Benthic marine algal colonisation on the new lava at Heimaey, Vestmannaeyjar archipelago, southern Iceland

KARL GUNNARSSON
Marine Research Institute, Skúlagata 4, 101 Reykjavík, Iceland, e-mail: karl@hafro.is

ABSTRACT

A new lava shore was formed during an eruption on the Island of Heimaey, Vestmannaeyjar archipelago, southern Iceland, in 1973. The benthic marine algae that had colonised the littoral and sublittoral zones of the new lava were studied during the summer 1998. A total of 62 species were found of which 21 were confined to the littoral zone. In the sublittoral zone the highest number of species was found at 5 m depth and the number decreased with increasing depth. The lower limit of the vegetation was at about 30 m. On a sheltered site at the entrance of the harbour, prolific fucoid vegetation was found in the littoral zone, on lava outcrops embedded in sand.

A comparison with the marine algal vegetation on Surtsey a volcanic island born 10 years earlier, showed that in terms of species number the colonisation has progressed faster on Heimaey. This is probably due to partly more sheltered habitats and the closeness of mature algal communities to the new lava in Heimaey.

INTRODUCTION

Marine algal colonisation on introduced substrata or on small artificially or accidentally denuded surfaces in the littoral or the sublittoral zone has been studied extensively (e.g. Dayton 1971, Kain 1975, Sousa 1980, Niell & Varela 1984, van Zyl & Robertson 1991, Williamson & Creese 1996). Studies on the colonisation on new volcanic lava are however scarce. Dawson (1954) studied the algal flora on littoral lava flows of different age in the San Benedicto Island in the Pacific, west of Mexico and noted a marked difference between the flora on the new lava and that of the older lava. Doty (1967) followed the algal colonisation on several lava flows of different age in Hawaii for 7 years. Doty followed successive stages in the colonisation until the algal vegetation reached a semi-climatic stage. The main factor reducing the succession rate was the instability of the substrate. In Jan Mayen Gulliksen (1974) studied the sublittoral vegetation of a lavaflow two years after the eruption stopped. He found five algal species growing on the lava, three of which he did not find on the surrounding old lava.

On Surtsey, a new volcanic island in the Vestmannaeyjar archipelago, southern Iceland, the colonisation by marine algae has been monitored on a regular basis since 1964, a year after the eruption started (see Jónsson *et al.* 1987). The first algae to colonise the shores of Surtsey and actually the first plants found on the island were diatoms found in August 1964 on new lava solidified shortly before (Jónsson 1966, 1970). The number of species found on the shores of Surtsey increased rapidly from 1964 to 1971 when about 40 species were found (Jónsson & Gunnarsson 1982). After 1971 the number of species increased slowly and in 1997, 34 years after the island was born, 47 species were found (Jónsson & Gunnarsson 2000).

A volcanic eruption started on Heimaey, another island of the Vestmannaeyjar archipelago in 1973 and ended in 1975. The lava flowed into the sea on the eastern shore of Heimaey and a new rocky shore of about 10 km in length was formed over part of the east shore (Thorarinsson *et al.* 1973). No studies have been reported on the benthic marine organisms on the new lava in Heimaey. The new lava in Heimaey is in direct contact with established algal communities and it was of interest to see if the colonisation differed from that observed in the isolated shoreline of Surtsey where the nearest algal community is at about 5 km distance. This paper reports results from a study of the benthic marine algae on the new lava in Heimaey conducted in June 1998.

MATERIAL AND METHODS

The present study was carried out during the period from 8 to 12 June 1998 on the new lava on the north-eastern coast of Heimaey (Fig. 1). Sampling was done on two sublittoral transects separated by about 200 m near the eastern tip of the new lava. In the littoral zone, two sites were studied, a sheltered site near the entrance of the harbour and a more exposed site at the extreme east of the new lava shore.

