the lower eulittoral. Furthermore, tide pools dominated by *Devaleraea ramentacea* were common along this area, while *Corallina officinalis* was rare, contrary to conditions found between Hornbjarg and Barðsvík. It seems, however, likely, that *Corallina officinalis* along with *Cystoclonium purpureum* and *Ceramium* species decreases in abundance along the northernmost area of Hornstrandir. *Fucus vesiculosus* and *Fucus distichus* were the main fucoids present, while *Fucus spiralis* was rare and *Ascophyllum nodosum* absent as association, with the exception of an enclave of fruiting plants in the middle area of the Bjarnarfjörður.

III AREA: EYVINDARFJÖRÐUR AND ÓFEIGSFJÖRÐUR

Both fjords, situated farther south along Hornstrandir, are open and rather exposed. The coast-line between the inner area of Eyvindarfjörður to Seljanes outside Ófeigsfjörður was studied in several spots, signed on the map (Fig.13). Investigations included also the open area between both fjords from Hrúteyjarnes to the outlet of the river Hvalá, including the island of Hrútey. Some characteristic profiles are given in Fig. 27.

Observations in this area started in the estuary of the river Eyvindarfjarðará. The sandy slopes were devoid of algal vegetation, while on pebbles and rocks a broad *Urospora wormskioldii* zone was observed, occupying the entire eulittoral slopes. In rocky fissures *Blidingia minima* was found and *Enteromorpha* species (*E. intestinalis, E. prolifera, E. clathrata*) in rocky pools. Lower down the eulittoral *Pilayella littoralis* occurred together with some

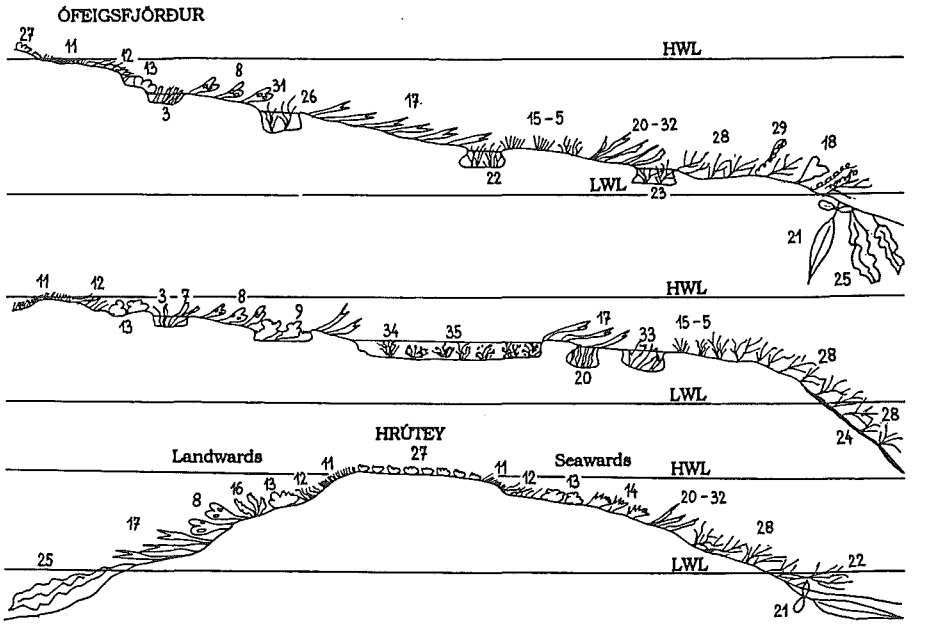


FIGURE 27. Ófeigsfjörður and Hrútey.

Fucus ceranoides. Around Álftabúðarhöfði *Porphyra purpurea* and *Enteromorpha compressa* were recorded in addition to the species named above. Fucoids were represented by estuarine growth forms of *Fucus vesiculosus* and by *F. distichus* ssp. *evanescens*. Farther out the fjord, the vegetation was distributed into distinct belts, with *Blidingia minima*, *Enteromorpha* species and filamentous brown algae (*Pilayella littoralis*, *Dictyosiphon chordaria*, *Ectocarpus siliculosus*) in a vertical sequence. Typically marine habitats were found in the outermost fjord area, in bays called Básar, which are surrounded by steep rocky walls. Exposure-induced variations in zonation patterns were observed within these bays and were most pronounced in the upper eulittoral. On high and steep rocks a complete zonation was found, with belts of *Prasiola stipitata*, *Ulothrix* spp. - *Urospora* spp., *Bangia atropurpurea* and *Porphyra umbilicalis*, while rocky fissures were overgrown by *Rhizoclonium riparium* in the level of the littoral fringe and by *Blidingia minima* in the uppermost eulittoral. In some sites these high-level belts were absent and the benthic vegetation started immediately with *Fucus vesiculosus*. Fucoids were represented by *Fucus vesiculosus* and *F. distichus* ssp. *edentatus*, while *Ascophyllum nodosum* was extremely rare and occurred only in single, scattered specimens. Between the fucoids and the broad *Devaleraea ramentacea* belt a narrow girdle of codominant *Acrosiphonia* spp. - *Pilayella littoralis* was interposed in most sites.

In this fjord the upper sublittoral was covered by *Laminaria saccharina* f. *linearis*, which was joined farther out by *Alaria esculenta*. In their undergrowth *Ralfsia fungiformis*, *Clathromorphum circumscriptum*, *Lithothamnion* spp. and *Sphacelaria radicans* were found.

At each tidal level, characteristic tide pool associations occurred: at the level of the littoral fringe *Enteromorpha intestinalis*, f. *microccoca* (unattached form), and attached forms of *E. intestinalis*, *E. prolifera* and *E. clathrata* in the uppermost eulittoral. At the *Fucus vesiculosus* level tide pools covered by *Stictyosiphon tortilis*, by *Cladophora oblitterata*, *Enteromorpha linza* or *Chaetomorpha melagonium* were usual. Lower down the eulittoral, at the level of *Fucus distichus*, pools covered by filamentous brown algae (*Chordaria flagelliformis* with epiphytic *Dictyosiphon foeniculaceus*, *Scytosiphon lomentaria*, *Ectocarpus siliculosus*), by *Fucus distichus* ssp. *distichus*, by diverse *Acrosiphonia* species and by heavily epiphytized *Devaleraea ramentacea*, were found. *Palmaria palmata* was also common in low-level tide pools. In one spot, *Dumontia contorta* was detected.

Along the open coast-line between Eyvindarfjörður and Ófeigsfjörður a similar vegetation was observed. Its characteristic feature was a broad and prolific *Devaleraea ramentacea* belt within which considerable amounts of *Rhodomela lycopodioides* occurred. Locally, both species were codominant. The admixture of several companion species into the *Devaleraea* belt (e.g. *Palmaria palmata*, *Ulva lactuca*, *Ceramium rubrum*, *Chordaria flagelliformis*, *Acrosiphonia grandis*) was a further characteristic of this area. In the upper sublittoral *Alaria esculenta* followed along the entire coast-line.

Around Hrúteyjarnes there are steep rocky formations with sandy inlets in between, whereas at Borg, Höfði and Strandatún the coast slopes gently and allows the formation of extensive coastal shallows and lagoons. They were fringed most usually by *Fucus distichus* ssp. *distichus* or rarely by F. *spiralis*. Filamentous brown algae were dominant in such lagoons (*Chordaria flagelliformis, Dictyosiphon foeniculaceus, Stictyosiphon tortilis, Eudesme virescens, Ectocarpus siliculosus*). In between their populations *Palmaria palmata, Ulva lactuca, Ceramium rubrum, Porphyra purpurea, Enteromorpha intestinalis, E. clathrata*, and *E. prolifera* were found.

On the island of Hrútey (Fig. 27) a different zonation pattern was found on the seaward and landward slopes. The high-level belts (*Ulothrix* spp., *Bangia atropurpurea, Porphyra umbilicalis*) were found on both sides, whereas differences were obvious in the mid- and lower eulittoral. Seawards *Fucus distichus* ssp. *anceps* was the only fucoid present, while landwards a complete zonation was found, with belts of *Fucus spiralis, F . vesiculosus* and *F. distichus* ssp. *edentatus* in a vertical sequence. Intermediate low-eulittoral belts were absent on the landward slopes and *Laminaria saccharina* followed immediately below the fucoids. Seawards a belt of *Petalonia* spp. and *Scytosiphon lomentaria* was interposed between the Fucus *distichus* ssp. *anceps* and *Devaleraea ramentacea* belts. *Alaria esculenta* followed in the upper sublittoral.

In the driftweed within sandy inlets several deep-water red algae were found beside stipes of *Laminaria hyperborea* and *Desmarestia* species: *Odonthalia dentata, Ptilota serrata, P. plumosa, Callophyllis cristata, Phycodrys rubens, Polysiphonia arctica, Delesseria sanguinea, Porphyra miniata* along with *Ceramium rubrum, Palmaria palmata* and *Rhodomela lycopodioides.*

Ófeigsfjörður extends from the estuary of the big river Hvalá to the promontory of Seljanes. Its vegetation was somewhat different from the one just described and a wider variation in zonation patterns was obvious. The Atlantic character of the vegetation was more pronounced than farther northwards and was accentuated first of all by the presence of notable amounts of *Mastocarpus stellatus, Corallina officinalis* and *Cladophora rupestris* in the tide pools and lagoons.

The estuary of the river Hvalá exhibited the usual vegetation, characteristic for low-salinity areas viz. a prolific *Urospora wormskioldii* belt in the upper eulittoral and a mixed population without distinct zonal distribution (*Fucus ceranoides, Pilayella littoralis, Enteromorpha compressa* and *E. intestinalis*). Estuarine forms of *Enteromorpha* species are, however, variable and difficult to identify.

Along the coast-line between Melgraseyri and Öxi steep rocks alternate with sandy inlets. Some variations in the upper-eulittoral belts were found. They could be represented by *Ulothrix* spp. and *Blidingia minima*, a complete zonation, viz. belts of *Ulothrix* spp.- *Urospora* spp., *Bangia atropurpurea* and *Porphyra umbilicalis* or even by high-level belts, characteristic for northern Iceland (*Pilayella littoralis, Acrosiphonia* sp., dwarf *Scytosiphon lomentaria,*

Petalonia filiformis). In inlets the eulittoral growth started immediately with *Fucus vesiculosus*. *Fucus spiralis* was rare and *Ascophyllum nodosum* absent. *Fucus distichus* ssp. *edentatus* was still the main fucoid present, only on vertical exposed slopes it was replaced by *F. distichus* ssp. *anceps*. Tide pools, found on the different eulittoral levels, were inhabited by similar associations as in the area, described above. Rocky and sandy pools in this area were usually covered by *Cladophora oblitterata* and *Chaetomorpha melagonium*. In some rocky pools *Punctaria plantaginea*, *Acrosiphonia sonderi* or *Scytosiphon lomentaria* were found. In the lower eulittoral pools covered by *Devaleraea ramentacea*, by filamentous brown algae or by *Acrosiphonia* species were usual, viz. by associations characteristic for cold-water regions of the Icelandic coastal area. It is noteworthy that *Chaetomorpha melagonium* occurred in pools and lagoons of different eulittoral levels, both on rocky and sandy substrata, and was usually densely epiphytized by e.g. *Eudesme virescens*, *Dictyosiphon foeniculaceus*, *Chordaria flagelliformis*, dwarf *Ulva lactuca*, dwarf *Porphyra miniata*.

On the emerged slopes two low-eulittoral belts were characteristic of this area: that of codominant *Acrosiphonia* spp. - *Pilayella littoralis* and the other represented by *Scytosiphon lomentaria* and *Petalonia* species. Both belts occurred between the fucoids and the *Devaleraea ramentacea* belt, but could likewise interrupt Fucacean fields in the shelter of protruding rocks. The *Devaleraea ramentacea* belt was discontinuous and locally replaced by a mixed belt of *Palmaria palmata* - *Rhodomela lycopodioides* (Fig.27).

At Öxl a land-locked lagoon was found, isolated from the surrounding sea by a treshold, covered by fucoids. Particular growth conditions, due to elevated temperatures and reduced water movement were found here. The lagoon was covered by dense populations of *Mastocarpus stellatus* and *Cladophora rupestris* growing on a ground of *Clathromorphum circumscriptum*, *Hildenbrandia rubra* and *Ralfsia fungiformis*.

Neighbouring tide pools were covered by the usual associations of *Fucus distichus* ssp. *distichus*, *Chordaria flagelliformis* and *Scytosiphon lomentaria*.

Along the shore-line between Sandvík and Ófræðavík sandy slopes are again interposed between the rocky formations. A luxuriant green-algae vegetation was characteristic for this location. Tide pools in the upper eulittoral were overgrown by dense mats of *Enteromorpha* species (*E. intestinalis*, *E. linza*, *E. prolifera*) and lower pools by *Monostroma* species. An extremely wide *Devaleraea ramentacea* belt was also characteristic of this area (up to 30 m in width), extending into the sublittoral, where Laminarians were absent. Some variations with depth were, however, found at different levels of the *Devaleraea* zone. At the upper levels the dominant species was heavily epiphytized by *Ectocarpus fasciculatus*, *Elachista fucicola*, *Monostroma grevillei* and *Ceramium* species and accompanied by *Palmaria palmata*, *Chordaria flagelliformis*, *Scytosiphon lomentaria*, *Ulva lactuca*, *Rhodomela lycopodioides*, *Dictyosiphon foeniculaceus*, *Pilayella littoralis* and *Acrosiphonia* species. At the lower levels of the *Devaleraea* zone, in the sublittoral, its population was

less dense and the dominant species was bare of epiphytes. Among companion species single *Alaria esculenta* plants were found.

Under overhanging rocks a sciaphilic association was found, with *Polysiphonia urceolata*, *Sphacelaria radicans*, *S. plumosa*, dwarf *Scytosiphon lomentaria* and *Petalonia fascia* on an undergrowth of *Audouinella purpurea* and crustose corallines.

In most sites within Ófeigsfjörður a mixed belt of *Laminaria saccharina* and *Alaria esculenta* was found. Among the fucoids *Fucus vesiculosus* and *F. distichus* ssp. *edentatus* dominated, while *F. spiralis* was rare. The usual zonation pattern in the lower eulittoral viz. in the intermediate zone between fucoids and Laminarians was: *Acrosiphonia* spp. - *Pilayella littoralis*, mixed belt of *Scytosiphon lomentaria* and *Petalonia* species, *Devaleraea ramentacea*.

Observations around the rocky formations of Stapar, near the river Húsá, revealed similar vegetation features. The head of the Ófeigsfjörður is sandy and bare of algal vegetation. Farther eastwards some stones, embedded into sand, were covered by *Ulothrix* spp., *Bangia atropurpurea* and *Acrosiphonia grandis*. Even further eastwards, around the estuary of the river Sýrá, an estuarine population of *Pilayella littoralis*, *Enteromorpha intestinalis* and *E. compressa* covered the pebbles.

