

Nomination of  
**SURTSEY**  
for the UNESCO World Heritage List

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January 2007



Ministry of Education, Science and Culture

2007

## Nomination of Surtsey for the UNESCO World Heritage List

### EXECUTIVE SUMMARY

#### State Party

Iceland.

#### State, Province or Region

Municipality of Vestmannaeyjar.

#### Name of Property

Surtsey.

#### Geographical coordinates to the nearest second

The nominated property is bounded by the following coordinates:

- 1) 63°16'08"N and 20°36'04"W;
- 2) 63°16'08"N and 20°40'00"W;
- 3) 63°17'52"N and 20°40'00"W;
- 4) 63°20'22"N and 20°35'31"W;
- 5) 63°18'15"N and 20°31'16"W.

#### Textual description of the boundary(ies) of the nominated property

The nominated property, Surtsey (Map, red line), represents the strictly protected component of the nationally designated Surtsey Nature Reserve. The 33.7 km<sup>2</sup> property encompasses the entire Surtsey volcano (of which 1.4 km<sup>2</sup> are above sea level and 13.2 km<sup>2</sup> are submerged) and surrounding ocean (19.1 km<sup>2</sup>).

The remaining 31.9 km<sup>2</sup> of the Surtsey Nature Reserve (Map, black line) represents a buffer zone for this nomination. Fishing is allowed within the buffer zone, but construction, mining and the use of firearms are prohibited.

## Justification

### Statement of Outstanding Universal Value

#### *Iceland and the Mid-Atlantic Ridge*

Running from Jan Mayen to Antarctica, the Mid-Atlantic Ridge is the Earth's largest continuous geological structure. Its discovery in the 1950s led, among other things, to the general acceptance of Wegener's theory of continental drift.

Iceland is an integral part of the Mid-Atlantic Ridge and also its largest supramarine (aerial) component. The crest of the ridge, which marks the boundary between the North American and Eurasian tectonic plates, crosses the country from southwest to northeast, forming a major rift belt that expands continuously by accreting new land through volcanic activity. As one of the most volcanically active countries on Earth, Iceland is constructed almost exclusively of volcanic rocks.

Surtsey is the product of one of Iceland's 29 active volcanic systems, the Vestmannaeyjar system. This is a young system comprising – if only what reaches above sea level is counted – seventeen identified Holocene volcanoes, which originally rose from the sea floor in the same manner as Surtsey. Two volcanic eruptions within this system during historical times are known with certainty: the Surtsey eruption 1963–1967 and the Eldfell eruption 1973 on Heimaey.

#### *Birth of an island*

The formation of a new volcanic island is a rare event occurring somewhere in the global system of volcanic belts on the average of about twice a century. Most of these islands have disappeared quickly and none has been as intensely investigated from the very beginning as Surtsey. This applies both to the eruption itself and to the posteruptional natural history of the island. In this regard, Surtsey has offered a natural laboratory in geology, geomorphology and ecology which is unparalleled anywhere in the world and has provided invaluable information on the creation and history of the Earth and its biosphere.

The Surtsey eruption immediately aroused avid interest among scientists and volcanologists agree that it is the best documented submarine eruption to date. It was a spectacular event in the picturesque surroundings of the Vestmannaeyjar archipelago. The scientific value of Surtsey was further acknowledged after it became evident that the island would persist and thus provide an exceptional opportunity to study the development of an oceanic volcano from its inception on the sea floor, through the formation of an island, to the modification of the newly erected structure by hydrothermal processes and wave abrasion. Surtsey is in reality the type locality of Surtseyan tephra (volcanic ash), produced by hydromagmatic (Surtseyan) eruptions. Surtsey is also one of the best preserved submarine tuya (tablemountain) on Earth.

### *Geological processes*

Geologists are paying increased attention to the formation of palagonite tuff in Iceland, partly because similar formations are uncommon elsewhere on Earth. Studies at Surtsey demonstrated for the first time that the conversion of tephra into tuff is a post-eruptive process, occurring at relatively low temperatures (usually below 100° C) and at low pressures. Furthermore, the process was shown to be highly temperature-dependent and to proceed much faster than anyone had envisaged. In 1969, two years after the eruption ceased, the first sign of palagonitisation was noticed at the surface of Surtsey. By 2004, some 85% of the tephra pile above sea level had been converted to palagonite tuff. In short, Surtsey has provided a well-documented case of the consolidation and alteration of basaltic tephra, a case which remains unparalleled.

Surtsey has provided a unique opportunity to study the evolution of a post-eruptive hydrothermal system. This system, discovered at the surface of the island in the spring of 1967, has been monitored ever since. The hydrothermal area at the surface continued to expand until around 1979 but then the rate of expansion slowed down, presumably because the consolidated tephra inside the island had started to affect the heat flux.

### *Island erosion*

The post-eruptive period has offered unique opportunities to study erosive forces in a coastal environment of strong wave activity. The erosion of Surtsey has been documented in detail through an extensive series of vertical aerial photos. The three principal geological formations of Surtsey – tephra, lava and palagonite tuff – react quite differently to marine abrasion, with tuff proving the most resistant. Since 1967, surf has eaten away about half the island, above all loose tephra and lava. For the first few years, 3–20 hectares disappeared annually, while recent years have seen an annual average of approximately one hectare washed away.

An attempt has been made to model the future of Surtsey by using the curve of cumulative areal change of Surtsey from 1967 to 2004. These models indicate that 120 years from now, only the core of palagonite tuff will be left. Surrounded at that point by steep palagonite cliffs, Surtsey will be fairly resistant to further erosion and remain standing for thousands of years, like its neighbours in the archipelago.

A series of nine bathymetric maps compiled between 1964 and 2000 on the Surtsey environs reveal that the underwater remnants of the islets Syrtlingur and Jólnir have suffered continuous, rapid submarine erosion, caused probably by both wave action and bottom currents. Since the data indicate that the rate of erosion is gradually decreasing, these submarine hills should survive for a long time. The data on submarine erosion at Surtsey is a unique scientific resource, as no comparable measurements are available on any volcanic islands elsewhere in the world.

### *Ecological laboratory*

From its inception, the Surtsey island has been strictly protected, with human presence limited to a few scientists for a short period each summer. At no other site have the flora and fauna of an entire, intact and undisturbed island been recorded so thoroughly as they naturally accumulated. This means that Surtsey provides an exceptional opportunity to further our understanding of colonisation, extinction and the carrying capacity of an isolated, single-island ecosystem. Added to this are the prospects of studying species numbers declining as the island erodes and shrinks. The opportunity for direct testing of classic island biogeography concepts is invaluable and certainly seldom on offer. Already, monitoring individual plants during their colonisation of Surtsey has provided an extensive record of natural invasion processes and species dynamics; in future, this demographic data provides a foundation for further investigations, e.g. exploring secondary dispersal from the species that are now established.

Surtsey has already allowed the scientific world to gain insights into the interaction of species and how it affects ecological succession. The establishment of a gull colony in the mid-1980s, with its resulting nutrient input, altered primary succession in dramatic ways. The evolving sharp contrast between the lush, species-rich plant community inside the colony and the sparse vegetation outside has been better documented at Surtsey than at any other primary succession site in the world.

The pristine volcanic island of Surtsey is no mere scenario or model, but an actual, natural laboratory and a globally outstanding example of ongoing geological, geomorphological and ecological processes in the development of landforms and biological communities. Therefore, it is hereby proposed that this scientifically unique site be recognised through the award of World Heritage Site status.

### **Criteria under which property is nominated**

It is proposed that Surtsey, Iceland, be inscribed on the World Heritage List under Criteria viii and ix (cf. Article 11.5 of the Convention Concerning the Protection of the World Cultural and Natural Heritage and Paragraph 77 of the Operational Guidelines for the Implementation of the World Heritage Convention).

**Criterion viii:** *to be outstanding examples representing major stages of earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features.*

The IUCN has recently reviewed the role of the World Heritage Convention in recognising and protecting geological sites (Dingwall et al. 2005). The report examines the four different natural elements relevant to geological and geomorphological science. Three of these are relevant to nominating Surtsey for World Heritage status. Quotation marks and italics set off the IUCN text from this report.

*a. Earth's history*

*'This subset of geological (as opposed to geomorphological) features are represented by phenomena that record important events in the past development of the planet.'* A relevant example mentioned by the report is the record of crustal dynamics and tectonism, linking the genesis and development of mountains and volcanoes.

In historical time, only a few volcanic islands have been formed in the world as a whole. Most of these islands have quickly disappeared and none has been as intensely investigated from its very beginnings as Surtsey. Thus Surtsey offers an outstanding example of a virgin volcanic island which is actively being created and shaped by geological and geomorphological processes.

*b. Significant ongoing geological processes in the development of landforms*

*'This element of Criterion viii is the first of two aspects related to geomorphology and ongoing geological processes such as volcanic eruptions. It relates to active processes that are shaping or have shaped the Earth's surface.'* Relevant examples mentioned by the report are volcanism and coastal or marine processes.

Surtsey is renowned for its contributions to earth science. Research on the island during and since the eruption has provided invaluable information and insight into several major geological and geomorphological processes. The Surtsey submarine eruption (1963–1967) is the most exactly described submarine eruption ever. Studies on Surtsey have documented in detail the conversion of tephra into palagonite tuff and also demonstrated for the first time that palagonitisation is a post-eruptive process and highly temperature-dependent. Finally, Surtsey has provided a rare chance to study the evolution of a post-eruptive hydrothermal system.

*c. Significant geomorphic or physiographic features*

*'This second primarily geomorphological element represents the landscape products of active or past processes, which can be identified as significant physical landscape features.'* Relevant examples mentioned by the report are volcanoes, volcanic systems and oceanic islands.

Surtsey's subaerial geomorphology, i.e. its growth and erosion, has been thoroughly documented, through studies on site and through fifty three sets of vertical aerial photographs taken between February 1964 and August 2004. Thus it has been possible to map the erosion of the island, as well as its main geological features, in great detail and predict its future size. This applies not only to the supra-marine part of the island, but the entire volcano as it stands on the sea bottom. The data on submarine abrasion of two transient islets and one submarine ridge appearing during the Surtsey eruption is unique, with no comparable measurements existing on any other volcanic islands in the world.

**Criterion ix:** *to be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.*

Surtsey's emergence has provided a rare opportunity for studying one of the central questions of ecology: the dispersal and colonisation of sterile ground by plants and animals and the development of communities through the processes of succession. The record of ecological research on Surtsey is remarkable in many ways: it spans 40 years of regular measurements; includes several decades of monitoring data on individual plant and animal species; allows a distinction between the arrival and establishment of a species; highlights how the interaction of birds, nutrients and plants impact primary succession; and provides a thorough census of an entire island. However, what truly makes Surtsey stand out in this regard, compared to similar areas of sterile ground where long-term measurements have been maintained, is how minimal the impact of humans has been.

### **Name and contact information of official local institution/agency**

#### **Icelandic Institute of Natural History**

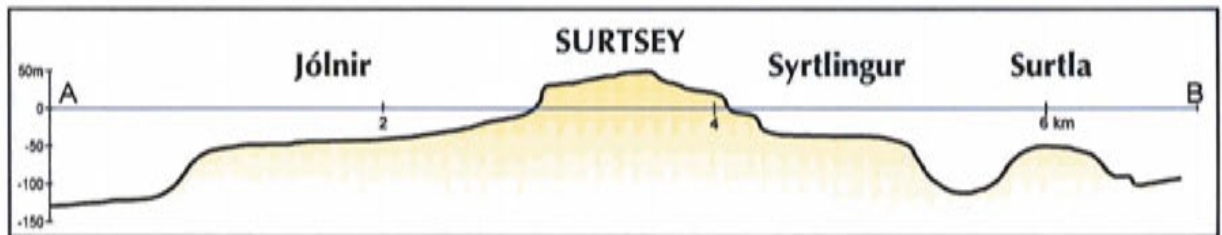
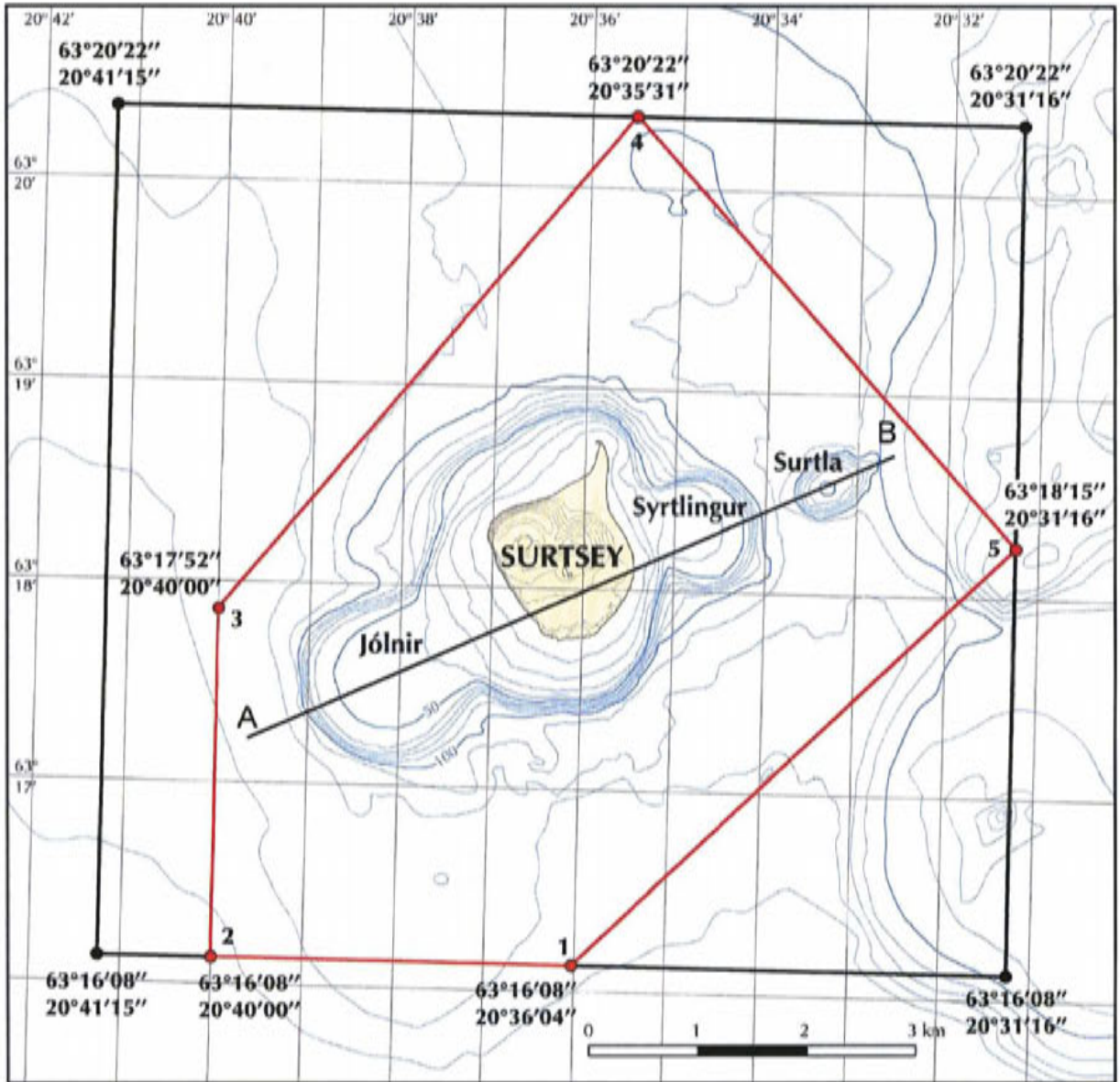
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### Surtsey – Nominated Area

Map of Surtsey, showing boundaries of the nominated area (red line) and buffer zone (black line).





Nomination of

# SURTSEY

for the UNESCO World Heritage List



Snorri Baldursson and Álfrheiður Ingadóttir (eds.)

2007



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# Preface

Surtsey is a scientifically unique area. It offers an outstanding example of a virgin, volcanic island that is being actively created and shaped by geological, geomorphological and ecological processes. The present nomination document proposes that the Surtsey Nature Reserve, including the entire Surtsey volcano and the surrounding sea, be recognised through the award of World Heritage Site status, in particular due to its international importance for the natural sciences.

It was on 15 November 1963 that Surtsey emerged as a new volcanic island in the picturesque Vestmannaeyjar archipelago. The formation of Surtsey provided the scientific community with a unique opportunity to study the development of an oceanic volcano from its inception on the sea floor to the creation of an island, and then throughout the modification of this newly erected structure by physical and ecological processes. Since its emergence, the island of Surtsey has been strictly protected and human influence restricted to a minimum. Surtsey has thus offered a natural laboratory in geology, geomorphology and ecology which has provided invaluable information on the creation and history of the Earth and its biosphere.

Preparations for this nomination have involved local and national authorities and various interested parties. Commissioned by the Icelandic World Heritage Committee, the Icelandic Institute of Natural History has compiled this nomination document with the assistance and advice of many people and institutions.

Our vision is that a World Heritage Site status will further the long-term conservation of Surtsey as a pristine nature reserve. Thus we feel it is both a delight and an honour to recommend this nomination to the World Heritage Committee of UNESCO.



Ragnheiður Helga Þórarinsdóttir  
Chair  
Icelandic World Heritage Committee



Steingrímur Hermannsson  
Chair  
Surtsey Research Society



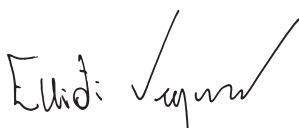
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This nomination has been commissioned by the Icelandic World Heritage Committee on behalf of the Ministry of Education, Science and Culture and the Ministry for the Environment. The editors and authors are responsible for all the presented results and conclusions.

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# SURTSEY

## island of Surt

In the ancient Eddic poem *Völuspá*, the prophetess describes the birth as well as the fate of life. She tells Odin about the world tree – the ash *Yggdrasil* – and about life as it was created and has evolved on earth but will in the end be destroyed by fires of the giant Surt, the dark ruler of fire. Upon *Ragnarök*, the final destruction of the world, Surt will lead the sons of *Muspel* against the gods. As he enters “burning everything in his path, men plunge to hell and the heavens are split apart”\*.

### **Völuspá**

52. vísa

Surtur fer sunnan  
með sviga lævi,  
skín af sverði  
sól valtíva,  
grjótbjörg gnata,  
en gífur rata,  
troða halir helveg,  
en himinn klofnar.

### **Völuspá: The Prophecy\***

Verse 52

Surt comes from the south  
with his wood-eating fire,  
sun glints on the sword  
of the godly warriors.  
Boulders slam together,  
sending trolls tumbling,  
men tread the path to Hell  
and the heavens cleave.

In 1963, when volcanic fires began erupting on the seabed south of Iceland and building up a tephra cone, it was found appropriate that the resulting island should be named Surtsey, a word formed in the normal Icelandic manner of including the possessive form of a person's name in a place name: Surtsey = Surt's island (*ey* meaning “island” in Icelandic) = the island of Surt, the fire giant.

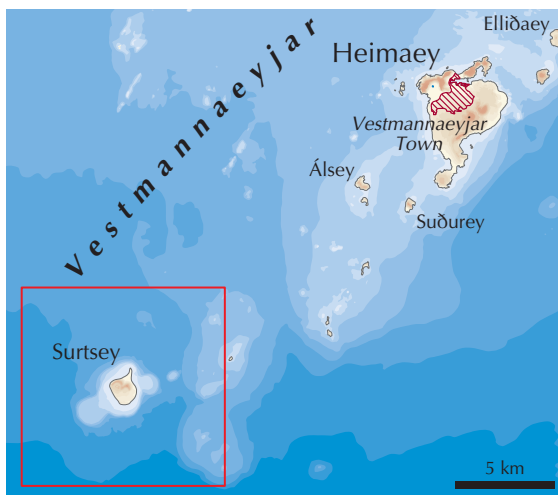
\**Völuspá: The Prophecy. The prophecy of the Vikings – the creation of the world.*  
Gudrun 2001. English translation by Bernard Scudder, p. 70.

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# Identification of the property



## 1.a Country

Iceland.

## 1.b State, province or region

Municipality of Vestmannaeyjar.

## 1.c Name of property

Surtsey.

## 1.d Geographical coordinates

The nominated property is bounded by the following coordinates:

- 1)  $63^{\circ}16'08''\text{N}$  and  $20^{\circ}36'04''\text{W}$ ;
- 2)  $63^{\circ}16'08''\text{N}$  and  $20^{\circ}40'00''\text{W}$ ;
- 3)  $63^{\circ}17'52''\text{N}$  and  $20^{\circ}40'00''\text{W}$ ;
- 4)  $63^{\circ}20'22''\text{N}$  and  $20^{\circ}35'31''\text{W}$ ;
- 5)  $63^{\circ}18'15''\text{N}$  and  $20^{\circ}31'16''\text{W}$ .

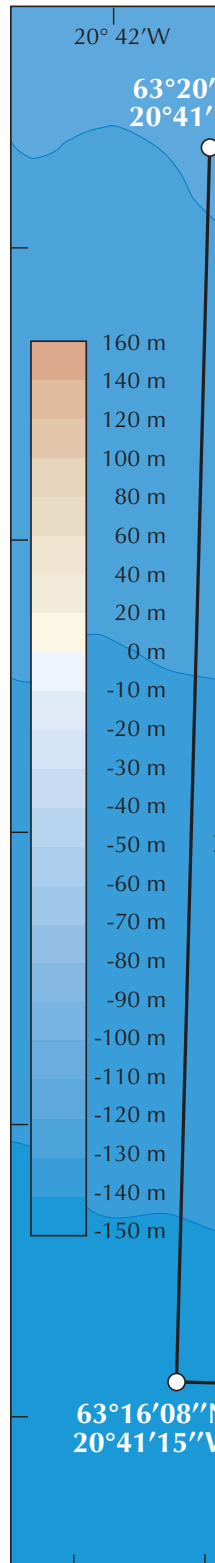
## 1.e Maps and plans showing the boundaries of the nominated property and buffer zone

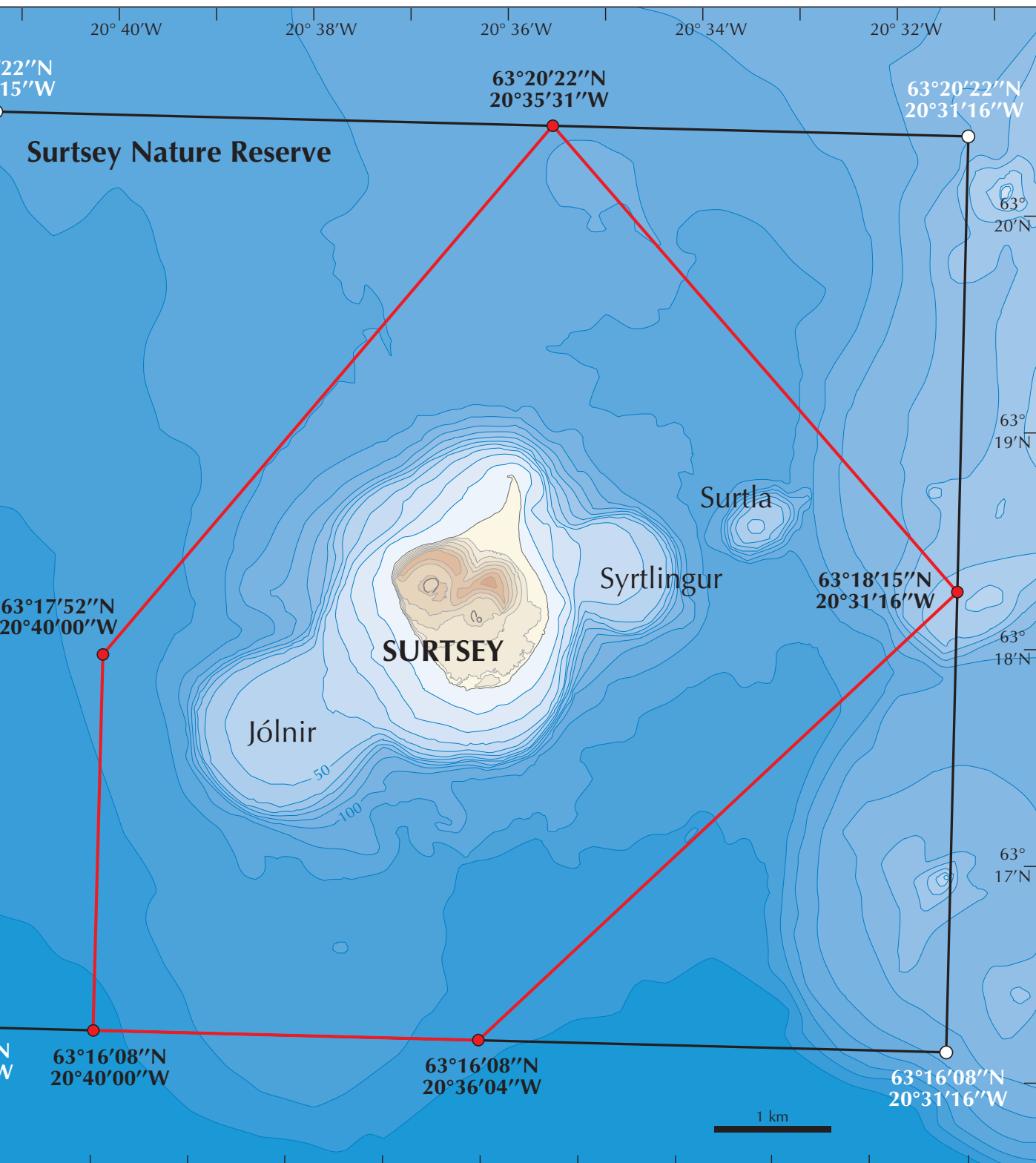
Figure 1.1 is a map showing the location and boundaries of the nominated area and its buffer zone.

## 1.f Area of the nominated property and the proposed buffer zone

The nominated property, Surtsey (Fig. 1.1, red line), represents the strictly protected component of the nationally designated Surtsey Nature Reserve. The  $33.7\text{ km}^2$  property encompasses the entire Surtsey volcano (of which  $1.4\text{ km}^2$  are above sea level and  $13.2\text{ km}^2$  are submerged) and surrounding ocean ( $19.1\text{ km}^2$ ). The remaining  $31.9\text{ km}^2$  of the Surtsey Nature Reserve (Fig 1.1, black line) represent a buffer zone for this nomination. Fishing is allowed within the buffer zone, but construction, mining and the use of firearms are prohibited.

Fig. 1.1. Map of Surtsey, showing boundaries of the nominated area and buffer zone. Smaller figures show the location of the nominated area within the Vestmannaeyjar archipelago, the location of Vestmannaeyjar off Iceland's south coast, and the location of Iceland in the northern hemisphere.









Aerial photograph of Surtsey, August 12th, 2004.  
(With permission from: Loftmyndir).

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# 2

## Description

### 2.a Description of property

#### Iceland – geological overview

Iceland is an integral part of the Mid-Atlantic Ridge and also its largest supramarine segment (Fig. 2.1) with a landmass of 103,000 km<sup>2</sup>. Sometimes described as a hot spot above a mantle plume, Iceland is built almost exclusively of volcanic rock, predominantly basalts, while sediments constitute about 10% of the island's overall volume. Since the land has been built up during the last 16 million years, it is geologically speaking a young country. Iceland's rocks can be divided into four geological formations: the Late Tertiary Basalt Formation, the Late Pliocene and Early Pleistocene Basalt Formation, the Late Pleistocene *Móberg* Formation, and the Holocene Formation (Fig. 2.2).

The crest of the Mid-Atlantic Ridge marks the boundary between the North American and Eurasian tectonic plates. These two plates move towards the west-northwest and east-southeast respectively, with an average spreading rate that is calculated to be  $\leq 1$  cm/yr in each direction in

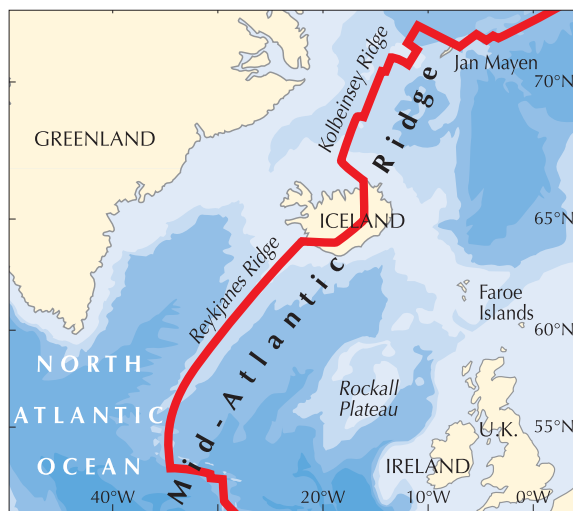


Fig. 2.1. The Mid-Atlantic Ridge in the region of Iceland, with a red line showing the boundary between the North American and Eurasian tectonic plates.

the region of Iceland. Because the centre of spread, running from southwest to northeast, crosses Iceland, the island expands continuously through a process of rifting apart and accreting new crust, which stems from volcanism along the crest zone of the Mid-Atlantic Ridge.