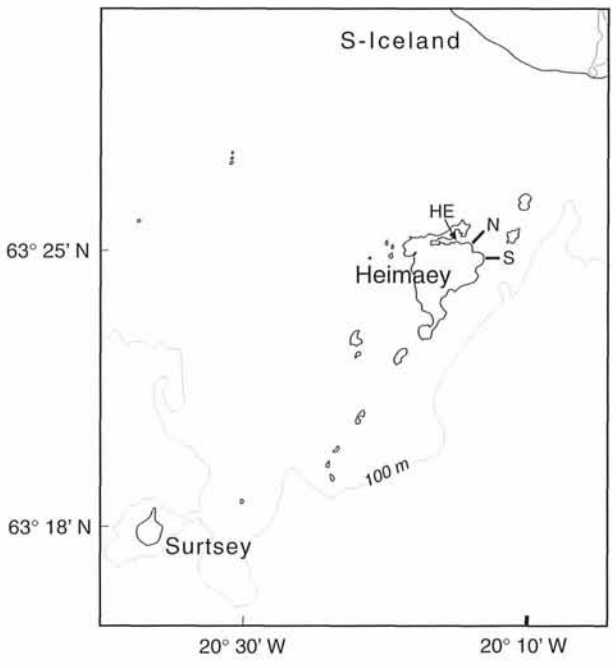

Figure 1. Vestmannaeyjar archipelago. The three transects studied on the new lava at Heimaey, south (S), north (N) and harbour entrance (HE) are marked on the map.

In the sublittoral zone SCUBA-divers sampled algae at 5 m depth intervals from 5 m to 35 m. At each depth the substrate and the general appearance of the vegetation and fauna was registered on a plastic writing pad and specimens of all algal species seen were sampled by hand. An effort was made to sample from as many different kinds of habitats as possible. Collecting bags with a 0.5 mm mesh size were used. In the littoral zone species were sampled during low water at spring tide.

The samples were brought fresh to the laboratory where they were examined and identified to species. Herbarium specimens were made of the macroscopic species and permanent slides were made of the microscopic species by mounting them on microscopic slides in Karo® corn syrup. The specimens are kept at the Marine Research Institute in Reykjavík. A list of species found at the three different sampling sites with author names is given in Table 1. Nomenclature is according to Gunnarsson & Jónsson (2000).

RESULTS

The substrate on the new lava flow on the north-eastern coast of Heimaey is a mixture of boulders, stones, gravel and sand. In the littoral zone at the more exposed site, the boulders were round and even, while at the sheltered site near the entrance of the harbour the substrate was rough lava bedrock surrounded by fine sand. In the sublittoral zone the stones and boulders get more rough and uneven and cover successively smaller part of the bottom as one goes deeper. The cover of sand and gravel increases with increasing depth.

Dominant sessile animals on the hard substrate in the sublittoral zone are hydrozoans and bryozoans with apparently increasing cover from shallow to deep water. In the deepest collecting sites at 20 to 30 m the octocoral *Alcyonium digitatum* was prominent in the fauna. Of the errant macrofauna sea urchins *Strongylocentrotus droebachiensis* and *Echinus esculentus* were most frequent.

A total of 62 benthic algal taxa were found in the littoral and sublittoral zones on the new lava. Amongst those taxa, 18 belong to the Ulvophyceae, 16 to Fucophyceae and 25 to Bangiophyceae (Table 1). In the littoral zone 33 taxa were found. In the sublittoral zone the highest number of species was found at 5 m depth, 33 species, and the number decreased with increasing depth and at 30 m depth only 3

Table 1. Vertical and horizontal distribution of marine algal species found on the new lava at Heimaey, in June 1998.