Along the eastern coast of the Ófeigsfjörður the vegetation was different from the one found along its western side. A more pronounced Atlantic character of the vegetation was obvious, accentuated by the presence of *Corallina officinalis*, *Mastocarpus stellatus*, *Cladophora rupestris* and *Ceramium* species in the tide pools and lagoons. The tide pool association of *Corallina officinalis* was rare or even absent all the way south of Bjarnarfjörður N. *Mastocarpus stellatus* which was recorded in single specimens around Hornbjarg, was absent all the way to Ófeigsfjörður. It was common in tide pools and lagoons along the eastern side of this fjord, where it formed an association with *Cladophora rupestris*.

It was obvious that a low-eulittoral association of this species, which is characteristic for Atlantic-water regions of Iceland, appeared as a tide pool association along Hornstrandir, though with a limited occurrence.

Further characteristic tide pool associations of this area were those of *Enteromorpha* species (*E. intestinalis*, *E. linza*), of diverse filamentous brown algae and of *Monostroma* species (*M. grevillei* as dominant). *Monostroma* species were common in the area around Hamrar and Seljanes and appeared also in the epiphytic cover of fucoids and of *Devaleraea ramentacea*.

A great variation in the sequence of the low-eulittoral belts was observed. The most usual pattern was a vertical sequence of *Acrosiphonia* spp. - *Pilayella littoralis*, *Scytosiphon lomentaria* with *Petalonia* species and *Devaleraea ramentacea*. In extremely exposed sites around Seljanes *Chordaria flagelliformis* replaced the *Devaleraea ramentacea* belt. Under conditions of less severe exposure this belt was interposed between *Devaleraea* and *Alaria* zones. In semi-exposed sites mixed belts of *Devaleraea ramentacea-Rhodomela lycopodioides-Palmaria palmata* were usual. Locally, around Seljanes, pure *Palmaria palmata* belts replaced *Devaleraea ramentacea*. It became ob-

vious, however, that in this area the low-eulittoral zonation was extremely variable in contrast to the rather uniform zonation pattern found between Bjarnarfjörður N and the head of Ófeigsfjörður.

Along the eastern coast *Alaria esculenta* appeared in its narrow form in exposed sites and was mixed with *Laminaria saccharina* in inlets. In deep lagoons *Alaria* appeared in its broad growth form.

A characteristic feature of this area were likewise populations of *Petalonia zosterifolia*, *P. fascia* and *Scytosiphon lomentaria*, found on boulders and behind the shelter of protruding rocks.

IV AREA: NORÐURFJÖRÐUR, TRÉKYLLISVÍK AND REYKJARFJÖRÐUR

The area which includes Norðurfjörður and Trékyllisvík is relatively sheltered (see map Fig.14). Here the Atlantic character of the vegetation was even more pronounced than along the eastern coast of Ófeigsfjörður. A great variation in the sequence of the low-eulittoral belts was found (Figs. 28 and 29).

Field studies carried out during the same summer as in Ófeigsfjörður revealed some differences from the latter. Vegetational differences between the two neighbouring areas are partly conditioned by the configuration of the coastal slopes within Trékyllisvík, were flat, mainly sand covered rocky surfaces prevail (Fig.19). They are interrupted by coastal shallows and lagoons (Fig.16). Sandy extenses were found in between the rocky slopes, especially around the outlet of the river Árnesá (Fig.18).

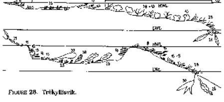


FIGURE 28. Trékyllisvík.

Differences from the neighbouring fjord center on the absence of a *Bangia atropurpurea* belt in Trékyllisvík and its sparce occurrence in Norðfjörður. In the upper eulittoral, however, associations characteristic for the North Icelandic coastal area were sporadically found (dwarf *Devaleraea ramentacea* and codominant dwarf *Pilayella littoralis*, *Scytosiphon lomentaria*, *Petalonia filiformis* and dwarf *Spongomorpha aeruginosa*). A particular high-level association was that of *Chordaria flagelliformis*, which formed dense mats above *Fucus vesiculosus* or above a *Devaleraea ramentacea* - *Ulva lactuca* association in sites, where fucoids were absent. *Fucus spiralis* was more frequent than farther north along Hornstrandir. It was found in sheltered sites on boulders or as fringing tide pools and lagoons. In the level of fucoids differences from the rest of Hornstrandir center on the presence of *Ascophyllum nodosum* on flat rocky surfaces. Its belt was, however, not found continuously throughout the area, where *Fucus vesiculosus* and *F. distichus* ssp. *edentatus* still dominated. *Ascophyllum* was devoid of its obligatory epiphyte *Polysiphonia lanosa* (Fig.28).

Ceramium species, *Cystoclonium purpureum* and *Corallina officinalis* were more abundant in tide pools than in the neighbouring area, while *Mastocarpus stellatus* was absent. A characteristic feature of Trékyllisvík were extensive sandy and rocky lagoons, covered by filamentous brown algae. Finds of *Saccorhiza dermatodea* and *Punctaria latifolia* in such lagoons are noteworthy. Mats of *Corallina officinalis* and of *Rhodomela lycopodioides* which inter-

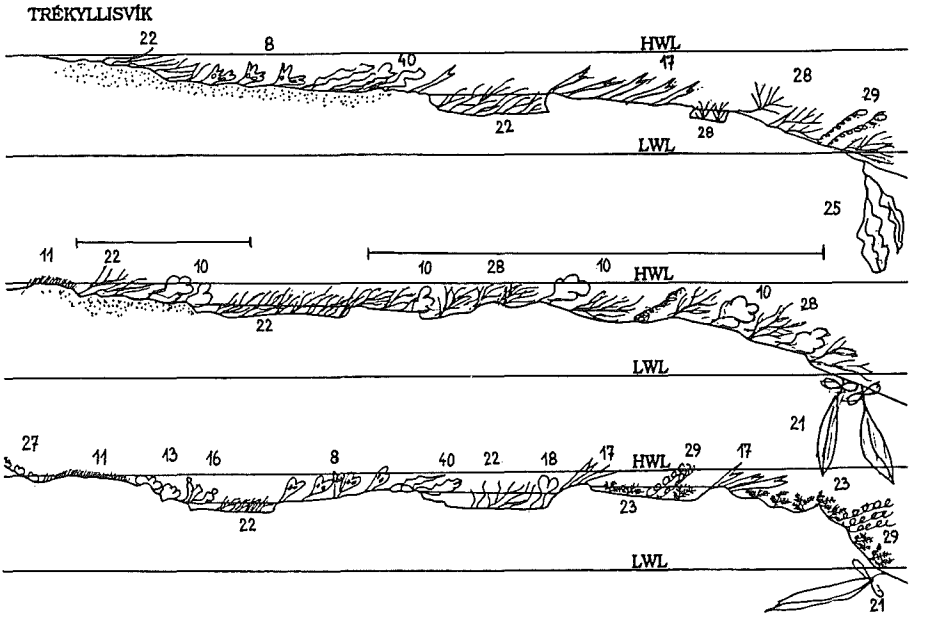


FIGURE 29. Trékyllisvík.

rupt fucoid fields, were a further distinguishing feature from the rest of the areas along Hornstrandir investigated.

Within Norðurfjörður Krossnes and Urðarnes were observed. On high cliffs a *Prasiola stipitata* belt was usual, and a complete sequence of upper-eulittoral belts below it. The *Bangia atropurpurea* belt was, however, narrow and discontinuous, while that of *Porphyra umbilicalis* was well developed. Below it *Fucus spiralis* was found in sheltered sites. Most usually *Fucus vesiculosus* and *F. distichus* ssp. *edentatus* followed throughout the eulittoral slopes. On horizontal rocks an *Ascophyllum nodosum* zone was interposed between belts of the two *Fucus* species. A mixed population of *Scytosiphon lomentaria, Petalonia zosterifolia* and P. *fascia* interrupted locally the Fucacean fields. The same was true for *Acrosiphonia* spp. populations. They were found likewise in the lower eulittoral in extensive mats (Fig. 39). Within Norðurfjörður a *Devaleraea ramentacea* belt was usual in the lower eulittoral (cf. Figs. 27 and 28). Locally pure *Palmaria palmata* belts replaced that of *Devaleraea* at the same level. In the upper sublittoral within Norðurfjörður a prolific belt of the narrow form of *Alaria esculenta* followed the coast. A vertical sequence in the undergrowth of the *Alaria* zone was observed. In its upper level *Devaleraea ramentacea* and *Ulva lactuca* predominated, whereas lower down *Chordaria flagelliformis, Rhodomela lycopodioides* and dwarf *Corallina officinalis* were observed. *Polysiphonia urceolata, Clathromorphum circumscriptum, Lithothamnion* sp. and *Ralfsia fungiformis* were found in the undergrowth at all the levels. Rocky pools were overgrown by *Punctaria plantaginea, Dictyosiphon foeniculaceus* and other filamentous brown algae, by *Acrosiphonia sonderi* and by *Corallina officinalis*. In shallow lagoons populations dominated by giant and heavily epiphytized *Palmaria palmata* were common. In its undergrowth crustose corallines and *Sphacelaria radicans* occurred. In deep lagoons *Laminaria saccharina* dominated and was accompanied by *Alaria esculenta* and *Saccorhiza dermatodea*. In the undergrowth *Corallina officinalis* formed dense mats like in lagoons below Hornbjarg. The admixture of *Palmaria palmata* into diverse lagoon associations was, however, more outstanding here than farther northwards along Hornstrandir.

Within Trékyllisvík there are flat rocky surfaces, interrupted by tide pools and lagoons. Due to a sandy layer on the rocks, the undergrowth of fucoids on these slopes was poor. Crustose floristic elements were in minority. *Porphyra abyssicola* dominated in the undergrowth in the upper, and *Acrosiphonia* species in the lower eulittoral level. Fucoids within Trékyllisvík were represented by *Fucus vesiculosus* and *Fucus distichus* ssp. *edentatus* (Fig.35). They occurred in diverse growth forms, which were found side by side within the same populations. *Ascophyllum nodosum* was rare. It formed a scattered belt between the zones of the two *Fucus* species or occurred only in patches or in single specimens. It was obvious that the relative frequency of the *Ascophyllum* component within Fucacean fields was even decreased during the last observation period, in 1980. *Fucus spiralis* was rare in the area, found on the sheltered sides of boulders or as fringing tide pools and lagoons. Some rocky surfaces were covered with juvenile fucoids. They were even

wider during the last observation period. This might indicate the first regrowth after the scouring action of ice. *Fucus* species are likely more successful primary colonizers than *Ascophyllum nodosum*.

In many sites within Trékyllisvík the upper eulittoral coincides with sandy slopes and the eulittoral vegetation starts immediately with *Fucus vesiculosus*. Typical high-level algal belts were only found on boulders and on rocky formations around Árnesstapar (*Ulothrix* spp. - *Urospora penicilliformis*, *Porphyra umbilicalis*). On high boulders *Prasiola stipitata* and Lichenes occurred at the level of the littoral fringe and were followed lower down the eulittoral by belts of *Ulothrix* spp. - *Urospora penicilliformis*, *Porphyra umbilicalis*, *Fucus spiralis*, *F. vesiculosus*, *Porphyra abyssicola*, *F. distichus* ssp. *edentatus* or ssp. *anceps*. Two different *Porphyra* belts were hence usual in between the fucoids.

Horizontal sand-covered rocks offer conditions for a particular vegetation pattern, depleted of fucoids. It was found in some spots within the bay of Hvalvík and in the vicinity of the Árnesá river, at Selsker and Krókur. *Chordaria flagelliformis* occurred in dense mats in the uppermost eulittoral, either for itself or as codominant with *Ulva lactuca*. The entire eulittoral zone was occupied by a *Devaleraea ramentacea* - *Ulva lactuca* association, which is characteristic of northern Iceland. It was found previously on the island of Grímsey (MUNDA 1977a). Companion species within this association were *Chordaria flagelliformis*, *Palmaria palmata*, *Acrosiphonia grandis*, *Petalonia fascia*, *Rhodomela lycopodioides* and *Pilayella littoralis*. In the sublittoral followed usually a belt of *Laminaria saccharina* f. *linearis*.

Some sandy slopes, interposed between the rocky formations, were devoid of macroalgae. They are rather extensive around the outlet of the river Árnesá (Fig.18). At the outlet of this river freshwater algae were observed, and after a vegetation-free zone filamentous algae in dense mats (*Enteromorpha ahlneriana*, *E. intestinalis*, *E. compressa*, *E. prolifera*, *Pilayella varia* cf., *Ectocarpus siliculosus*) while pebbles were coated by *Urospora wormskioldii* and *Ulothrix* species. A scattered estuarine vegetation was found farther out (Fig.19). A salinity-induced gradient in the sequence of benthic algae was observed. *Fucus ceranoides* and *Dictyosiphon chordaria*, which joined the filamentous algae, mentioned above, were replaced farther out by estuarine growth forms of *Fucus vesiculosus*, by *F. distichus* ssp. *evanescens* as well as by *Dictyosiphon foeniculaceus*, *Acrosiphonia sonderi*, *Spongomorpha aeruginosa* and *Scytosiphon lomentaria* (Fig.33). The estuarine fucoids were densely covered by epiphytes. On rocky slopes farther out, *Enteromorpha* species occupied high-level tide pools. *Ceramium* species, *Cladophora oblitterata*, codominant *Stictyosiphon tortilis-Punctaria plantaginea* and also *Dumontia contorta* were common. Around the eulittoral/sublittoral junction *Palmaria palmata* dominated within mixed populations.

In the central part of Trékyllisvík, under normal salinity conditions, the vegetation was typically North Icelandic (surroundings of Árnes, Oddi and Skarðsvík). *Devaleraea ramentacea* interrupted in patches the fucoid fields and formed a prolific and pure belt in the lowermost eulittoral (Figs. 37 and

38). It was likewise common in tide pools and lagoons. Where there are rocky slopes in the uppermost eulittoral, a high-level *Devaleraea* belt of dwarf specimens was found above the fucoids or above the mentioned high-level *Chordaria* belt. In this area there are likewise extensive *Acrosiphonia* spp. mats (cf. Fig. 39) in patches in between the fucoid fields, in tide pools as well as in the lower eulittoral, above the *Devaleraea* belt. A typical North Icelandic high-level association of codominant *Petalonia zosterifolia*, dwarf *Scytosiphon lomentaria* and dwarf *Pilayella littoralis* was likewise found in this area.