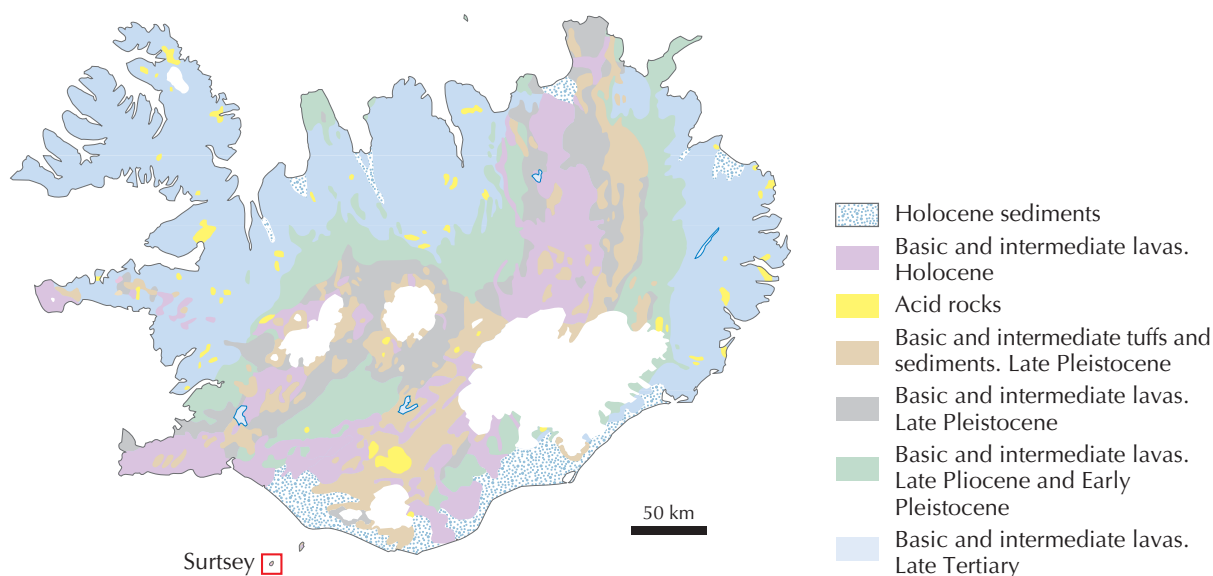


Fig. 2.2. Simplified geological map of Iceland, displaying the principal geological formations.

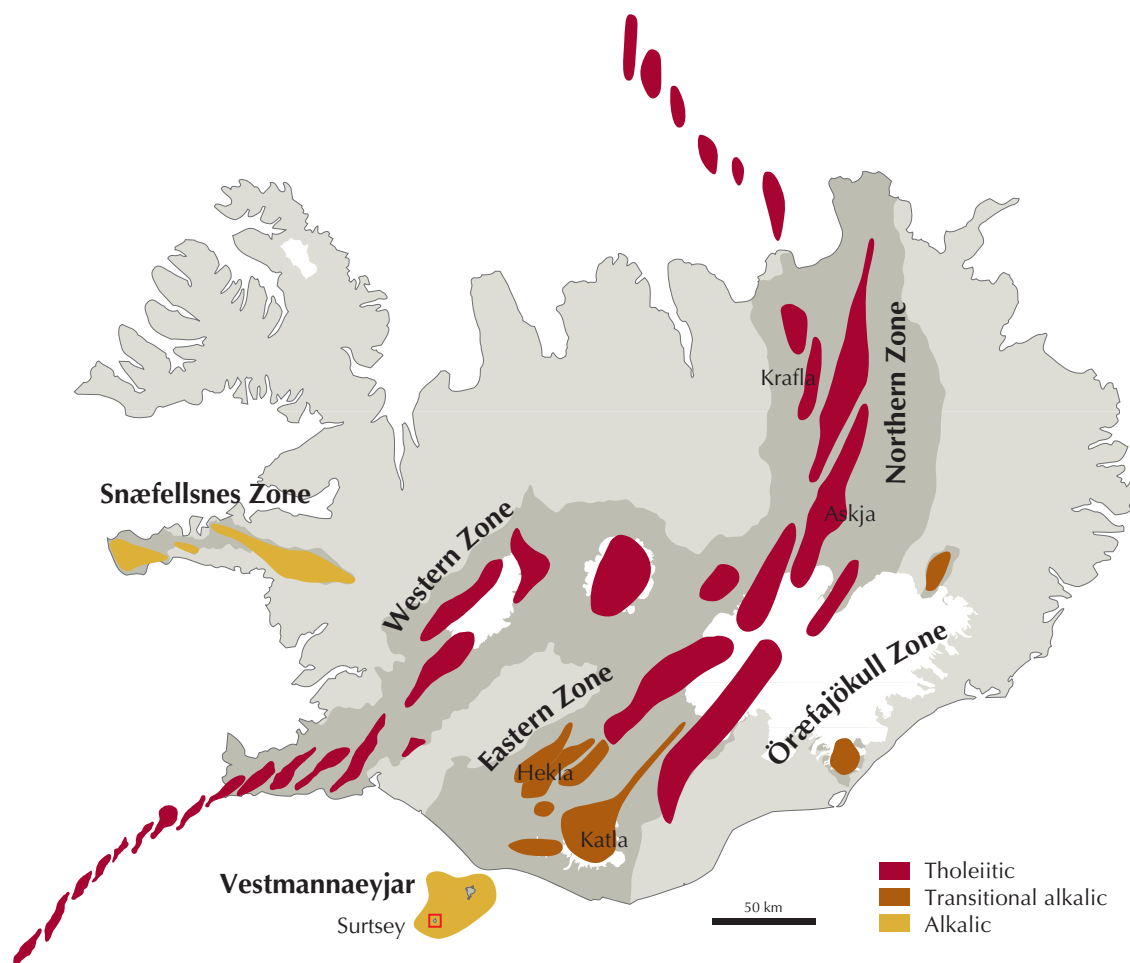


Fig. 2.3. Active volcanic systems in Iceland and on its insular shelf, grouped according to petrological criteria. The distribution of rocks from the Late Pleistocene and Holocene (dark grey) is also shown.

The volcanic zones of Iceland (Fig. 2.3), are among the most active on Earth, with an eruption occurring every three years on average. Moreover, the country's volcanic activity is associated with vigorous hydrothermal activity.

Icelandic volcano-tectonics appear to have been characterised by volcanic systems throughout the island's geological history. A volcanic system is a spatial grouping of eruption sites, including feeder dikes and possibly shallow magma chambers, that usually have in common certain structural, petrographic and geochemical characteristics within the bounds of the system. Volcanic production is generally most intense around the middle of each system, where many have developed a central volcano with the concomitant production of intermediate and acid rocks. High-temperature hydrothermal activity is

often connected with the central part of each system, evidenced by steaming vents and solfataras.

In Iceland and on its insular shelf, about 44 volcanic systems have erupted at least once during the Holocene and Late Pleistocene (Fig. 2.3), the most active being the Hekla, Katla, Askja and Krafla systems. The Hekla central volcano has erupted 19 times during the country's historic period (i.e. since AD 870), most recently in the year 2000. The subglacial central volcano of Katla has during the same period erupted on average twice a century, including the most recent eruption in 1955. The latest eruption within the Askja caldera occurred in 1961, while the Krafla volcanic system produced nine small eruptions from 1975 to 1984 (Ari Trausti Guðmundsson 2001).

### Vestmannaeyjar archipelago

Surtey island is a part of the Vestmannaeyjar archipelago (Fig. 2.4), which consists of 18 islands and a number of skerries, and is situated on the insular shelf off the central south coast of Iceland. Heimaey is the largest island (13.6 km<sup>2</sup>) and the only one to be inhabited (4,200 residents). It has one town which is also called Vestmannaeyjar and the most important fishing harbour along the south coast of Iceland.

Vestmannaeyjar constitutes a separate volcanic system at the southern end of Iceland's Eastern Volcanic Zone (Fig. 2.3). This is a young system, having probably commenced activity some 100,000 years ago, and its oldest part, the Norðurklettur Formation, is exposed on the

northernmost end of Heimaey. Norðurklettur Formation was built up by small volcanoes which probably erupted through an ice cap, leaving behind palagonite tuffs and tuff breccias capped by lavas. No high-temperature hydrothermal activity has been discovered at the surface in Vestmannaeyjar (Sveinn P. Jakobsson 1979).

During the Holocene (during the last 11,500 years), volcanism has remained at low intensity in the Vestmannaeyjar system. Seventeen volcanoes, of which three are on Heimaey, have been identified above sea level. These volcanoes originally rose from the sea floor in the same way as Surtsey, even at similar sea levels. The largest of the volcanoes comprise the islands of Bjarnarey, Elliðaey and Suðurey, and include

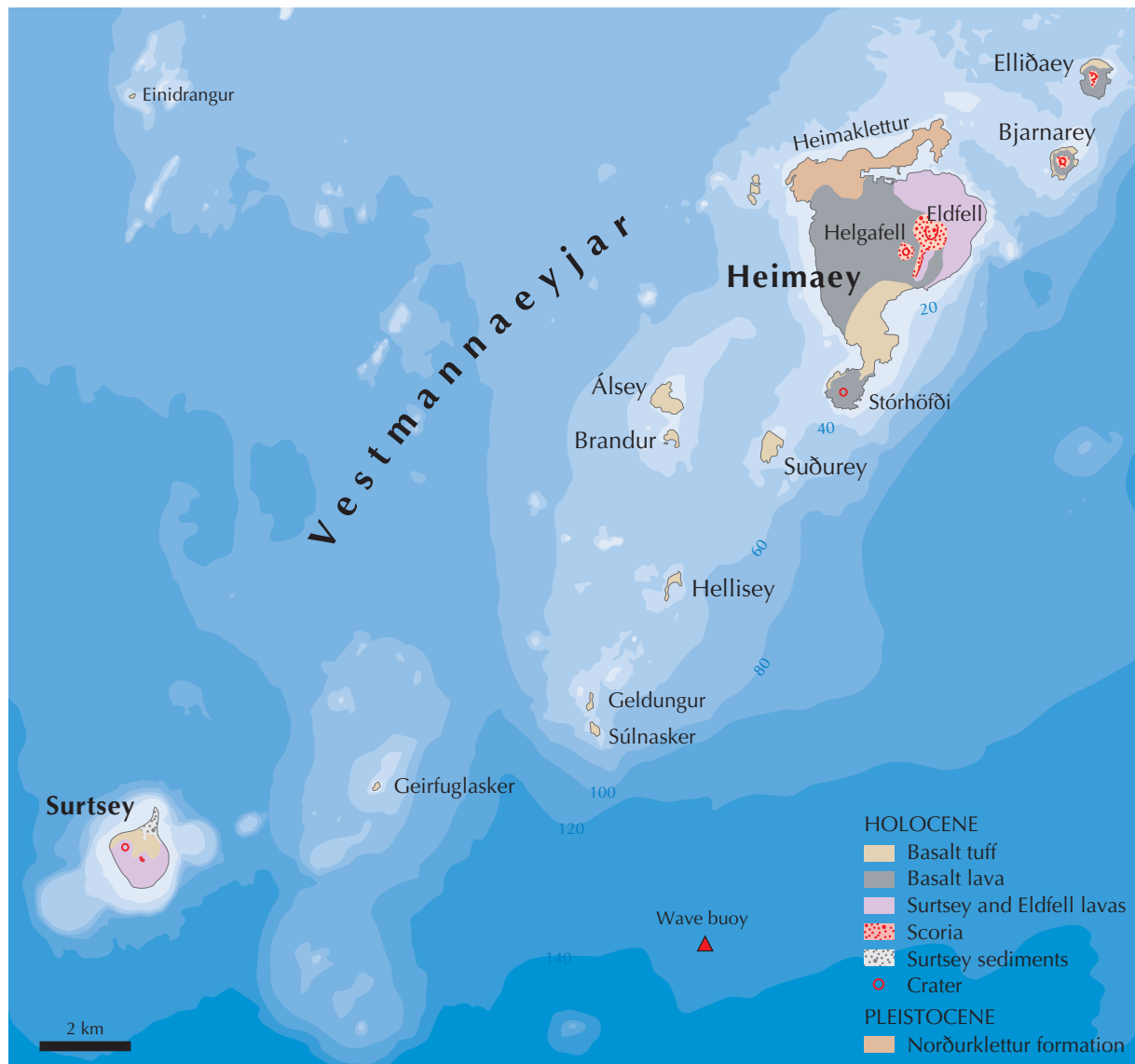


Fig. 2.4. Simplified geological map of the Vestmannaeyjar archipelago. Depth contour lines in meters.

Stórhöfði and Sæfell-Helgafell on the island of Heimaey. Two volcanic eruptions are known with certainty in historic times: the Surtsey eruption of 1963–1967 and the 1973 Eldfell eruption on Heimaey. A small submarine eruption may have occurred on the sea floor southeast of Hellisey in 1896. Furthermore, four young submarine volcanoes have been discovered, so that altogether 24 volcanic eruptions are known to have occurred within the Vestmannaeyjar system during the Holocene (Sveinn P. Jakobsson 1979). In addition to the submarine rises produced by the Holocene eruptions, numerous hills and peaks on the sea floor (Fig. 2.4) presumably represent remnants of more than 40 Late-Pleistocene submarine volcanoes. Most of the volcanoes in the Vestmannaeyjar system are relatively small.

As a large part of the Vestmannaeyjar volcanic system is submarine, its geographical limits are difficult to delineate exactly; however, it reaches about 38 km from southwest to northeast and 29 km from northwest to southeast, covering an area of 900–1000 km<sup>2</sup>, where the average depth of the



Aerial view to the southwest of the Vestmannaeyjar archipelago. Elliðaey and Bjarnarey are in the foreground, Heimaey in the middle and Surtsey in the far background. (Photo: Ragnar Th. Sigurðsson 2000).



sea is about 70 m. The volume of volcanic rock extruded within the Vestmannaeyjar volcanic system during the Holocene period has been estimated as  $\geq 3.5 \text{ km}^3$ , which is one order of magnitude less than the output of the highly active Hekla and Katla volcanic systems. Investigations on the Vestmannaeyjar shelf (Sveinn P. Jakobsson 1982; Kjartan Thors and Jóhann Helgason 1988) indicate that local submarine as well as subaerial volcanism was the source of the material building up the marine shelf and that for the most part this build-up has probably been ongoing for the last 100,000 years.

The main activity in the Vestmannaeyjar volcanic system has occurred in and around Heimaey (Fig. 2.4), which has accordingly formed a topographic high. Indeed, it has been proposed that Heimaey is evolving into a central volcano (Sveinn P. Jakobsson 1979). On the other hand, there are strong indications that Vestmannaeyjar system volcanism is episodic. The youngest Late-Pleistocene tuffs and lavas of the Norðurklettur Formation seem to have all been deposited within a short time interval. There also appears to have been a major volcanic episode 5,000–6,000 years ago, leading to the formation of Stórhöfði and Helgafell on Heimaey

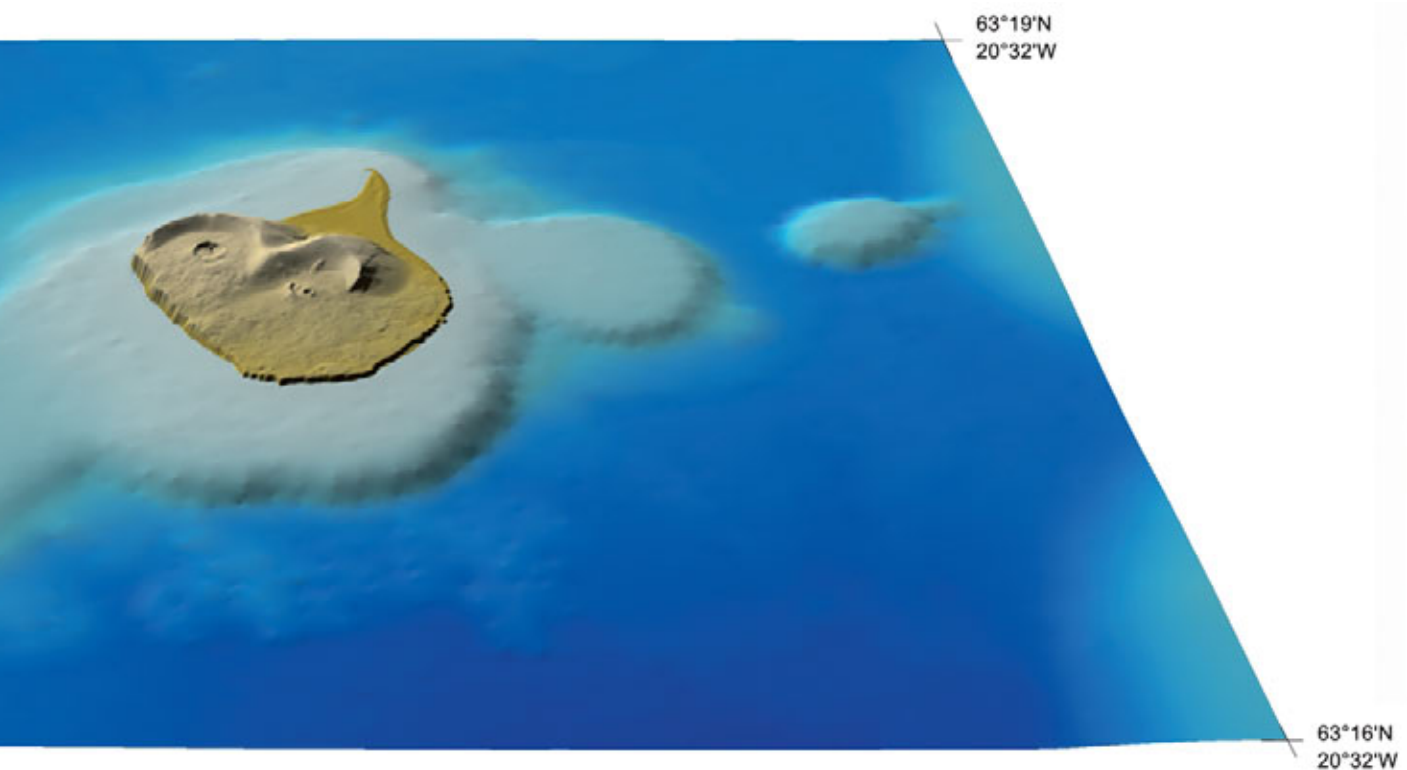


Fig. 2.5. Three-dimensional model of the Surtsey volcano (oblique view from the south), prepared by the Institute of Earth Sciences, University of Iceland, based on aerial photographs from 2004 (Loftmyndir) and depth soundings of the seabed from 2000 (Hydrographic Department).

and of the islands of Bjarnarey and Elliðaey northeast of Heimaey. The most recent volcanic episode may have started with the reported submarine eruption in 1896, followed by the Surtsey eruption of 1963–1967 and the Eldfell eruption in 1973.

In contrast to the Surtsey eruption, which had an insignificant effect on the residents of Heimaey, the Eldfell eruption on their island in January to June 1973 had disastrous effects (Williams and Moore 1983). A 3-km-long eruption fissure opened up at the eastern outskirts of town; 350 houses (30% of the total) were destroyed by lava or tephra and a further 400 were damaged. Miraculously, only one life was lost, as all the islanders were evacuated from the island within hours. About two-thirds of the residents returned in following summer, or about 3500 out of 5300 pre-eruption inhabitants. The Eldfell eruption is considered to be one of the most destructive volcanic eruptions in the history of Iceland.

### Topography

The Surtsey volcano, which belongs to the Vestmannaeyjar volcanic system, rose from the sea floor in a volcanic eruption occurring from 1963 to 1967. The eruption history of Surtsey volcano is described in Chapter 2b. At the end of the eruption in 1967, the island of Surtsey had attained a surface area of 2.65 km<sup>2</sup> and the total volume of erupted material was estimated to be 1.1 km<sup>3</sup>, about 70% of which was tephra and 30% lava. The island is the subaerial segment of the complete Surtsey volcano, which forms a mainly submarine ridge approximately 5.8 km long and oriented southwest-northeast. Measured from northwest to southeast, the volcano's maximum width is 2.9 km and its base area encompasses some 13.2 km<sup>2</sup> (Fig. 2.5). The Surtsey volcano has changed considerably since the eruption ended in 1967, and the following topographical and geological description is based mainly on data collected in the summer of 2004. The description of bottom topography is based on depth measurements by the Icelandic Maritime Administration in the summer of 2000.

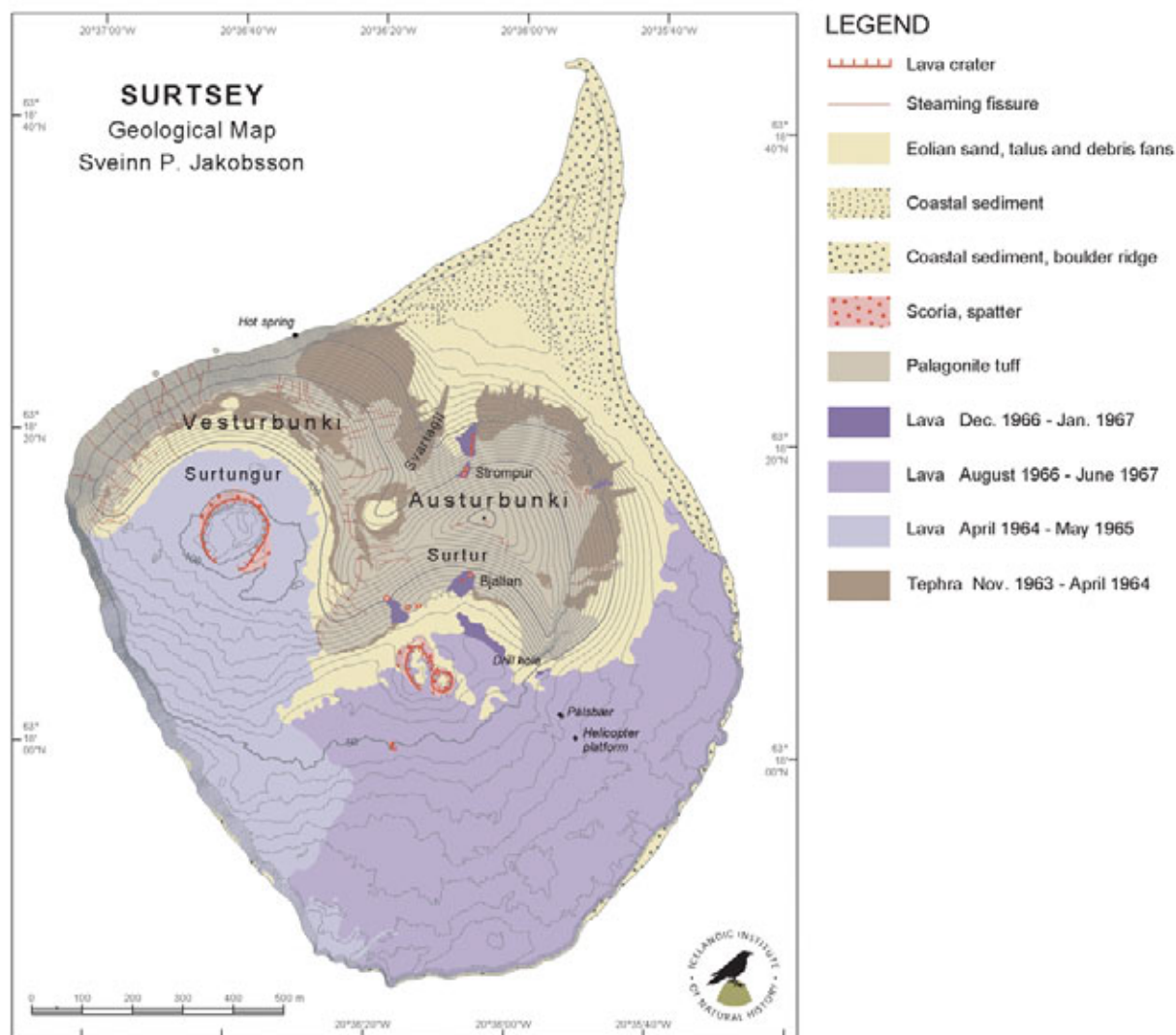


Fig. 2.6. Geological map of Surtsey. Topography is based on aerial photographs from August 2004. See also enclosed map in the scale of 1:5000.

Surtsey has a surface area of 1.41 km<sup>2</sup>, a maximum width from west to east of 1.33 km and a maximum length from north to south of 1.80 km (Fig. 2.6; see also enclosed map). It is the second largest island of the Vestmannaeyjar group, followed by Elliðaey (0.46 km<sup>2</sup>) and Bjarnarey (0.33 km<sup>2</sup>). Although the highest elevation on Surtsey is only 155 m, the sea depth prior to the eruption was about 130 m, so that the true height of the volcano is 285 m.

Surtsey's prominent topographical features are two crescent-shaped cones composed of tephra and palagonite tuff, along with a lava field that caps the southern half of the island. Rising to an elevation of 155 m, the eastern cone, Austurbunki, is marked by several small lava

craters and fissures. The western cone, Vesturbunki, whose height is 141 m, has large slump scars due to marine abrasion on its western side, where a 135-m-high sea cliff has formed. From the tuff cones, the main lava field forms a shield gently dipping to the south and east. Transported coastal sediments have mainly been deposited at the north end of the island, constructing a broad spit.

The shape of Surtsey is constantly modified by the harsh weather conditions which prevail in the sea south of Iceland, particularly during winter. Heavy sea waves erode the coast and produce coastal sediments. Being easily eroded and transported by the wind, loose, unconsolidated tephra has collected as aeolian deposits along the

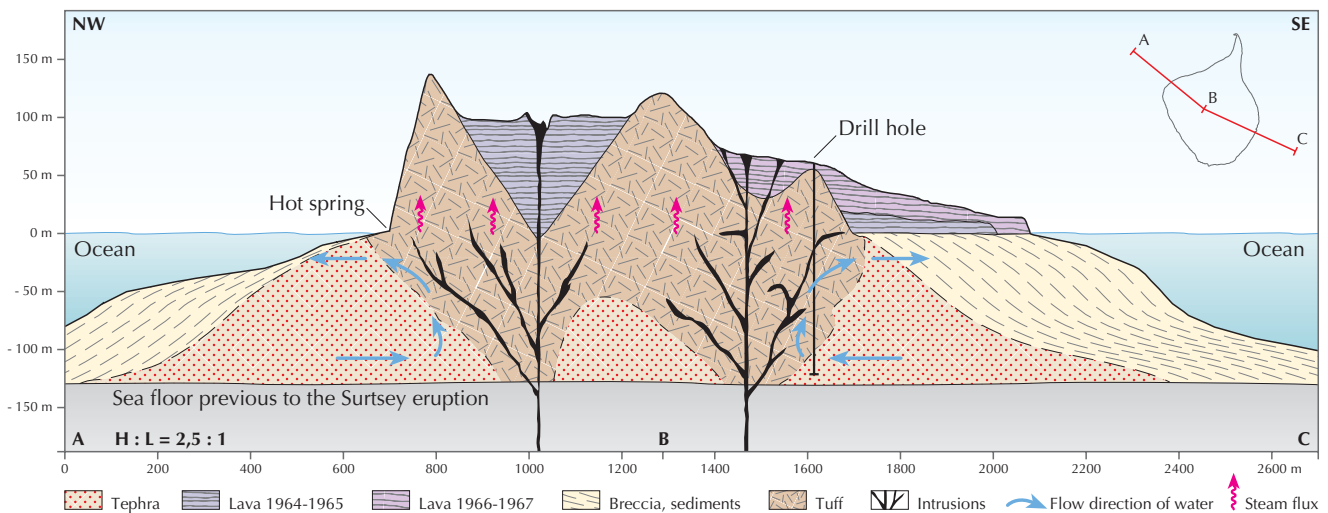


Fig. 2.7. NW-SE profile through the Surtsey volcano.

flanks of the two cones, as well as on the lava field. Wind deflation is conspicuous in the island's tuff, where it has at places created potholes up to 0.5 m deep and 1.5 m in diameter.

Running water is rarely observed on the surface of the tephra and lava because of their high porosity, although small, temporary streams do appear on the tuff surface after exceptionally heavy precipitation. These temporary streams have eroded the unconsolidated tephra which in most places surrounds the tuff and built fans at the base of slopes, so that mudflow channels have developed at several points on the tuff cone slopes. On the northern slopes of Vesturbunki and Austurbunki, these mudflow channels are usually 0.5–2 m wide and reach down to the foot of the slope. On the inner slope of Austurbunki, smaller mudflow channels can be observed that have solidified into rock since their original formation in unconsolidated tephra.

Apart from Surtsey, eruptions occurred on the sea floor at three sites, concurrent with the Surtsey eruption. About 2.5 km north-northeast of Surtsey, a submarine tephra ridge, Surtla, was built up between December 1963 and January 1964. Recent depth measurements indicate its length as 0.9 km and its width as 0.6 km, and it rises 60 m above the sea floor (Fig. 2.6). At a distance of 0.6 km to the east-northeast of Surtsey, explosive activity formed the island of Syrtlingur in 1965. Today, however, only a submarine platform remains, measuring 1.2 km in diameter and rising 70–80 m above the sea

floor. In 1965–1966 yet another island, called Jólnir, was formed by explosive activity 1 km southwest of Surtsey. Today it is only represented by a seamount with a diameter of 1.7 km and an elevation of 60–70 m above the sea floor (Norrman and Erlingsson 1992).

## Geology

The surface of Surtsey has been mapped in detail, using conventional methods. Furthermore, a 181 m deep research hole was drilled in 1979 at the southeast corner of Austurbunki in order to investigate the subsurface constitution and structure of the island. Surtsey, designated as a submarine tuya (Sigurður Þórarinnsson 1966; Guðmundur Kjartansson 1966), has now become the best-studied volcano in Iceland. While the term tuya was originally restricted to subglacial volcanoes, it has since been extended to include volcanoes that have erupted into lakes or shallow seawater. Surtsey is considered to be one of the world's best preserved submarine tuyas. The two primary geological units formed during the Surtsey eruption are tephra and lava. Basal pillow lava, an important part of most subglacial tuyas, apparently did not develop in Surtsey because of the shallow water depth (Sveinn P. Jakobsson and Moore 1986). The eruptive products at Surtsey are composed of alkali basalt with phenocrysts of olivine, plagioclase and chromian spinel. In addition, three secondary geological units are found there: palagonite tuff, aeolian and talus sediments, and coastal sediments (Fig. 2.6).