taxa	depth (m):	south section 5	10	15	20	25	30	north section litt	5	10	20	30	Harbour entrance, littoral
Acrochaetiaceae sp.									x	x			
Acrosiphonia arcta (Dillwyn) J.Agardh		x	x		x			x					x
Alaria esculenta (Linnaeus) Greville		x	x	x				x	x	x			
Antithamnionella floccosa (O.F. Müller) Whittick					x	x	x		x				
Audouinella membranacea (Magnus) Papenfuss				x	x								
Blidingia minima (Nägeli ex Kützing) Kylin								x					x
Callophyllis cristata (C.Agardh) Kützing				x					x	x			
Chorda filum (Linnaeus) Stackhouse													
Conchocelis sp.				x		x				x			
Corallina officinalis Linnaeus		x											
Cruoria pellita (Lyngbye) Fries									x				
Crustose corallines			x	x		x			x	x	x		
Delesseria sanguinea (Hudson) Lamouroux		x	x	x	x				x				
Derbesia marina (Lyngbye) Solier				x	x	x							
Desmarestia aculeata (Linnaeus) Lamouroux		x	x	x					x	x			
Desmarestia viridis (O.F.Müller) Lamouroux		x	x	x					x	x			
Ectocarpus fasciculatus Harvey								x					
Ectocarpus siliculosus (Dillwyn) Lyngbye			x	x				x	x				
Elachista fuciola (Velley) Areschoug													x
Enteromorpha flexuosa (Wulfen) J.Agardh													x
Enteromorpha intestinalis (Linnaeus) Nees								x					x
Enteromorpha linza (Linnaeus) J.Agardh								x					x
Enteromorpha prolifera (O.F.Müller) J.Agardh								x					x
Fimbrifolium dichotomum (Lepeschin) G.Hansen					x								
Fucus disticus Linnaeus													x
Fucus spiralis Linnaeus													x
Fucus vesiculosus Linnaeus													x
Haplospora globosa Kjellman				x									
Laminaria hyperborea (Gunnerus) Foslie		x	x	x	x				x	x			
Lomentaria clavellosa (Turner) Gaillon		x							x				
Lomentaria orcadensis (Harvey) Collins ex W.R.Taylor		x	x	x	x				x	x			
Mastocarpus stellatus (Stackhouse) M.Guiry								x					x
Meiodiscus spetzbergensis (Kjellm.) Saund. & McLachlan					x				x				
Membranoptera alata (Hudson) Stackhouse		x	x						x				
Monostroma grevillei (Thuret) Wittrock		x						x	x				x
Palmaria palmata (Linnaeus) Kuntze		x						x	x				x
Petalonia fascia (O.F. Müller) Kuntze								x					
Petalonia zosterifolia (Reinke) Kuntze								x					
Phycodrys rubens (Linnaeus) Batters		x	x	x	x				x				
Plocamium cartilagineum (Linnaeus) Dixon		x	x	x					x				
Polysiphonia stricta (Dillwyn) Greville		x	x	x	x		x	x	x	x			
Porphyra miniata (C.Agardh) C.Agardh		x	x						x	x			
Porphyra umbilicalis (Linnaeus) Kützing								x					x
Porphyropsis coccinea (J.Agardh) Rosenvinge									x	x			
Prasiola stipitata Suhr in Jessen													x
Pterosiphonia parasitica (Hudson) Falkenberg			x						x				
Ptilota gunneri P.Silva, Maggs & L.Irvine		x	x		x		x		x				
Pylaiella littoralis (Linnaeus) Kjellman								x					x
Rhizoclonium riparium (Roth) Harvey													x
Rhodochorton purpureum (Lightfoot) Rosenvinge								x					x
Rosenvigiella polyrhiza (Rosenvinge) P.Silva													x
Scytosiphon lomentarius (Lyngbye) Link								x					x
Sphacelaria caespitula Lyngbye									x				
Sphacelaria sp.			x	x	x			x					
Spongomorpha aeruginosa (Linnaeus) van den Hoek									x				
Ulothrix flacca (Dillwyn) Thuret in Le Jolis								x					x
Ulothrix sp.													x
Ulva lactuca Linnaeus								x					
Ulvaria fusca (Postels & Ruprecht.) Ruprecht		x	x										
Urospora bangioides (Harvey) Holmes & Batters								x					
Urospora penicilliformis (Roth) Areschoug									x				x
Urospora sp.					x								
Total		18	18	17	14	4	3	22	27	12	1	0	23