A characteristic feature of Trékyllisvík are wide coastal shallows and lagoons. Most of them are populated by filamentous brown algae, with *Chorda filum* as dominant (Fig. 34). Its main companion species were *Dictyosiphon foeniculaceus*, *D. chordaria*, *Chordaria flagelliformis*, *Ectocarpus siliculosus*, *Pilayella littoralis*, *Eudesme virescens*, while in the undergrowth *Ralfsia fungiformis* and *Sphacelaria radicans* were usual. In nearshore shallow lagoons *Dictyosiphon foeniculaceus* could dominate in a similar association, while *Chorda filum* and *Ralfsia fungiformis* were absent. In other lagoons a *Palmaria palmata* association was frequently found, the dominant species being heavily epiphytized. *Fucus distichus* ssp. *distichus* was also a frequent lagoon association, found all throughout Trékyllisvík, with crustose corallines in its undergrowth.

In the central part of Trékyllisvík *Laminaria saccharina* f. *linearis* was common in the upper sublittoral, while *L. digitata* was subordinate at this level.

Special attention was paid to the rocky formations of Árnesstapar (Figs. 16 and 17). On the vertical rocky slopes there were different zonation patterns, as e.g. *Ulothrix* spp. - *Porphyra umbilicalis* - *Fucus spiralis*; or *F. vesiculosus* only, without other high-level belts. In the surrounding sandy-rocky lagoons filamentous brown algae dominated, forming an association, as described above. A separate association within these extensive lagoons was that of giant, heavily epiphytized *Punctaria latifolia*, accompanied by *Saccorhiza dermatodea* and filamentous brown algae.

On flat rocky surfaces around these lagoons, fucoids occurred in their usual vertical sequence, viz. *Fucus vesiculosus* and *F. distichus* ssp. *edentatus*. *Ascophyllum nodosum* was rare. Below the fucoids an association of codominant *Acrosiphonia* spp. - *Pilayella littoralis*, which is characteristic of semi-exposed sites followed the slopes. Lowermost *Devaleraea ramentacea* was found either in a pure belt or mingled with *Rhodomela lycopodioides*. In rocky pools of the mid-eulittoral level, *Punctaria plantaginea* with *Stictyosiphon tortilis*, *Dictyosiphon foeniculaceus*, *Ceramium* species with *Cystoclonium purpureum* and *Devaleraea ramentacea*, formed separate associations.

In the bay of Hvalvík and around Melar, viz. the western side of Trékyllisvík, the vegetation exhibited several typical Atlantic features, which were even more pronounced during the second period of field studies. Contrary to the middle area of Trékyllisvík, *Corallina officinalis* was outstanding in the vegetation, occupying tide pools, lagoons, rocky fissures and eulittoral slopes in between the fucoid fields. There it alternated with populations of *Devaleraea*

ramentacea. *Corallina* was found likewise in the lowermost eulittoral, like in the western fjords. In such cases it was epiphytized with *Leathesia difformis*, which was not found in this area during the first observation period. In some deep lagoons *Corallina* formed a dense undergrowth below *Laminaria saccharina*, like in lagoons found below Hornbjarg.

Corallina mats were in some sites interrupted by mats of *Rhodomela lycopodioides* in a mozaic-like pattern (Fig. 40). *Rhodomela* was likewise dominant in some shallow lagoons. In several sites within Trékyllisvík it formed either scattered mats or a continuous zone in the lowermost eulittoral, above *Alaria esculenta* (Fig. 41). The Atlantic character of the vegetation was further accentuated by populations of *Ceramium* species with *Cystoclonium purpureum* and of *Dumontia contorta* in mid-eulittoral tide pools. It is noteworthy that some nearshore lagoons were occupied solely by crustose corallines with a few specimens of *Chaetomorpha melagonium* and *Corallina officinalis* as the only inhabitants.

Within Trékyllisvík the greatest variations were, however, found in the lowermost eulittoral, where belts of *Corallina officinalis*, *Rhodomela lycopodioides* and *Devaleraea ramentacea* alternated, while pure or mixed belts of *Palmaria palmata* were sporadically found. *Devaleraea* occurred in different associations at this level viz. a pure belt or a mixed belts with *Rhodomela lycopodioides*; an association of codominant *Devaleraea ramentacea - Ulva lactuca*, which occupied the entire eulittoral slopes or a mixed belt of codominant *Devaleraea ramentacea - Palmaria palmata - Rhodomela lycopodioides*, which fringed Fucacean fields in semi-exposed sites.

Further low-eulittoral associations which occurred above the named belts were those of codominant *Acrosiphonia* spp. - *Pilayella littoralis*, as well as extensive mats of *Acrosiphonia* spp.

Variations were conspicuous, though less pronounced in the tide pools and lagoons where Atlantic and North Icelandic vegetation features were found side by side. Filamentous brown algae were conspicuous in this area, with *Chorda filum* as dominant in lagoons, and *Dictyosiphon foeniculaceus*, *Stictyosiphon tortilis* and *Punctaria plantaginea* in tide pools.

In the upper sublittoral either *Laminaria saccharina* or *Alaria esculenta* dominated, while L. *digitata* was subordinate (Fig. 36).

As mentioned above, the extensive Fucacean fields of this area (Fig. 35) were dominated by *Fucus vesiculosus* and *F. distichus* ssp. *edentatus*. *Ascophyllum nodosum*, which was absent or found in single scattered specimens along Hornstrandir, was found here in patches between the zones of the two *Fucus* species. Its quantity was decreased during the second observation period, obviously due to the scouring action of ice during the years between the two field observations.

Contrary to the extreme variations found within Trékyllisvík, the benthic algal vegetation of the neighbouring Reykjarfjörður seemed more uniform and typically North Icelandic. The main study area within this fjord was at Naustavíkurhöfði in the middle fjord area.

The zonation pattern was as follows: a narrow and discontinuous *Ulothrix* spp. girdle, followed downwards by *Fucus vesiculosus*, *Fucus distichus* ssp. *evanescens* and a mixed zone of filamentous brown algae, dominated by *Chordaria flagelliformis* and accompanied by *Dictyosiphon* species, *Ectocarpus siliculosus*, *Pilayella littoralis* and single *Chorda filum*. *Laminaria digitata* followed in the upper sublittoral. This type of vegetation was mainly attached to small stones. A prolific undergrowth of *Porphyra abyssicola* below the fucoids was characteristic, whereas crustose floristic elements were sparse. Between the belts of *Fucus vesiculosus* and *F. distichus* populations of the named *Porphyra* species (Fig. 42) and of *Acrosiphonia sonderi* were locally interposed.

On rocky slopes, which are steep in the upper eulittoral, the zonation pattern was somewhat different, starting with *Fucus spiralis*, while *Fucus distichus* was represented as ssp. *edentatus*. *Devaleraea ramentacea*, accompanied and epiphytized by *Ceramium rubrum* was found in the lowermost eulittoral, and *Laminaria digitata* sublittorally. In the *Fucus vesiculosus* level the undergrowth was dominated by *Porphyra abyssicola*, which was likewise belt-forming above *Fucus distichus* ssp. *edentatus*. In the undergrowth of the latter *Palmaria palmata* dominated. It is noteworthy, that *Ascophyllum nodosum* was absent from the vegetation.

The outlet of a small river at Naustavíkurhöfði was coated with dense mats of *Pilayella varia* cf., while farther out it was joined by *Ulva lactuca*, *Enteromorpha linza* and by single *Fucus vesiculosus*.

Main algal associations

The distribution of the low-eulittoral-, tide pool- and lagoon associations along Hornstrandir is presented in Tables 2 to 4.

Vegetation units with the predominance of one or more species have been recognized previously for different areas of the Icelandic coast, such as the South, Southwest, Northwest and East (Munda 1976a, 1978, 1980a, b, 1983, 1985, 1987). There were no data for the mainland of the North Icelandic coastal area up to this date, only the vegetation of the island of Grímsey in Eyjafjarðarsýsla was treated separately (Munda 1977a).

ASSOCIATIONS OF THE LITTORAL FRINGE

Prasiola stipitata was relatively rare as association along the Hornstrandir coast. It was found on tops of high boulders in the northernmost part of this area, but was extremely rare in Trékyllisvík, where flat, sand-covered rocky slopes prevail. Its usual companion species *Prasiola crispa* and *P. furfuracea* along with *Rosenvingiella polyrhiza* were found likewise along Hornstrandir.

Rhizoclonium riparium occupied rocky fissures on high, steep rocky slopes and exhibited a similar distribution-pattern to the association, named above.

Blidingia minima is usually a high-level association of the uppermost eulittoral in estuarine habitats. Around Hornbjarg, in Látravík, it protruded

in dense mats high over the HWL in the vicinity of waterfalls (Fig. 21).

***Ulothrix* spp. - *Urospora penicilliformis*.** This association belongs likewise to the level of the upper eulittoral zone, but on the high, surf-swept rocky walls it protruded into the level of the littoral fringe (Fig. 21).

ASSOCIATIONS OF THE UPPER EULITTORAL.

Ulothrix* spp. - *Urospora penicilliformis was usual on steep rocks and boulders all throughout the Hornstrandir coast. It was wider and more outstanding than in the Northwest of Iceland (cf. MUNDA 1978) where it was found first of all in the level of the littoral fringe. Species found within this belt were *Ulothrix flacca, U. pseudoflacca, U. subflaccida, Urospora penicilliformis* and dwarf *Spongomorpha aerugnosa.*

Bangia atropurpurea was well developed as association and found usually between the *Ulothrix-Urospora* and *Porphyra umbilicalis* belts. It

TABLE II. Distribution of low-eulittoral associations along Hornstrandir.

	I AREA					II AREA		III AREA		IV AREA		
	1	2	3	4	5	6	7	8	9	10	11	12
DEVALERAEA RAMENTACEA					—	—		—		—		
D. RAMENTACEA - ULVA LACTUCA										—		
PALMARIA PALMATA	—	—	—	—								
P. PALMATA - RHODOMELA LYCOPODIOIDES				—		—						
codominant: P. PALMATA - DEVALERAEA RAMENTACEA -												
RHODOMELA LYCOPODIOIDES				—		—		—		—		
CORALLINA OFFICINALIS										—		
fields of crustose corallines	—											
ACROSIPHONIA SPP.	—	—	—	—		—		—		—		
ACROSIPHONIA SPP. PILAYELLA LITTORALIS						—		—		—		
ANTITHAMNIONELLA FLOCCOSA - POLYSIPHONIA												
URCEOLATA	—											
RHODOMELA LYCOPODIOIDES										—		
CHORDARIA FLAGELLIFORMIS								—				

Legend to tables 2-4:

I AREA:
1. Látravík
2. Öxl
3. Barðsvík
4. Bolungavík
5. Furufjörður

II AREA:
6. Bjarnarfjörður
7. Drangar

III AREA:
8. Eyvindarfjörður
9. Ófeigsfjörður

IV AREA:
10. Norðurfjörður
11. Trékyllisvík
12. Reykjarfjörður

followed rocky slopes of the northernmost part of Hornstrandir, but was absent in Trékyllisvík and rare in Norðurfjörður. Its zonal position was above the two named belts in western Iceland, whereas it overlapped with the *Ulothrix* belt in the East (MUNDA 1983).

Porphyra umbilicalis* f. *umbilicalis was prolific and well developed in the northernmost area of Hornstrandir as well as locally within Ófeigsfjörður and Norðurfjörður, but rare on the flat rocky formations around Drangar and within Trékyllisvík. Along Hornstrandir, *Ulothrix* species, *Pilayella littoralis* and *Isthmoplea sphaerophora* were observed in the undergrowth.

Pilayella littoralis was found as a separate, high level association on the steep rocky walls around Hornbjarg, most usually below a *Porphyra* or

TABLE III. Distribution of tide pool associations along Hornstrandir.

	I AREA					II AREA		III AREA		IV AREA		
	1	2	3	4	5	6	7	8	9	10	11	12
DEVALERAEA RAMENTACEA					—	—		—		—	—	
ACROSIPHONIA SPP.	—	—	—	—	—	—		—		—	—	
CORALLINA OFFICINALIS	—	—	—	—				—		—	—	
ENTEROMORPHA SPP.				—		—		—		—	—	
E. LINZA - ULVA LACTUCA	—	—	—	—				—				
CLADOPHORA OBLITTERATA						—		—		—	—	
CHAETOMORPHA MELAGONIUM				—		—		—		—	—	
CERAMIUM SPP.								—		—		
STICTYOSIPHON TORTILIS - PUNCTARIA PLANTAGINEA						—		—		—		
CHORDARIA FLAGELLIFORMIS						—		—		—	—	
FUCUS DISTICHUS SSP. DISTICHUS								—		—	—	
PALMARIA PALMATA							—	—		—	—	
MONOSTROMA SPP.	—	—	—	—				—				
MASTOCARPUS STELLATUS - CLADOPHORA RUPESTRIS								—				

TABLE IV. Distribution of lagoon associations along Hornstrandir.

	I AREA					II AREA		III AREA		IV AREA		
	1	2	3	4	5	6	7	8	9	10	11	12
LAMINARIA SACCHARINA - CORALLINA OFFICINALIS	—	—	—	—								
CHORDA FILUM WITH FILAMENTOUS BROWN ALGAE							—		—	—	—	
DEVALERAEA RAMENTACEA							—	—	—	—	—	
PALMARIA PALMATA							—	—	—	—	—	—
CORALLINA OFFICINALIS	—	—	—	—							—	—
FUCUS DISTICHUS SSP. DISTICHUS								—	—	—	—	—
PUNCTARIA LATIFOLIA											—	
MASTOCARPUS STELLATUS								—	—			

Enteromorpha belt.

Blidingia minima, which had a wide vertical extension around waterfalls, was usually found as a high level association in estuarine habitats on rocky slopes. It was mixed with *B. chadefaudii* (Fig. 21) and most prolific below Hornbjarg. Farther southwards along Hornstrandir it was usual in inner fjord areas (e.g. in Eyvindarfjörður, Ófeigsfjörður) and around local estuaries.

Enteromorpha intestinalis followed usually below *Blidingia* belts around waterfalls and in estuarine areas. It was accompanied by *E. prolifera*, *E. compressa* and *E. ahlneriana*. This association occurred above *Fucus vesiculosus* (or *F. ceranoides*) or above other filamentous algae, as e.g. *Pilayella littoralis*.

Chordaria flagelliformis. This high-level association was characteristic for the Trékyllisvík area, where it occurred on flat, sand-covered rocks. Locally, during the summer aspect of the association, *Ulva lactuca* occurred as the only companion species within it.

Devaleraea ramentacea in a reduced growth form. This high-level association which is clearly discernible from the low-level and tide pool associations of the same species was described in detail (Munda 1976b). It is a characteristic vegetational feature of northern Iceland and was found sporadically along Hornstrandir. *Ulothrix* species could be found in its undergrowth and dwarf *Pilayella littoralis* and *Scytosiphon lomentaria* as companion species.