View to the west over the crater Surtungur. (Photo: Daniel Bergmann 2003).

### Tephra

During the explosive submarine phase of the Surtsey eruption, from November 1963 to April 1964, basalt tephra (volcanic ash) was produced through the quenching of hot magma by cold sea water. The resulting tephra formed two crescent-shaped cones which merged, and today cover an area of 0.34 km<sup>2</sup>. The cones are built up of tephra layers which to a considerable extent have consolidated into tuff due to post-eruptive hydrothermal activity. Geologists call craters of this type tephra or tuff rings, depending on which material dominates. The eastern tuff cone, named Surtur or Austurbunki, has a crest-width of 0.43 km, and the western tuff cone, Surtungur or Vesturbunki, has a crest-width of 0.52 km. On the scale of other Icelandic tuff or tephra craters, the Surtsey tuff craters are medium-sized.

Characterised by poor sorting and varying grain size, Surtsey tephra ranges in its constituents from silt to boulders (Lorenz 1974), although it is mainly made up of fine glass shards less than 2 mm in diameter, along with mineral phenocrysts and small rock fragments. The tephra deposited above sea level forms finely-bedded layers and is poorly sorted, contrasting to the tephra below sea level, which is more chaotic in structure and whose grains sometimes demonstrate considerable size sorting. The porosity of the tephra layers above sea level must rate as very high, or 45–50% by volume.

Surtsey has come to be the world type locality

for Surtseyan tephra (Walker and Croasdale 1972; Walker 1973), i.e. tephra produced by hydro-magmatic explosions in shallow water. The island is also an important site for accretionary lapilli (Sveinn P. Jakobsson and Moore 1982), whose individual pellets there reach the exceptional diameter of 3.5 cm. Also, Surtsey was one of the first localities in the world where vesiculated tuff was noted and described, i.e. tuff that contains independent vesicles between particles, where steam was trapped while the original tephra was being deposited (Lorenz 1974).

### Lava

The Surtsey eruption evolved from an explosive phase into an effusive phase at the western crater (Surtungur) in April 1964, when the island was large enough to isolate that vent from inflowing seawater. Altogether, seven Surtsey craters and crater fissures emitted lava between April 1964 and June 1967 (Fig. 2.6). The first major effusive phase (1964–1965) produced a lava shield extending 100 m above sea level and containing, when finished, a total volume of 0.3 km<sup>3</sup>, while the second phase (1966–1967) produced a 70-m-high lava shield with a volume of 0.1 km<sup>3</sup>. Both of these shields consist of two structural units: an inner lava cone and an outer lava apron (Thorvaldur Thordarson 2000). Together they form a lava field that slopes gently to the south and east. Added to this are five small lava flows on the slopes of Austurbunki. Today the lavas cover an area of 0.72 km<sup>2</sup>.

When lava flows into water it brecciates and gradually builds up a submarine delta in front of the shore. Such a delta is foreset-bedded and consists of the products of the quench-fragmentation of molten lava and the disintegration of subaerial lava flows. At Surtsey the final layers in the western lava crater have achieved a total thickness of 230 m, resting on a 130-m-thick brecciated foundation which lies below sea level.

Due to heavy marine abrasion, high lava cliffs have formed on Surtsey and now tower a height of 80 m over the southwest shoreline. These cliffs provide excellent outcrops for viewing the internal structure of the subaerial lava shield, which was constructed by multiple lava flows whose thickness varies but averages 1–2 m. The morphology of the lava surface is very interesting, particularly



Typical ropy lava surface at the southern coast of Surtsey. (Photo: Borgþór Magnússon 2005).

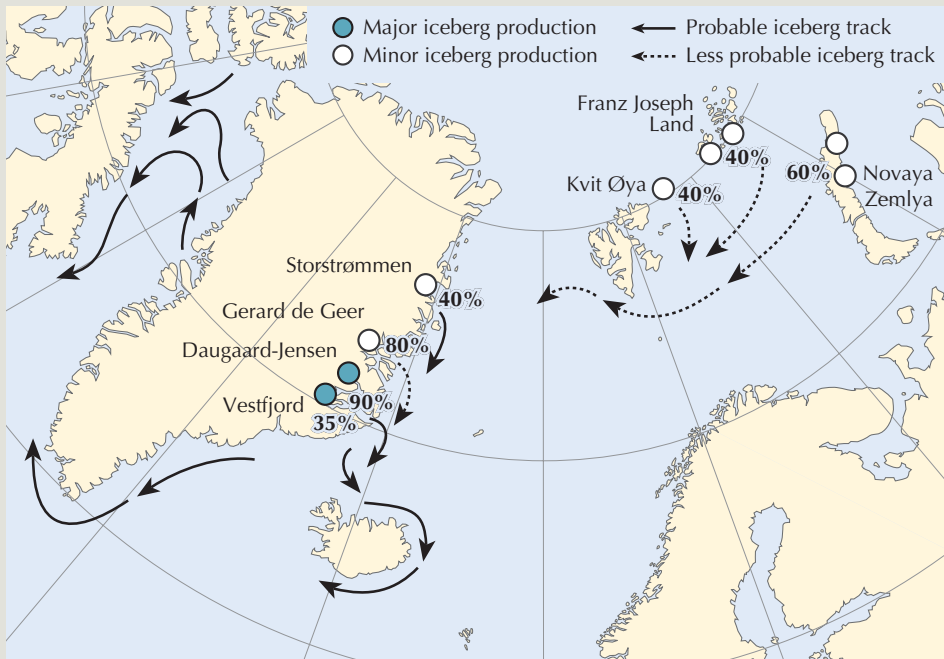
through the possibility of referring to the modifications it underwent, according to the detailed contemporary descriptions by Sigurður Þórarinnson (1966, 1967, 1969) and Þorleifur Einarsson (1966). The Surtsey lava flows are mostly smooth *pahoehoe* flows, even if rugged *aa* flows are also evidenced, mainly in two areas in the lava produced from 1966 to 1967.

Being basaltic and having a low viscosity, the Surtsey lavas tended to flow in tubes or closed trenches, especially from Surtungur, the western lava crater. Many of the lava tubes were left hollow. Tumulus structures are common, with

observations showing that tumuli form when the lava crust becomes inflated above a wide pool of molten lava. Surtsey also has hornitos at several locations, and one small pit crater remains southwest of the Surtungur where the roof of a large lava tube collapsed (Fig. 2.6).

The geometry and profile of the subaerial segments of the Surtsey lava shields are strikingly similar to those of other monogenetic lava shields in Iceland and everywhere else, which permits the study of the effusive activity at Surtsey as an analogue for establishing a conceptual model of lava shields in general.

### Possible origin of exotic xenoliths found in the Surtsey tephra



Possible origin of the exotic xenoliths from Surtsey. Numbers refer to the proportion of the exotic xenoliths that match formations presented on geological bedrock maps of each area. Several factors combine to make Daugaard-Jensen glacier in East Greenland the most probable origin of the exotic xenoliths. Most of the samples from Surtsey can be traced to its surrounding area. (From Reynir Fjalar Reynisson 2006).



Typical samples of the exotic xenoliths from Surtsey, including granite, gneiss, quartzite and dolomite. (Photo: Kristján Jónasson 2006).

Rock fragments of exotic origin are not uncommon in the Surtsey tephra. Since these fragments are quite diverse, they have been classified into five main groups, each offering valuable information on a specific geological issue. A conspicuous example of these groups is fossiliferous bits which the submarine explosions blasted upwards from the site's former sea floor. Another group, whose fragments include granite, gneiss, quartzite, dolomite and schist, has attracted special attention, since such rock types cannot be of local origin. It has been suggested that icebergs transported them from East Greenland to the environs of Vestmannaeyjar, probably

for the most part during the early Holocene. According to this theory, icebergs containing terrestrial debris drifted with ocean currents from their place of origin to the Vestmannaeyjar vicinity. As the icebergs melted there in the warmer ocean, the rock debris they had brought from a far-off land sank to the seabed. While the Surtsey eruption was in its explosive submarine phases, this debris originating from icebergs was blasted into the atmosphere, along with pieces of the uppermost sea floor. As the blasted material settled, it mixed with the tephra in Surtsey (Fig. 2.6). (Reynir Fjalar Reynisson 2006).

## Geological definitions

**Accretionary lapilli:** Spheroidal pellets consisting of cemented or consolidated tephra and measuring generally between 1 mm and 1 cm in diameter. Formed in the explosion column by the accretion of wet particles around a nucleus which is usually a rock fragment.

**Alkali basalt:** A silica-undersaturated basalt, uncommon in Iceland.

**Breccia:** A coarse-grained rock composed of angular rock fragments.

**Encrustation:** A mineral crust formed on a rock surface.

**Holocene:** The youngest geological epoch, representing the last 11,500 years of the geological record.

**Hornito:** A topographically insignificant mound or rise of spatter from around an opening in the roof of an underlying lava tube.

**Hydromagmatic eruption:** An explosive volcanic eruption caused by magma interacting with ground water, surface water or sea water.

**Magma:** Molten rock material that contains suspended crystals (phenocrysts) and is generated within the upper mantle or crust. Upon extrusion in Surtsey, the temperature of the magma was 1,155° –1,180° C.

**Móberg:** An Icelandic term for brownish, consolidated tephra, of basaltic or intermediate composition.

**Móberg Formation:** A chronostratigraphical term spanning all Icelandic deposits from the Late Pleistocene, i.e. between 0.78 and 0.01 million years ago.

**Palagonite:** An altered, hydrated, basaltic glass, of brown or yellow colour. The term is related to the alteration process, called palagonitisation.

**Phenocryst:** A relatively large, conspicuous crystal in a fine-grained or glassy groundmass.

**Pillow lava:** Lava displaying pillow structure and formed in a subaqueous environment.

**Plate tectonics:** A theory of global tectonics according to which the lithosphere is divided into a number of plates; these undergo horizontal movements leading to seismic and volcanic activity along plate boundaries.

**Pleistocene:** The geological epoch just previous to the Holocene, starting 1.8 million years ago and ending 11,500 years ago.

**Silt:** Sediment finer-grained than sand but coarser than clay.

**Solifluction:** Slow, viscous, downslope flow of waterlogged surface material.

**Spit:** A small point or low tongue or narrow embankment of land, commonly consisting of sand or gravel deposited by longshore transport.

**Talus:** Coarse rock fragments derived from a cliff and lying at its base.

**Tephra:** Unconsolidated rock particles expelled through volcanic vents or produced by steam explosions. Classified according to its particle size, tephra consists mainly of basaltic glass.

**Tuff:** Tuff is cemented or consolidated tephra, while tuff breccia contains coarse fragments of basalt.

**Tumulus:** Isolated cupola-shaped mound that protrudes from a lava surface and is typically 1.5–3 m high and 5–15 m in diameter.

**Tuya:** A relatively flat-topped volcano formed by an eruption into water thawed from an ice cap, or into a lake or seawater. Also called a table mountain, a tuya is mainly composed of tephra and is usually capped by subaerial lava.

**Vesiculated tuff:** Tuff that contains vesicles left by steam which was trapped between particles during deposition of the original tephra.



Scientists measuring temperature at a steaming fissure on the western crest of Surtungur. (Photo: Sveinn P. Jakobsson 1997).

### Lava caves

Surtsey has four emptied, subhorizontal lava caves which have been mapped; the longest such cave measures 181 m. Emptied, near vertical lava feeder dikes to craters can be described as a second type of cave on the island. Five caves of this type have been mapped, the largest of which extends about 20 m down. Stalactites and stalagmites of lava are common in the lava caves and reach a length of 20 cm. The occurrence of lava caves and caverns in the comparatively small lava field on Surtsey exceeds what has been observed in other Icelandic lava fields (Björn Hróarsson 1990).

### Encrustations

Fumarolic gases in the cooling lavas resulted in colourful volcanogenic mineral encrustations that are especially abundant close to craters. Some of these encrustations, being water soluble, quickly disappeared, while others were easily affected by general weathering processes. In some of the deeper lava caves, however, abundant volcanogenic encrustations are still present (Sveinn P. Jakobsson et al. 1992). Another type of encrustation is of the evaporitic sort. Not only does down-seeping precipitation on Surtsey contain a high proportion of ocean spray, but seawater seeping into the island presumably boils where it comes into contact with hot intrusions at

#### I. Formed by encrustation upon the cooling and degassing of lava

Sulphur S
Halite NaCl
Fluorite CaF <sub>2</sub>
Carnallite KMgCl <sub>3</sub> · 6H <sub>2</sub> O
Ralstonite Na <sub>x</sub> Mg <sub>x</sub> Al <sub>2-x</sub> (F,OH) <sub>6</sub> · H <sub>2</sub> O
Opal-A SiO <sub>2</sub> · nH <sub>2</sub> O
Calcite CaCO <sub>3</sub>
Thenardite Na <sub>2</sub> SO <sub>4</sub>
Aphthitalite (K,Na) <sub>3</sub> Na(SO <sub>4</sub> ) <sub>2</sub>
Glauberite Na <sub>2</sub> Ca(SO <sub>4</sub> ) <sub>2</sub>
Anhydrite CaSO <sub>4</sub>
Galeite Na <sub>15</sub> (SO <sub>4</sub> ) <sub>5</sub> F <sub>4</sub> Cl
Kieserite MgSO <sub>4</sub> · H <sub>2</sub> O
Blodite Na <sub>2</sub> Mg(SO <sub>4</sub> ) <sub>2</sub> · 4H <sub>2</sub> O
Gypsum CaSO <sub>4</sub> · 2H <sub>2</sub> O
Loweite Na <sub>12</sub> Mg <sub>7</sub> (SO <sub>4</sub> ) <sub>13</sub> · 15H <sub>2</sub> O
Kainite KMg(SO <sub>4</sub> )Cl · 3H <sub>2</sub> O
New World mineral Na <sub>2</sub> Ca <sub>5</sub> (SO <sub>4</sub> ) <sub>6</sub> · 3H <sub>2</sub> O (JCPDS 35-137)

#### II. Formed in the hydrothermal system as alteration products of basalt tephra

Opal-A SiO <sub>2</sub> · nH <sub>2</sub> O
Calcite CaCO <sub>3</sub>
Anhydrite CaSO <sub>4</sub>
Gypsum CaSO <sub>4</sub> · 2H <sub>2</sub> O
Tobermorite Ca <sub>5</sub> Si <sub>6</sub> O <sub>16</sub> (OH) <sub>2</sub> · 4H <sub>2</sub> O
Xonotlite Ca <sub>6</sub> Si <sub>6</sub> O <sub>17</sub> · (OH) <sub>2</sub>
Nontronite Na,K,Ca; Al,Mg,Fe-silicate
Analcime NaAlSi <sub>2</sub> O <sub>6</sub> · H <sub>2</sub> O
Phillipsite (K,Na,Ca) <sub>1-2</sub> (Si,Al) <sub>8</sub> O <sub>16</sub> · 6H <sub>2</sub> O
Chabazite CaAl <sub>2</sub> Si <sub>4</sub> O <sub>12</sub> · 6H <sub>2</sub> O

Table 2.1. Secondary minerals formed at Surtsey.

sea level (Fig. 2.7). Such conditions facilitate the formation of quite exceptional encrustations, whose evaporitic specimens have for instance formed stalactites reaching below cave roofs as far as 45 cm. Altogether, eighteen mineral species have been identified; one of which appears to be a new world mineral (Table 2.1).

### Hydrothermal anomaly

In the spring of 1967, a mild hydrothermal anomaly was discovered at the surface in Austurbunki. The extent of this anomaly is clearly related to how the lava craters are distributed

(Friedman and Williams 1970). Although there has been a postvolcanic decline in thermal flux, vapour emissions still remain visible from numerous open fissures in the tuff. In 2002 a small hot spring with temperatures at 80°C was discovered at the western shore of Surtungur (Figs. 2.6 and 2.7).

The drill hole on Surtsey provided important insights into the character of the hydrothermal system in the volcano. Figure 2.7 is a geological cross-section of Surtsey from northwest to southeast, based on the documented sequence of eruption events and on information from the drill hole. These data strongly suggest that the heat in the hydrothermal system was provided by intrusions which formed both below and above sea level from 1965 to 1966 at Vesturbunki, and from December 1966 to January 1967 at Austurbunki, in conjunction with lava extrusions in these areas (Sveinn P. Jakobsson 1978; Valgarður Stefánsson et al. 1985).

Because of the high porosity of Surtsey formations, any water at sea level inside Surtsey is presumed to be boiling, which leads to vapour dominating the hydrothermal system above sea level and to temperatures of around 100° C

prevailing in the porous tephra pile (Friedman et al. 1976). Below sea level, on the other hand, temperatures of several hundred degrees C may occur, especially close to the inferred intrusions.

### Palagonite tuff

The basalt tephra has been observed to alter rapidly within the hydrothermal portions of Surtsey, concluding with consolidation of the tephra into palagonite tuff. In 2004 the tuff area covered 0.24 km<sup>2</sup>, and some 85% of the volume of the tephra cones above sea level is estimated to have changed into hard palagonite tuff. During the alteration process, the original glass shards in the tephra are chemically modified, devitrified and hydrated to produce palagonite. This process is called palagonitisation and had not previously been monitored happening in nature (Sveinn P. Jakobsson 1972; 1978). During the process, a number of chemical elements are released from the original glass in the tephra to form an array of new secondary minerals which eventually fill the voids in the rock and at the same time cements its particles together (Sveinn P. Jakobsson and Moore 1986). Ten types of minor secondary minerals are found in the palagonite tuff (Table 2.1).



Tuff sea cliff on the west coast. The red colour indicates oxidation of the tuff caused by the overlying lava. (Photo: Daníel Bergmann 2003).

A further aspect to note is that signs of bacterial activity have been observed in many tuff samples from Surtsey (Thorseth et al. 1992; Sveinn P. Jakobsson 1996), and it appears possible that bacteria contribute to altering the tephra there.

The transformation of tephra to tuff has an important implication for the future of Surtsey, since tuff has proved itself to be much more resistant to marine abrasion than tephra and even than lava. Through the formation of tuff, Surtsey has been ensured a longer life.

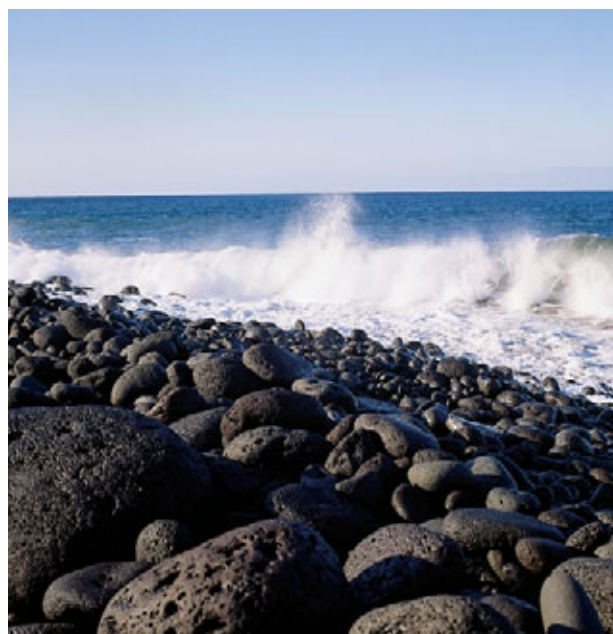


The tuff sea cliffs on the northwestern coast are up to 130 m high and have changed little since 1980. (Photo Sveinn P. Jakobsson 1985).

### Sediments

The ferocity of wave action in the sea surrounding Surtsey has come as a surprise to geologists. Coastal erosion has been rapid, modifying the coastline markedly from year to year, above all during winter storms. Thus coastal sediments (Fig. 2.6), consisting mainly of boulders and cobbles derived from the break-up of lava (Norrman 1980; Calles et al. 1982), now covers an area of 0.15 km<sup>2</sup>. Most of the lava shore terrace has been eroded by longshore drift towards the north, and the boulders, among which the largest are about 1.5 m in diameter, have mainly been deposited in the northern spit. Partly covered with sand originating in the tephra and tuff of the two cones, the northern spit also has overflow channels where stranded driftwood indicates the floodline on the spit every winter. Coastal material is lost downhill, probably in intermittent slump motions, to form the 130-m-deep submarine slope of Surtsey.

Surtsey presents conspicuous aeolian deposits, whose source material is mainly tephra. These wind-driven deposits can be divided into two groups: firstly, the sand dunes and ripples capping the slopes of the tephra and tuff cones and, secondly, sand blowing onto and covering the lava field (Calles et al. 1982). The aeolian deposits are characterised by considerably better



The northern spit is made up of boulders, cobbles and sand. (Photo: Karl Gunnarsson 1998).



Erosion of tephra by temporary streams of water at the northern side of Austurbunki. (Photo: Sigurður H. Magnússon 2005).

sorting than the original tephra, with the dominant grain sizes belonging to the sand and silt fractions. The aeolian deposits (>0.5 m thick) now cover an area of 0.20 km<sup>2</sup>.

Mud flow and talus deposits appear on the slopes of the two tephra and tuff cones, mainly at the north sides. This material, which has been transported by the force of gravity and running water, is characterised by poor sorting. In addition to this, some solifluction material is found on the northern sides of the cones.

### The climate

Automatic meteorological observations were conducted at Surtsey over a two-month period in the late autumn and early winter of 1996. The observation station, which was at an exposed location 154 m above sea level, gave results strongly indicating that the Surtsey weather conditions and those 19 km to the northeast, at Stórhöfði lighthouse on Heimaey, are very similar. The Stórhöfði station is also at a very exposed location, standing 118 m above sea level, and has kept a continuous record of observations

since 1921. During the two-month period the average temperature difference was less than 0.1° C, although the wind speed at Surtsey measured higher than at Stórhöfði during the same period. All climatological references below refer to the Stórhöfði station, unless otherwise indicated.

The maritime climate of Surtsey is characterised by relatively warm winters and cool summers. While the average monthly sea surface temperature is higher than the air temperature in every month of the year, the average difference in the winter months exceeds 4° C. On individual days in any season, though especially in the summer, the sea can become colder than the air – circumstances that commonly cause fog or extremely low clouds. All the winter months (December to March) have average temperatures between 1.5 and 2.0° C, whereas the warmest months at Stórhöfði, slightly higher than sea level, are July and August, whose average temperatures lie close to or just below 10° C (Fig. 2.8). The annual temperature range (difference between the warmest and coldest months) is thus only about 8.5° C, compared with the range in annual sea



surface temperatures of about 5° C. On average, the minimum temperature drops below 0° C on 80 days of the year; however, since the maximum exceeds 0° C on most of those days, round-the-clock freezing is only experienced for 18 days per year, on average. The frost-free period lasts on average for 5 to 7 months; during the last 50 years, the longest frost-free period lasted 8 months and the shortest about 15 weeks. Maximum temperatures in excess of 20° C are quite rare; Stórhöfði has experienced only 2 such days during the last 85 years. Frost below -15° C is also extremely rare.

Stórhöfði receives ample precipitation, totalling annually about 1600 mm. Whereas June is the driest month of the year (93 mm), October comes out on average as the wettest month (156 mm), though in fact the entire fall and winter period from August to March resembles October (Fig. 2.8). Snowfall is rather slight; in fact, its sum (60 mm) comprises only around 4% of the total annual precipitation. A mixture of snow and rain falls frequently, resulting in approximately another 30% of the overall precipitation, while the remaining 66% falls as rain. During the summer, there is no snowfall. Humidity is generally high, with frequent overcast and low-cloud conditions.

Winds are strong at the nearby Stórhöfði lighthouse, where on over 130 days per year the 10-minute average exceeds 20 m/s at least once, and a sustained 10-minute hurricane force (>32.7 m/s) is exceeded on an average of 15 days per year (Fig. 2.8). Concurrent measurements at Surtsey and Stórhöfði indicate that the ridge wind at Surtsey is even stronger than at Stórhöfði; presumably, however, Surtsey's lower-level winds are considerably less violent. In any case, the sea state is often highly agitated.

Most of the weather systems affecting Surtsey arise out of the west (SW to NW). However, the westerlies aloft are usually undercut by shallow air masses from the northeast, so for most of the year easterly winds prevail in the area and are reinforced by the barrier of the South Iceland glaciers (Fig. 2.9).

### Offshore waves

Iceland's wave climate is severe, including measured offshore significant wave heights (the

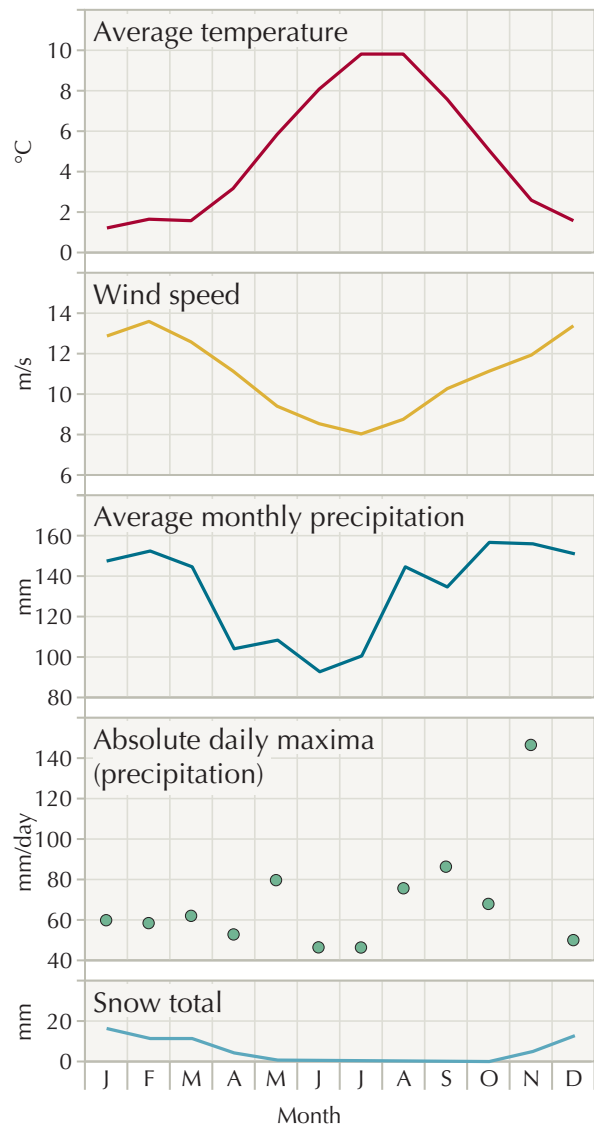


Fig. 2.8. Average temperature (red trace) and wind speed (yellow trace) at Stórhöfði, 1971–2000; average monthly precipitation (blue trace); snow totals (light blue trace) and absolute daily maxima (shown by green dots, in mm per day). (Modified from the Icelandic Meteorological Office.)

average height of one-third of the waves observed during a given period of time) of over 16 m and wave peak periods of up to 20 seconds. Cyclones from North America pass over Iceland from the southwest, generating high waves upon reaching Southwest Iceland. Deep cyclones sometimes stagnate east or north of the country for several days and also generate high waves.

In January 1990, for example, an extreme storm hit the south coast of Iceland. At its peak intensity, the atmospheric pressure plunged to

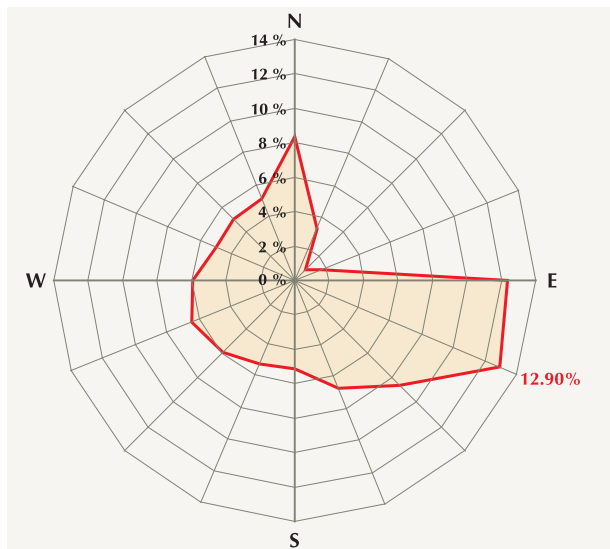


Fig. 2.9. Wind direction frequency (%) at Stórhöfði, 1971–2000. Easterly winds prevail, with the low frequency of northeasterly winds being owed to the sheltering effect of the Eyjafjallajökull glacier and mountain mass on the mainland. (Modified from the Icelandic Meteorological Office.)