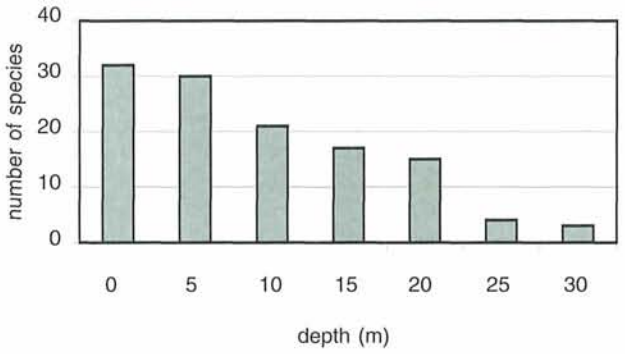

Figure 2. Bar diagram showing the decrease in number of species with increasing depth on the new lava in Heimaey in 1998.

species were recorded (Fig. 2). The flora of the sublittoral zone was similar at the two transects, although 14 of the sublittoral species were confined either to one transect or the other. These were mostly small inconspicuous species that might easily have been overlooked in one of the transects.

The vegetation of the littoral zone was studied at a sheltered site near the entrance to the harbour and at an exposed site at the extreme east of the new lava. About the same number of species was found at the two sites, but the species composition was quite different. Of the 33 species found in the littoral zone, 10 were common to both sites. The littoral vegetation at the exposed site was dominated by *Urospora bangioides* and *Enteromorpha linza* in the lower part, but in the upper part *E. prolifera* and *Sphacelaria* sp. were most abundant. No fucoids were found at the exposed site.

Near the harbour the littoral vegetation was dominated by fucoids with high cover of *Fucus spiralis, F. vesiculosus* and *F. distichus*. In addition *Porphyra umbilicalis, Enteromorpha prolifera, Pilayella littoralis, Monostroma grevillei* and *Palmaria palmata* were common (Table 1).

In the sublittoral zone, the vegetation at shallow depths consisted predominantly of *Alaria esculenta* and red algae *Polysiphonia stricta, Delesseria sanguinea, Phycodrys rubens, Plocamium cartilagineum* and *Lomentaria clavellosa*. At about 8 to 13 m depth, dense stands of *Laminaria hyperborea* were found on the top of the highest boulders, but the smaller stones were covered by *A. esculenta* and *Desmarestia aculeata* and the red algae *D. sanguinea, P. rubens* and *Porphyra miniata*. At 15 m depth crustose corallines and *Lomentaria orcadensis* were found in abundance amongst *A. esculenta, D. sanguinea* and *P. rubens* that were dominant. At 20 m depth the vegetation cover was very low, spread plants of *P. rubens, L. orcadensis* and *Derbesia marina* were found on a bottom mostly covered with hydroids and octocorals. At 30 m the plants were primarily small species growing on hydroids.

DISCUSSION

There was a marked difference in the vegetation between the two littoral study sites on the new lava of Heimaey. At the sampling site near the entrance to the harbour the new lava is sheltered from wave exposure and stable enough to support perennial fucoid vegetation on rock outcrops embedded in sand (Fig. 3). Three species, *Fucus spiralis, F. vesiculosus* and *F. distichus* were found growing there. At the more exposed site the vegetation on the rocks was dominated by ephemeral green algae of the genera *Urospora* and *Enteromorpha*. The vegetation at the more exposed site resembled the vegetation found on the extremely exposed littoral zone of Surtsey (Jónsson *et al.* 1987). Similar vegetation of ephemeral green algae has been found to represent the first stages of colonisation in a number of studies (Sousa 1979, 1984, van Zyl & Robertson 1991, Dye 1993). The difference in vegetation between the two littoral sites of equal age on Heimaey is most likely due to the constant erosion of the exposed shore line. The same factor is likely to affect the littoral vegetation in Surtsey where hardly any part of the coastline is un-