***Petalonia* spp.** is likewise a typical high-level association of northern Iceland and was described for the island of Grímsey (Munda 1977a). It includes dwarf *Petalonia fascia*, *P. filiformis* and *P. zosterifolia* as associated codominants. It was found within Trékyllisvík with dwarf *Pilayella littoralis*, *Scytosiphon lomentaria* and *Spongomorpha aeruginosa* as companion species. It differed from the association described for Grímsey by the absence of *Chordaria flagelliformis* and dominance of *Petalonia filiformis* among the three associated *Petalonia* species.

FUCACEAN ASSOCIATIONS

Fucus spiralis. This association was rather rare along Hornstrandir, found on some sheltered boulders and around tide pools.

Fucus vesiculosus is an important Fucacean association all along the Hornstrandir coast. It was found in widely different variants and the dominant species appeared in different growth forms. Below Hornbjarg, in Látravík, it covered flat rocky surfaces below the vertical rocky slopes (cf. Fig. 5). It was likewise outstanding on flat rocky slopes within other areas investigated, such as Furufjörður, Drangar, Ófeigsfjörður and Trékyllisvík (Fig. 9, 15, 35). On moderate slopes its zonal position was between belts of *Porphyra umbilicalis*, *Ulothrix* spp. or *Chordaria flagelliformis* (high-level association) and *Fucus distichus* ssp. *edentatus*. On boulders, however, it occurred below the barnacles without any high-level algal associations above it. In the undergrowth, crustose floristic elements were usual on rocky slopes (*Hildenbrandia rubra*, *Phymatolithon lenormandii*, *P. laevigatum*, *Ralfsia* species, *Lithothamnion* sp.). On sand-covered rocks *Porphyra abyssicola* and *Sphace-*

FIGURE 30. *Devaleraea ramentacea* as Fucacean undergrowth and narrow belt in Furufjörður.

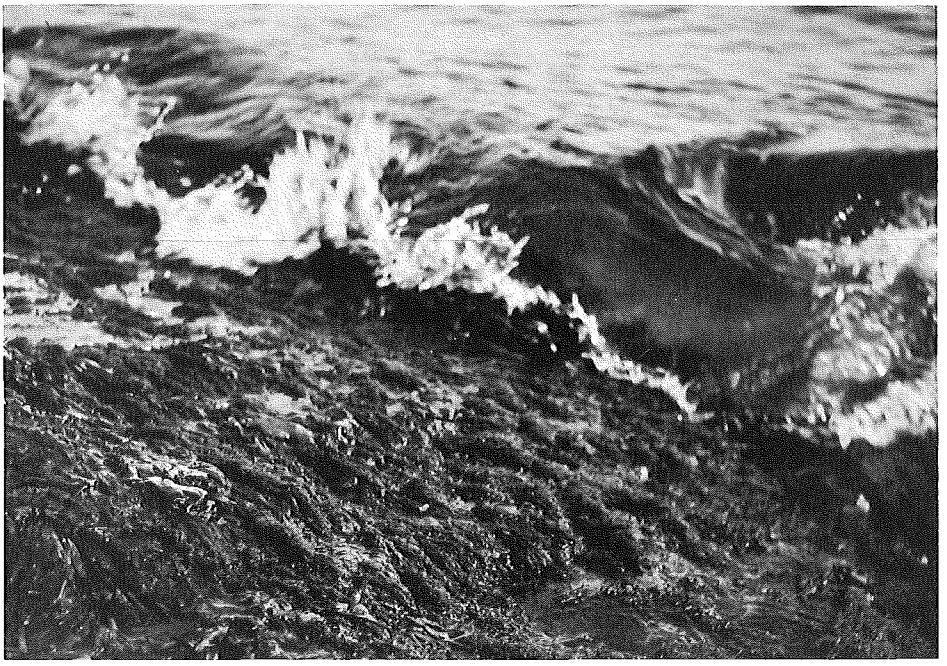


FIGURE 31. *Devaleraea ramentacea* belt at Drangar.

larla radicans were usual in the lowest stratum of the association. Among epiphytes and companion species *Ectocarpus siliculosus*, diverse *Enteromorpha* species, *Pilayella littoralis*, *Ulva lactuca* and *Acrosiphonia grandis* were usual.

The dominant species was present mainly as f. *sphaerocarpa* and as f. *vadorum*.

Fucus distichus* ssp. *anceps is an association of highly exposed sites. It was common on the steep rocky walls around Hornbjarg as well as on surfswept moderate slopes. Its usual zonal position was between belts of *Porphyra umbilicalis* and *Acrosiphonia* spp. meadows. Downwards it could limit likewise directly to *Alaria esculenta* or to the usual low-eulittoral belt of *Devaleraea ramentacea*. Its floristic composition was similar as described for the Dýrafjörður (Munda 1978).

Fucus distichus* ssp. *edentatus is the dominant Fucacean association of the Hornstrandir coast. It was found usually below the *Fucus vesiculosus* association or below a belt of *Porphyra abyssicola*, which could be locally interposed between the two fucoid belts. It could likewise occur below *Fucus*

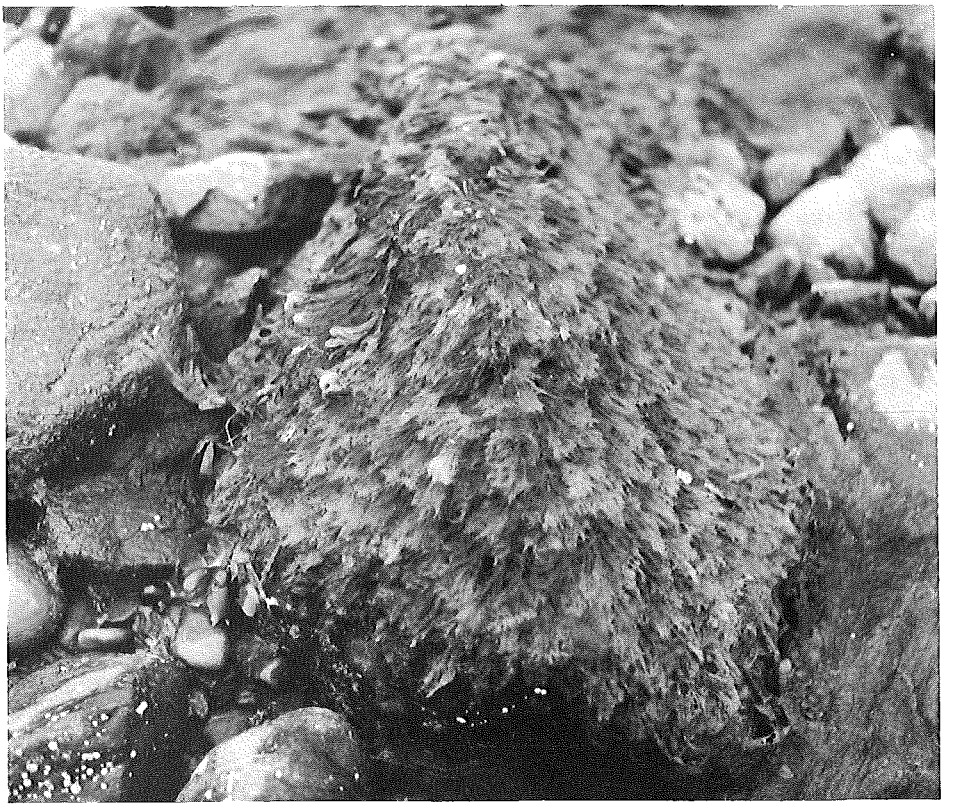


FIGURE 32. *Acrosiphonia sonderi* belt at Drangar.

distichus ssp. *anceps* under varying exposure conditions along the same transect. At its lower level it could touch diverse associations, characteristic for the intermediate zone (e.g. that of *Devaleraea ramentacea - Palmaria palmata - Rhodomela lycopodioides, Acrosiphonia* spp. - *Pilayella littoralis, Corallina officinalis*) or directly to *Alaria esculenta* or *Laminaria saccharina*. In its undergrowth *Porphyra abyssicola, Sphacelaria radicans* and *Acrosiphonia grandis* were usual on sand-covered rocks, whereas on smooth surfaces crustose floristic elements, including *Ralfsia fungiformis* and *Clathromorphum circumscriptum*, were well developed. The floristic composition of the association found along Hornstrandir differed from the one found in the Dýrafjörður (MUNDA 1978) by the absence of typical Atlantic floristic elements, such as *Meembranoptera alata, Mastocarpus stellatus, Plumaria elegans* and *Ceramium* species; and by a general floristic impoverishment. It showed, however, more likeness with the same association found in the subarctic regions of eastern Iceland (MUNDA 1983).

This Fucacean association could be interrupted by populations of other species, which were represented within it as companion species (e.g. *Mono-*

FIGURE 33. Estuarine vegetation in Trékyllisvík (*Enteromorpha* spp., filamentous brown algae).

stroma grevillei and *Ulva lactuca* below Hornbjarg and *Devaleraea ramentacea, Acrosiphonia* spp., *Petalonia* spp. - *Scytosiphon lomentaria* in other areas; while in Trékyllisvík *Corallina officinalis* and *Rhodomela lycopodioides* were common).

Ascophyllum nodosum was absent as association along Hornstrandir. Single, scattered specimens were found in between *Fucus distichus* ssp. *edentatus* fields. Only in Bjarnarfjörður N and locally in Trékyllisvík continuous populations of a minimal extension were found, and did not influence the vegetation pattern. It is noteworthy that the amount of the *Ascophyllum* component within the Fucacean vegetation was even decreased during the second observation period in the same areas. Along Hornstrandir *Ascophyllum* was devoid of its obligatory epiphyte *Polysiphonia lanosa.*

LOW EULITTORAL ASSOCIATIONS

Associations which occupy the level of the eulittoal/sublittoral junction and the lowermost eulittoral viz. the level between the fucoids and Laminarians, were extremely variable along the Hornstrandir coast. The abrupt vegetational change around Hornbjarg was first of all obvious in the absence of low-eulittoral associations of *Mastocarpus stellatus, Corallina officinalis* and *Callithamnion sepositum.* The typical North Icelandic vegetation pattern was, on the other hand, created gradually along Hornstrandir. In the transitional area between Hornbjarg and Furufjörður the following low-level associations were observed:

***Acrosiphonia* spp.** This association includes several *Acrosiphonia* species (*A. grandis, A. centralis, A. arcta, A. sonderi*). It occurred as dense mats below the fucoids or for itself and occupied considerable surfaces on flat rocks. This association is common and wide-spread along Hornstrandir (Figs. 22, 25A, 32, 39), but was rare and subordinate in the western fjords. It seems likely that it replaces the wide *Corallina* mats, which are a characteristic feature of Atlantic water regions of Iceland.

Crustose corallines. Fields of diverse crustose corallines, which were found sublittorally in outer areas of western fjords, were situated in the lower eulittoral around Hornbjarg. *Clathromorphum circumscriptum, Lithothamnion* sp., *L. glaciale, Pseudolithophyllum orbiculatum* were detected within this association, which coated locally also insolated lagoons. These fields of crustose corallines alternated with *Acrosiphonia* spp. meadows or occupied the greater part of the eulittoral slopes (Fig. 22). Single specimens of *Corallina officinalis, Eudesme virescens, Chordaria flagelliformis, Chaetomorpha melagonium* and *Enteromorpha linza* were found attached to the crustose corallines.

Palmaria palmata. This low-level association is characteristic for the surroundings of Hornbjarg, as fringing *Acrosiphonia* spp. meadows or crustose corallines. It was conspicuous likewise farther south along Hornstrandir. This association was found as prolific and well developed on the northern slopes of the Snæfellsnes Peninsula and on the island of Grímsey (MUNDA 1977a, 1987).

Palmaria palmata* - *Rhodomela lycopodioides. A belt of the two associated codominants was observed farther south along Hornstrandir, around

Barðsvík and Furufjörður as well as in the Bjarnarfjörður and at Drangar. It occupied the lowermost eulittoral zone above *Laminaria saccharina* or *Alaria esculenta*. Crustose corallines and *Ralfsia fungiformis* were found in the undergrowth and *Chordaria flagelliformis* as a companion species.

***Antithamnionella floccosa* - *Polysiphonia urceolata*.** This association was found on the lowermost edges of rocky slopes, fringing most usually the *Palmaria palmata* belt. *Scytosiphon lomentaria* was a conspicuous companion species. It was limited to the vicinity of Hornbjarg, where it most likely replaces the *Callithamnion sepositum* association, found under similar conditions in the western fjords.

The above named associations were characteristic for the northernmost area of Hornstrandir.

Devaleraea ramentacea is a characteristic low-level association of northern and eastern Iceland. It was still absent along the northernmost area of Hornstrandir. It is likely that it was formed gradually along this coastal area, where it appeared firstly as a dense undergrowth in the lower levels of the fucoid fields. In Furufjörður, the first narrow *Devaleraea* belt was observed (Fig. 30). Farther southwards it was prolific and well developed as e.g. already in the Bjarnarfjörður N and at Drangar (Fig. 31). The dominant species appeared usually as f. *robusta* and was devoid of epiphytes and companion species. The width of the association varied from a relatively narrow to a several meters broad belt. In some places, as e.g. in Ófeigsfjörður *Devaleraea* dominated the entire eulittoral zone and protruded into the upper sublittoral in sites where Laminarians were absent.

In sites where the association was floristically rich, a certain variation with

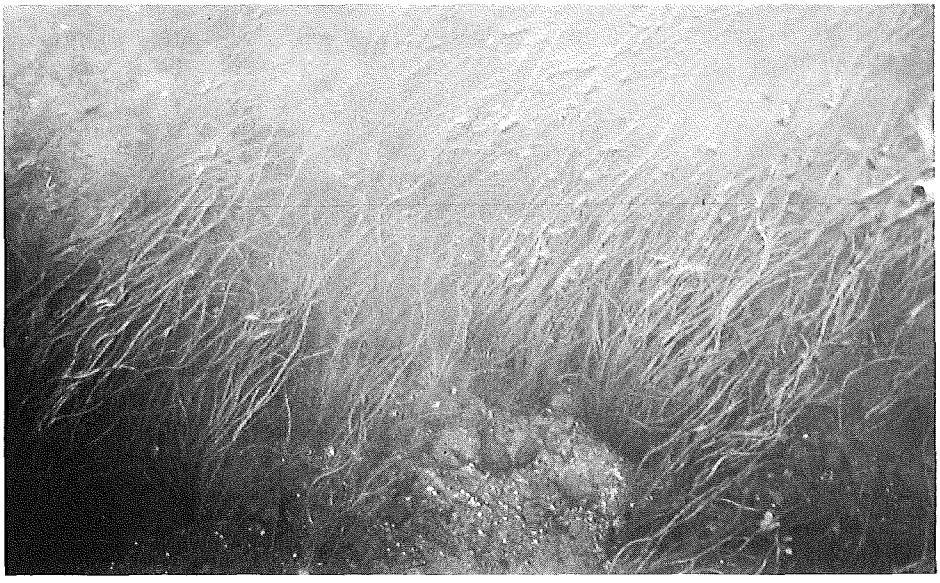


FIGURE 34. Lagoon with filamentous brown algae.

depth could be observed. *Monostroma grevillei, M. undulatum, Porphyra mintata, Ectocarpus fasciculatus, Elachista fucicola, Acrosiphonia* sp. and *Dictyosiphon foeniculaceus* were found in the epiphytic cover and *Chordaria flagelliformis, Palmaria palmata* and *Rhodomela lycopodioides* as companion species in the upper levels of the association. Lower down the eulittoral and in the upper sublittoral the density of the population and its floristic diversity decreased. Finally, the dominant species was devoid of epiphytes and companion species. In the undergrowth crustose floristic elements prevailed (*Hilden-*

FIGURE 35. Fucacean fields in Trékyllisvík (*Fucus vesiculosus* and *F. distichus* ssp. *edentatus*.