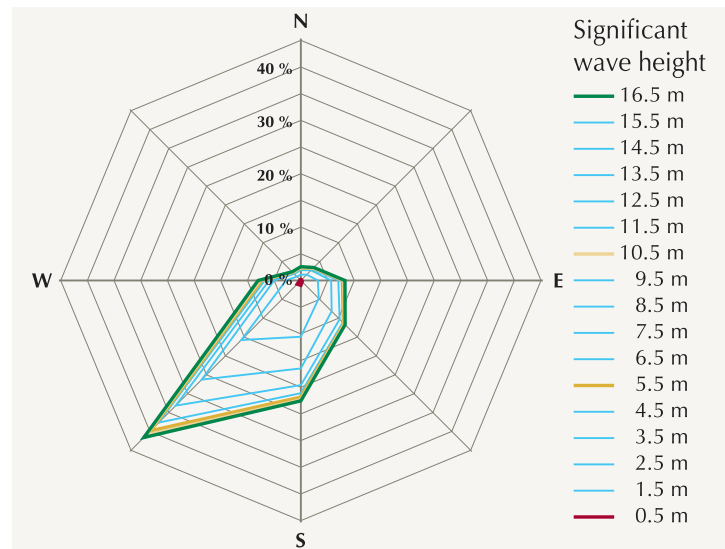


Fig. 2.10. Offshore wave statistics based on significant wave heights off Surtsey at location 63°N,21,0°W for the ECMWF hindcasted data for the period 1979 to 2004. (Model: Icelandic Maritime Administration). The offshore wave statistics explain why the marine abrasion of Surtsey is greatest at the southwest and south coast, cf. Fig 2.24.

928 millibars at a location 200 km southwest of the country. The offshore wave buoy at Surtsey recorded significant wave height of 16.68 m, with peak period of 19.4 seconds.

Offshore wave data is available since 1988, measured off Surtsey (63°17'14"N, 20°20'70"W) at a depth of 130 m and off Garðskagi (64°03'27"N, 22°56'57"W) a depth of 80 m (Fig. 2.10). Wave hindcast data are available from the European Centre for Medium-Range Weather Forecasts (ECMWF).

## Terrestrial life

### Flora

Plant colonisation has been closely studied on Surtsey ever since the island was formed. Microbial moulds, bacteria and fungi were quick to establish themselves in the fresh volcanic substrate (Schwabe 1970a, Smith 1970). The first vascular plant to be noted growing on the island was found in 1965 (Sturla Friðriksson 1966a; Eyþór Einarsson 1968), mosses became visible in 1968 (Bergþór Jóhannsson 1968) and the first lichens were discovered on the lava in 1970 (Hörður Kristinsson 1972). Vascular plants have proved of far greater significance in vegetation development than mosses and lichens.

Consequently, this element of the flora has been studied most intensely. The island has been visited every summer by a team of botanists and a record kept of colonising species and their fate.

### Vascular plants

The biological expedition to Surtsey in 2005 recorded 51 vascular species. On the other hand, an overall total of 60 species has been recorded since 1965. In other words, there have been nine unsuccessful colonisation attempts. About 30 species have managed to establish viable populations and spread on the island, and most of these are now found in some of the 23 permanently established study plots. While forb and grass species are most prominent (32 and 14 respectively) in the flora, other prominent taxonomic groups include sedges and rushes (5 species), shrubs (4 species) and ferns (2 species) (Table 2.2, Appendix 2). The most widespread plant species on Surtsey are sea sandwort *Honckenya peploides*, procumbent pearlwort *Sagina procumbens*, common mouse-ear *Cerastium alpinum*, annual meadow-grass *Poa annua* and lyme grass *Leymus arenarius* (Table 2.3).

	Species status in 2005			
	1965–2005	Existing	Viable populations	Within permanent plots
Pterydophytes	3	3	1	
Monocots				
Grasses	14	12	7	7
sedges and rushes	6	5	1	2
Orchids	1			
Dicots				
forbs	32	27	19	15
dwarf shrubs	4	4	2	1
	60	51	30	25

Table 2.2. Overview by taxonomic group of vascular species recorded on Surtsey, showing their success of establishment.

Most of the vascular plant species on Surtsey are common elsewhere in the Vestmannaeyjar archipelago, which is probably the main source of species colonising Surtsey. As for the Icelandic mainland, it has every plant species that has been noted on Surtsey. Although Surtsey is the southernmost island of Iceland, there has been no indication of species colonising the island from distant sources (Borgþór Magnússon et al. 1996).

Species	Number of plots
Sea sandwort <i>Honckenya peploides</i>	18
Procumbent pearlwort <i>Sagina procumbens</i>	12
Common mouse-ear <i>Cerastium fontanum</i>	10
Annual meadow-grass <i>Poa annua</i>	9
Lyme-grass <i>Leymus arenarius</i>	8
Smooth meadow-grass <i>Poa pratensis</i>	8
Common chickweed <i>Stellaria media</i>	8
Common scurvygrass <i>Cochlearia officinalis</i>	7
Arctic fescue <i>Festuca rubra</i>	7
Oysterplant <i>Mertensia maritima</i>	7
Sea mayweed <i>Tripleurospermum maritimum</i>	6
Reflexed saltmarsh-grass <i>Puccinellia coarctata</i>	6

Table 2.3. The most common vascular plants on Surtsey and the number of permanent plots where each species was observed in a 2004 survey.

The wild flora of Heimaey contains some 150 species of vascular plants. Other islands in the Vestmannaeyjar archipelago harbour only 2–30 species, corresponding to their aerial size, which ranges from 0.01 to 0.46 km<sup>2</sup> (Sturla Friðriksson and Björn Johnsen 1967). Thus the number of species growing on Surtsey has actually surpassed that of the smaller islands in the archipelago. This may be explained by Surtsey's considerably larger size and its greater diversity of habitats compared to the other volcanic islands, which are much

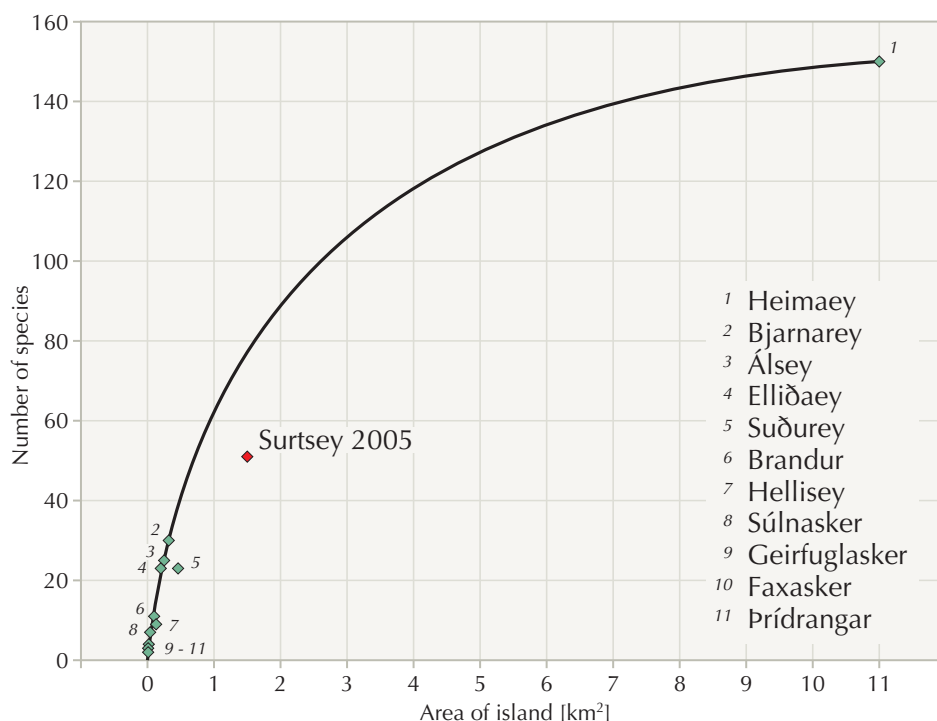


Fig. 2.11. Number of vascular plant species found on individual islands in the Vestmannaeyjar archipelago in relation to their areal size (Sturla Friðriksson and Björn Johnsen 1967). A curve was drawn to indicate the relationship and show the current (2005) position of Surtsey.



Sea sandwort and lyme grass on the sand-filled lava on eastern Surtsey. The species are widely dispersed on the island. Like other plant species, they have colonised Surtsey from the neighbouring islands and the mainland seen in the background. (Photo: Borgþór Magnússon 2005).

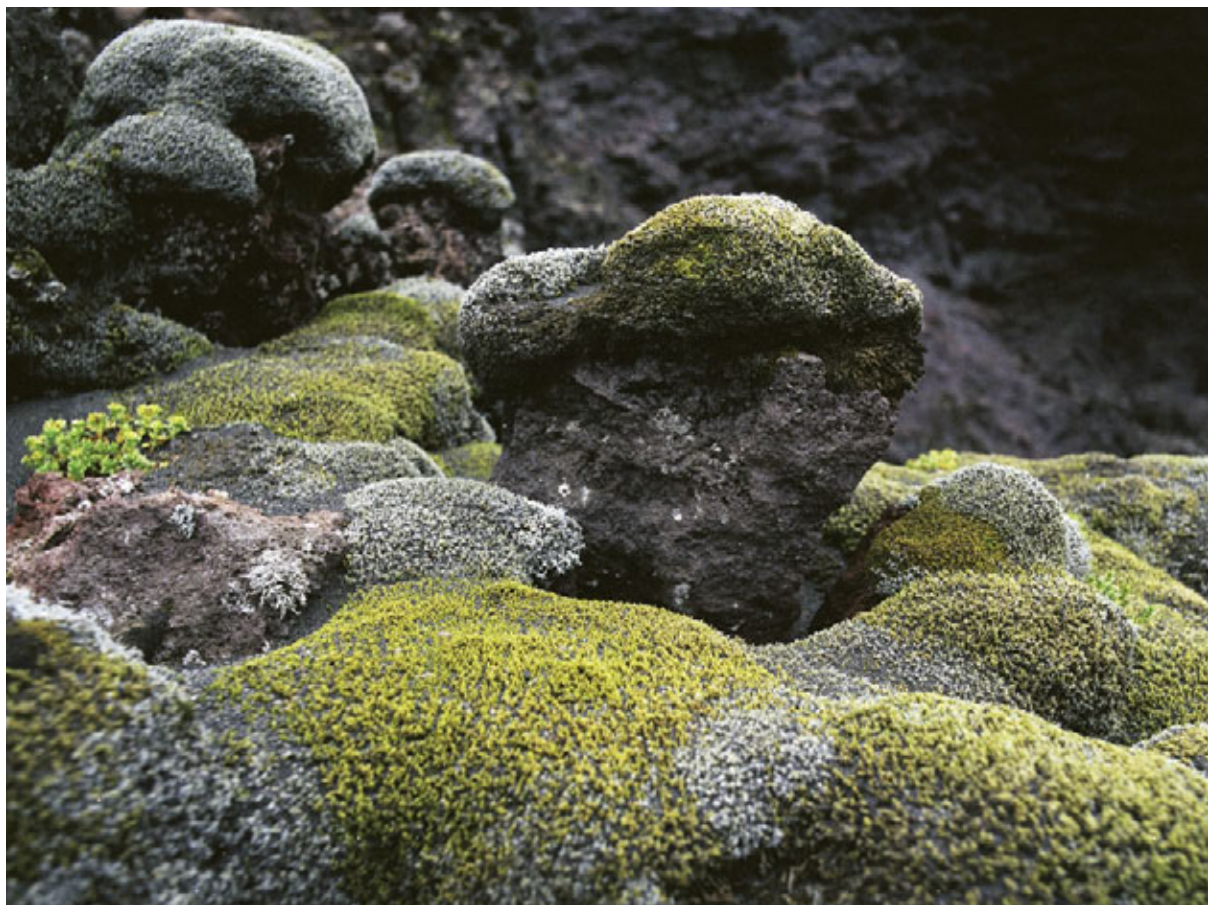
older and more eroded. It is likely that species richness will continue to increase on Surtsey during the next few decades and peak at about 70–90 species, after which it is expected to decline with the continual erosion and shrinking of the island (Fig. 2.11).

### Bryophytes

Bryophyte colonisation was carefully documented during the first decade after the eruption ended. In 1967 the first two moss species, *Funaria hygrometrica* and *Bryum argenteum*, were found growing close to steam holes (Bergþór Jóhannsson 1968). Already in 1973, 69 species of bryophytes had been recorded (Skúli Magnússon and Sturla Friðriksson 1974). The most recent survey of bryophytes, carried out within permanent vegetation plots in 2003, also added a few new species to former finds. By 2003, 75 species of bryophytes had been recorded on Surtsey, sixteen of which

were found within the permanent study plots. (Appendix 3). The most common and widely dispersed bryophytes on the island in 2003 were the mosses *Schistidium maritimum*, *Bryum dichotomum*, *B. argenteum*, *Ceratodon purpureus* and *Racomitrium eriocides* (Table 2.4). Another moss, *Racomitrium lanuginosum*, is abundant in the large, sheltered western crater, Surtungur, where it has formed a moss carpet that somewhat resembles the extensive *Racomitrium* carpets covering recent lava flows in areas of high precipitation on the Icelandic mainland.

The bryophytes colonizing the lava of Surtsey are similar to the flora found in young lava flows and volcanic areas of southern Iceland. However, maritime species are more prominent in the Surtseyan flora. All bryophytes discovered on Surtsey so far have been found elsewhere in Iceland.



Lava blocks overgrown by the moss *Racomitrium lanuginosum*. (Photo: Hervé Jezequel 2005).

Species	Number of plots
<i>Schistidium maritimum</i>	12
<i>Bryum dichotomum</i>	10
<i>Bryum argenteum</i>	8
<i>Ceratodon purpureus</i>	6
<i>Racomitrium ericoides</i>	6

Table 2.4. The most common bryophyte species on Surtsey and the number of permanent plots where each particular species was found in a 2003 survey.

### Lichens

Altogether 71 species of lichens have been recorded on Surtsey (Appendix 4). The first lichen to be found there was *Trapelia coarctata*, in July 1970 (Hörður Kristinsson 1972). It was growing around steam holes on the outside wall of the crater Surtungur and had numerous mature ascocarps, which strongly indicates that it had been there since at least the year before. Also in 1970, a further two species of lichens, *Stereocaulon vesuvianum* and *Placopsis gelida*,

were found in the lava fields around the crater. Although these specimens were barely visible at the time, they developed quickly over the next few years. By 1973, 12 species of lichens had been recorded from Surtsey, including *Stereocaulon capitellatum*, which together with the above-mentioned species became one of the foremost colonisers of the lava fields; *Acarospora smaragdula*, which colonised all the lava peaks; and *Psilolechia leprosa*, which became the main coloniser of rifts and caves in the lava field.

The next decades saw the addition of only a few more species, until a rapid increase in the number of lichen species following gull colonisation in the mid-1990s. Thus only some 32 species of lichens had been recorded by 1990, but by 1998 species numbers jumped to 58. The reasons for the rapid increase in lichen species included favourable conditions within the relatively sheltered crater of Surtungur as well as soil formation around the seagull colony, which



The lichen *Xanthoria parietina* and the moss *Ulota phyllantha* growing on a lava surface. (Photo: Erling Ólafsson 2005).



While the fungus *Entoloma sericeum* is a common grassland species in Iceland, it was not until 2005 that a specimen was first found on Surtsey. (Photo: Sigurður H. Magnússon 2005).

provided conditions for various kinds of soil-inhabiting lichens such as *Cladonia* spp., *Leptogium lichenoides* and *Peltigera canina*. Several rock-inhabiting species were also brought in directly by the birds, e.g. *Caloplaca verruculifera* and *Xanthoria parietina*.

All lichens recorded on Surtsey, with the exception of one or two inconspicuous species, have been found elsewhere in Iceland. Colonisation of the new lava fields is also characterized by the same pioneer species as in other lava fields on the southern coast of Iceland. It is however remarkable that some of the most common basaltic lichens in Iceland, including *Rhizocarpon geographicum* and *Tremolecia atrata*, have not yet been found on Surtsey.

### Fungi

So far, 24 species of fungi have been identified from Surtsey (Appendix 5), although the island's specific mycota has yet to be studied in detail.

By April 1965, five species of marine fungi were identified on bits of driftwood and dead algae, primarily *Ascophyllum*, together with at least three unidentified species of *Pythium* and *Phoma* (Johnson 1966; Johnson and Cavaliere 1968). In 1968 three species of anamorphic fungi (moulds) grew in raw cultures of algae from substrates of moist tephra and lava taken near fumaroles near the two craters (Schwabe 1970a). Henriksson and Henriksson (1974) isolated and identified 10 species of fungi from soil samples of

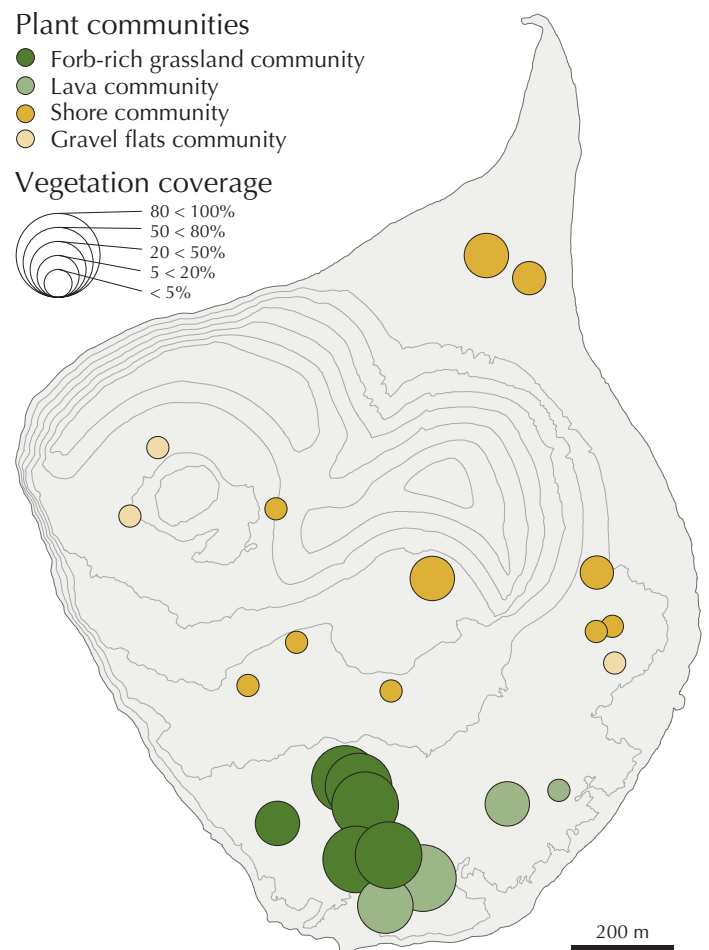


Fig. 2.12. Permanent study plots on Surtsey and community classification of the vegetation found within them in 2004. Total vegetation cover is also shown.



Shore community on the northern coast of Surtsey, composed of sea sandwort, lyme grass, oyster plant and sea rocket. (Photo: Borgþór Magnússon 2005).

the surface layer (0–20 mm) that were collected at 21 localities in July 1972. No soil- or freshwater-inhabiting aquatic fungi were found on Surtsey between 1964 and 1972, when their possible presence was being monitored by T. W. Johnson together with his students and co-workers.

The first mushroom, *Arrhenia rustica*, was found in several places in 1975, growing among mosses. In 1990 it was common in the bird colony (Sturla Friðriksson 2005). A second agaric species was collected once in 1975, an unidentified *Galerina* sp. In June 1990 three discomycetes were collected, *Peziza varia* growing along the

concrete foundation of the hut, *Lamprospora crouanii* growing amongst low moss on sloping palagonite tuff at Strompur, and *Octospora auxillaris* growing on sand amongst *Bryum* near a fish bone. In 1994 the feather stalkball *Onygena corvina* grew on feathers from a regurgitated bird pellet. In the last ten years a *Panaeolus* sp. has been found among grasses in the bird colony and recently the silky pinkgill *Entoloma sericeum* was added to that community. In 2005 two agarics, mycorrhizal partners of the tea-leaved willow had produced fruiting bodies around the plant.

Studies in 1996 on the microbial activity in three different soils (Frederiksen et al. 2000) showed that there were few fungal hyphae in bare soil, a medium number in areas with shore community, while by far the most hyphae were measured in the soils of the gull colony.

### Vegetation

Plants have dispersed and become established in all parts of Surtsey. The only sections of the island which remain mostly devoid of plant life are the steep palagonite hills in the middle of the island. However, the plant cover is still relatively thin, except at the gull colony on the southern lava plain (Fig. 2.12), where dense and rather diverse vegetation has developed over the last 20 years.

In 2004, vegetation analyses of the permanent



Lava community on southern Surtsey. Procumbent pearlwort, reflexed saltmarsh-grass and scurvygrass are the most prominent species in this community. (Photo: Borgþór Magnússon 2004).

study plots revealed four main vegetation types or communities on Surtsey.

The most widespread vegetation community is the **shore community**, which is found on sand substrates on the island. The main species are sea sandwort, lyme grass and oyster plant *Mertensia maritima*. On the low-lying point at the north end of the island, occasional sea rocket plants *Cakile arctica* are also found within this community. The plant cover ranges from 1–25%, and the species richness of vascular plants is only 1–4 per 100 m<sup>2</sup> plot. Due to the loose substrate, hardly any bryophytes are recorded. This community is common on the sandy shores of southern Iceland.

The first stages of a **gravel flat community** have started to develop on the upper part of the island. Growing on fine-textured lava and tephra substrate, the gravel flat community is most common on the lava flats around the large western crater of Surtungur. The characteristic species are northern rock-cress *Arabidopsis petraea*, sea campion *Silene uniflora* and thrift *Armeria maritima*, but sea sandwort also occurs. Plant cover ranges from 1–5%, and the species richness is 3–7 species per plot, slightly exceeding that of the shore community. Scattered bryophyte growth occurs, with the main two species being *Racomitrium ericoides* and *Schistidium flexipile*.

**The lava community**, thriving on the fringes of the gull colony, may be seen as the first stage in vegetation succession driven by nutrient enrichment from the birds. The main species of this community are the procumbent pearlwort, reflexed saltmarsh-grass *Puccinellia coarctata*, and common scurvygrass *Cochlearia officinalis*. The procumbent pearlwort is usually the first of these species to colonise any area of new lava that is being affected by expansion of the gull colony. In this community the plant cover varies tremendously, or from 1–95%, depending on how long the site has been affected by the gulls. Species richness is relatively high for Surtsey, or 4–9 vascular species per plot. This community includes several bryophyte species, whose total cover reaches up to 10% and whose most common species are *Bryum dichotomum*, *Ceratodon purpureus* and *Schistidium maritimum*.

In the central and oldest part of the gull colony, a **forb-rich grassland community** has developed. This community type is found both on



Forb-rich grassland in the middle of the seagull colony on southern Surtsey. Sea mayweed in the foreground. (Photo: Borgþór Magnússon 2005).

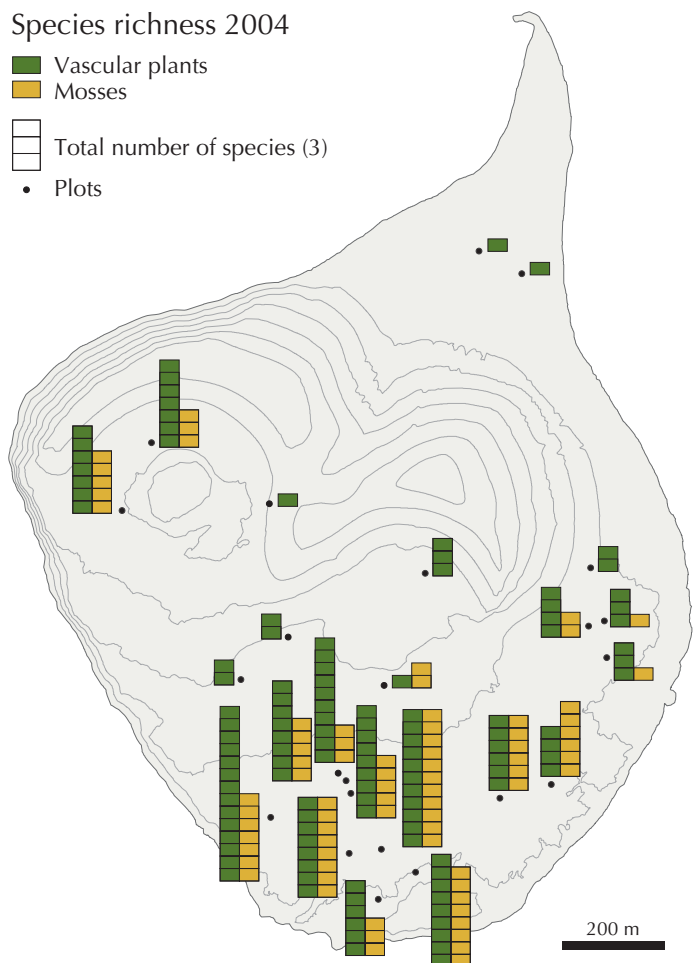


Fig. 2.13. Diversity of moss and vascular plant species in permanent study plots on Surtsey in 2004. Plots within the gull colony in the southern part of the island show the highest species diversity.





Northern fulmar was the second bird confirmed breeding on Surtsey in 1970 and is now the most common breeding bird on the island. (Photo: Torgny Nordin 2003).

exposed lava and on lava stretches filled over with sand, with the species composition varying slightly according to the substrate. The forb-rich grassland is strongly affected by the breeding gulls through their provision of rich nutrients, introduction of new plant species and nest-building activities. Having the densest and most diverse vegetation on Surtsey, this community demonstrates plant cover ranging from 40–100% and a species richness for vascular plants varying from 6 to 14 per plot (Fig. 2.12; 2.13). The dominant and characteristic grass species of this community are smooth meadow-grass, annual meadow-grass *Poa annua*, arctic fescue *Festuca rubra* and lyme grass. Common forbs include the common mouse-ear, sea mayweed *Tripleurospermum maritimum*, common chickweed *Stellaria media*, scurvygrass and sea sandwort. Bryophyte diversity is relatively high, with permanent plots yielding 3–9 species, of which *Bryum dichotomum*, *Bryum argenteum* and *Schistidium maritimum* are most common. Surtsey's forb-rich grassland is beginning to resemble older eutrophic grasslands found in bird colonies elsewhere in the Vestmannaeyjar archipelago.

### Birds

Surtsey had just risen above the ocean surface when the first birds made their landfall. Gulls were seen touching down on the island between eruption bursts on 1 December 1963, only two weeks after the eruption started (Sturla Friðriksson 1964; Finnur Guðmundsson 1966). Since then, a number of bird species have been recorded on or near the island. Some of them are on feeding trips from their breeding colonies at neighbouring islands in the Vestmannaeyjar archipelago. Others are transient migrants, en route between breeding areas elsewhere in Iceland or the Arctic and their wintering grounds in Europe or Africa. Some are straggling immature birds or non-breeders from other parts of Iceland. Still others are incidental vagrants from either side of the North Atlantic (Ævar Petersen 1993).

Birds on Surtsey were observed regularly from 1966 to 1980, primarily to record migrants staging there in spring and autumn but also to monitor vagrant species and indications of breeding. Museum specimens were collected during these visits. During these early years, the entire island was monitored at intervals,

carefully recording any observations of birds on land. After the first confirmed breeding on the island in 1970, nests were mapped and birds counted in conjunction with other biological surveys. Thus the main aspects of avian history on Surtsey are fairly well known (Borgbór Magnússon and Erling Ólafsson 2003). In 1990 and 2003, a breeding bird census was conducted on the island, and bird distribution maps were compiled.

### General composition of the bird fauna

Altogether, 89 bird species have been found on Surtsey (Appendix 6); half (45) of them are water birds, while the other half (44) are terrestrial (here including freshwater) birds. Fifty-seven (57) species breed elsewhere in Iceland. The remaining species (32) are: vagrants in regard to Iceland (12), birds which are primarily vagrants but also rare or incidental breeders (9), regular transient migrants that breed in Greenland or Canada (5), and winter visitors (6). Of the vagrant species, the majority are European in origin, one is Holarctic and still another is North-American in origin.

### The breeding species

By 2005, thirteen species of birds had been found nesting on the island, of which twelve appear to breed annually (Table 2.5). In addition, a few pairs of arctic terns *Sterna paradisaea* nested (unsuccessfully) in 1975–1978 and the raven *Corvus corax* has built nests in the walls of the large lava crater, without ever laying eggs.

The black guillemot *Cephus grylle* and northern fulmar *Fulmarus glacialis* were the first bird species found breeding on Surtsey; this was in 1970, three years after the cessation of volcanic activity (Erling Ólafsson 1971; Finnur Guðmundsson 1972). As early as 1966, however, the kittiwake *Rissa tridactyla* and black guillemot had begun prospecting for nest sites, but were probably prevented from actual nesting by the volcanic activity at the nearby crater islands, Syrtlingur and Jólnir (Finnur Guðmundsson 1967). By 1968, the northern fulmar had also been sighted as starting to occupy ledges (Finnur Guðmundsson 1970).

In 1990 a census was organised of the numbers and distribution of breeding birds; six breeding species were recorded, with the fulmar ranking as the most common breeder (120 pairs), followed closely by the lesser black-backed gull. Similar census in 2003 revealed eleven breeding species. Northern fulmar was still the most common species (350–400 pairs), followed by the lesser black-backed gull (150–200 pairs), kittiwake (130 pairs) and then the great black-backed gull, black guillemot and herring gull (each with 35–40 pairs). With only a single pair, the white wagtail *Motacilla alba* was the rarest of the Surtsey breeding birds in 2003 (Table 2.5). In 2004 food was seen delivered to at least two puffin nests, the first evidence of breeding, and in 2005 birds attended two likely nest sites.