Figure 3. Rock outcrops surrounded by sand at the harbour entrance in Heimaey. Fucoids dominate the vegetation on the rocks.

changed from year to year (Norrman & Erlingsson 1992). It was only in 1997, 34 years after the eruption, that the first fucoid was detected in the littoral zone on Surtsey. A juvenile plant of *Fucus spiralis* was found in a small rock crevice in the lava (Jónsson & Gunnarsson 2000). There has probably been no lack of fucoid germlings, as fertile fucoid plants have frequently been observed drifted ashore at Surtsey.

In the sublittoral zone on the new lava in Heimaey stones were embedded in sand that is moved about by current and waves. On the smaller stones, less than 0.5 m in height, only small ephemeral algae were observed. It seems likely that the scouring and burial action of the sand prevents the establishment of perennial vegetation on the smaller stones. On top of the larger stones a dense vegetation of *Laminaria hyperborea* had developed. The *Laminaria* plants were up to 8 years of age (counting growth zones in the stipes). *Laminaria hyperborea* forest is considered to be a climax vegetation in the cold temperate region of the Northwest Atlantic (Svendsen 1972, Kain 1975). Both the number of species and the vegetation cover diminished rapidly below 15 m depth. At greater depths light is the most probable factor limiting the establishment and growth of the vegetation.

In terms of number of species the vegetation of new lava in Heimaey has developed further than the vegetation of Surtsey. A total of 62 species were found on Heimaey in 1998 compared with 44 on Surtsey in 1997. Many of the species that were found on the new lava on Heimaey have never been recorded on Surtsey (Jónsson *et al.* 1987, Jónsson & Gunnarsson 2000). In the littoral zone these are *Elachista fucicola, Fucus distichus, Fucus vesculosus, Mastocarpus stellatus, Palmaria palmata, Prasiola stipitata, Rhizoclonium riparium* and *Rosenvingiella polyrhiza*. All of them were found at the sheltered site at the entrance to the harbour, although *M. stellata* and *P. palmata* were also found growing on the more exposed littoral site.

In the sublittoral zone *Corallina officinalis, Cruoria pellita,* crustose corallines, *Fimbrifolium dichotomum, Pterosiphonia parasitica* and *Ptilota gunneri* were found on the new lava of Heimaey, species but have not been found on Surtsey (Jónsson *et al.* 1987, Jónsson & Gunnarsson 2000). On the new lava at Heimaey the crustose corallines are a prominent element in the sublittoral vegetation found at all depths from 5 to 20 m (Fig. 4). At Surtsey this group is absent.

Figure 4. Crustose coralline algae at depth of 30 m at the north transect on the new lava in Heimaey in 1998.

The most likely explanation for this is that the spores of the crustose corallines are negatively buoyant and therefore have a limited dispersal capacity (Okuda & Neushul 1981). Crustose corallines have succeeded in colonising the new lava in Heimaey from nearby algal communities, while the distance from the nearest mature vegetation (5 km) has presumably prevented the establishment of crustose corallines on Surtsey.

ACKNOWLEDGEMENTS

I am greatly indebted to Halldóra Skarphéðinsdóttir for assistance during sampling in Vestmannaeyjar, and analysing the material, to Erlendur Bogason for diving assistance, Georg Skaeringsson for navigating rb Fridrik Jesson when sampling and to Hafsteinn Gudfinnsson for providing laboratory facilities at the Marine Research Institute's branch office in Vestmannaeyjar. I also thank Sigurdur Jónsson and Gudrún Thórarinsdóttir for constructive comments on the manuscript. The study was partly financed by the Icelandic Democracy Fund.