FIGURE 36. *Laminaria digitata* and *Alaria esculenta* beds in Trékyllisvík.

brandia rubra, Clathromorphum circumscriptum, Lithothamnion glaciale, Ralfsia verrucosa, R. fungiformis).

The *Devaleraea* association occurred likewise in a variant with the admixture of considerable quantities of *Rhodomela lycopodioides* and was found as such within Ófeigsfjörður and Trékyllisvík.

Different *Devaleraea ramentacea* associations from Icelandic waters were described previously in detail (MUNDA 1976 b).

Devaleraea ramentacea - Ulva lactuca. This summer association was found previously on the island of Grímsey and at the Snæfellsnes Peninsula (MUNDA 1977A, 1987). It was outstanding in Trékyllisvík where it covered locally the entire eulittoral zone on sand-covered rocks. The association was floristically rich (companion species: *Chordaria flagelliformis, Palmaria palmata, Rhodomela lycopodioides, Pilayella littoralis, Petalonia fascia*). The sandy layer prevented a development of crustose floristic elements in the undergrowth, where *Sphacelaria radicans* and *S. plumosa* dominated.

Chordaria flagelliformis is a typical association of cold-water regions of Iceland. Along Hornstrandir it was found only at one spot within Ófeigsfjörður.

Two low-level associations with an overall distribution in Icelandic waters and characteristic for semi-exposed sites were found likewise along Hornstrandir within fjords and in sheltered bays:

Acrosiphonia spp. - Pilayella littoralis occurs as belt below fucoids and is usually devoid of companion species. It was absent in the northernmost, exposed area of Hornstrandir.

Devaleraea ramentacea - Palmaria palmata - Rhodomela lycopodioides. The assemblage of three associated codominants occurs usually lower down than the association mentioned above. It was found all throughout Hornstrandir, with exception of the northernmost sites around Hornbjarg. The floristic composition corresponds to the one, described for the Dýrafjörður (MUNDA 1978) though *Ceramium* species and *Cystoclonium purpureum* were poorly represented within this belt.

Corallina officinalis. This low-level association is characteristic of Atlantic water regions in Iceland. Its northernmost limit was around Hornbjarg and it was absent all the way southwards along Hornstrandir. An enclave of this association was found again within Trékyllisvík (Fig. 40), where it was extremely prolific and alternated with a *Rhodomela lycopodioides* association. It is noteworthy that *Laethesia difformis* was a conspicuous epiphyte in this area, while it was absent in the tide-pool *Corallina* association northwards along Hornstrandir.

Rhodomela lycopodioides. This association was characteristic for Trékyllisvík, occupying the lowermost eulittoral and interrupting Fucacean fields. It alternated with the association, described above and was not found elsewhere along Hornstrandir (Fig. 41).

Petalonia spp. - Scytosiphon lomentaria is an inconspicuous association, which most usually interrupted the lower level of *Fucus distichus* ssp. *edentatus* fields. Locally it was found higher up than the *Devaleraea ramentacea* association.

TIDE POOL ASSOCIATIONS

A great variety of tide pool associations was found along the Hornstrandir coast. Atlantic and typical North Icelandic associations were found side by side. Their distribution is presented in Table 3.

In the level of the littoral fringe and in the upper eulittoral tide pools were inhabited by the same *Enteromorpha* spp. associations, as found in the Dýrafjörður and Reyðarfjörður. They exhibit, however, an overall distribution around the Icelandic coast:

Enteromorpha intestinalis* var. *asexualis* f. *cornucopiae inhabits pools at the level of *Prasiola stipitata*, and

Enteromorpha intestinalis* var. *intestinalis (accompanied by *E. compressa* and *E. clathrata*; locally by *E. prolifera*) pools were usual at the level of *Ulothrix* species. It was likewise found in pools among *Fucus spiralis* or *F. vesiculosus* settlements.

***Enteromorpha linza* - *Ulva lactuca*.** This association was especially prolific around Hornbjarg, found in pools of the mid-eulittoral. Crustose corallines and *Hildenbrandia rubra* were found in its undergrowth.

***Monostroma* spp.** including *M. grevillei* and *M. undulatum* was found likewise in mid-eulittoral pools and exhibited a similar distributional pattern as the association, named above. Assemblages of *Monostroma* species were found likewise on eulittoral slopes around Hornbjarg, interrupting *Acrosiphonia* spp. meadows.

FIGURE 37. *Devaleraea ramentacea* belt in Trékyllisvík - upper level.

***Acrosiphonia* spp.** This association was widely distributed along Hornstrandir. It was found in the mid-eulittoral in pools among *Acrosiphonia* spp. meadows or Fucacean fields. *Acrosiphonia grandis* was usually dominant within the association.

Cladophora oblitterata was association-forming in the upper and mid-eulittoral. It was found in sand-covered tide pools within Trékyllisvík while in the rest of the areas it occupied pools coated with crustose corallines.

Chaetomorpha melagonium. This association was found in fully insolated rocky pools of the mid-eulittoral. The dominant species was attached to an undergrowth of crustose corallines (*Clathromorphum circumscriptum, Lithothamnion* sp., *Phymatolithon lenormandii*) and was accompanied by *Acrosiphonia grandis, Corallina officinalis* and *Cladophora oblitterata.* The dominant species was epiphytized by *Ectocarpus fasciculatus*, dwarf *Ulva lactuca, Porphyra miniata* and *Dictyosiphon foeniculaceus.* The same association was found likewise in sandy pools in Trékyllisvík, depleted of the crustose undergrowth.

Stictyosiphon tortilis* - *Punctaria plantaginea is an association of the upper eulittoral level. Both codominant species formed separate associations in the western- and in the eastern fjords. This association was not found be-

FIGURE 38. *Devaleraea ramentacea* belt in Trékyllisvík - lower level.

tween Hornbjarg and Furufjörður, but was frequent around Drangar, in Ófeigsfjörður and Trékyllisvík.

Chordaria flagelliformis was association-forming in low-eulittoral pools as well as in splash pools. It was accompanied by other filamentous brown algae, such as *Dictyosiphon foeniculaceus* and *Ectocarpus siliculosus*, which occurred likewise in the epiphytic cover. Further epiphytes and companion species were *Petalonia fascia, Eudesme virescens, Ectocarpus fasciculatus* and *Scytosiphon lomentaria.*

Fucus distichus* ssp. *distichus was association-forming in tide pools of different eulittoral levels in Ófeigsfjörður, Norðurfjörður and Trékyllisvík. These pools were most frequently encountered at the mid-eulittoral level. The usual morphocline of the dominant species was found from the upper to the lower pools (cf. MUNDA 1983) with a similar gradient in the floristic composition as in the Dýrafjörður (MUNDA 1978).

Palmaria palmata is a widespread tide pool association along Hornstrandir, but was absent in the first investigated area. Its companion species were *Devaleraea ramentacea, Rhodomela lycopodioides, Chordaria flagelliformis* and *Acrosiphonia* species. Tide-pool specimens of *Palmaria* were usually heavily epiphytized by *Dictyosiphon foeniculaceus, Chordaria flagelliformis, Ectocarpus fasciculatus, Elachista fucicola, Ceramium rubrum* and by diverse microphytes, such as *Chilionema foecundum, C. occelatum, Microspongium globosum, Hecatonema maculans.*

Corallina officinalis is a tide pool association characteristic of Atlantic water regions of Iceland. Contrary to the low-level association of the same species, the tide pool one has a wider distributional range. It was found as prolific in the area below Hornbjarg and again in Ófeigsfjörður and in Trékyll-

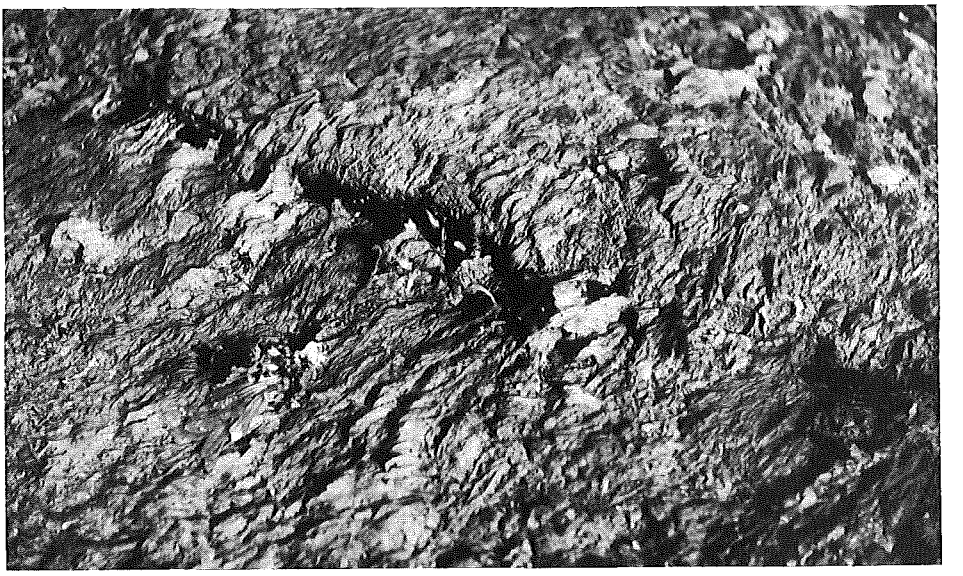


FIGURE 39. *Acrosiphonia* spp. belt in Norðurfjörður.

FIGURE 40. *Corallina officinalis* and *Rhodomela lycopodioides* populations in Trékyllisvík.

isvík, whereas the areas of Drangar and Eyvindarfjörður were devoid of *Corallina* associations. The dominant species occurred in an almost pure growth, with single *Eudesme virescens, Scytosiphon lomentaria, Chaetomorpha melagonium* and *Ceramium rubrum* as companion species. In the epiphytic cover *Leathesia difformis* was outstanding, especially in Trékyllisvík. Further species from the epiphytic stratum were dwarf *Ulva lactuca, Monostroma* sp., *Porphyra miniata* and *Audouinella* species. Crustose corallines, *Sphacelaria radicans* and *Ralfsia fungiformis* were common in the undergrowth. The floristic diversity was decreased if compared with the same association, described for the western fjords (MUNDA 1978).

***Ceramium* spp.** is likewise an association of warm-water regions of Iceland. It includes several *Ceramium* species (cf. MUNDA 1978) and *Cystoclonium purpureum* as the main companion species. For the Snæfellsnes Peninsula a codominance of both within the association was noticed (MUNDA 1987). This association was relatively rare along Hornstrandir, found in Ófeigsfjörður and Trékyllisvík. In the last named area *Dumontia contorta* was found locally within the association and could even appear as codominant. It is noteworthy, however, that Hornbjarg appeared as the distributional limit for several *Ceramium* species in Iceland.

Mastocarpus stellatus* - *Cladophora rupestris is a typical warm-water association, which had not been detected in any other area of the Icelandic coast. It was found only in Ófeigsfjörður in some sheltered pools with elevated water temperatures. *Mastocarpus stellatus* is a typical low level species in Iceland (MUNDA 1977b) and forms conspicuous, broad belts in southern, southwestern and northwestern Iceland. The distributional limit of this low level association is around Hornbjarg, where *Mastocarpus* occurred only in single specimens. It was absent from the vegetation all the way south to Ófeigsfjörður, where both tide-pool and lagoon associations of the same species were found. The displacements of the low-level *Mastocarpus* association to tide pools and lagoons is a characteristic feature of the Hornstrandir vegetation. In this association several companion species were found, such as *Acrosiphonia grandis, Ulva lactuca, Chaetomorpha melagonium, Chaetomorpha capillaris.* In the undergrowth there were crustose corallines (*Phymatolithon lenormandii, Lithothamnion* sp., *Clathromorphum circumscriptum*) and *Hildenbrandia rubra.*

Devaleraea ramentacea. This tide pools association is a characteristic feature of the North and East Icelandic vegetation and was still rare in the Dýrafjörður. It was described in detail (MUNDA 1976b). Its distributional pattern is wider than that of the low-level association and a high floristic diversity was found within all the strata of the association. The dominant species was usually heavily epiphytized by *Elachista fucicola* (reported as *Myriactula lubrica* in MUNDA 1976b), *Ectocarpus siliculosus, E. fasciculatus, Dictyosiphon foeniculaceus, Pilayella littoralis,* dwarf *Palmaria palmata, Ceramium areschougii, Acrosiphonia* sp., *Spongomorpha aeruginosa* and dwarf *Ulva lactuca,* occasionally also *Monostroma undulatum.*

This association was conspicuous in the vegetation south of Furufjörður and especially prolific in Trékyllisvík.

LAGOON ASSOCIATIONS

The configuration of coastal rocks in the different areas of Hornstrandir has created conditions for several typical lagoon associations. Their distribution is presented in Table 4.

Laminaria saccharina* f. *linearis with ***Corallina officinalis*** in the undergrowth was typical for rocky lagoons in the northernmost area of Hornstrandir (Fig. 6). Single *Alaria esculenta* plants were found within the association, whereas *Corallina* was accompanied by *Ceramium rubrum, Rhodomela lycopodioides, Chaetomorpha melagonium* and *Ulva lactuca.*

Corallina officinalis occupied shallow lagoons in the same area. Such lagoons were usual in the middle of fields populated by crustose corallines. The dominant species was accompanied by *Monostroma grevillei, Ulvaria obscura,* dwarf *Ulva lactuca, Chaetomorpha melagonium, Acrosiphonia grandis, Eudesme virescens* and *Scytosiphon lomentaria* and was devoid of epiphytes. In both types of lagoons crustose corallines, such as *Clatromorphum circumscriptum, Lithothamnion* sp., *L. glaciale* were usual in the undergrowth.