On the whole, Surtsey bird populations have stayed more or less stable or have increased

Species breeding		Year first confirmed	No. of breeding pairs in 1990	No. of breeding pairs in 2003
Black guillemot	<i>Cephus grylle</i>	1970	15	35–40
Northern fulmar	<i>Fulmarus glacialis</i>	1970	120	350–400
Great black-backed gull	<i>Larus marinus</i>	1974	35	35
Kittiwake	<i>Rissa tridactyla</i>	1975	4	130
Arctic tern	<i>Sterna paradisaea</i>	1975	0	0
Herring gull	<i>L. argentatus</i>	1981	25	35–40
Lesser black-backed gull	<i>L. fuscus</i>	1985	120	150–200
Glaucous gull	<i>L. hyperboreus</i>	1993		4–5
Snow bunting	<i>Plectrophenax nivalis</i>	1996		11
White wagtail	<i>Motacilla alba</i>	2002		1
Greylag goose	<i>Anser anser</i>	2002		2
Meadow pipit	<i>Anthus pratensis</i>	2002		2
Puffin	<i>Fratercula arctica</i>	2004		

Table 2.5. Breeding birds on Surtsey.

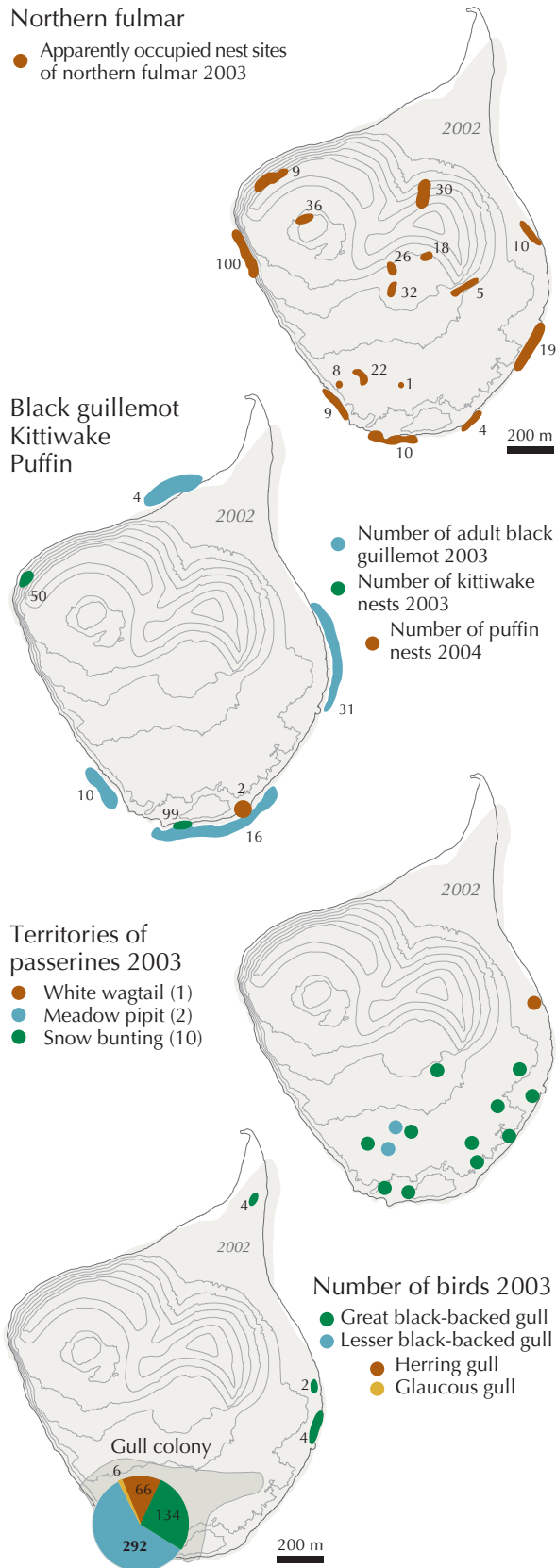


Fig. 2.14. Distribution maps for breeding birds on Surtsey.

over time, with the exception of the arctic tern, which only bred there between 1975 and 1978. The fulmar and lesser black-backed gull have greatly increased in numbers, which is in line with their general population trends elsewhere in Iceland (Ævar Petersen 1998). The 2003 distribution of breeding species is shown on Fig. 2.14.

The four species of breeding gulls form a common breeding colony on the lava fields in the southern part of the island. This sort of community nesting involving four gull species is unique in Iceland. As a result of increasing population, the colony area has expanded in every direction except to the north, where blowing sand appears to be the limiting factor. Great black-backed gulls nest primarily in the epicentre of the gull colony; lesser black-backed gulls and herring gulls flank them towards the southwest, south and east; and glaucous gulls choose their sites primarily east of the epicentre. In addition, five great black-backed gull pairs nested solitarily outside the main colony in 2003.

**Migratory birds and vagrants**

Bird migration was monitored by observers stationed on the island from 1966 to 1971, mainly during spring but also in autumn (Finnur Guðmundsson 1966, 1970, 1972) when the island was almost completely barren. Insect-feeding passerine species, such as the wheatear *Oenanthe oenanthe*, meadow pipit *Anthus pratensis* and white wagtail, have been among the most frequent migrants and are common breeders in Iceland. High-Arctic migrants have included the turnstone *Arenaria interpres* (a wader) and snow bunting *Plectrophenax nivalis* (a passerine). The latter were found to have grit (mineral stones) in the stomachs, originating from the British Isles (Sturla Friðriksson and Haraldur Sigurðsson 1969). Despite being relatively inconspicuous in the Icelandic bird fauna, passerines have featured highly among terrestrial migrants visiting Surtsey. The wader staging there most frequently is the oystercatcher *Haematopus ostralegus*.

The numbers of straggling species (vagrants) recorded depends principally on the length of period and time of year when observations are



A newly fledged snow bunting in Surtsey. Snow bunting was the first landbird to breed on Surtsey, beginning in 1996. (Photo: Daníel Bergmann 2003).

carried out. In the early years of the island's formation, observers were stationed on the island during the migration periods of spring and autumn. Two very rare vagrant species have been sighted on Surtsey: the European squacco heron *Ardeola ralloides* and the North American northern oriole *Icterus galbula*. The former is the only one recorded for Iceland, while the latter was the third. Other vagrant species sighted on Surtsey generally include annual vagrants common to Iceland.

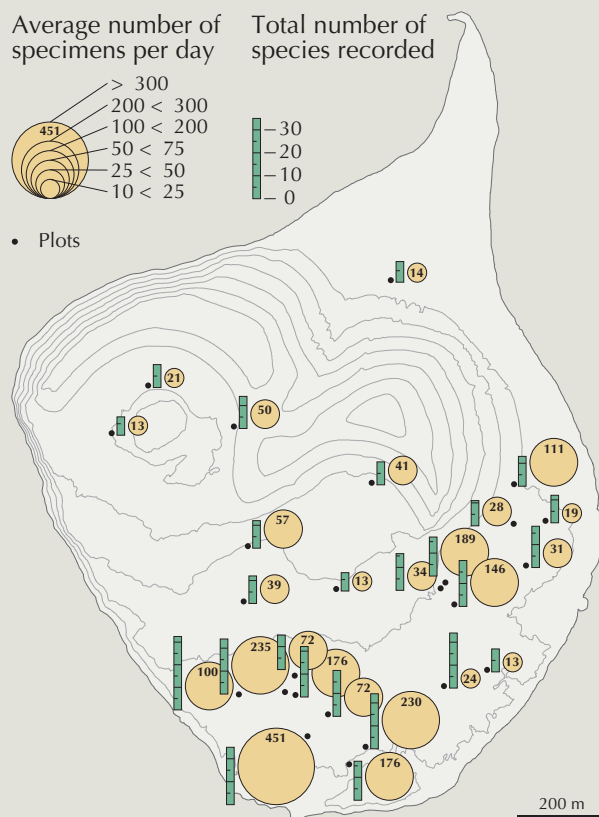
In terms of migratory birds, Surtsey should be considered from an international perspective. Migratory birds link this location to other corners of the world, whether to the south (where the birds over-winter) or north (where they seek their breeding grounds). Furthermore, birds bring with them and on them life forms such as seeds and insects; these play their own roles of whatever significance to the developing island ecosystem (Sturla Friðriksson 1968, 1970b; Sturla Friðriksson and Haraldur Sigurðsson 1969).

## Invertebrates

Phylum/Order	English name	Number of identified species
ARTHROPODA	Joint-legged animals	
Collembola	Springtails	24
Protura	Proturans	1
Hemiptera	True bugs	7
Thysanoptera	Thrips	3
Mallophaga	Lice	1
Neuroptera	Lacewings	1
Trichoptera	Caddis flies	4
Lepidoptera	Butterflies and moths	21
Coleoptera	Beetles	22
Hymenoptera	Hymenopterans	28
Diptera	True flies	136
Siphonaptera	Fleas	1
Araneae	Spiders	13
Acari	Mites and ticks	62
ANNELIDA	Segmented worms	
Oligochaeta	Earthworms	2
MOLLUSCA	Molluscs	
Gastropoda	Snails and slugs	2
NEMATODA	Roundworms	2
ROTIFERA	Rotifers	6
Total		336

Table 2.6. Terrestrial invertebrates on Surtsey. Number of species found until 2004.

## Invertebrate diversity on Surtsey island



The tiny weevil *Ceutorhynchus insularis*, which is abundant on scurvygrass on Surtsey, was first discovered in 1968 on one of the Vestmannaeyjar islands. It was originally believed to be a new species to science and was described as such in 1971. Later on, similar specimens were discovered in samples from the Hebrides Islands off Scotland.

The forb-rich grassland vegetation of the gull colony supports a higher diversity and abundance of invertebrates than do other parts of the island.

The results of pitfall trapping within permanent plots show that the diversity of Surtseyan invertebrates is considerably greater within the gull colony than in other parts of the island. Furthermore, the abundance, or number of individuals, is also shown to be greater (Fig 2.15).

However, a few permanent plots, located in a shore community on the eastern part of the island also appear to be relatively rich in invertebrates. One of these plots is located at the helicopter platform, where gulls tend to rest and enrich the soil with nutrients. The high abundance recorded at two other sites is caused by numerous individuals of a single species, the thrip *Taeniothrips atratus*, which has sea sandwort as its host plant.

A total of 335 invertebrate species has been found on Surtsey (Appendix 7; Table 2.6). These include arthropods, molluscs, annelids, nematodes and rotatorians, approximately half of which have become permanently established. Although flying insects are most conspicuous, soil animals are most numerous. There are as of yet no endemic invertebrates on Surtsey. One species of special interest is *Ceutorhynchus insularis*, a very small

snout beetle that feeds on scurvy grass and is extremely rare on a global scale.

The establishment of a gull colony clearly boosted the insect fauna on Surtsey (Fig. 2.15). A few species such as *Atheta graminicola* are completely dependent on the gull colony, even though others such as *Amara quenseli* prefer the harsh tephra ground elsewhere (see box on this page).

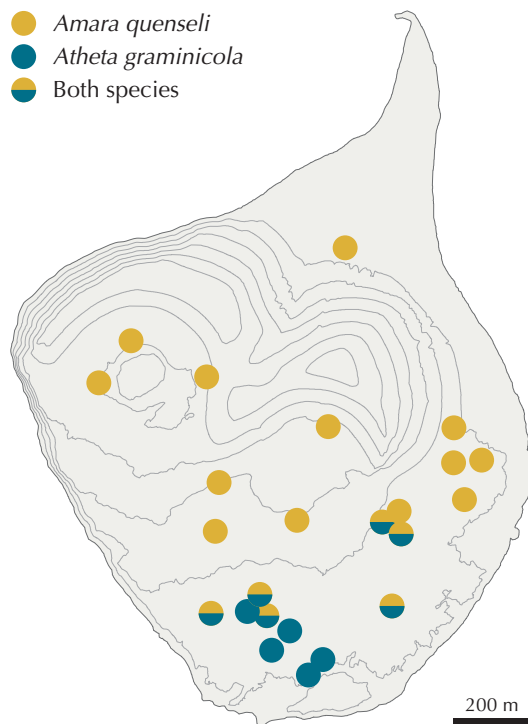


Fig. 2.15. The diverse, forb-rich grassland vegetation in the gull colony is favoured by some, but not all, species of invertebrates. The staphilinid beetle *Atheta graminicola* is found only within the gull colony and by the helicopter platform, where similar vegetation occurs. The carabid beetle *Amara quenseli*, in sharp contrast, prefers a barren, sandy substrate, as occurs in the open gravel flat- and shore communities.

## Marine life

### Benthos

Monitoring of the marine benthos around Surtsey began in 1964. About 80 species of macroalgae and 180 benthic animal species have been identified in the rocky littoral and hard-bottom sublittoral zones around Surtsey (Appendices 8 and 9a and b). The number of benthic species found along the coast of neighbouring islands in the Vestmannaeyjar archipelago is considerably higher. With respect to marine vegetation, the most striking difference in Surtsey is its complete lack of the large fucoids which dominate littoral vegetation by the other islands. In Surtsey's sublittoral zone, there is also a lack of crustose red algae, whereas red crusts, especially crustose corallines, are prominent among vegetation along the coast of other Vestmannaeyjar islands. The instability of the Surtseyan substrate is probably

what prevents perennial fucoids from establishing viable populations in Surtsey's littoral zone. Certainly there is no lack of propagules, because each year fertile fragments of fucoids are found as drift on Surtsey. For the sublittoral crustose species, erosion and sand scouring could pose potential problems; additionally, many of the crustose species have heavy spores that currents are unlikely to sweep far away. For comparison, it might be pointed out that crustose red algae are already well established on the lava formed in 1973 at Heimaey, 10 years after the Surtsey eruption. This lava is, however, adjacent to established macroalgal vegetation that was unaffected by the eruption (Karl Gunnarsson 2000).

### Littoral zone

Along the west, south and east coast of Surtsey, the littoral zone substrate is composed of bedrock and large boulders. In the northern area, the substrate consists mostly of sand or boulders embedded in sand. The entire shoreline has been constantly eroded by heavy breakers, especially during severe southerly storms. A buoy monitoring waves just south of Surtsey has registered wave heights of some 16 m during winter storms (see above). The southwestern shore has been most intensely affected, in some years receding over 50 m. Although the most stable shore borders the eastern side of Surtsey, frequent scouring takes place even there, with waves and currents transporting sand northwards and depositing it on the northern spit.

Rocks all around Surtsey display algal growth. Even the boulders embedded in sand on the northern spit support fast-growing algae during calm summer periods, and various annual algae species have colonised littoral cliffs on the eastern, southern and western shores. In the beginning, there were very few species and cover was scanty, but in recent years a number of species are found in the littoral zone and have achieved a total cover of over 60%. The most common species are diatoms in mucilage tubes (*Schizonema* type) and the green filamentous algae *Ulothrix flacca*, which together comprise over 80% of vegetation cover in the littoral zone.

In the island's southern and western sections, erosion has formed steep cliffs, rendering the shore inaccessible. Since 1970, the only part of



The vegetation in the Surtsey littoral zone is characterised by two distinct algal communities (see Fig. 2.16). (Photo: Karl Gunnarsson 1991).

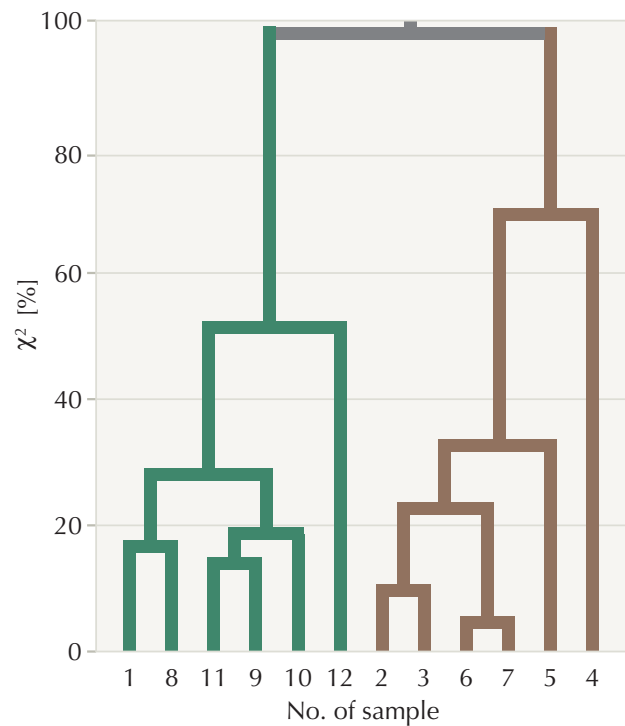


Fig. 2.16. Cluster analysis of samples from varying depths in the Surtsey littoral zone. Two communities can be distinguished: an upper one dominated by green algae and a lower one dominated by diatoms and brown algae. The numbers refer to sampling depths. Sample 1 is taken at low water mark at spring tide; sample 12 is taken at the highest water level.

the shoreline which has a hard substrate and has also been accessible and therefore possible to examine is the eastern shore.

Two algal belts are distinguishable in the littoral zone (Fig. 2.16): an upper belt, green in colour and dominated by the green algae *Ulothrix flacca*, *Enteromorpha intestinalis* and *Urospora penicilliformis*; and a lower belt dominated by brown-coloured species, among which *Petalonia fascia*, *Petalonia zosterifolia*, *Scytosiphon lomentarius*, *Ectocarpus siliculosus* and *Porphyra umbilicalis* (a brown-coloured red algae) are most common. At the lowest extreme of the littoral zone, the brown kelp species *Alaria esculenta* encroaches from the sublittoral zone, covering most of the rocks (Sigurður Jónsson et al. 1987).

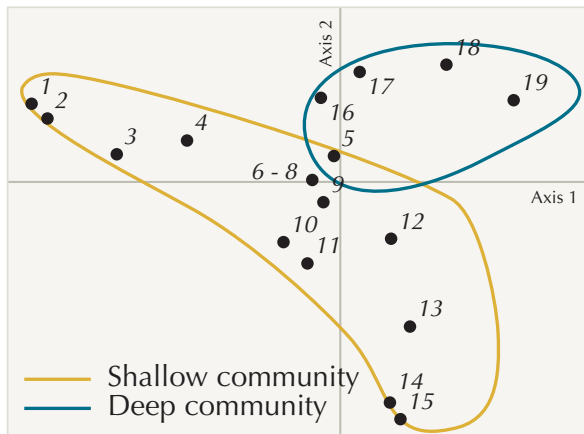
The littoral fauna is poor, although small crustaceans have been found amongst the filamentous algae, including the harpacticoid *Harpacticus arcticus*. The sessile animal most often observed in Surtsey's littoral zone is the acorn barnacle *Semibalanus balanoides*, which colonises the

lower part of the littoral zone each spring, only to disappear the following winter. In summer tiny young mussels *Mytilus edulis* are also found in the littoral zone (Erlingur Hauksson 2000).

In general, most plant species that have been identified in the littoral zone are annual species. All of the perennial species found were still in their first year and without exception disappeared again before the following spring. None of the large perennial fucoids dominating the mainland coast and rocky shores elsewhere in the Vestmannaeyjar archipelago were found to be growing in Surtsey until 1997, when a small *Fucus spiralis* plant from earlier the same summer was noted. No fucoid plants could be found upon examining the same site a year later (Sigurður Jónsson and Karl Gunnarsson 2000).

#### Sublittoral zone

The substrate in the sublittoral zone west, south and east of the island is made up of bedrock and boulders, often with sand in-between. In the



- |                                |                                |
|--------------------------------|--------------------------------|
| 1 <i>Halosiphon tomentosum</i> | 11 <i>Porphyra miniata</i>     |
| 2 <i>Desmarestia viridis</i>   | 12 <i>Laminaria hyperborea</i> |
| 3 <i>Monostroma grevillei</i>  | 13 <i>Oscillatoria</i> sp.     |
| 4 <i>Polysiphonia stricta</i>  | 14 <i>Chorda filum</i>         |
| 5 <i>Lomentaria orcadensis</i> | 15 <i>Desmarestia aculeata</i> |
| 6 <i>Diatoma</i>               | 16 <i>Delesseria sanguinea</i> |
| 7 <i>Ectocarpus</i> sp.        | 17 <i>Phycodrys rubens</i>     |
| 8 <i>Haplospora</i> sp.        | 18 <i>Conchocelis rosea</i>    |
| 9 <i>Desmarestia ligulata</i>  | 19 <i>Derbesia marina</i>      |
| 10 <i>Alaria esculenta</i>     |                                |

Fig. 2.17. Factorial correspondence analysis of principal algal species in the Surtsey sublittoral zone. Two communities can be distinguished: a shallow-water community dominated by fast-growing annual species, mostly brown algae (delineated by a yellow line) and a deeper-water community dominated by perennial red algae (bounded by the blue line).

northern sublittoral zone, the seabed is covered by sand. As vegetation is limited to hard substrate and little animal life occurs in the sand due to its constant motion, monitoring since 1969 has been confined to the hard substrate on the west, south and east coasts of Surtsey.

In recent years, two different communities have been noted on the sublittoral hard bottom (Fig. 2.17). Shallow water harbours a community of fast-growing opportunistic species like the brown algae *Alaria esculenta*, *Chorda filum* and *Desmarestia aculeata* and the red algal species *Porphyra miniata* and *Polysiphonia stricta*, with the dominant animal in this community being the mussel. In deeper waters from the 15-m level and farther down is a community of perennial vegetation including the large forest-forming kelp species *Laminaria hyperborea* and its undergrowth of red algal species such as *Delesseria sanguinea*, *Lomentaria orcadensis* and *Phycodrys rubens*. The sponge *Grantia compressa*, hydroids and bryozoans, the brittle star *Ophiopholis aculeata*, and various bivalves

and gastropods are the most common invertebrate species in this community. The sea star *Asterias rubens* is frequently found devouring mussels and barnacles in both communities.

At depths of 25 to 30 m, hard substrate becomes scarcer, as sand covers most of the seabed. The hard-bottom community is dominated by sessile animals. Though the most conspicuous organism is the soft coral *Alcyonium digitatum*, which covers large areas of the hard substrate, hydroids also form extensive cover on the rocks at this depth range, especially the hydroid *Tubularia larynx*. Sea slugs are commonly found feeding on the hydroids.

Sand covers not only most of the bottom at the northern end of Surtsey but also predominates in the lower ranges of slopes all around the island. Its biota is not adequately studied. Early sampling of the sand and gravel substrate



Lemon sole, *Microstomus kitt*, lying on sand between rocks at a depth of 15 m in the sublittoral zone, Surtsey. (Photo: Karl Gunnarsson 1991).





Dense stands of the kelp species *Laminaria hyperborea* have developed on top of large boulders at depths of 10 to 20 m on the sublittoral slopes of Surtsey. This perennial plant is a structuring species in the sublittoral communities of nearby islands in the Vestmannaeyjar archipelago, forming a forest that serves as habitat for a number of epiphytic and turf-forming species of algae and animals. (Photo: Karl Gunnarsson 1997).

revealed that a number of species, mostly bristle worms and bivalves, had settled on the slopes. The majority of the animals were relatively small and sparsely distributed, the two most common species being *Pectinaria koreni* (bristle worm) and

*Abra prismatica* (bivalve). Most of the species recorded were also common on the local areas of seabed that had escaped volcanic impact (Nicolaisen 1970).



At a depth of 5 to 10 m in the sublittoral zone at Surtsey, algal cover is at its maximum. The most common species are annuals such as the *Porphyra miniata*, *Chorda filum* and *Desmarestia viridis* pictured here. (Photo: Karl Gunnarsson 1997).



At 20- to 25-m depths, algae become rare and animals start to dominate Surtsey's hard bottom community. The orange-coloured soft coral *Alcyonium digitatum* is conspicuous in association with sponges and hydroids. (Photo: Karl Gunnarsson 1997).

### Marine mammals

Marine mammals have been observed in the waters around Surtsey every year since the formation of the island (Table 2.7). Seals started basking on Surtsey shortly after the island's formation. Due to the constantly changing shoreline, however, they did not start breeding on the island until the 1980s, when erosion had begun to slow down.

There is no direct evidence of common seals *Phoca vitulina* breeding on Surtsey, but it seems likely, as pups have been seen at the shoreline in summer. Groups of common seals (0–20 adults and juveniles) are commonly seen at Surtsey during summer. Grey seals *Halichoerus grypus*, on the other hand, started pupping on the island as far back as 1983. In recent years, 30–50 newborn grey seal pups have been observed every autumn on the northern part of the island, lying on the sand as well as among the rocks. Their numbers peak in late September or October (Erlingur Hauksson 1992a).



Grey seal pups are born with the white natal hair cover which is shed 3 to 4 weeks after birth. During that period the pups stay on shore in their lairs and are fed by their mother a few times per day. (Photo: Karl Gunnarsson 2000).



Grey seals *Halichoerus grypus* breed on the northern spit of Surtsey, with pup birth usually peaking in October. This photo, showing two grey seal pups in Surtsey, was taken in October 1998. (Photo: Karl Gunnarsson).

Whales are frequently spotted just off the Surtsey coast. Three species have been positively identified: the killer whale *Orcinus orca*, minke whale *Balaenoptera acutorostrata* and harbour porpoise *Phocoena phocoena*. Dolphins *Lagenorhynchus* sp. have also been seen in pods close by the coast. The species most commonly noted during the summer is the killer whale, which has been seen in pods of three to seventy animals of different sizes, foraging near Surtsey.

Seals	
Grey seal	<i>Halichoerus grypus</i> (Fabricius, 1791)
Common seal	<i>Phoca vitulina</i> (Linnaeus, 1758)
Cetaceans	
Minke whale	<i>Balaenoptera acutorostrata</i> , Lacepède, 1804
Killer whale	<i>Orcinus orca</i> (Linnaeus, 1758)
Harbour porpoise	<i>Phocoena phocoena</i> Linnaeus, 1758
Dolphins	<i>Lagenorhynchus</i> sp.

Table 2.7. Marine mammals observed on or in close proximity to Surtsey.



Lightning flashes in the eruption column during the submarine phase of the Surtsey eruption, December 1, 1963. (Photo: Sigurgeir Jónasson).

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## 2.b History and development

### Geological history

#### The Surtsey eruption

The eruption history of Surtsey island and its two short-lived neighbours, Syrtlingur and Jólnir, is well known, mainly through the work of Sigurður Þórarinnsson (1966, 1967; 1969) and Þorleifur Einarsson (1966). In addition, general outlines have been published (Sveinn P. Jakobsson and J. G. Moore 1982). Nevertheless, since the history of the eruption is of vital importance to understanding Surtseyan geology, the main

events are listed below and are further summarised in Table 2.8.

The visible eruption started with hydromagmatic explosions along a 300 to 400 m long fissure trending 035°. This was on 14 November 1963, although the eruption had presumably broken through the sea floor a few days earlier without being noticed. The most recent pre-eruption sounding in the area had been taken in 1901 by the Royal Danish Hydrographic Office, showing a water depth of 128 m at the point recorded closest to the eruption site. Based on the general bathymetric configuration, the

Year	Month	Day(s)	
1963	Nov.	10?	Approximate beginning of eruption on the sea floor
	Nov.	14	First visible explosive activity at water surface, near the eastern vent
	Nov.	15	Emergence of the island of Surtsey
	Dec.	28	Submarine activity (Surtla) first visible 2 km ENE of Surtsey
1964	Jan.	6	Surtla activity over, after building a 100-m-high submarine ridge
	Jan.	31	Activity over at eastern Surtsey vent
	Feb.	1	Beginning of explosive activity at western Surtsey vent
	Apr.	4	Explosive activity over at western Surtsey vent; beginning of effusive phase
	Apr.	29	Completion of lava effusion from western Surtsey vent
	July	9	Resumption of lava effusion from western Surtsey vent
1965	May	11?	Possible beginning of submarine activity at Syrtlingur site
	May	17	Effusion of lava ceased at western Surtsey vent
	May	22	Beginning of visible explosive activity at Syrtlingur, 0.6 km ENE of Surtsey
	Oct.	17	Cessation of explosive activity at Syrtlingur
	Oct.	24	Syrtlingur completely washed away
	Oct.	end?	Probable beginning of eruptive activity, 1 km SW of Surtsey
	Dec.	26	Visible explosive activity SW of Surtsey
Dec.	28	Emergence of the island of Jólnir	
1966	May	late	Fault-bounded lagoon develops in northern part of Jólnir
	Aug.	10	Cessation of explosive activity in Jólnir
	Aug.	19	Beginning of effusive activity at eastern Surtsey vent
	Oct.	31	Jólnir completely washed away
	Dec.	12–17	Minor lava flow from vent on inner northwest wall of eastern tephra cone
1967	Jan.	1–4	Lava flows into north lagoon from vent on outer north slope of eastern tephra cone
	Jan.	1–8	Lava eruption from vent on inner north wall on eastern tephra cone
	Jan.	2	Tiny lava flow from vent on outer northeast slope of eastern tephra cone
	Jan.	2–7	Faults form on inner wall of eastern tephra cone; minor lava flow from lower fault
	June	5	Cessation of effusive activity at eastern Surtsey vent

Table 2.8. History of the Surtsey eruption, based on Sigurður Þórarinnsson (1966, 1969).



The Surtsey eruption column on November 16, 1963. (Photo: Sigurður Þórarinnsson).

pre-eruption water depth at the eruption site is estimated to have been  $130 \pm 5$  m.

Emerging on 15 November 1963, the island grew rapidly in size. Two types of submarine, hydromagmatic explosions were most common: intermittent “cock's-tail” jets and a continuous uprush of tephra. All of these explosions were caused by hot magma being quenched in cold sea-water. Calculations and measurements on site indicate that the temperature of the magma was  $1155^{\circ}$ – $1180^{\circ}$  C, whereas the sea temperature in this area is around  $10^{\circ}$  C.