References

Dawson, E.Y. 1954. The marine flora of Isla San Benedicto following the volcanic eruption of 1952-1953. Allan Hancock Foundation Publications, 16: 1-25.

Dayton, P.K. 1971. Competition, disturbance and community organization: the precision and subsequent utilisation of space in rocky intertidal community. Ecol. Monogr. 41: 351-389.

Doty, M.S. 1967. Pioneer intertidal population and the related gen-

eral vertical disrtibution of marine algae in Hawaii. Blumea 15: 95-105.

Dye, A.H. 1993. Recolonization of intertidal macroalgae in relation to gap size and molluscan herbivory on a rocky shore on the east coast of southern Africa. Mar. Ecol. Progr. Ser. 95: 263-271.

Gulliksen, B. 1974. Marine investigations at Jan Mayen in 1972. K. norske Vidensk. Selsk. Museet, Misellanea 19: 1-46.

Gunnarsson, K. & S. Jónsson 2000. Benthic marine algae of Iceland: revised checklist. Cryptogamie-Algologie (in press).

Jónsson S. 1966. Le commencement du peuplement benthique des côtes rocheues du Surtsey, la nouvelle île volcanique dans l'Atlantique nord. C. R. Acad. Sci. Paris 262: 915-918.

Jónsson S. 1970. Meeresalgen als Erstbesiedler der Vulkaninsel Surtsey. Schr. Naturv. Ver. Schlesv. -Holst. Sonderband 21-28.

Jónsson S. & K. Gunnarsson 1982. Marine algal colonization at Surtsey. Surtsey Res. Progr. Rep. 9: 33-45.

Jónsson, S. & K. Gunnarsson 2000. Seaweed colonisation at Surtsey, the volcanic island south off Iceland. Surtsey Res. 11: 59-68.

Jónsson S., K. Gunnarsson & J.-P. Briane 1987. Évolution de la nouvelle flore marine de l'île volcanique de Surtsey, Islande. Rit fiskideildar 10(1): 1-30.

Kain, J.M.1975. Algal recolonization of some cleared subtidal areas. J. Ecol. 67: 739-765.

Niell, F.X. & M. Varela 1984. Initial colonization stages on rocky coastal substrates. P.S.Z.N.I: Mar. Ecol. 5: 45-56.

Norrman, J.O. & U. Erlingsson 1992. The submarine morphology of Surtsey volcanic group. Surtsey Res. Progr. Rep. 10, 45-56.

Okuda, T. & M. Neushul 1981. Sedimentation studies of red algal spores. J. Phycol. 17: 113-118.

Sousa, W.P. 1979. Experimental investigations of disturbance and ecological succession in a rocky intertidal algal community. Ecological Monographs 49: 227-254.

Sousa, W.P. 1980. The responses of a community to disturbance: The importance of successional age and species' life history. Oecologia (Berl.) 45: 72-81.

Sousa, W.P. 1984. Intertidal mosaics: Patch size, propagule availability, and spatial variable patterns of succession. Ecology 65: 1918-1935.

Svendsen, P. 1972. Noen observasjoner over taretråling og gjenvekst av stortare, Laminaria hyperborea. Fiskets Gang 22: 448-460.

Thórarinsson, S., S. Steinthórsson, Th. Einarsson, H. Kristmansdóttir & N. Óskarsson, 1973. The eruption in Heimaey, Iceland. Nature 241: 372-375.

van Zyl, P. & B.L. Robertson 1991. Seasonal and species-environmental succession on an eastern Cape rocky shore. S. Afr. J. Sci. 87: 327-330.

Williamson, J.E. & R.C. Creese 1996. Colonisation and persistence of patches of the crustose brown alga Pseudolithoderma sp. J. Exp. Mar. Biol. Ecol. 203: 191-208.