***Chorda filum* with filamentous brown algae** was a conspicuous association in sand-covered rocky lagoons (Fig. 34) found throughout Trékyllisvík and also in some sites within Ófeigsfjörður and around Drangar. Diverse filamentous brown algae were codominant with *Chorda filum* (*Chordaria flagelliformis, Dictyosiphon foeniculaceus, Ectocarpus siliculosus, Eudesme virescens, Stictyosiphon tortilis, Scytosiphon lomentaria* and *Petalonia* species). In the undergrowth *Sphacelaria radicans* was outstanding. Several species were found in the epiphytic cover of *Chorda,* such as *Ectocarpus fasciculatus, E. siliculosus* and diverse microphytes. As a variant of this association of filamentous brown algae a dominance of *Dictyosiphon foeniculaceus* was observed in shallow, near-shore lagoons.

Fucus distichus* ssp. *distichus as lagoon-association, was found in Ófeigsfjörður and Trékyllisvík. It was limited to the mid-eulittoral level and to rocky lagoons. A high floristic diversity was noted, *Palmaria palmata, Rhodomela lycopodioides, Devaleraea ramentacea, Chordaria flagelliformis, Dictyosiphon foeniculaceus, Petalonia* species, *Ulva lactuca, Scytosiphon lomentaria, Cystoclonium purpureum, Ceramium rubrum, Eudesme virescens* and *Acrosiphonia* species were present as common companion species. In the epiphytic cover of *Fucus, Elachista fucicola, Ectocarpus* species, *Spongonema tomentosum, Spongomorpha aeruginosa, Porphyra miniata* and *Monostroma* species were most usual, whereas in the undergrowth *Hildenbrandia rubra, Phymatolithon lenormandii, Clathromorphum circumscriptum, Audouinella purpurea, Polysiphonia urceolata, Ralfsia verrucosa* and *Sphacelaria radicans* were found on a rocky ground. In some sand-covered lagoons the undergrowth was reduced to *Sphacelaria radicans* and *Polysiphonia urceolata.* The dominant species occurred in different growth forms within the lagoons. A pronounced morphocline, dependent on the tidal level was found previously for this species (MUNDA 1978, 1981a, 1983).

Punctaria latifolia was association-forming in the extensive rocky lagoons around Árnesstapar, accompanied by *Saccorhiza dermatodea.* This as-

sociation was not found elsewhere along Hornstrandir. Diverse filamentous brown algae were richly represented within it.

Mastocarpus stellatus was found as an exceptional lagoon association in Ófeigsfjörður, in extensive land-locked lagoons around Öxl. The floristic composition was similar as in the above described tide pool association, in which *Cladophora rupestris* occurred as codominant. This species was richly repre-

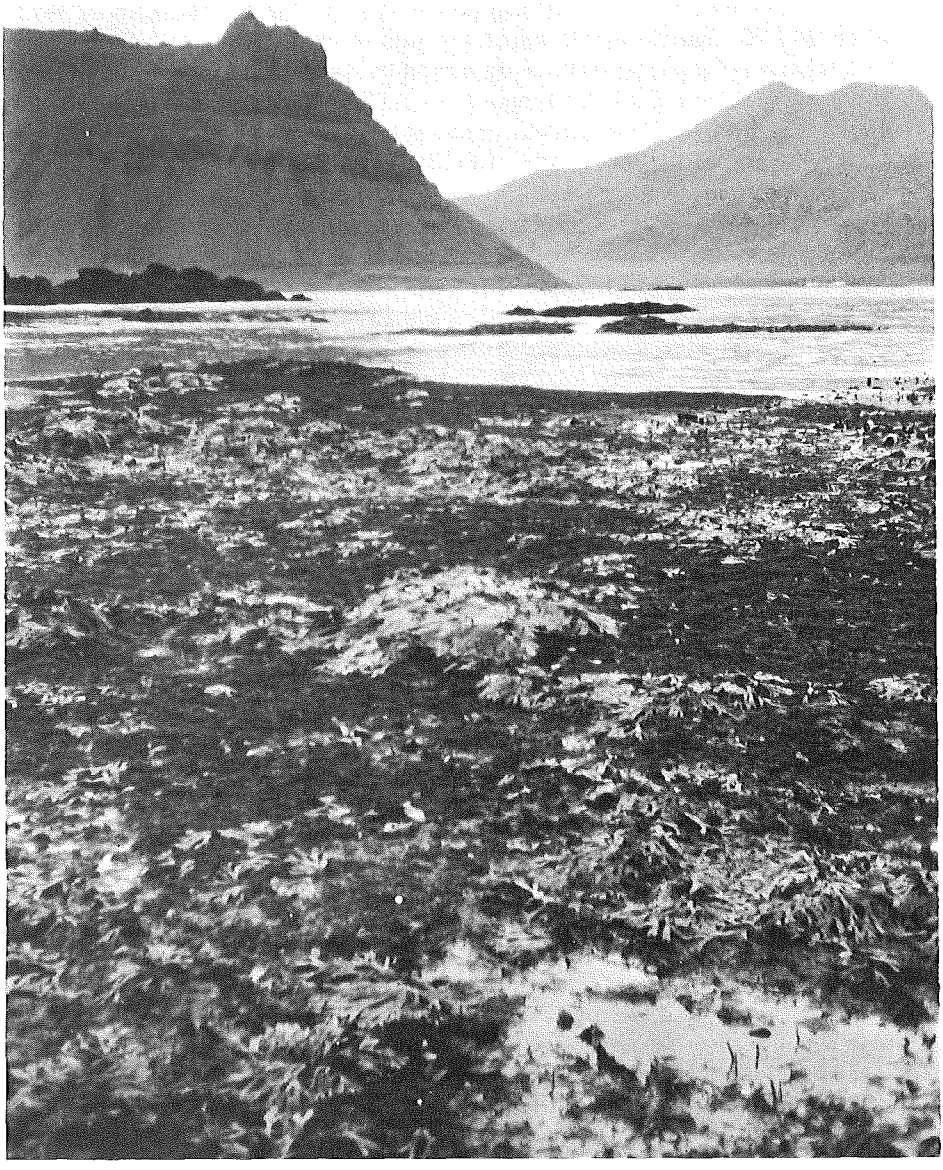


FIGURE 41. *Rhodomela lycopodioides* population in Trékyllisvík.

sented likewise within the lagoon association, along with *Monostroma* and *Acrosiphonia* species.

Contrary to the associations just described, those of *Devaleraea ramentacea* and of *Palmaria palmata* were wide-spread along Hornstrandir, with exception of the northernmost area. Extensive lagoons, situated in the mid-eulittoral and occupied by the two associations mentioned above, were outstanding around Drangar as well as in Trékyllisvík. A lagoon association of *Devaleraea ramentacea* was described previously for the Trékyllisvík area (MUNDA 1976b). A luxuriant growth of filamentous brown algae within the association was noted, both as companion species and as epiphytes.

Palmaria palmata formed a conspicuous lagoon association at Drangar, in Ófeigsfjörður and in Trékyllisvík, mostly in the mid-eulittoral in between the Fucacean fields. The dominant species occurred in different growth forms (cf. MUNDA 1981b) and was heavily epiphytized by *Ectocarpus fasciculatus, Elachista fucicola, Dictyosiphon foeniculaceus, Chordaria flagelliformis, Ceramium areschougii* and by diverse microphytes (*Chiltonema foecundum, C. ocellatum, Microspongium globosum*). Numerous companion species were

FIGURE 42. *Porphyra abyssicola* belt in Reykjarfjörður.

usual within this association, such as *Rhodomela lycopodioides, Ceramium* species, *Devaleraea ramentacea, Ulva lactuca, Chordaria flagelliformis, Dictyosiphon foeniculaceus, Monostroma grevillei, Ulvaria obscura, Cystoclonium purpureum, Dumontia contorta, Chaetomorpha melagonium.* In the undergrowth there were crustose corallines (*Phymatolithon lenormandii, Clathromorphum circumscriptum, Lithothamnion* sp., *L. glaciale*), *Ralfsia fungiformis, R. verrucosa* and *Sphacelaria radicans.*

ESTUARINE ASSOCIATIONS

were inconspicuous along the open coast-line of Hornstrandir. They were found locally around river outlets and on sandy slopes in Trékyllisvík around the estuary of the river Árnesá (Figs. 18, 19 and 33). A mixed association of diverse filamentous green algae was common in the oligohalinikum, including *Enteromorpha* species (*E. ahlneriana, E. prolifera, E. intestinalis*), *Percursaria percursa, Cladophora fracta,* and *Capsosiphon fulvescens.* It is noteworthy, that *Pilayella varia* coated usually small stones higher up the rivers than the filamentous green algae.

Fucus ceranoides with different filamentous brown algae, which occurred in entangled mats, was association-forming in the oligo- and mesohalinikum near outlets of big rivers (Hvalá, Húsá, Meyjará, Eyvindarfjarðará, Árnesá, Sýrá). The floristic composition of the association is salinity-dependent and varied with the distance from the river outlets. Beside the *Enteromorpha* species, named above, *Chaetomorpha capillaris, Dictyosiphon chordaria, D. foeniculaceus, Ectocarpus siliculosus, Pilayella littoralis* along with *Enteromorpha clathrata* were found, while *Percursaria percursa* and *Capsosiphon fulvescens* were absent. Single *Ulva lactuca, Porphyra purpurea* and *Monostroma grevillei* appeared in the mesohalinikum.

SUBLITTORAL ASSOCIATIONS

In the upper sublittoral along Hornstrandir two main associations predominated:

Alaria esculenta. This association followed the greater part of the Hornstrandir coast. *Alaria* was present in its narrow growth form. An uplift of its belt was observed under severe surf conditions. A vertical sequence in its undergrowth was observed in detail in the Norðurfjörður, where *Devaleraea ramentacea* and *Ulva lactuca* appeared at the upper level and *Rhodomela lycopodioides, Chordaria flagelliformis* and *Corallina officinalis* at the lower level. *Ralfsia verrucosa, R. fungiformis, Clathromorphum circumscriptum, Lithothamnion* sp., *L. glaciale, Polysiphonia urceolata* and *Sphacelaria radicans* were usual in the undergrowth all over the area.

Laminaria saccharina f. linearis alternated with the association, named above and exhibited a similar floristic composition. Single *L. digitata* could be found within the same belt. This association was found in sheltered sites and was rather common in Trékyllisvík (Fig. 38).

Laminaria hyperborea. This association belongs to the lower sublittoral and was inaccessible. From the driftweed it was possible to establish its dis-

tribution along open coast-lines and its floristic composition. Beside *Laminaria hyperborea*, the following species were common in the drift: *Desmarestia aculeata, D. viridis, Palmaria palmata* (giant specimens) *Rhodomela lycopodioides, Fimbrifolium dichotomum, Callophyllis cristata, Phycodrys rubens, Delesseria sanguinea, Polysiphonia arctica, Ptilota plumosa, P. serrata, Odonthalia dentata, Porphyra miniata.* In addition, *Audouinella purpurea, Petrocelis hennedyi, Polysiphonia urceolata, Peyssonnelia rosenvingii, Pseudolithophyllum orbiculatum* and *Rhodophysema elegans* were usual epiphytes on the stipes of *Laminaria hyperborea.*

This association was apparently absent in Trékyllisvík, where there are sandy slopes.

Regarding the Laminarian associations along Hornstrandir it became obvious that *Alaria esculenta* (in its narrow growth form) is dominant in the upper sublittoral of open and highly exposed coast-lines. It alternates with belts of *Laminaria saccharina,* which was outstanding within fjords and bays, whereas *L. digitata* was not association-forming in the area investigated.

SCIAPHILIC ASSOCIATIONS

were rare along Hornstrandir. Under overhanging rocks *Polysiphonia urceolata* was found associated with dwarf *Petalonia fascia, Scytosiphon lomentaria, Sphacelaria radicans, S. plumosa* and single *Corallina officinalis,* on an undergrowth of *Audouinella purpurea.*

Discussion and conclusions

The vicinity of Hornbjarg in the extreme Northwest is considered as the northernmost boundary of typical Atlantic regions of Iceland regarding the benthic algal vegetation. They include the South, Southwest and Northwest of Iceland and are characterized first of all by low-eulittoral associations of *Mastocarpus stellatus,* of *Corallina officinalis,* and *Callithamnion sepositum;* and secondly by tide pool associations of *Ceramium* species with *Cystoclonium purpureum,* of *Corallina officinalis, Chondrus crispus, Ahnfeltia plicata* and *Dumontia contorta.*

From the hydrographic aspect the North Icelandic coastal area is still influenced by the Irminger Current waters as well as by other primary and secondary water masses. In this mixing area, where the proportion of Atlantic water gradually decreases from west to east, a particular North Icelandic vegetation pattern has developed (MUNDA 1975). It is characterized by low-eulittoral associations of *Devaleraea ramentacea,* of *Chordaria flagelliformis* and by extensive meadows of *Acrosiphonia* species, which cover low- and mid-eulittoral slopes and can likewise interrupt the Fucacean fields. In the tide pools, associations of *Devaleraea ramentacea, Chordaria flagelliformis* with diverse filamentous brown algae and of *Acrosiphonia* species were common in northern Iceland. A characteristic feature of the tide pool vegetation was a high proportion of *Ralfsia fungiformis* in the undergrowth.

The Hornstrandir coast, which is treated in detail in the present contribution, is a transitional area between the two vegetation types, as far as its

northernmost area is concerned viz. the coast-line between Hornbjarg and Furufjörður (I area).

Off Hornbjarg there is a pronounced hydrographic discontinuity (STEFÁNSSON 1954, 1962, 1969b, 1984, MALMBERG 1969, TÅNING 1943) created by the diminished influx of Atlantic water, intrusion of cold water masses from the East Greenland Current and the influence of drift ice, which varies from year to year. This hydrographic limit is reflected in a rather sharp distributional boundary for several species of benthic algae and for the low-eulittoral associations, mentioned above.

On the contrary, tide pool associations of *Ceramium* species with *Cystoclonium purpureum* and of *Corallina officinalis* have a wider distributional pattern (cf. MUNDA 1981a) and were found all along the North Icelandic coastal area, where they alternate with the typical North Icelandic tide pool associations, named above. Associations of *Chondrus crispus*, *Ahnfeltia plicata* and *Dumontia contorta* are, on the other hand, limited only to the South and Southwest of Iceland (MUNDA 1976a, 1980a,b, 1987).

After an abrupt vegetational change around Hornbjarg, compared to conditions in the western fjords (e.g. Dýrafjörður, Önundarfjörður, Súgandafjörður) a particular vegetation pattern was observed, which belongs neither to the typical Atlantic nor to the North Icelandic vegetation type. The high-level belts of *Ulothrix* spp. - *Urospora* spp. were wider and more pronounced than on the western side of the NW peninsula. In the mid- and lower eulittoral wide *Acrosiphonia* spp. meadows were observed. Such meadows were still rare and inconspicuous in the western fjords. They alternated with wide fields of crustose corallines, which locally occupied the greater part of the eulittoral slopes. Such fields were found sublittorally in some spots outside the western fjords. Around Hornbjarg they occurred in the mid- and lower eulittoral and were almost bare of companion species. They were most usually fringed by pure belts of *Palmaria palmata*, whereas the lowermost eulittoral belt was represented by codominant *Antithamnionella floccosa* - *Polysiphonia urceolata*. The absence of either typical low-eulittoral belts (viz. Atlantic or North Icelandic ones) and the bare surfaces covered by crustose corallines could be tentatively explained by the adverse conditions in the northernmost area of Hornstrandir and the occasional scouring effects of drift ice.