A crescent-shaped crater of finely-bedded tephra layers was built up between November

1963 and January 1964 (Fig. 2.18). On 31 January 1964, eruptions ceased in the eastern vent (Surtur), which until then had been the sole source of activity. On the following day, however, eruptions broke out once more in a northeast-trending fissure at the northwest side of that crater, where another crescent-shaped tephra crater soon formed (Surtungur), merged with the eastern tephra crater, and finally achieved a maximum height of 173 m above sea level. During the winter of 1963–1964, storm waves were severely destructive, carving broad abrasional platforms into the loose tephra of these two cones. On 4 April 1964, the eruption in Surtungur switched to an effusive Hawaiian-type lava phase. Clearly the island had at this point grown large enough to isolate the vent from inflowing seawater and thus protect the hot magma from being quenched.

Between 28 December 1963 and 6 January 1964, explosive submarine activity was visible about 2.0 km east-northeast of Surtsey. The eruption fissure there, estimated as 250 m long, created a submarine ridge called Surtla to over 100 m above the sea floor, but never raised it above the water surface. Apparently nothing but tephra was produced at this site.

At Surtsey, effusive lava activity continued in the western crater until 17 May 1965, so that gradually a flat lava shield was formed southwards from the crater, while foreset-bedded breccia was produced by submarine flow. The lava shield was gradually stacked to a height of 100 m above sea level.

On 22 May 1965, explosive activity again made itself apparent above the sea floor about 600 m east-northeast of Surtsey, creating this time a small tephra island, Syrtlingur, which climaxed at a height of 70 m and a maximum area of  $0.15$  km<sup>2</sup>. Since no lava was emitted to harden into armour, this island was washed away by wave action a few days after the eruption ceased, i.e. on about 17 October 1965. Yet another island of tephra, Jólnir, was created by explosive submarine activity starting 1 km southwest of Surtsey on 26 December 1965. At its maximum, this island had a height of 70 m and an area of  $0.28$  km<sup>2</sup>. The eruption died out on 10 August 1966 and Jólnir had disappeared in late October the same year.

Soon after the Jólnir activity died out, lava



Lava effusion on Surtsey, April 21, 1964. (Photo: Garðar Pálsson).



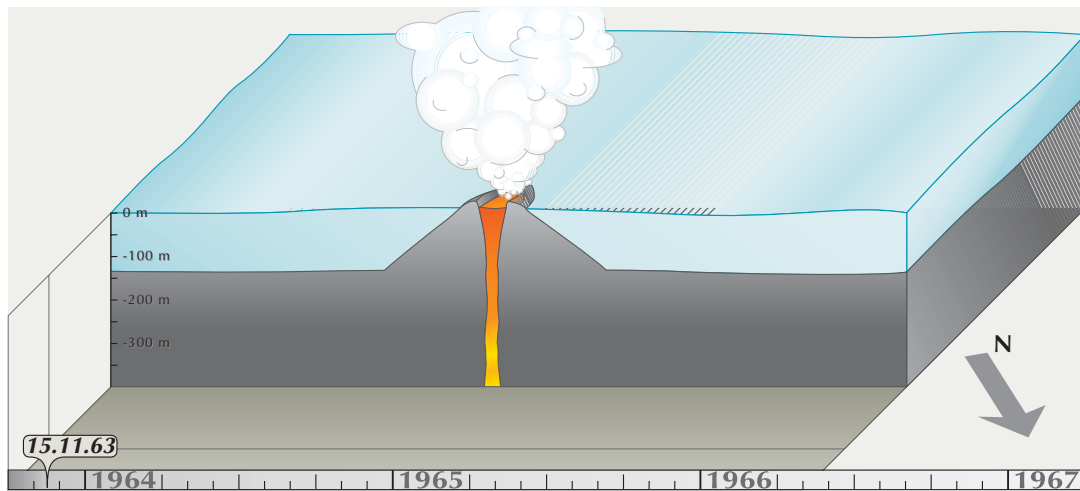
The eruption column of Syrtlingur in the spring of 1965. (Photo: Sigurður Þórarinnsson).

began erupting once more as a 220-m-long fissure opened on 19 August 1966 along the floor of Surtsey's eastern crater, Surtur, which had been inactive since early February 1964. Lava flowed incessantly from this fissure throughout late 1966 and early 1967, covering the landscape to the south and east and constructing the island's second lava shield. Between 12 and 17 December 1966, another fissure became active in the northwestern inside wall of the eastern tephra crater, producing a small lava flow. Then, during the period of 1–8 January 1967, lava broke through the eastern tephra cone, Austurbunki, at four additional sites, but the southernmost eruption site is now covered with sand dunes. Lava was last seen to flow on Surtsey on 5 June 1967.

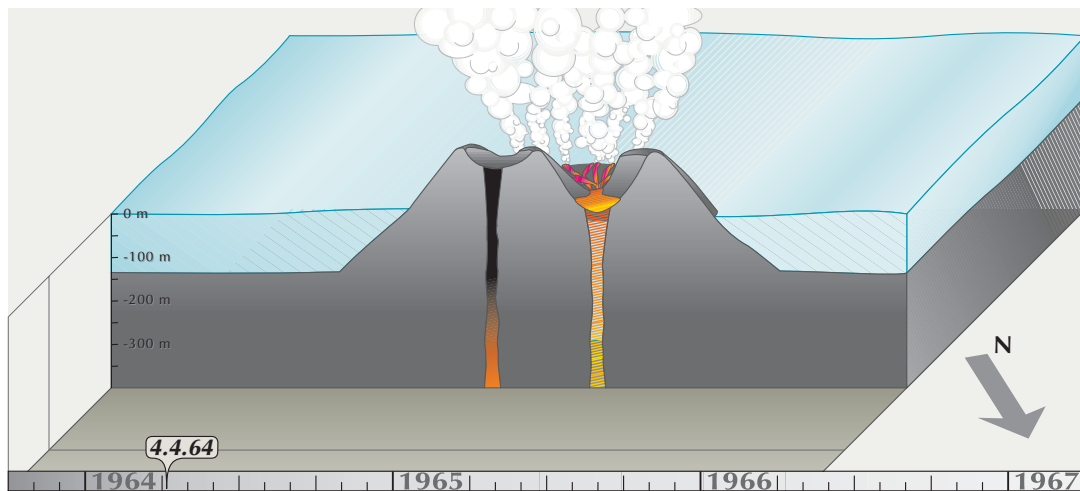
At the end of the eruption in June 1967, Surtsey had achieved a size of 2.65 km<sup>2</sup>, and the total amount of eruptive material was estimated to be 1.1 km<sup>3</sup>, about 70% of which was tephra and 30% lava. The height of the island at that time was 175 m above sea level, and as the sea water depth before the eruption had been about 130 m, the total height of the volcano was 305 m. A simplified geological map of Surtsey is shown in Fig. 2.19, based on July 1967. As far as is known, the Surtsey eruption is Iceland's longest continuous volcanic eruption in historical times (i.e. since AD 900). For example, it can be compared with the Hekla eruption of April 1766 to May 1768 and the Tröllahraun eruption of 1862–1864, although several other historic eruptions have emitted greater volume than that of Surtsey.



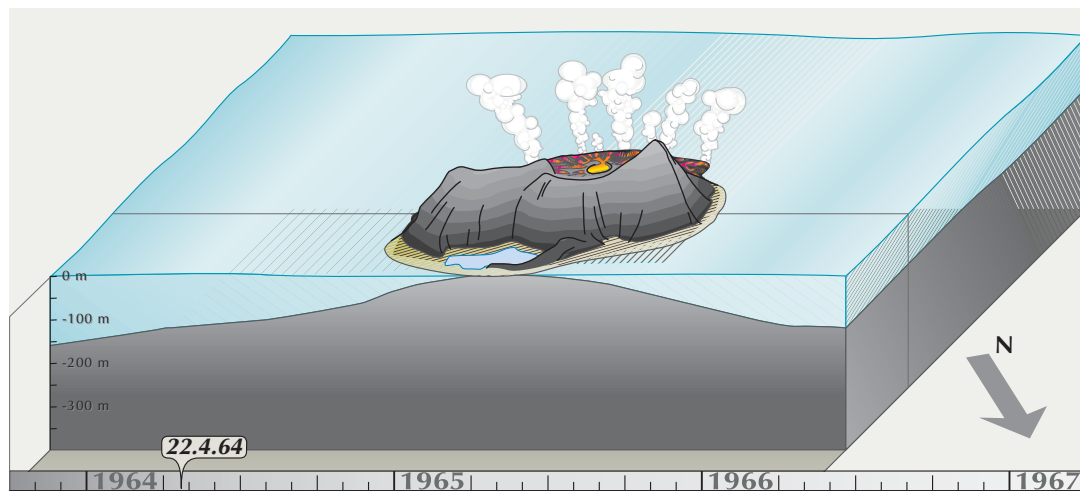
Steam rises from lava flowing into the sea. (Photo: Hjálmar R. Bárðarson 1967).



(A) 15 November 1963: the island of Surtsey emerges.

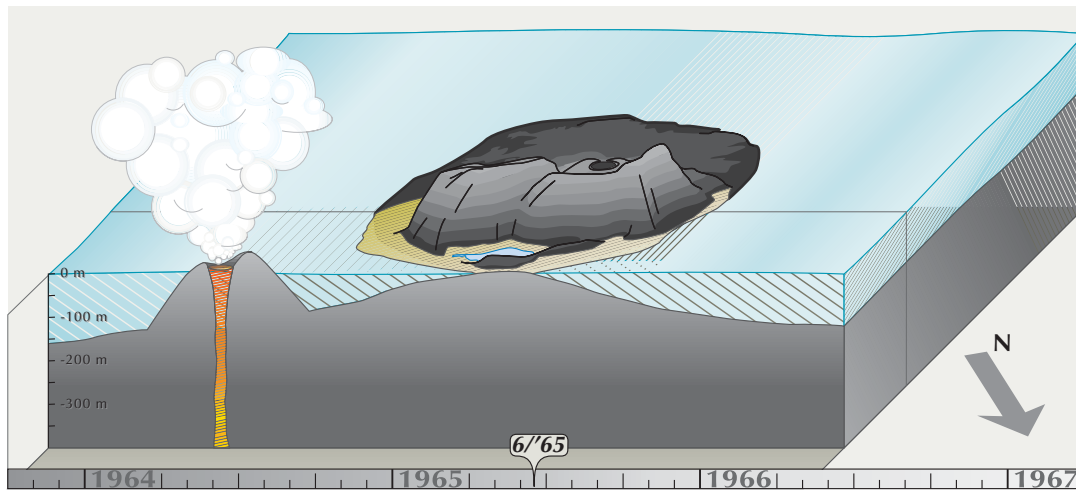


(B) 4 April 1964: the western crater (Surtungur) starts erupting lava.

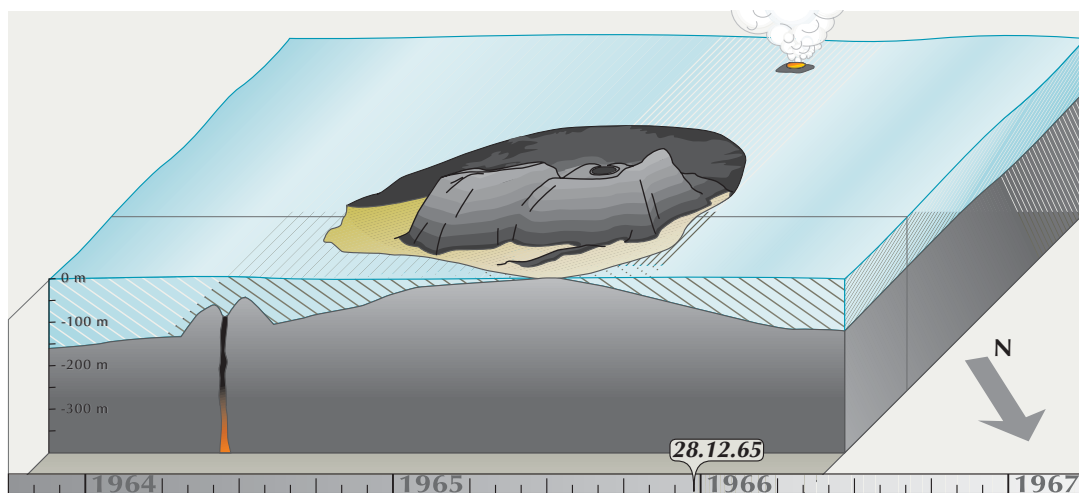


(C) 22 April 1964: the lava eruption at its maximum.

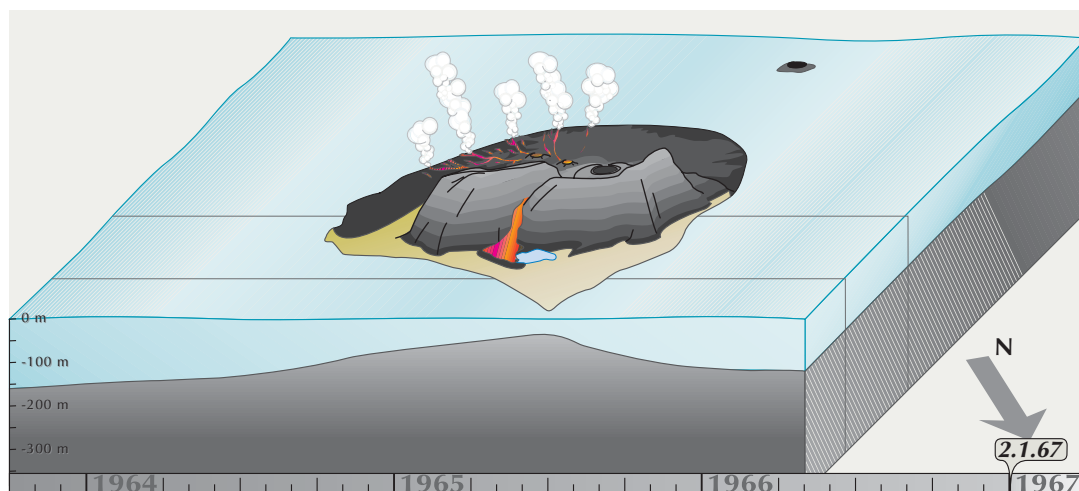
Fig. 2.18. Block diagrams illustrating the development of the Surtsey volcano, cf. Table 2.8.



(D) June 1965: activity on Surtsey has ceased temporarily and a new island, Syrtlingur, has emerged.



(E) 28 December 1965: the island of Jólnir emerges.



(F) 2 January 1967: Surtsey's last lava crater opens, after a renewal of activity on the island.



**Research work**

The Surtsey eruption immediately aroused a great deal of interest, both among scientists and the general public. As a spectacular eruption in the picturesque surroundings of the Vestmannaeyjar archipelago, it attracted many Icelandic and foreign visitors. The research value was further acknowledged by the scientific community after it became evident that Surtsey would prove lasting, because then it was clear that Surtsey offered an exceptional opportunity to study the development of an oceanic volcano from its inception on the sea floor, through the formation of an island, to the new land's modification by hydrothermal processes and wave abrasion. Scientists, including earth scientists and biologists, first stepped ashore on 16 December 1963. After that, numerous visits and expeditions to the island followed.

The course of this exceptional, many-faceted event was observed from the air as well as from surface elevations. Vertical aerial photographs were thus taken on 19 flights during the Surtsey eruption, in the period from February 1964 to



Sigurður Þórarinnsson, professor and volcanologist (1912–1983) at work in Surtsey on April 16, 1964 by Surtsey lagoon. The Vestmannaeyjar archipelago is seen in the background. (Photo: Hjálmar R. Bárðarson).

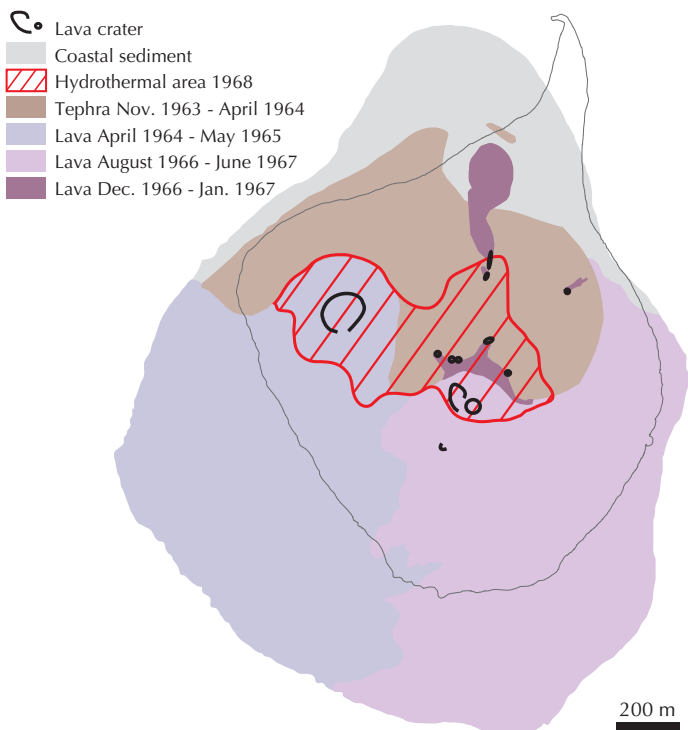
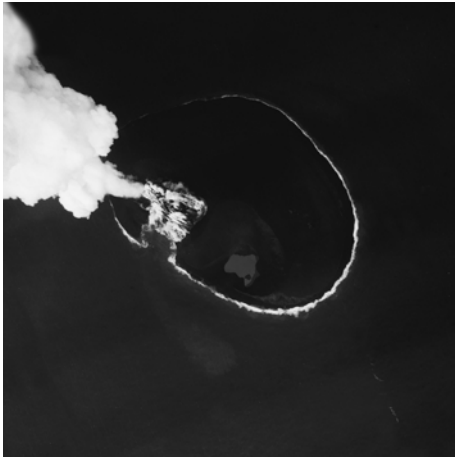


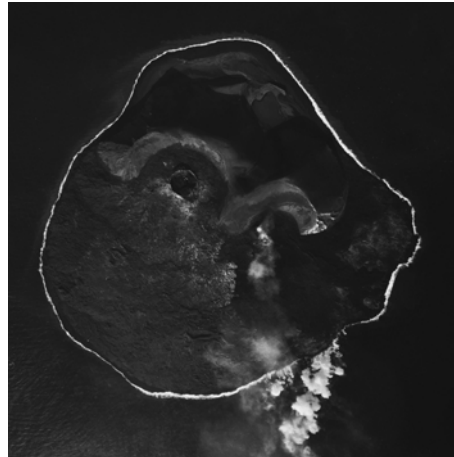
Fig. 2.19. Simplified geological map of Surtsey in 1967, with the approximate extent of the hydrothermal area indicated as it was in 1968. The shoreline of Surtsey, as it was in 2004, is shown for comparison.

March 1967. Such trips have continued since the eruption ceased and have now yielded 53 aerial photosets, most recently from August 2004. The photos overlap 60–80% and are of generally high quality; six are reproduced here in Fig. 2.20. This documentation of the construction and obliteration of volcanic islands is unique, with no comparable coverage existing anywhere else. In addition, several detailed topographic and bathymetric maps were compiled during and after the eruption.

Numerous geological and geophysical studies have been linked to the Surtsey eruption. Lightning activity, for instance, typifies subaquatic/subglacial eruptions, so during the Surtsey eruption, field and laboratory experiments were devised to elucidate the cause. The conclusion was that the contact of sea water with glowing lava at the vent led to charge separation, resulting in negatively-charged tephra and positively-charged steam. Lightning jumped between the oppositely charged clouds whenever the difference in voltage exceeded the insulating resistance of the intervening air (Sveinbjörn Björnsson et al. 1966; Blanchard and Sveinbjörn Björnsson 1967).



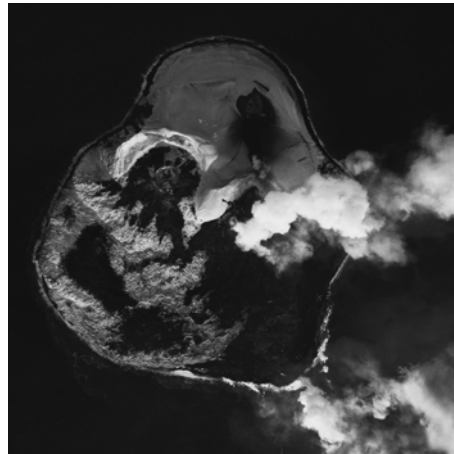
17 February 1964: hydromagmatic eruption in the western tephra crater (Surtungur). The eastern tephra crater has ceased activity and is partly filled by a pond.



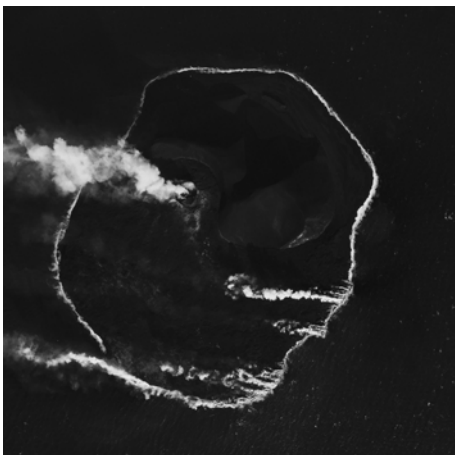
2 October 1966: lava erupting from vents within the eastern tephra crater.



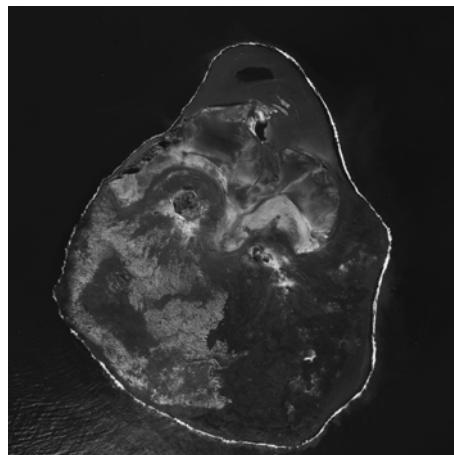
11 April 1964: lava erupting from the western crater. A lagoon has formed in the northern part of the island.



3 January 1967: lava erupting from five vents in the eastern tephra cone. The snow has melted in areas over subsurface heat.



23 February 1965: the eruption from the western crater has continued to build up a large lava shield.



18 July 1967: the Surtsey eruption has come to an end.

Fig. 2.20. Aerial photographs of the Surtsey eruption taken between 1964 and 1967, cf. Table 2.8. Published with permission of the National Land Survey of Iceland.

Physical conditions during the Surtsey eruption allowed the collection of the first-ever samples of volcanic gases virtually uncontaminated by atmosphere. Comparison with a mineralogical geobarometer showed the volcanic gas to have been in equilibrium with the magma from which it evolved (Guðmundur E. Sigvaldason and Gunnlaugur Elísson 1968; Sigurður Steinþórsson 1972; Symonds et al. 1994). According to radioactive geochemistry, the water content of the undegassed magma was 0.6%, which may be typical for alkali basalt (Sveinbjörn Björnsson 1968). Further examples of research which the eruption facilitated included measuring the lava for its temperature and viscosity, and conducting magnetic surveys on the entire island during its development.

Petrological and mineralogical studies of the tephra and the lava, ongoing until after the eruption ceased, demonstrated a striking chemical modification of the basalt magma as the eruption proceeded. This indicated a layered magma chamber beneath Surtsey, down in the lower part of the Earth's crust (Sigurður Steinþórsson 1965; Sveinn P. Jakobsson 1968; Furman et al. 1991).

Small-scale experiments with pumping seawater onto molten lava were conducted in Surtsey by Thorbjörn Sigurgeirsson in 1967. The purpose was to examine the cooling and hardening effect on the lava in order to verify whether lava flow could be systematically diverted, impeded or stopped. After a few hours of pumping on one side of a minor lava stream, it solidified and the flow was diverted to the other side. This experiment is considered to have been the first of its kind in the world. Drawing on the field observations at Surtsey, seawater was pumped on a large scale at Heimaey in 1973 so as to block or divert a lava tongue from Eldfell whose advance threatened to close the entrance to the Vestmannaeyjar harbour.

Volcanologists agree that for shallow waters the Surtsey event was the best-documented chain of submarine eruptions to date. A particular geological focus was on the conditions under which the submarine eruption shifted to a subaerial eruption emitting lava. All things considered, the Surtsey eruption and the eruption products were studied with exceptional care, considering the methods and knowledge available at the time.

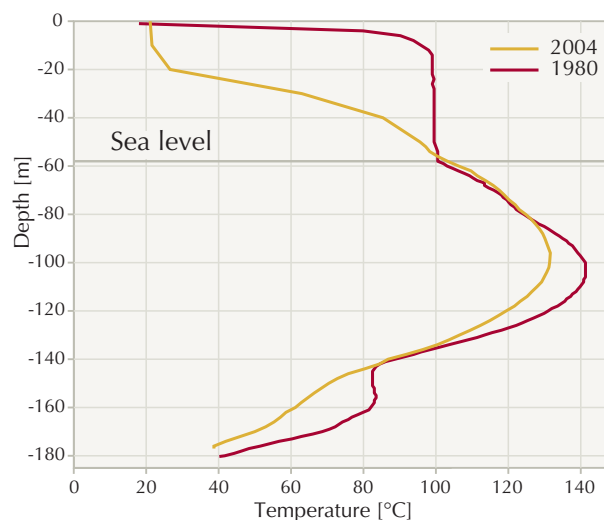


Fig. 2.21. Temperature measurements in the drill hole at Austurbunni as of September 1980 and August 2004. The seawater level is at a depth of 58 m.

## Post-eruptional history

### Hydrothermal activity

The hydrothermal system on Surtsey, described in Chapter 2a, has on the average been monitored and mapped every third year since it began to evolve. What made its development remarkable was how quickly tephra within the system was altered and consolidated into dense palagonite tuff.

Discovered by accident in the spring of 1967, Surtsey's hydrothermal anomaly had apparently not yet reached the surface by the summer of 1966, according to infrared air photos taken in August of that year. However, the anomaly was clearly noticeable in the eastern tephra cone through infrared aerial photos taken in August of 1968 (Friedman and Williams 1970, see Fig. 2.19). It has therefore been suggested that subsequent to lava extrusion, intrusive action occurred from December 1966 to January 1976 and led to the development of a hydrothermal system within the core of the eastern tephra cone (Sveinn P. Jakobsson and Moore 1986). Moreover, it appears possible that hydrothermal activity also occurred at some depth in the western cone, as a consequence of lava extrusion from April 1964 to May 1965. Characterised as "low-temperature", this hydrothermal system is quite different from the well-known "high temperature" hydrothermal systems at the centre of many active volcanic systems in Iceland.

The hydrothermal area at the surface continued to expand until approximately 1979, when it included segments of the western tephra cone, but then ceased to expand so fast, presumably because tephra consolidation had started to affect heat flux through the rock. Since about 1995, surface temperatures appear to have been on the decline. In the tephra cones, the highest near-surface temperatures within the hydrothermal area have typically measured about 100° C, indicating how vapour dominates the heat flux above sea level. Temperatures within the lava fields, especially next to the lava craters, have regularly declined after lava was extruded. By 1995 the lava surface generally conformed to ambient temperatures.

Temperature measurements have also been carried out at Austurbunki, on the eastern border of the hydrothermal area, taking advantage of a 181-m-deep hole drilled in 1979 (Fig. 2.6). These measurements show a general regular cooling of the hydrothermal system deep inside the island (Sveinn P. Jakobsson et al. 2000), with the maximum temperature down at 104 m declining from a calculated temperature of 154° C in 1966 and 1967 to a measured temperature of 130° C in 2004. The general rate of cooling at the drill hole location is  $\leq 1^\circ$  C per year (Fig. 2.21). Monitoring will continue at the drill hole, providing the unparalleled opportunity of observing the evolution of a posteruptional mild hydrothermal system over time. It appears probable that similar hydrothermal systems developed at many of the Icelandic volcanoes which erupted subglacially during the Late Pleistocene.

### **Alteration of the tephra**

The hydrothermal activity caused the Surtsey tephra to alter rapidly. In fact, palagonite tuff was observed at the surface in September 1969, at the southeast corner of the eastern tephra cone (Sveinn P. Jakobsson 1972). Upon this discovery a monitoring programme was established, measuring areas of tephra and tuff on average every third year (Sveinn P. Jakobsson 1978; Sveinn P. Jakobsson et al. 2000). Each time, rock samples have been taken and a new map prepared to show the expanding area of palagonite tuff.

The palagonitisation and consolidation rates of the Surtsey tephra were estimated on the basis

of surface observations in 1969–1977 (cf. Fig. 2.22). Compiled for 11 localities where the temperature was considered to be roughly constant during that period, the results indicate that at 100° C (referring to the greater part of the tephra pile lying above sea level) it takes one to two years for the tephra to convert into dense palagonitised tuff, with a volume of over 10% palagonite. Furthermore, the results point to the rate of palagonitisation falling considerably when temperatures drop below about 40° C (Sveinn P. Jakobsson 1978). Fig. 2.6 shows the stage of tuff expansion in 2004. The 1979 drill core (Chapter 2a) provided additional information on the nature of basaltic tephra conversion.

By 2004 some 55% of the exposed tephra had been transformed into palagonite tuff (Fig. 2.6). However, as the tephra that still remains unaltered constitutes only a relatively thin blanket encircling the tuff segment of the Surtseyan surface, it is estimated by volume that some 85% of what is left above sea level from the original tephra pile has been converted to palagonite tuff. Field observations allow the inference that the core of tuff now represents an area of 0.4 km<sup>2</sup> at sea level.