In the tide pools and extensive lagoons around Hornbjarg *Corallina officinalis* was outstanding, either for itself or as undergrowth of *Laminaria saccharina*. Green algae were prolific in the summer vegetation of this area, both in tide pools and on eulittoral slopes (*Ulva lactuca*, *Enteromorpha linza*, *Monostroma* species), while fucoid stands were reduced due to the high exposure of this area. *Fucus distichus* ssp. *anceps* and *F. distichus* ssp. *edentatus* were the main fucoids found in the northernmost area of Hornstrandir. On horizontal slopes, which follow below vertical rocky walls, *Fucus spiralis* and *F. vesiculosus* joined the Fucacean fields (cf. Fig. 5); while *Ascophyllum nodosum* was absent. The absence of an *Ascophyllum nodosum* association was one of the characteristic features of the entire Hornstrandir coast investigated. This fucoid occurred only locally in single specimens or in patches, as

e.g. in Bjarnarfjörður N and Trékyllisvík, while it was dominant on the western side of the NW peninsula.

The typical North Icelandic low-level association of *Devaleraea ramentacea* appeared gradually along the coast-line between Látravík and Furufjörður (cf. MUNDA 1975, 1976b), where the first narrow *Devaleraea* belt was observed (Figs. 25b, 30). It was formed by a downwards extension of the Fucacean undergrowth. South of Látravík, however, the *Devaleraea* component increased gradually in the tide pool vegetation and as Fucacean undergrowth, with a simultaneous decrease of *Corallina officinalis*. The *Corallina* component in the vegetation was negligible south of Látravík and its association absent all the way south to the eastern banks of the Ófeigsfjörður.

Devaleraea ramentacea, on the other hand, formed wide and prolific belts south of Furufjörður, as e.g. in the Bjarnarfjörður N, along the Drangar area as well as farther southwards (Figs. 26, 27, 28, 31, 37, 38). It was likewise dominant in most low-level tide pools and lagoons. Along with *Devaleraea ramentacea* also *Acrosiphonia* species increased in abundance (Figs. 26,27, 32, 39) both in tide pools and on low-eulittoral slopes. The associations of these species are the main characteristic features of the North Icelandic vegetation pattern. Furufjörður could hence be considered as its northwesternmost boundary.

We might conclude, however, that Hornbjarg represents the NW distributional boundary for the typical Atlantic vegetation pattern in Iceland, while the area south of it, to Furufjörður, bears a non-typical vegetation. The Atlantic vegetation pattern thus exhibits an abrupt discontinuity, whereas the North Icelandic one is formed gradually along the northernmost area of Hornstrandir.

Farther south within the entire area investigated, enclaves of Atlantic vegetation features, mainly regarding tide pool associations, were again found within the sheltered areas of Ófeigsfjörður and Trékyllisvík. There *Corallina officinalis* was quite prolific in the tide pools and lagoons, reaching its maximum abundance within Trékyllisvík. During the second observation period, in 1980, its quantity was even increased, indicating more favourable temperature conditions than previously. At this time, mats of *Corallina officinalis* were locally found in the lower eulittoral, as in the western fjords (Figs. 29, 40). They alternated with prolific mats of *Rhodomela lycopodioides* (Fig. 41). The Atlantic character of the vegetation was accentuated also by increased quantities of *Ceramium* species, *Cystoclonium purpureum* and *Dumontia contorta* in the tide pools, as well as of *Leathesia difformis*, which was epiphytic on *Corallina*. The latter species was rare in the northernmost area of Hornstrandir, where *Dumontia contorta* was absent. *Dumontia* was still rare in the Ófeigsfjörður and had not been detected during the first period of field studies along Hornstrandir. It was likewise rare in the western fjords. In this connection the tide pool association of *Mastocarpus stellatus*, detected within Ófeigsfjörður, should be mentioned. It was accompanied by *Cladophora rupestris*. *Mastocarpus* was rare or absent along Hornstrandir, while it forms conspicuous and broad belts along the greater parts of southern, southwestern and northwestern coastal areas of Iceland. Its displacement from the

lower eulittoral into tide pool habitats was a further characteristic feature of the Hornstrandir vegetation.

The irregular distribution of *Corallina officinalis*, *Ceramium* species, *Cystoclonium purpureum*, *Dumontia contorta*, *Mastocarpus stellatus*, *Cladophora rupestris* and *Leathesia difformis* cannot be explained in terms of the temperature data available. It was obvious, however, that the rather sheltered areas within Ófeigsfjörður and Trékyllisvík, with their extensive lagoons, are favourable for the formation of enclaves of Atlantic water associations in the tide pools, and locally likewise on low-eulittoral slopes. In Trékyllisvík, however, North Icelandic and Atlantic vegetation features mingle.

Long-term variations of vegetation patterns along Hornstrandir refer likewise to the even diminished amounts of *Ascophyllum nodosum* within fucoid fields. They could relate to annual variations of the surface water temperatures, in particular to the critical winter minima, as well as to severe ice seasons, which occurred between the periods of field studies along Hornstrandir.

The distribution of benthic algae has been most often interpreted in terms of surface water temperatures (e.g. SETCHELL 1915, 1920, HUTCHINS 1947, KAPRAUN 1980, van den HOEK 1982a, 1982b, 1984, SEARLES 1984). Van den HOEK (1975, 1984) had established phytogeographic regions on the basis of ocean isotherms. Thus Iceland falls within the limits of the cold temperate NE Atlantic region, shared with the Faeröes and the Norwegian coast as a whole. These two regions have relatively uniform temperature conditions and vegetation patterns, due to the influence of Atlantic water masses. Iceland, on the other hand, is surrounded by water masses of widely different origins and thermal regimes, which create dissimilar vegetation patterns within a relatively small area.

Recent studies have revealed, however, that markedly dissimilar vegetation types occur along the eastern and western side of the NW peninsula of Iceland, viz. along the same latitudinal range. These differences can only be explained by the differnt temperature regimes and amounts of drift ice on both sides of this peninsula.

Further studies about temperature responses of individual species, which are outstanding in the different vegetation patterns, would be needed in order to elucidate their distributional boundaries. Experimental tests of temperature and combined temperature-daylight responses were already carried out by e.g. BOLTON (1983), LÜNING (1980, 1984), MCLACHLAN and BIRD (1984), YARISH et al. (1984) and STEWART (1984) for several species of benthic algae. Strains of *Dumontia contorta* from southern Iceland were tested for their temperature and daylight responses by RIETEMA and van den HOEK (1984) and *Scytosiphon lomentaria* strains from northern Iceland by LÜNING (1980). *Devaleraea ramentacea* from northern Iceland was studied under different temperature conditions by MUNDA (1977c). This circumpolar species exhibited its maximum growth rate at temperatures between 6° and 9° C, which correspond to summer temperatures in Iceland. Growth was delayed at 15°C, a temperature never achieved in Iceland, while 18°C proved to be lethal.

It seems likely, however, that the ranges of temperature tolerance of individual species are the key to answer phytogeographic questions.

The descriptive phase of the present work may therefore initiate further investigations into the autecology of some species which are characteristic of the different vegetation patterns in Iceland.

Floristic list

The distribution of most conspicuous species found along Hornstrandir is presented in Table 5. Not all the microphytes are included. Data on sublittoral species were collected on the basis of driftweed. Hence not all the crustose corallines from deeper water layers are mentioned in the list.

The aim of this study was, however, a survey of the eulittoral and upper sublittoral vegetation along Hornstrandir, with emphasis on the gradual formation of a typical North Icelandic vegetation pattern.

The abundance of species in the four areas investigated is presented in accordance to the same scale as in previous works:

A = abundant; M = relatively abundant; R = rare; RR = very rare; S = single specimens; D = dominant within the association; CD = codominant.

The mode of occurrence is presented in terms of littoral levels: U = upper eulittoral and littoral fringe; M = mid-eulittoral; L = lower eulittoral; TP = tide pools and lagoons; S = sublittoral; F = rocky fissures and shady habitats; and substrate configurations: R = rock; SR = sand-covered rock; S = sand.

Basically the check-list of PARKE and DIXON (1976) was used for floristic lists of different areas of the Icelandic coast (e.g. MUNDA 1976a, 1977a, 1978, 1979, 1980a,b, 1983, 1985, 1987). A regrouping of the Rhodophyta and the Phaeophyceae (Fucophyceae) along with nomenclatural changes was carried out in accordance with recent works of DIXON and IRVINE (1977), IRVINE (1983), BOLD and WYNNE (1978), GUIRY (1978), GUIRY et al. (1984), CHRISTENSEN (1980), PEDERSEN (1978a,b, 1979, 1984) and FLETCHER (1981, 1984, 1987).

For the Chlorophyta the works of BLIDING (1963, 1968), SÖDERSTRÖM (1963), van den HOEK (1963), KORNMANN (1962, 1970) and KORNMANN and SAHLING (1962, 1977) were considered. Species of the genus *Cladophora* were not treated in detail because of their exceeding polymorphism and lack of possibilities to cultivate and study living material. The genus *Acrosiphonia* from Icelandic waters needs further revision. The same is true also for some genera of the Rhodophyta, as e.g. representatives of the genus *Ceramium* (cf. GARBARY et al. 1978).

Of the total recorded species along Hornstrandir 40% belong to the Phaeophyta, 32% to the Rhodophyta and 28% to the Chlorophyta. In the Dýrafjörður, on the other hand, red algae were numerically best represented and the Rh/Ph ratio was 1.2. At Hornstrandir the Rh/Ph ratio was 0.8, like in the East of Iceland.

These estimations are, however, approximate, since not all floristic elements were included in our surveys.

TABLE 5. Species distribution along Hornstrandir.

Area	I	II	III	IV	Tidal level	Substrate	Association-forming	Remarks
RHODOPHYTA, Bangiophyceae								
Bangiales, Bangiaceae,								
Bangia atropurpurea (Roth.) C.Ag.	A	M	M		U	R	D	
Porphyra purpurea (Roth.) C.Ag.		R	R	R	U,M,	SR,S		near estuaries
P. umbilicalis (L.) J.Ag.	A	A	A	R	U	R	D	
P. miniata (C.Ag.) C.Ag.	M	M	M	R	S, TP	R, various host plants		
P. abyssicola Kjellm.		M	R	A	M,L	R, SR		
Florideophyceae								
Nemaliales, Acrochaetiaceae								
Audouinella purpurea (Lightf.) Woelk	M	M	A	R	U,M,TP,L.	R, Laminaria hyperborea stipes		
A. spetsbergensis (Lightf.) Woelk.		R	R	RR	L, S	R, Hydrozoa		
A. parvula (Kylin) Dixon	R	RR	RR	RR	L, S	epiphytic on various host plants		
A. virgatula (Harv.) Dixon			RR	RR	L, TP, S	epiphytic on Corallina		
A. alariae (Jónss.) Woelk.		R	R		TP, S	on Alaria esculenta from lagoons		
Gigartinales, Cruoriaceae								
Cruoria pellita (Lyngb.) Fries		R	R	RR	TP, S	R, Laminaria hyperborea hapterae		tentatively tetrasporangial phase of Turnerella pennyi (South et al., 1972)
Rhodophyllidaceae								
Cystoclonium purpureum (Huds.)Batt.	R	R	M	A	TP, M	R	CD in pools	
Fimbrifolium dichotomum (Lepech.) Gobi	R	M	R	RR	S	R		
Soleriaceae								
Turnerella pennyi (Harv.) Schmitz		R	R		S	R		in the driftweed
Gigartinaceae								
Mastocarpus stellatus (Stackh. in With.) Guiry	S		A		TP	R	D and CD	forming in enclave in Ófeigsfjörður
Petrocelis hennedyi (Harv.) Batt.	R	RR	R		S	R, stipes of Laminaria hyperborea		
Cryptomeniales, Dumontiaceae								
Dumontia contorta (Gmel.) Rupr.			R	A	TP, M	R	locally CD in pools	
Kallymeniaceae								
Callophyllis cristata (C.Ag.) Kütz.	R	RR	M	RR	S	R, Laminaria hyperborea hapterae		
Peyssonneliaceae								
Peyssonnellia rosenvingii (Schm.) in Rosenv.	RR		RR		S	stipes of Laminaria hyperborea		
Palmariales, Palmariaceae								
Palmaria palmata (L.) O.Kuntze	A	A	A	A	U,M,L, TP,S	R	D in pools and low eulittoral	extremely abundant and widespread (cf. Munda 1976, 1981b)
Devaleraea ramentacea (L.) Guiry	R	A	A	A	U,M,L, TP,S	R	D and CD in various associations in different growth forms	
Rhodophysema elegans (Crouan frat.) Dixon	RR	R	R	R	L, TP, S	R and epiphytic		
Hildenbrandiales, Hildenbrandiaceae								
Hildenbrandia rubra (Sommerf.) Menegh.	M	M	M	R	U,M,L, TP,S	R	undergrowth in tide pools	
Corallinales, Corallinaceae								
Corallina officinalis L.	A		M	A	TP,M,L,S	R	D	dominant in pools and lagoons following Adey (1968)
Lithothamnion sp.	A	M	M	M	TP,L,S	R		a common, yet undetermined species
Lithothamnion glaciale Kjellm.	A	M	M	R	TP,S	R		
Leptophytum laeve (Strömf.) Adey	R	RR	RR		S	R		in the driftweed

TABLE 5, continued:

Area	I	II	III	IV	Tidal level	Substrate	Association-forming	Remarks
Phytatolithon lenormandii (Aresch.) Adey	M	M	M	R	M,L,S	R		undergrowth in tide pools
P. laevigatum (Foslie) Foslie			RR	R	M,L,S	R		near estuaries
Clathromorphum circumscriptum (Strömf.) Foslie	A	A	M	M	TP,L,S	R		conspicuous on the fields of crustose corallines
Pseudolithophyllum orbiculatum (Foslie) Lemoine	R	RR	RR	RR	S	R, stipes of Laminaria hyperborea		
Ceramiales, Ceramiaceae								
Antithamnionella floccosa (O.F.Müll.) Whittick	A	M	RR	RR	L,S	R	CD	northernmost area
Antithamnion boreale (Gobi) Kjellm.		RR	RR		S	on Ptilota plumosa		
Ceramium rubrum (Huds.) C.Ag.	R	RR	M	A	M, TP, L	R, epiphytic	D and CD	
C. areschougii Kylin	M	R	R	A	M, TP, L	R, epiphytic	CD	
C. strictum Harvey	R		R	M	M, TP	R, epiphytic	CD	
Ptilota serrata Kütz	R	M	M	M	S	R, epiphytic		
P. plumosa (L.) C.Ag.	R	M	M	M	S	R, epiphytic		
Delesseriaceae								
Delesseria sanguinea (Huds.) Lam.	R	R	M	M	S	R and epiphytic on Laminaria hyperborea stipes		
Phycodrys rubens (L.) Batters.	R	M	M	M	S	R and epiphytic		
Rhodomelaceae								
Polysiphonia arctica J.Ag.	RR	RR	R		S	R		in the driftweed
P. urceolata (Lightf.) Grev.	A	A	A	A	M,TP,L,F,S, S	R, epiphytic on Laminaria hyperborea stipes	CD	belt-forming with Antithamnionella floccosa
Odonthalia dentata (L.) Lyngbn.	R	R	R	R	S	R		
Rhodomela lycopodioides (L.) C.Ag.	A	A	A	A	M,L,TP,S	R, epiphytic on Laminaria hyperborea	D and CD	treated separately from R. confervoides
R. confervoides (Kütz.) Silva	R	M	M	A	TP	R		
PHAEOPHYTA, Phaeophyceae								
Ectocarpales, Ectocarpaceae								
Ectocarpus siliculosus (Dillw.) Lyngb.	R	R	M	A	U,M,TP	R, epiphytic on various hosts		conspicuous among filamentous algae in lagoons and estuaries
E. fasciculatus Harv.	R	R	M	A	TP,M,L	R, epiphytic on various hosts		
Spongonema tomentosum (Huds.) Kütz.		R	R	M	TP,U,M,L,	R, epiphytic on fucoids		
Giffordia ovata (Kjellm.) Kylin			RR	RR	S	epiphytic on Ptilota species		
Lithodermataceae								
Pseudolithoderma extensum (Crouan frat.) Lund.	RR		RR	RR	TP,L,S	R, crustose corallines		
Petroderma maculiforme (Wollny) Kuckuck			R	R	TP,L	R		
Elachistaceae								
Elachista fucicola (Vell.) Aresch.	R	A	A	A	U,TP,M,L	on fucoids, Devaleraea ramentacea, Palmaria palmata, Chaetomorpha melagonium, Ulva lactuca, Porphyra species		epiphytic on tide pool specimens, referred as Myriactula lubrica (Rupr.) Jaasund in previous works (Jaasund 1965).
Leptonematella fasciculata (Reinke)Silva		RR	RR	RR	TP,S	Laminaria fronds		
Corynophlaeaceae								
Leathesia difformis (L.) Aresch.	RR		R	A	TP,L	R, on Corallina officinalis		
Myrionemataceae								
Microspongium globosum Reinke			M	A	TP,L,S	on Palmaria palmata and other hosts		

TABLE 5, continued:

Area	I	II	III	IV	Tidal level	Substrate	Association-forming	Remarks
Myrionema corunnae Sauv.			RR	RR	L,S	on Laminaria fronds		
Myrionema strangulans Grev.		RR	RR	RR	TP,M,L,	on various hosts		
Ulonema rhizophorum Foslie				RR	TP	on Dumontia contorta		
Myriogloeaceae								
Microsiphar porphyrae Kuckuck			R	R	L,S	on Porphyra miniata		
M. polysiphoniae Kuckuck	RR			R	TP,L	on Polysiphonia urceolata		
Chordariaceae								
Chordaria flagelliformis (O.F.Müll.) J.Ag	R	M	A	A	U,M,TP,L,S	R, various hosts	D-upper eulittoral, D-lower eulittoral, CD-lagoons	
Eudesme virescens (Carm. ex Harv. in Hook.) C.Ag.	R	R	M	M	M,TP,L	R		
Mesogloia vermiculata (Sm.) S.F.Gray				RR	TP	R		
Phaeostroma pustulosum Kuckuck			R	R	TP,L	on Chordaria flagelliformis and Dictyosiphon spp.		
Tilopteridales, Pogotrichaceae								
Pogotrichum filiforme (Reinke) Batters			RR	RR	TP,S	on Laminaria saccharina		sensu Pedersen (1978a)
Pilayellaceae								
Pilayella littoralis (L.) Kjellm.	M	A	A	A	U,TP,M,L,	R,SR,S, epiphytic on various hosts		
P. varia (L.) Kjellm.		R	R	M	U,M	R,SR	pioneer in estuaries	
Isthmoplea sphaerophora (Harv.) Kjellm.	RR	RR	RR	RR	U,M	R		
Myriotrichaceae								
Litosiphon laminariae (Lyngb.) Harv.	R		RR	RR	TP,L,S	on Chorda filum, Saccorhiza dermatodea, and Laminaria sp.		
Myriotrichia clavaeformis Harv.			R	M	TP,L	on Punctaria latifolia		Pedersen (1978b)
Punctariaceae								
Punctaria latifolia Grev.				A	TP	R,SR	D	giant specimens in lagoons
P. plantaginea (Roth.) Grev.	RR	R	M	A	TP	R	CD	
Chilionema foecundum (Strömf.)Fletcher		R	M	A	TP,L	on Palmaria palmata		Fletcher (1987)
C. occelatum (Kütz.)Kuckuck			R	R	TP,L	on Palmaria palmata		
Hecatonema maculans (Collins) Sauv.	RR	R	RR	RR	TP,L,S	on Palmaria palmata and Laminaria fronds		Fletcher (1984)
Dictyosiphonaceae								
Dictyosiphon foeniculaceus (Huds.) Grev.	R	A	A	A	TP,M,L	R, on Chordaria flagelliformis and other hosts		outstanding in tide pools and lagoons
D. chordaria Aresch.			M	M	M,TP	R,SR,S		near estuaries
D. ekmani Aresch.			RR		M	on Scytosiphon lomentaria		
Striariaceae								
Stictyosiphon tortilis (Rupr.) Reinke	R	M	M	A	TP	R	CD	
Scytosiphonales, Scytosiphonaceae								
Scytosiphon lomentaria (Lyngb.) Link.	M	M	M	A	U,TP,M,L	R	CD	previously S. pygmaeus Reinke treated separately
Petalonia fascia (O.F.Müll.) Kuntze	R	R	M	A	M,TP	R	CD	
P. zosterifolia (Reinke) Rosenv.	R	R	R	M	M,TP,L	R	CD	
P. filiformis (Batt.) Kuntze	R	R	R	R	U	R	CD	Fletcher (1981)
Ralfsia verrucosa (Aresch.) J.Ag.	M	M	A	A	U,M,TP,L	R		
R. fungiformis (Gunn.) Stech et Gardn.	M	A	A	A	TP,M,L,S	R		undergrowth in most tide pools
R. spp.	M	M	M	M	TP,M,L	R		includes undetermined crustose brown algae

TABLE 5, continued:

Area	I	II	III	IV	Tidal level	Substrate	Association-forming	Remarks
Desmarestiales, Desmarestiaceae								
Desmarestia aculeata (L.) Lam.	M	M	M	M	S	R		
D. viridis (O.F.Müll.) Lam.		RR	R	R	TP,S	R		
Sphacelariales, Sphacelariaceae								
Sphacelaria radicans (Dillw.) C.Ag.	A	A	A	A	TP,M,L,S,F	R,SR,S		undergrowth in most associations
S. britannica Sauv.		RR	RR	RR	TP,F	R		
S. plumosa Lyngb.	M	M	R	M	TP,F	R		
Laminariales, Chordaceae								
Chorda filum (L.) Stackh.		R	M	A	TP,L,S	R,SR	D	
Laminariaceae								
Laminaria saccharina (L.) Lam. f. linearis J.Ag.	A	A	A	A	TP,S	R	D in lagoons and upper sublittoral	
L. digitata (Huds.) Lam.	R	R	M	R	TP,S	R		subordinate in the vegetation
L. hyperborea (Gunn.) Foslie	M	M	A	R	S	R	D	heavily epiphytized
Saccorhiza dermatodea (De la Pyl.) J.Ag.				M	TP	R	CD	
Alariaceae								
Alaria esculenta (L.) Grev. (narrow growth form)	A	A	A	A	TP,S	R	D	dominant in the upper sublittoral
Fucales, Fucaceae								
Fucus ceranoides L.			R	R	M,L	SR,S	D and CD	in estuaries
Fucus spiralis L.	R	M	M	M	U	R	D	a subordinate Fucacean association
Fucus vesiculosus L.	M	M	A	A	M	R	D	found in different growth forms
Fucus distichus L. emend. Powell ssp. ssp. ssp. evanescens (C.Ag.) Powell		R	M	R	M	R,SR		
ssp. edentatus (De la Pyl.) Powell	A	A	A	A	M,L	R	D	dominant fucoid along Hornstrandir
ssp. anceps (Harv. et Ward. ed Carruthers) Powell	A	A	A	M	U,M	R	D	
ssp. distichus Powell	R	R	A	A	TP	R	D	found in different growth forms
Ascophyllum nodosum (L.) Le Jol.		RR	RR	RR	M	R		subordinate in the vegetation
CHLOROPHYTA, Chlorophyceae,								
Ulotrichales, Ulotrichaceae								
Ulothrix flacca (Dillw.) Thur.	A	A	M	R	U	R	D	wide belt on rocky walls near Hornbjarg
U. pseudoflacca Wille	A	M	M	RR	U	R	CD	
U. subflaccida Wille	M	M	RR	RR	U	R	CD	
Stichococcus marinus (Wille) Hazen	RR				U	R		on highly exposed rocks
Chaetophorales, Chaetophoraceae								
Pseudopringsheimia fucicola (Rosenv.) Wille	RR	RR	RR	RR	U,M,L	on fucoids		
Codiolales, Codiolaceae								
Urospora wormskioldii (Mert. in Hornem.) Rosenv.	M	M	RR	RR	U,M	R		on pebbles
Urospora penicilliformis (Roth.) Aresch.	A	A	M	R	U	R	CD	
Prasiolales, Prasiolaceae								
Prasiola stipitata (Suhr.) in Jessen	M	M	R	RR	U	R	D	littoral fringe together with Lichens Xanthoria parietina and Verrucaria sp.

TABLE 5, continued:

Area	I	II	III	IV	Tidal level	Substrate	Association-forming	Remarks
P. crispa (Lightf.) Menegh.	R	R	RR		U	R		
P. furfuracea (Mertens) Menegh.	RR	RR			U	R		
Rosenvingiella polyrhiza (Rosenv.) Silva	RR	RR	RR		U	R		
Ulvales, Ulvaceae								
Ulva lactuca L.	A	A	A	A	U,M,TP,L	R and epiphytic	CD	with Devaleraea ramentacea-low eulittoral with Enteromorpha linza in tide pools
Ulvaria obscura (Kütz.) Gayral	M	M	R	RR	M,TP	R,SR		
Blidingia minima (Näg. ex Kütz) Kylin	A	A	M	M	U	R	D	wide belts on exposed rocks, protruding to the level of the littoral fringe
B. marginata (C.Ag.) Dang.	M	M	M	A	U	R		
B. chadefaudii (Feldm.) Bliding	A	A	M	M	U	R	CD	
Enteromorpha intestinalis (L.) Link.	A	A	A	A	U,M	R and epiphytic	D	prolific in estuaries
var. asexualis Bliding f. cornucopiae Lyngb.		M	M	RR	U,TP	R	D	in uppermost tide pools
var. intestinalis Bliding		M	M	M	U,TP	R	D	in tide pools
E. linza (L.) J.Ag.	A	A	A	A	TP,M,L	R	CD	in tide pools and on littoral slopes
E. compressa (L.) Grev.	A	A	M	A	TP,M	R		mainly in tide pools
E. clathrata (Roth.) Grev.	M	M	M	M	TP,U,M	R and epiphytic		in tide pools and near estuaries
E. ahlneriana Bliding		R	M	M	U,M	SR, S	CD	in estuaries (Bliding 1963)
E. prolifera (O.F.Müll.) J.Ag. (incl. subsp. prolifera Bliding and subsp. radiata Bliding).	A	A	A	A	U,M,TP	R,SR,S and epiphytic		in different growth forms in tide pools and estuaries
Capsosiphonaceae								
Capsosiphon fulvescens (C.Ag.) Setch. et Gardn.			M	M	U,M	SR,S		in estuaries
Percursariaceae								
Percursaria percursa (C.Ag.) Rosenv.			R	M	U	SR,S		in estuaries
Monostromataceae								
Monostroma grevillei (Thur.) Wittr.	A	A	A	A	TP,M	R and epiphytic	CD	outstanding around Hornbjarg as Ulvopsis grevillei (Thur.) Gayral in Gayral (1965).
Monostroma undulatum Wittr.	A	A	A	A	TP,M	R and epiphytic	CD	
Cladophorales, Cladophoraceae								
Rhizoclonium riparium (Roth.)Harv.	R	R	R	RR	U	R	D	
Cladophora rupestris (L.) Kütz.	R	R	A	A	TP,M,L	R	CD	rare around Hornbjarg and prolific longer south
C. oblitterata Söderström	A	A	A	A	TP,M	R,SR	D	sensu Söderström (1963)
C. fracta (Vahl) Kütz.		R	M	M	U,M	SR,S		in estuaries
Chaetomorpha capillaris (Kütz.) Börg.		RR	RR	R	TP	SR,S		in loose mats
C. melagonium (Web. et Mohr.) Kütz.	A	A	M	A	TP,M	R	D	
Acrosiphoniales, Acrosiphoniaceae								
Acrosiphonia grandis Kjellm.	A	A	A	A	M,L,TP	R	CD	Kornmann (1962, 1970)
A. centralis (Lyngb.) Kjellm.	A	A	A	A	L,TP	R	CD	Acrosiphonia species were
A. sonderi (Kütz) Kornm.	M	M	M	A	M,TP	R	CD	codominant in tide pools and
A. arcta (Dillw.) J.Ag.	M	M	R	R	U,M,L	R	CD	on eulittoral slopes
Spongomorpha aeruginosa (L.) Hoek.	R	R	M	M	U,M,TP	R and epiphytic		
LICHENES								
Xanthoria parietina (L.) Th.Fr.		RR	RR	RR	U	R		higher up than Prasiola species undergrowth of fucoids
Verrucaria mucosa Wahlenb.		RR	RR		U,M	R		
V. maura Wahlenb.		RR	RR		U	R		

ACKNOWLEDGEMENTS

Algological studies along Hornstrandir and in the Icelandic coastal area as a whole were supported by yearly grants from the Icelandic Research Foundation (Visindasjóður), Reykjavík. Grateful thanks are due to the families at Drangar, in Ófeigsfjörður and Trékyllisvík as well, as to Mr. Jóhann Pétursson from the lighthouse at Hornbjarg (Hornbjargsviti) for their efficient help and hospitality during the field work. Further thanks are due to Dr. J.W. Markham, the University of Santa Barbara, California, for reading a part of the manuscript.

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