So far, tephra outside the hydrothermal area has not been observed to convert at all. In fact, comparison with other Icelandic tuff localities implies that conversion into palagonite takes thousand of years at the ambient weathering temperatures of this country. For Vestmannaeyjar, average monthly temperatures lie between 1° and 10°C, although diurnal and seasonal variations can reach twice this value.

Studies of the Surtsey material demonstrated for the first time (Sveinn P. Jakobsson 1972, 1978; Fisher and Schmincke 1984) that the palagonitisation process is posteruptional, occurring at low pressures and at relatively low temperatures, mostly under 100° C. A further discovery was that the process is highly temperature-dependent and can potentially proceed much faster than anyone had envisaged. In short, Surtsey offers a well-documented case on the consolidation and alteration of basaltic tephra in nature – a case that remains unparalleled.

### **Wind and water erosion**

Wind was freely eroding Surtsey's tephra cones even before the eruption was over. Their slopes

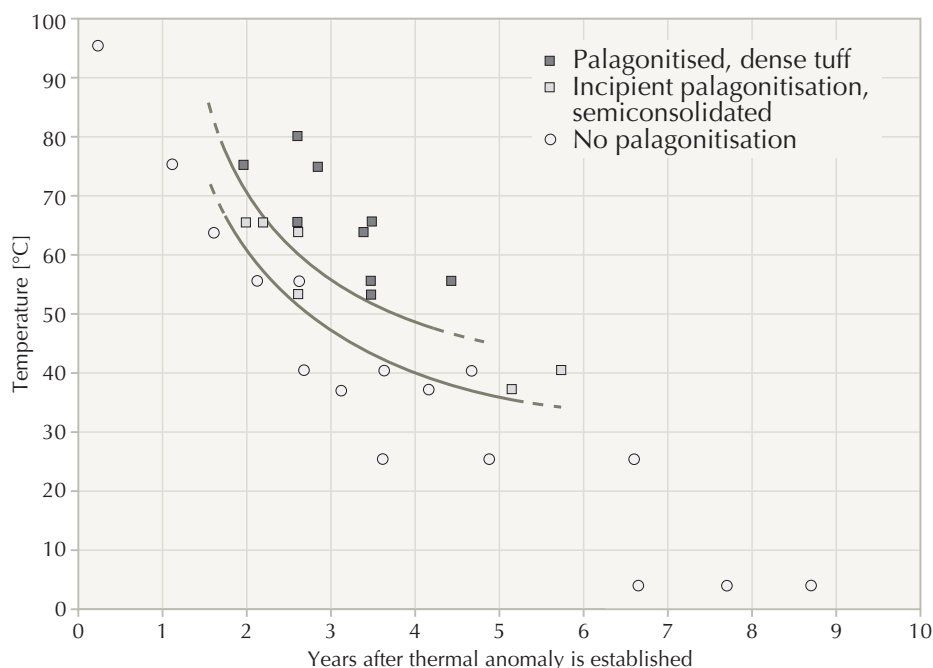


Fig. 2.22. Rate of palagonitisation and consolidation at the Surtsey surface as a function of temperature and time, based on surface observations at 11 locations between 1969 and 1977. (Modified from: Sveinn P. Jakobsson 1978).

have also been subject to mudflow and solifluction (Sigurður Þórarinnsson 1966, 1968; Calles et al. 1982). Although Surtsey thus offered an outstanding example of the interaction between erosion and deposition in an environment of strong winds and heavy rainfall, these processes were not fully monitored from the start. The tephra cone rims were estimated in 1980 as having been lowered by 1.5–2 m due to wind erosion (Ólafur Ingólfsson 1982) and by 2004 as having been lowered over 4 m. Eolian action may have removed some 10 m (vertical thickness) of tephra from the center inner slope of the eastern cone. Although much of the eroded tephra was carried into the sea, the remainder was deposited along the flanks of the two cones and on the lava field. The extensive erosion of tephra by water has been photographically documented on the northern slopes of Austurbunki and Vesturbunki since 1985.

### Reduction by coastal erosion

As mentioned in Chapter 2a, Surtsey was sometimes heavily eroded by sea waves during the eruption. Though the ease with which tephra erodes surprised no geomorphologist, the speed at which lava was abraded came quite unexpectedly. At times, a storm of only a few days would suffice to transform a coastline of gently-sloping, newly-formed lava into sea cliffs several metres

high, footed with beaches of rounded boulders (Sigurður Þórarinnsson 1964, 1966, 1969).

During the winter of 1963–1964, an exceptionally rapid retreat was observed in the tephra cliffs on the southern coast, which receded a maximum of 140 m and an average of 40 m (Norrman 1970; 1980). Clearly Surtsey would not have survived such fast marine abrasion for more than a few years after the end of the eruption, if subaerial lava had not flowed over and protected the southern area of the volcano. Not only did this serve to fortify the subaerial tephra and reduce erosion rates, it also enlarged the island considerably.

The posteruptive period has offered unique opportunities to study erosive forces in a coastal environment of strong wave activity (Norrman 1980, 1985). Moreover, fine coverage by vertical aerial photography enables meticulous research into the island's shrinkage through marine abrasion (Williams 1983; Sveinn P. Jakobsson et al. 2000; Garvin et al. 2000; Daði Björnsson 2004). Surtsey's three principal geological units – tephra, lava and palagonite tuff – react quite differently to such abrasion. Fig. 2.23 shows the cumulative areal modification of Surtsey as well as distinct changes in each of these three units during the island's construction period, 1963–1967. The subsequent depletion after eruptions ceased in 1967 is also shown, with the diagram demon-

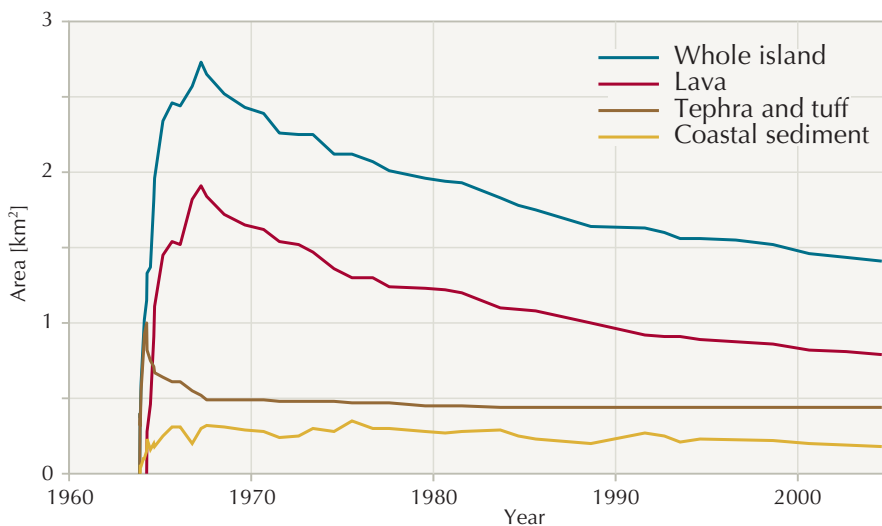


Fig. 2.23. Areal changes in Surtsey and its three principal geological formations, 1963–2004 (in km<sup>2</sup>). The measurements are based on aerial photographs on a scale of 1:5,000. Aerial measurements during the eruption, 1963–1967, were made by Sigurður Þórarinnsson (1966, 1969).

strating that lava erosion is the most important factor in island reductions. The coastal sediment on the northern spit undergoes perceptible variations in area, probably depending primarily on winter storm intensity, but was in general seen to diminish slightly during the period.

Figure 2.24 shows how the Surtsey outline changed from 1967 to 2004, as the surface area shrank from a maximum of 2.65 km<sup>2</sup> in 1967 to 1.41 km<sup>2</sup> in 2004. Marine abrasion appears likely to proceed at a considerable rate until the resistant core of palagonite tuff, the volcanic necks, and the lava that overlays tuff have been exposed on every side. Marine abrasion wore its way to the palagonite core at the western cliffs as early as 1980; when this core has been reached on other sides, erosion will subside considerably.

#### Submarine erosion

As was mentioned previously and summarised in Table 2.8, eruptions occurred at three sites on the seabed apart from Surtsey itself.

Bathymetric maps of the Surtsey surroundings were prepared on nine occasions, from 1964 to 2000, (Norrman 1970; Sveinn P. Jakobsson 1982; Norrman and Erlingsson 1992; Icelandic Maritime Administration 2002) and demonstrate considerable changes in the submarine environment (Fig. 2.25). During this time the Surtsey platform was widened considerably, due to beach material deposited from the island. These bathymetric maps also reveal that Surtla and the submarine remnants of Syrtlingur and Jólnir islands have suffered

constant, rapid erosion, probably caused by both wave action and bottom currents (Fig. 2.26).

In 2000 Surtla still stood 70 m above the surrounding sea floor, having been lowered by some 30 m, while the depths to the top of the former islands of Syrtlingur and Jólnir were 32 m

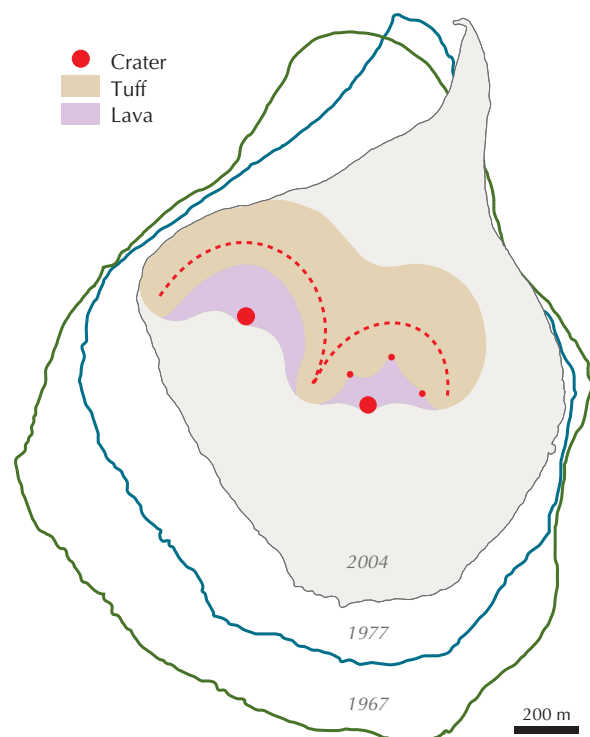


Fig. 2.24. Changes in the shoreline of Surtsey between 1967 and 2004. The estimated extent of the central core (about 0.4 km<sup>2</sup>) is indicated, consisting of palagonite tuff (brown), craters (red) and lava resting on tuff (violet).

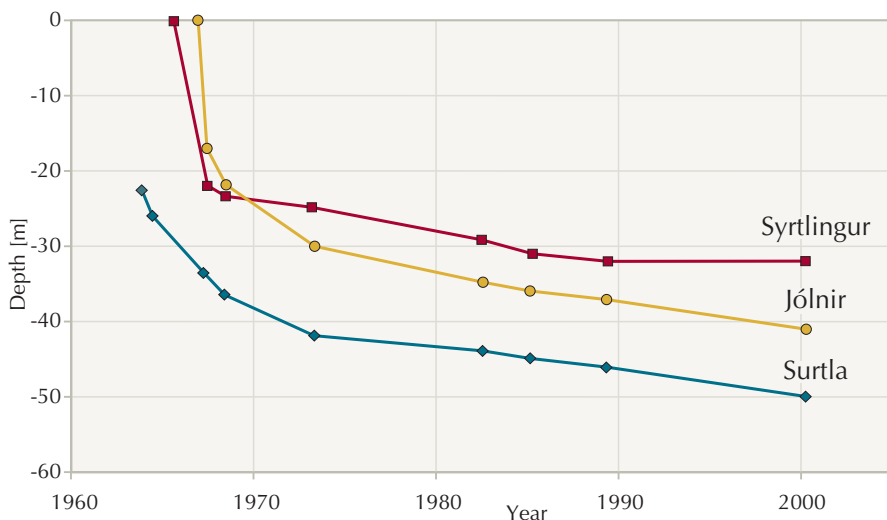


Fig. 2.25. Abrasion of the seamounts Surtla, Syrtlingur and Jólnir, with reference to the mean depth of the top platform.

and 41 m, respectively. Since data show the rate of erosion to be decelerating, these submarine hills seem likely to survive far into the future. The possible development of palagonite tuff in the cores of these seamounts would hinder erosion appreciably. However, data from the Surtsey volcano shows a particularly fast, steady rate of erosion of submarine volcanic deposits, unlike anything that has been monitored previously. No comparable information has come to light elsewhere.

### Future development of Surtsey

The curve of cumulative areal change in Surtsey after 1967 is fairly regular (Fig. 2.23), which facilitates the prediction of future developments. Island erosion has thus been modelled by using a

cone to approximate the shape of Surtsey and assuming the rate of erosion to be proportional to coastal length (Sveinn P. Jakobsson et al 2000; Sveinn P. Jakobsson and Guðmundur Guðmundsson 2003). The estimated parameters of the model were based on observed values, which resulted in the extrapolated curve coinciding with the area of the palagonite core (0.4 km<sup>2</sup>) about 160 years after the end of the eruption (Fig. 2.26).

When the core of the Surtsey volcano has been reached, the island will resemble some of the islands and sea stacks of the Vestmannaeyjar archipelago, especially Bjarnarey and Elliðaey (Fig. 2.4). These two islands, dated by tephrochronology to be about 6,000 years old, were formed in the same manner as Surtsey. The comparison enables us to predict that Surtsey will survive for a long time, probably for thousands of years.

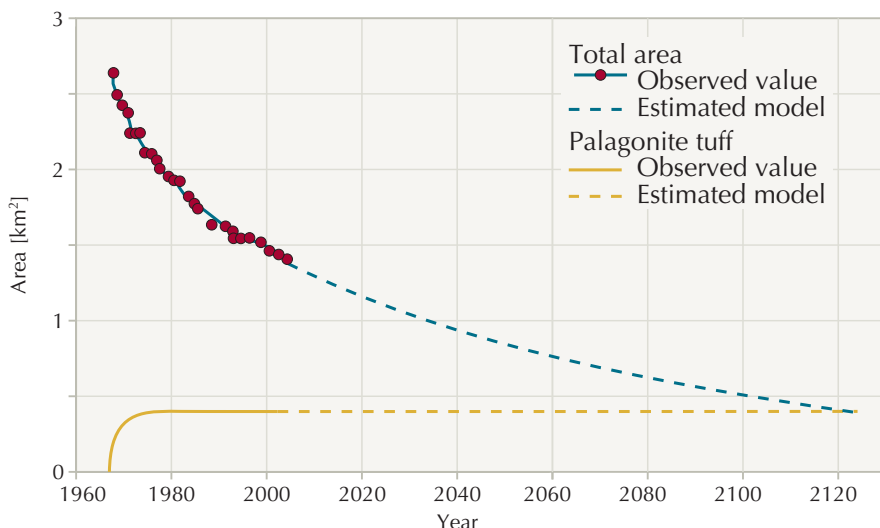


Fig. 2.26. Observed changes in the area of Surtsey since June 1967. The prediction model and estimated developments in the palagonite tuff core are also shown. The model predicts that about 160 years will elapse from the end of the eruption until only the palagonite tuff is left above sea level.



Sea rocket was the first plant species to colonise Surtsey in 1965. Its seeds were dispersed by sea and washed upon the shore of the island. (Photo: Sturla Friðriksson 1966).

## History of life

### Influx of terrestrial organisms

The appearance of Surtsey provided a unique opportunity to study the colonisation and succession of life on a sterile island surface. By 1965, the island was already protected by law, with strict visitation restrictions to ensure that no plants or animals would be transferred to the island by humans. Due to this foresight among Icelandic scientists and the authorities, species colonisation and ecosystem development on Surtsey has occurred without human interference. In particular, the study of plant colonisation has revealed that ocean currents, winds and birds are the leading agents in transporting new species to the island.

### Dispersal by sea

In 1964, during the first spring after Surtsey rose from the sea, seeds and other plant parts were discovered that had washed onto the freshly-formed shore. Some of these seeds were collected and found to germinate in the laboratory (Sturla Friðriksson 1966b). This was early evidence that seeds carried by ocean currents would prove to be the first pioneers. In the spring of 1965, close to the shoreline, the first vascular plant seedling was discovered, the sea

rocket *Cakile arctica*. Other coastal species, such as the sea sandwort *Hockenya peploides*, lyme grass *Leymus arenarius* and oyster plant *Mertensia maritima*, soon followed this pioneer. Occasionally a few plants of the long-stalked orache *Atriplex glabriuscula* have also been observed growing in the drift line. The seeds of these pioneering coastal species are rather large,



Tea-leaved willow provides an example of a species which has been dispersed by wind to Surtsey. (Photo: Erling Ólafsson 2005).



float easily and tolerate the salty seawater, adapting them very well to sea transport, which is their main route of long-distance dispersal. Probably the island's pioneers originated from parent plants growing on the sandy shores of Heimaey or along the southern coast of Iceland, where they are abundant. The distance from Surtsey to Heimaey is 18 km, while 32 km separate Surtsey from the mainland.

Seeds have also been dispersed to Surtsey by being attached to drifting materials. Living plant parts and small animals have been carried to the island on floating driftwood, clumps of grass turf and root tangles from nearby islands. Even skate eggs have been found washed upon shore with numerous plant seeds attached to their surface (Sturla Friðriksson 1975).

#### Dispersal by wind

Seeds and fruits from plants that are adapted to wind dispersal, such as cotton grass *Eriophorum* spp. and groundsel *Senecio vulgaris*, have frequently been found on Surtsey during the latter part of summer when the wind blows off the mainland to the island; however, neither of these species has yet been found growing on the island. Other species adapted to wind dispersal, such as the dwarf willow *Salix herbacea*, woolly willow *Salix lanata*, tea-leaved willow *Salix phylicifolia*, dandelion *Taraxacum* spp. and autumn hawkbit

*Leontodon autumnalis*, have become established on Surtsey and have most likely been carried there by the wind.

Mosses, lichens, fungi and algae reproduce by tiny spores and fruiting bodies that are picked up by air currents and dispersed by the wind. It seems obvious that the majority of species in these groups have been brought to Surtsey by air currents, since their scattered, widespread distribution at sites offering favourable growing conditions strongly implies this type of transport.

#### Dispersal by birds

It is a well-known fact that birds serve as seed carriers. Many bird species eat berries or fruits that contain seeds, only to expel them later as waste in new locations. Seeds can even end up in a bird's digestive tract when it consumes prey. In addition, seeds may stick to birds and fall off at far-removed locations. Similarly, the spores and soredia of rock lichens may remain externally on a bird's feet as it flies from one roosting site to another. Finally, birds carry nest building material from plants over significant distances.

There is considerable evidence of birds having carried seeds to Surtsey. Several migratory species use it as a resting spot on their way from the rest of Europe over the Atlantic. In the late 1960s, a study of the digestive tract contents of migrating snow buntings *Plectrophenax nivalis* revealed intact seeds, indicating long-distance dispersal (Sturla Friðriksson and Haraldur Sigurðsson 1969). Scurvygrass *Cochlearia officinalis* became an early colonist of Surtsey and was first noticed at a point where seagulls rested. In addition, the lichens *Xanthoria candelaria*, *Caloplaca verruculifera*, *Lecania subfuscula* and *Lecanora poliophaea* were first discovered at sites frequented by birds, since they are partly nitrophilous and are all commonly found along coastal cliffs where birds rest and excrete their droppings.

In the years following the establishment of a seagull colony on Surtsey in 1986, numerous new plant species colonised the island. The gulls probably carried nesting material to Surtsey from neighbouring islands, bringing with it seeds or other propagules of such plants as the crowberry *Empetrum nigrum*, meadow buttercup *Ranunculus acris*, smooth meadow-grass *Poa pratensis*, Bering's tufted hairgrass *Deschampsia beringensis* and northern dock *Rumex longifolius*.



Scurvygrass on Surtsey, a common species of seabird cliffs and colonies in Iceland. The species was initially found at roosting sites of seagulls, which probably were the dispersal agents. (Photo: Erling Ólafsson 2004).

### Arrival of marine organisms

The methods that marine organisms have for dispersing to Surtsey are probably quite numerous. Most algae, for example, have planktonic spores or zygotes that are transported by currents, while many marine invertebrates have planktonic larvae that likewise are spread by ocean currents. Such organisms can be distributed over relatively long distances.

Marine animal species with young that resemble the adult form rather than being planktonic are usually not dispersed by ocean currents. Colonising a new area can be difficult for such organisms, since they must crawl, swim or be carried to the new destination to be able to settle there.

Animals with sessile larval stages living on the seabed off Surtsey when the eruption began had an advantage compared to other benthic species, because they were able to colonise the new bottom substrate as soon as the eruption ceased. In November 1964, dredge samples from the base of the volcano, which lies at a depth of 100 m, included the swimming crab *Polybius holsatus*, aesop shrimp *Pandalus montagui* and brown shrimp *Crangon allmanni*. These species, as well as most of the other animals identified in the following years at the base of the volcano, were common in the benthos community immediately outside the area disturbed by the eruption.

In addition to the previously mentioned methods of dispersal, birds may have brought the spores and larvae of marine organisms in their feathers, as many seagulls and wading birds forage in the littoral zone. Drifted algae have regularly been observed on the shores of Surtsey,

allowing the assumption that some algae populations have become established through drifted individuals. Moreover, some epiphytic animals were probably carried by drifting seaweed.

### Plant and bird colonisation and ecosystem development

#### 1965–1974: The invasion of coastal species

During the first decade, 1965–1975, the sands and lava of Surtsey were extremely barren and nearly devoid of nitrogen in the soil. Shore plants, which characterised vegetation development during that decade (Figs. 2.27 and 2.28), together with a few moss and lichen species (see later), are among the few plants adapted to such nutrient-poor soils and harsh conditions.

The first vascular plant species found growing on Surtsey was sea rocket, in 1965. Moreover, it was observed again the following year, along with lyme grass, while oyster plant and sea sandwort lengthened the list in 1967 (Sturla Friðriksson 1970a). Among other plant species that managed to become established on the volcanic sands of Surtsey during its first decade were the curved sedge *Carex maritima*, which is likewise adapted to sandy environments, and scurvygrass, which grew poorly, obviously limited by the lack of nutrients (Fig. 2.29). The brittle bladder-fern *Cystopteris fragilis* was among the pioneers, managing to establish itself in moist, moss-covered crevices within craters and lava caves. Clearly, the spores of this species had been transported to the island by wind.

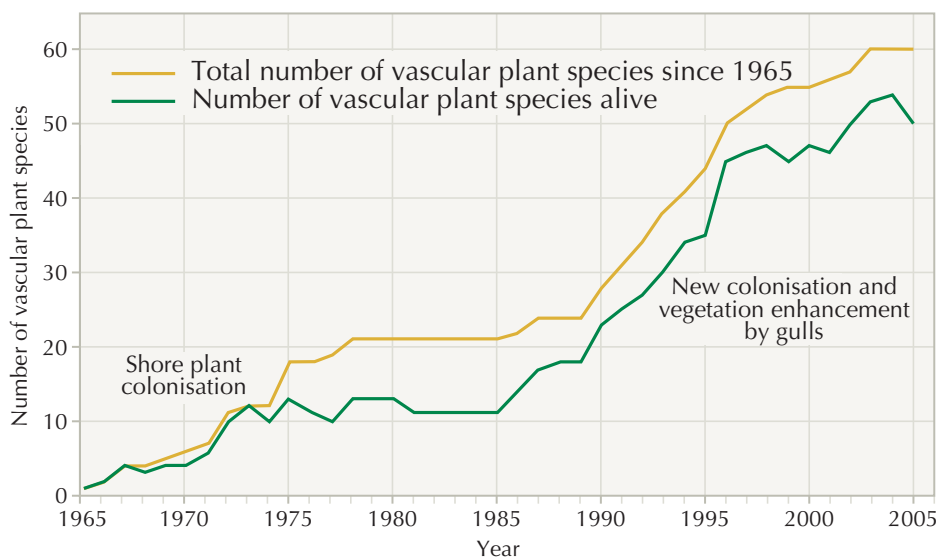


Fig. 2.27. Colonisation and survival of vascular plant species on Surtsey during 1965–2005.

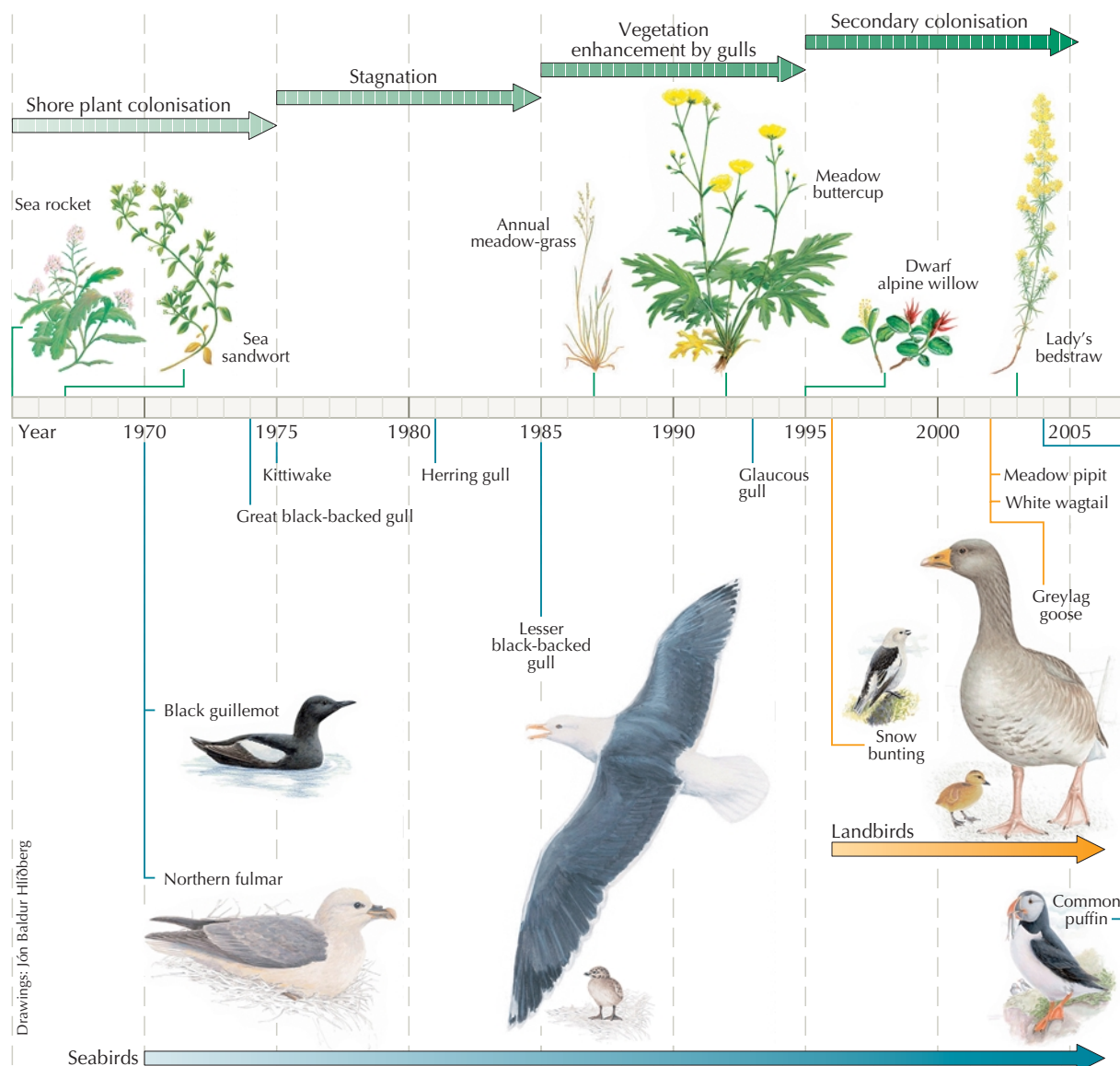


Fig. 2.28. Main steps in species colonisation and ecosystem development of plant communities and birdlife on Surtsey. A large increase in the number of breeding seagulls on the island after 1985 improved its nutrient status and enhanced development of its vegetation and invertebrate communities, enabling the first landbirds to settle on the island ten years later.

In 1974, at the close of the first decade of plant life on Surtsey, 12 species of vascular plants had been found on the island and 10 of them had become established (Sturla Friðriksson 1978). Species survival was thus relatively high for the initial period (Fig. 2.27).

**1975–1984: Period of stagnation**

After the momentous first decade, the rate of colonisation and succession stagnated. Although several new plant species were discovered on the island during the second decade, 1975–1984,

very few became established (Fig. 2.27), probably due above all to the lack of essential soil nutrients. The sole new species managing to overwinter and to establish itself during this period were the common mouse-ear *Cerastium fontanum* and sheep's sorrel *Rumex acetosella*. Attempting but unsuccessful new species included the field horsetail *Equisetum arvense*, sea campion *Silene uniflora*, mountain rock-cress *Arabidopsis petraea*, common meadow-grass *Poa pratensis* and procumbent pearlwort *Sagina saginoides*. However, all of these achieved greater success

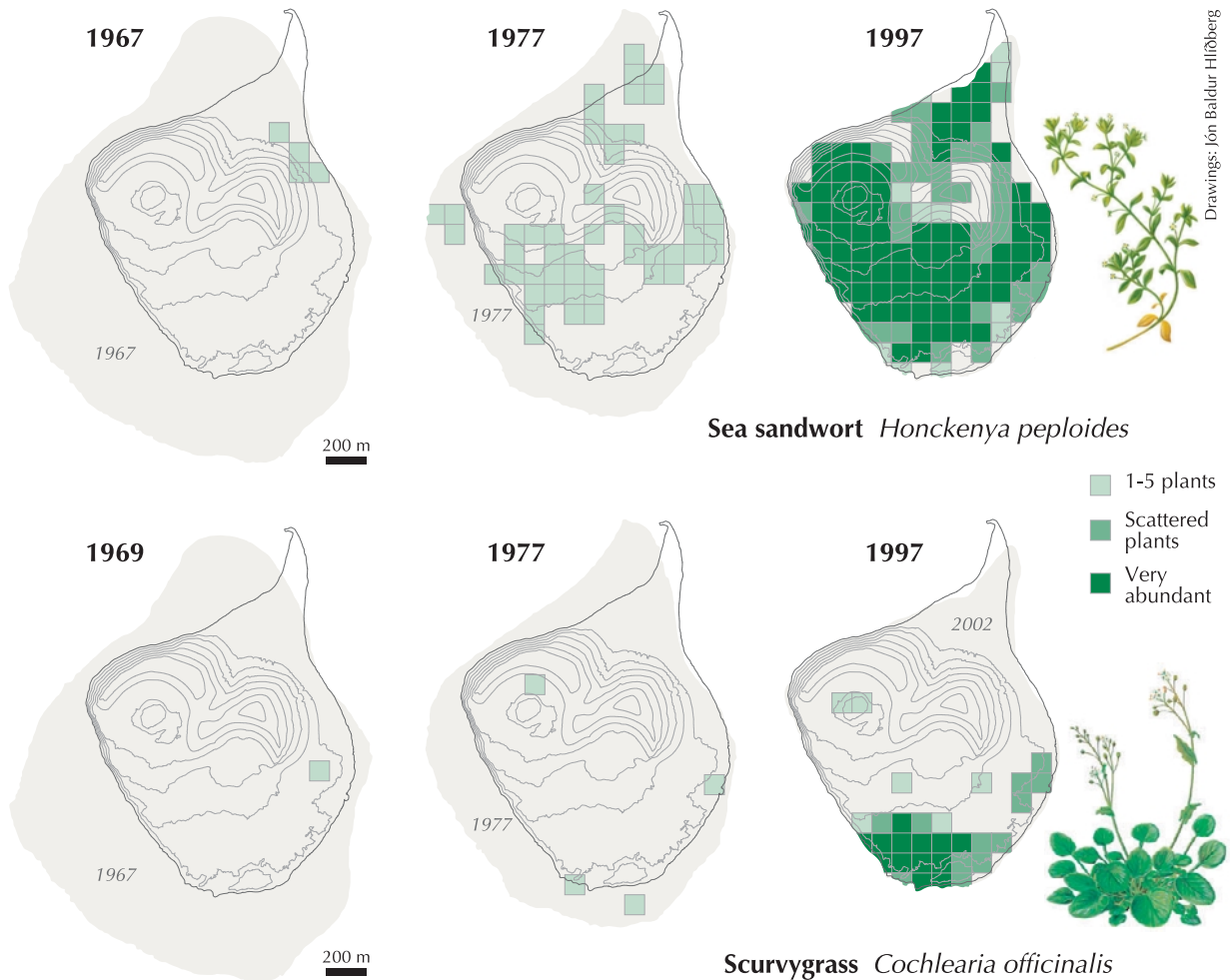


Fig. 2.29. Distribution of sea sandwort *Honckenya peploides* and scurvygrass *Cochlearia officinalis* on Surtsey in 1967, 1977 and 1997, shown on a 100 x 100 m grid of the island. The darker the colour, the more abundant the species. The sea sandwort was the most common plant on Surtsey in 1997 and is found on sand and tephra substrates throughout the island. The scurvygrass is more nitrogen dependant and first began to thrive after the formation of seagull colony on the southern part of the island.

upon later attempts after growing conditions had improved.

The shore plants sea sandwort, lyme grass and oyster plant, not being as hampered by the poor soil conditions, continued flourishing and spreading during the 1975–1984 period. On the other hand, it was not until 1977–1979 that lyme grass and oyster plant began seeding and spreading effectively over the sand and pumice. Another landmark was that in the latter half of this period, the first plant community, composed of lyme grass, patches of sea sandwort and scattered oyster plants, formed on sand-covered lava in the eastern part of the island. Gulls became an important factor in this community,

taking advantage of the developing lyme grass dunes, which were excellent sites for nest building and for sheltering their chicks. The plants in turn benefited from growth-enhancing nutrients introduced by the breeding gulls.

Similar stagnation was observed with regard to the lichens and mosses of the lava fields. The relatively quick colonisation by *Placopsis*, *Stereocaulon* and *Racomitrium* was followed by retrogression due to increased erosion, so that few additional species were discovered.

By 1984, the total number of vascular plant species found on Surtsey had increased to 21; however, only 11 of them had managed to become established (Sturla Friðriksson 1992)



Sea sandwort, the first plant species to overwinter on Surtsey, soon began seeding and spreading extensively. (Photo: Erling Ólafsson 2005).



Ripening seed capsules on a Surtseyan specimen of sea sandwort. (Photo: Erling Ólafsson 2004).

(Fig. 2.27). Hence, the relatively successful colonisation period of 1965–1974 was unexpectedly followed by much poorer survival during 1975–1984. A whole new picture was emerging of biological colonisation and succession processes on new insular terrain.

#### **1985–1994: New wave of colonisation and succession, facilitated by breeding gulls**

The avian impact on vegetation development remained limited throughout the island's first two decades. Breeding birds were relatively few and their nests mostly confined to the sea cliffs. In 1986, the first sign of a seagull colony, consisting of 10 nests built by lesser black-backed *Larus fuscus* gulls and herring gulls *L. argentatus*, was noted on the black, barren lava in the southern part of the island. A sharp increase in the breeding population followed, with the number of nesting pairs reaching 180 by the summer of 1990, when great black-backed gulls *L. marinus* were also breeding in the colony. Concomitant to the population explosion of gulls was a new wave of plant colonisation and succession; the stagnation characterising previous years was finally broken. Not only were a number of new species discovered, but many of the species which had previously attempted colonisation without success reappeared. Most of this development took place within the gull colony (Borgþór Magnússon and Sigurður H. Magnússon 2000). Another change was a considerable improvement in species survival, against the previous period

(Fig. 2.27). The rapid plant colonisation, vigorous vegetation succession and much improved plant survival now evidenced were clearly driven by the gulls. Apparently, they not only improved plant survival and growth by applying soil nutrients through their excreta and bits of lost chick feed, in addition to the decaying carcasses of young and adult birds, but they also facilitated plant dispersal to Surtsey (Borgþór Magnússon and Erling Ólafsson 2003).

Several plant species, e.g. the sea-mayweed *Tripleurospermum maritimum* and scurvygrass *Cochlearia officinalis* (2.29b), Richardson's fescue *Festuca rubra* and common sea meadow-grass *Puccinellia coarctata*, having barely survived previously, were quick to take advantage of the improved soil nutrient condition by expanding their range on the island. Among the more important plant species taking a foothold during this period were smooth meadow-grass, annual meadow-grass *Poa annua*, common bent *Agrostis capillaris* and common chickweed *Stellaria media*. Within a few years, the centre of the gull colony had turned green with a continuous cover of vegetation, and a forb-rich grassland community had arisen on Surtsey.

Gulls also affected lichen colonisation on Surtsey, mainly in two ways. Firstly, soil formation around the breeding colony enabled the colonisation of such soil lichens as *Cladonia* spp. Secondly, nutrients introduced by the gulls provided the potential for a special crustose lichen community to colonise the lava rocks around the breeding

colony, a community composed mainly of *Lecania subfuscula* and *Lecanora poliophaea* together with *Caloplaca verruculifera* and *Xanthoria parietina*.

By 1994, the number of higher plant species recorded on Surtsey had doubled (from 21 to 41) and the number of surviving species had tripled (from 11 to 34), which demonstrates the profound effects of the breeding gulls on plant colonisation and survival (Figs. 2.27 and 2.28).

### 1995–2004: Secondary plant colonisation, first breeding by landbirds

The relatively high plant invasion rate continued between 1995 and 1999, with 13 new species recorded on the island. Then the invasion rate began to level off and no new plant species has been recorded since 2003. It thus appears that most of the species which can potentially benefit from the gull transport bridge and nutrient enrichment have already arrived.

An interesting aspect of the history of Surtseyjan flora since 1995 is the establishment of several secondary plant colonisers. They include three willow species: the dwarf willow, woolly willow and tea-leaved willow. In all likelihood, seeds of these three species were routinely dispersed to Surtsey by wind, but met with unfavourable conditions for their growth and development until the most recent decade. Improved nutrient status was probably also the main prerequisite for other recent plant colonisers gaining a foothold, such as the cold eyebright *Euphrasia wettseinii*, lady's bedstraw *Galium verum* and northern green orchid *Platanthera hyperborea*, which have all appeared within the gull colony since 2001. The cold eyebright is a semi-parasitic plant that poaches resources from its host plants through root connections. While lady's bedstraw and northern green orchid are both common species on Icelandic grasslands and heathlands, they are never encountered in barren or extensively disturbed habitats (Hörður Kristinsson 1998).

By 2004, the number of vascular plant species that had been recorded on Surtsey reached 60. Of those, 54 still existed there, the highest number yet in that respect. By 2005, however, the number of species found dropped again to 50 (Fig. 2.27). Notwithstanding this temporary reduction, the number of species on Surtsey will probably rise somewhat over the next 40–50



Lady's bedstraw, a quite new coloniser of grass swards of the seagull colony on Surtsey, exemplifies the secondary plant colonisation that has occurred in the last few years. (Photo: Borgþór Magnússon 2005).

years, after which it is expected to fall once more, because of ongoing erosion and island shrinkage.

The great increase in plant diversity and cover subsequent to the gull invasion had profound effects on ecosystem development at Surtsey (Fig. 2.28). Insect life was enriched immensely, and in 1996 the first landbird was found breeding there: the snow bunting *Plectrophenax nivalis*, which feeds its chicks on flying insects. Snow buntings have bred on Surtsey ever since, in increasing numbers. Two passerines, the white wagtail *Motacilla alba* and meadow pipit *Anthus pratensis*, have also bred on Surtsey in recent years. Starting in 2002, a pair of greylag geese, *Anser anser*, bred on the island and still nests there. Thus the first vertebrate grazer has entered the young ecosystem evolving on Surtsey. The geese feed on the lush grass swards in the gull colony (Borgþór Magnússon and Erling Ólafsson 2003).




Birds can influence the development of vegetation in various ways. They may locally slow down succession through trampling, pulling out plants and scraping to build nests. On the other hand, the overall outcome considering nest materials, carcasses, food remains, pellets and other excreta, etc. has positive effects on the development of both flora and small fauna (see

## Effects of breeding gulls on ecosystem development

The effects of gulls on Surtseyjan ecosystem development have been studied with reference to permanent plots since 1990. In plots outside the gull colony, changes have proceeded very slowly, compared to plots within the colony. An example is given in the table below, which compare plant colonisation and succession along with several other parameters related to ecosystem development on the basis of two permanent plots that are located outside and inside the gull colony but otherwise represent similar tephra-covered lava. The measurements are taken from the 2004 survey.

In 1994, Plot 13 was delineated on the eastern part of the island, where plant succession has not been affected by gulls. The total plant cover increased from 1.7 to 3.1% from 1994 to 2004, but species richness and composition stayed constant throughout the period (sea sandwort, lyme grass and oyster plant). Thus it appears that by 1994 the plant community had already reached environmental barriers (e.g. nutrient status) determining plant succession.

Plot 1 was positioned in 1990 in an area where nutrient enrichment from the gulls was already evident. During the same ten-year period as above, plant cover increased from 28.5 to 98.8%, while species richness increased from 2 to 7; in this manner a barren, species-poor shore community with sea sandwort as the dominant species had changed to a closed forb grassland that was relatively rich in species. Nutrient input from the breeding gulls is without doubt the deciding factor for such rapid turnabouts.

Plots as photographed in July 2004	P13 – outside the gull colony	P1 – inside the gull colony
		
<b>Plants:</b>		
Species richness	3	9
Total plant cover %	3.1	98.8
Dominant species and cover %		
<i>Honckenya peploides</i>	2.1	25.6
<i>Leymus arenarius</i>	0.9	17.3
<i>Poa pratensis</i>		41.3
Plant biomass g dw/m <sup>2</sup>	10.5	427
<b>Soil*</b>		
pH	7.73	6.81
C %	0.04	0.87
N %	0.006	0.067
Soil respiration $\mu\text{mol}/\text{m}^2 \text{ s}^{**}$	0.1	5.7
<b>Insects:</b>		
Species richness	12	22
Catch – specimens/day	19	176

\*The soil was sampled in 2003, in order to analyse it for pH, C and N. \*\*Bjarni Diðrik Sigurðsson, unpublished data

Results of the 2004 investigations into plant communities and biomass, soil chemistry and respiration, and invertebrate diversity and abundance in areas outside and inside of the gull colony on Surtsey.

Erling Ólafsson 1982; Gjelstrup 2000). Nests, for instance, can be sources for seed colonisation, and dead tissue provides food for small animals. Pulling out plants to build nests, in itself destructive, can in the final analysis be positive for ecosystem development.

Birds breeding on Surtsey clearly play a leading role in the formation of soil and the development of plant and insect communities there. This is especially obvious in the gull colony which provides an excellent research opportunity on the development of multi-species communities as well as the colony's interaction with vegetation and terrestrial invertebrate fauna. This gull colony is largely unaffected by humans, while elsewhere in Iceland gulls are generally persecuted.

### Invertebrate colonisation

The first terrestrial invertebrate to be discovered on Surtsey was the midge *Diamesa zernyi*, in May 1964 (Oliver 1965). Further specimens were subsequently discovered, and by the end of the summer of 1965 seven additional invertebrate species had been found (Lindroth 1967). As might be expected, the initial visitors were mostly flying insects, which were brought by northerly winds from two main sources: the Icelandic mainland or other islands in the Vestmannaeyjar archipelago. Nonetheless, long-distance travellers, such as migrating moths and butterflies, were also recorded, carried to Surtsey by southerly winds from the European continent. For instance, a specimen of the non-native moth *Autographa gamma* was found on the island in 1965 (Lindroth et al. 1973). Even flightless invertebrates have been blown to the island by air currents, such as a small spider of the family Linyphiidae which was found in 1966 on northern Surtsey, after apparently gliding to the island on its long spinning threads.

Many invertebrates have been transported to Surtsey by the ocean, either with or without the aid of other drifting materials. Such specimens, both dead and alive, have been found on the beach after being washed ashore. The means of transport include driftwood and floating clumps of turf, which arrive on shore carrying numerous small invertebrates such as springtails and mites, as well as the sole proturan yet noted on the



Of all the spider species that have reached Surtsey, *Erigone arctica* is by far the most common. Spider eggs are often found in clusters on the underside of stones and driftwood. (Photo: Erling Ólafsson 2004).

island. Birds have carried invertebrates not only in their plumage, but probably also with nesting material. In fact, there are examples of species carried by birds migrating from Europe, viz. the well-known tick *Ixodes ricinus* and the blood-sucking hippoboscid fly *Ornithomyia avicularia* (Lindroth et al. 1973).

Although the number of invertebrates found on the island amounted to 136 species by 1970, only a few had managed to establish themselves under the hostile conditions prevailing on the harsh volcanic substrate. For the majority of species, colonisation was prevented by the lack of suitable food sources, meaning that species which proved capable of settling on the island had to depend on the organic matter washed ashore by the sea. Due to these reasons, the early settlers include the fly *Heleomyza borealis*, which breeds on fish and bird carcasses along the coast of Surtsey; the springtail *Archistoma besselsi*, which disperses by sea currents and colonises beaches all around Iceland; and the chironomid midge *Holocladius variabilis*, which breeds in shallow pools in the tidal zone (Lindroth et al. 1973). However, it was not until permanent vegetation appeared, that a local invertebrate fauna began to develop.

By 1974, nonetheless, a total of 170 species of terrestrial invertebrates had been identified on the





The carabid beetle *Amara quenseli* is common in Iceland, favouring open vegetation and sandy soil. The species was found in Surtsey as early as 1967 and is now found on sparsely vegetated areas throughout the island. (Photo: Erling Ólafsson 2004).



The common tortricid moth *Eana osseana*, whose larvae feed on grass, has found its ideal habitat in the gull colony. (Photo: Erling Ólafsson 2004).

island, equivalent to approximately 13% of the registered terrestrial invertebrate fauna of Iceland at that time. Furthermore, several species had become permanently established, forming a simple insect community composed of herbivores, saprotrophs and carnivores. By this time, a few scattered pairs of both great black-backed gulls and herring gulls had started to breed on the island. Each of the gulls' nesting sites, with accompanying plant growth, provided a base for the invertebrate community. Following the establishment of a distinct gull colony in 1985, vegetation and soil fertility underwent a dramatic change, while the number of soil and ground invertebrates, such as mites and springtails, escalated.

In the summer of 1993, the first earthworms were discovered, living in soil samples taken from the gull colony. These were juveniles of the chestnut worm *Lumbricus castaneus* (Hólmfríður Sigurðardóttir 2000). A survey of soil invertebrates in 1995 showed the number of mites to have climbed to a total of 62 species. Eight species of springtails were found, six of which were new to the island. Prior to 1995, a total of 16 species of springtails had been recorded, which means that only a couple of the original pioneers had been able to survive and establish themselves.

Although import of organisms has been strictly controlled, humans have brought at least two insect species to Surtsey: the lathridid beetle *Lathridius minutes* and the drosophilid fly *Drosophila funebris*, both found within the research station and shelter "Pálsbær" and no doubt coming as stowaways in food supplies.

### Benthos colonisation

The first plants found growing on Surtsey were marine diatoms discovered in the coastal zone on recently formed lava in August 1964 (Sigurður Jónsson 1966). The annual number of benthic marine species observed around Surtsey rose rapidly from 1964 until 1970. Then the increase levelled off, and about 40 species of macroalgae have been recovered on each sampling occasion since 1977, with a similar pattern presented by benthic fauna (Erlingur Hauksson 1992b; Sigurður Jónsson and Karl Gunnarsson 2000) (Fig. 2.30).

Soon after the full cessation of volcanic activity, it became possible to observe distinctive communities. Sessile plants and animals were found growing on rocks in the sublittoral zone. At first only fast-growing opportunists, such as *Alaria esculenta* and *Desmarestia viridis*, were found in the summertime on larger stones. Vegetation



The slug *Deroceras agreste* was the first of two terrestrial molluscs found on Surtsey and was probably carried by birds. It is fairly common in the dense vegetation of the gull colony. (Photo: Erling Ólafsson 2004).



The brown kelp species *Alaria esculenta* was among the first seaweeds to colonise the sublittoral slopes of Surtsey. The species was at first confined to the depth range 15 to 25 m. In recent years it grows most gregariously at 5–10 m depth. (Photo: Karl Gunnarsson 1997).

remained scarce at first, confined to depths below 6 m and to boulders surrounded by sand and gravel. The highest plant cover occurred at depths of 15–20 m. A similar pattern was noted for benthic animals, whose dominant groups were hydroids and mussels. On the other hand, the cover and number of species grew fast until about 1971, when the number of species per sampling occasion started to level off. By that time a number of red turf algae had appeared, e.g. *Lomentaria orcadensis*, *Phycodrys rubens* and *Polysiphonia stricta*, while amongst invertebrates, the bivalves *Heteranomia squamula* and *Hiatella arctica* and crustaceans such as the acorn barnacle *Verruca stroemia*, the crab *Hyas coarctatus*, and

shrimps had become common (Erlingur Hauks-son 2000; Sigurður Jónsson and Karl Gunnarsson 2000; Aðalsteinn Sigurðsson 2000).

As the substratum has increasingly stabilised, especially at the east coast, the number of colonisers has climbed steadily. At depths of 0–15 m algae are dominant. With increasing depth, the cover of sessile animals becomes denser, whereas algae disappear below depths of 25–30 m (Sigurður Jónsson et al. 1987; Erlingur Hauks-son 1992a).

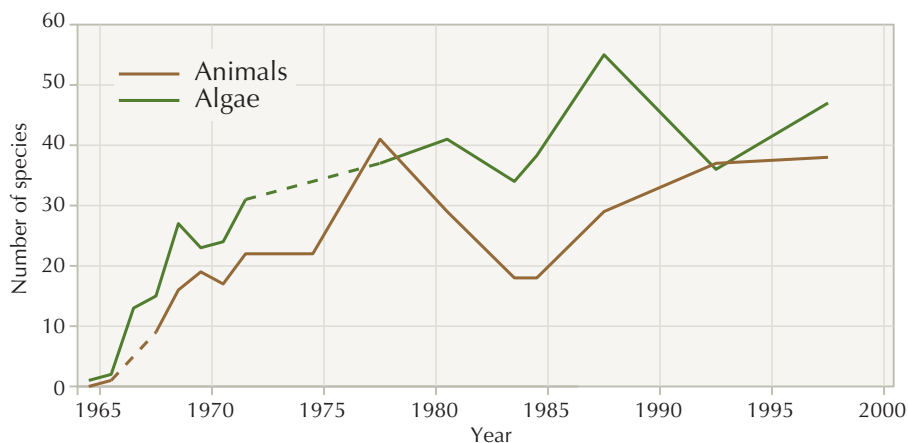


Fig. 2.30. Developments in the number of algae and animal species found in the Surtsey littoral and sublittoral zones on each sampling occasion from 1964 to 1997. Only groups monitored regularly are included, i.e. red, brown and green algae and the following animal groups: sponges, anthozoans, soft corals, molluscs, crustaceans (except amphipods), echinoids and ascidians.



Surtsey has offered a natural laboratory in geology, geomorphology and ecology. (Photo: Daniel Bergmann 2003).

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# 3

## Justification for inscription

### 3.a Criteria under which inscription is proposed

It is proposed that Surtsey, Iceland, be inscribed on the World Heritage List under Criteria viii and ix (cf. Article 11.5 of the Convention Concerning the Protection of the World Cultural and Natural Heritage and Paragraph 77 of the Operational Guidelines for the Implementation of the World Heritage Convention).

**Criterion viii:** *to be outstanding examples representing major stages of earth's history, including the record of life, significant ongoing geological processes in the development of landforms, or significant geomorphic or physiographic features.*

The IUCN has recently reviewed the role of the World Heritage Convention in recognising and protecting geological sites (Dingwall et al. 2005). The report examines the four different natural elements, inherent in Criterion viii, which are relevant to geological and geomorphological science. Three of these are relevant to nominating Surtsey for World Heritage status. Quotation marks and italics set off the IUCN text from this report.

#### a. Earth's history

*'This subset of geological (as opposed to geomorphological) features are represented by phenomena that record important events in the past development of the planet.'*

A relevant example mentioned by the IUCN report is the record of crustal dynamics and tectonism, linking the genesis and development of mountains and volcanoes.

In historical time, only a few volcanic islands have been formed in the world as a whole. Most of these islands have quickly disappeared and none has been as intensely investigated from its very beginnings as Surtsey. Thus Surtsey offers



The lava from 1967 on the northeast side of Austurbunkei; erosion has revealed the feeder dike to the lava crater. (Photo: Sveinn P. Jakobsson 2002).

an outstanding example of a virgin volcanic island which is actively being created and shaped by geological and geomorphological processes.

#### b. Significant ongoing geological processes in the development of landforms

*'This element of Criterion viii is the first of two aspects related to geomorphology and ongoing geological processes such as volcanic eruptions.'*



Finely bedded tuff at the crest of Austurbunki, brought out by wind erosion. (Photo: Sveinn P. Jakobsson 1998).

*It relates to active processes that are shaping or have shaped the Earth's surface.* Relevant examples mentioned by the report are volcanism and coastal or marine processes.

Surtsey is renowned for its contributions to earth sciences. Research on the island during and since the eruption has provided invaluable information and insight into several major geological processes. The Surtsey submarine eruption (1963–1967) is the most exactly described submarine eruption ever. Studies on Surtsey have documented in detail the conversion of tephra into palagonite tuff and also demonstrated for the first time that palagonitisation is a posteruptional process and highly temperature-



Lesser black-backed gull with fledglings on the southern lava of Surtsey. (Photo: Daníel Bergmann 2003).

dependent. Finally, Surtsey has provided a rare chance to study the evolution of a posteruptional hydrothermal system.

### c. Significant geomorphic or physiographic features

*This second primarily geomorphological element represents the landscape products of active or past processes, which can be identified as significant physical landscape features.* Relevant examples mentioned by the report are volcanoes, volcanic systems and oceanic islands.

Surtsey's subaerial geomorphology, i.e. its growth and erosion, has been thoroughly documented, through studies on site and through fifty three sets of vertical aerial photographs taken between February 1964 and August 2004. Thus it has been possible to map the erosion of the island, as well as its main geological features, in great detail and predict its future size. This applies not only to the supra-marine part of the island, but the entire volcano as it stands on the sea bottom. The data on submarine abrasion of two transient islets and one submarine ridge appearing during the Surtsey eruption is unique, with no comparable measurements existing on any other volcanic islands in the world.

**Criterion ix:** *to be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.*

Surtsey's emergence has provided a rare opportunity for studying one of the central questions of ecology: the dispersal and colonisation of sterile ground by plants and animals and the development of communities through the processes of succession.

The record of ecological research on Surtsey is remarkable in many ways: it spans 40 years of regular measurements; includes several decades of monitoring data on individual plant and animal species; allows a distinction between the arrival and establishment of a species; highlights how the interaction of birds, nutrients and plants impact primary succession; and provides a thorough census of an entire island. However, what truly makes Surtsey stand out in this regard, compared to similar areas of sterile ground where long-term measurements have been maintained, is how minimal the impact of humans has been.

### 3.b Proposed statement of outstanding universal value

#### **Iceland and the Mid-Atlantic Ridge**

Running from Jan Mayen to Antarctica, the Mid-Atlantic Ridge is the Earth's largest continuous geological structure. Its discovery in the 1950s led, among other things, to the general acceptance of Wegener's theory of continental drift.

Iceland is an integral part of the Mid-Atlantic Ridge, and also its largest supramarine (aerial) component. The crest of the ridge, which marks the boundary between the North American and Eurasian tectonic plates, crosses the country from southwest to northeast, forming a major rift belt that expands continuously by accreting new land through volcanic activity. As one of the most volcanically active countries on Earth, Iceland is constructed almost exclusively of volcanic rocks.

Surtsey is the product of one of Iceland's 29 active volcanic systems, the Vestmannaeyjar system. This is a young system comprising – if only what reaches above sea level is counted – seventeen identified Holocene volcanoes, which originally rose from the sea floor in the same manner as Surtsey. Two volcanic eruptions within this system during historical times are known with certainty: the Surtsey eruption of 1963–1967 and the 1973 Eldfell eruption on Heimaey.

#### **Birth of an island**

The formation of a new volcanic island is a rare event occurring somewhere in the global system of volcanic belts on the average of about twice a century. Most of these islands have disappeared quickly, and none has been as intensely investigated from the very beginning as Surtsey. This applies both to the eruption itself and to the post-eruptive natural history of the island. In this regard, Surtsey has offered a natural laboratory in geology, geomorphology and ecology which is unparalleled anywhere in the world and has provided invaluable information on the creation and history of the Earth and its biosphere.

The Surtsey eruption immediately aroused avid interest among scientists and volcanologists agree that it is the best documented submarine eruption to date. It was a spectacular event in the picturesque surroundings of the Vestmannaeyjar archipelago. The scientific value of Surtsey was further acknowledged after it became evident that the island would persist and thus provide an exceptional opportunity to study the development of an oceanic volcano from its inception on the sea floor, through the formation of an island, to the modification of the newly erected structure by hydrothermal processes and wave abrasion. Surtsey is in reality the type locality of Surtseyan tephra (volcanic ash), produced by hydromagmatic (Surtseyan) eruptions. Surtsey is also one of the best preserved submarine tuya (tablemountain) on Earth.

#### **Geological processes**

Geologists are paying increased attention to the formation of palagonite tuff in Iceland, partly



Surtsey in February 1964. (Photo: Sigurður Þórarinnsson).

because similar formations are uncommon elsewhere on Earth. Studies at Surtsey demonstrated for the first time that the conversion of tephra into tuff is a post-eruptive process, occurring at relatively low temperatures (usually below 100° C) and at low pressures. Furthermore, the process was shown to be highly temperature-dependent and to proceed much faster than anyone had envisaged. In 1969, two years after the eruption ceased, the first sign of palagonitisation was noticed at the surface of Surtsey. By 2004, some 85% of the tephra pile above sea level had been converted to palagonite tuff. In short, Surtsey has provided a well-documented case of the consolidation and alteration of basaltic tephra, a case which remains unparalleled.

Surtsey has provided a unique opportunity to study the evolution of a post-eruptive hydrothermal system. This system, discovered at the surface of the island in the spring of 1967, has been monitored ever since. The hydrothermal area at the surface continued to expand until around 1979 but then the rate of expansion slowed down, presumably because the consolidated tephra inside the island had started to affect the heat flux.

### **Island erosion**

The post-eruptive period has offered unique opportunities to study erosive forces in a coastal environment of strong wave activity. The erosion of Surtsey has been documented in detail through an extensive series of vertical aerial photos. The three principal geological formations of Surtsey – tephra, lava and palagonite tuff – react quite differently to marine abrasion, with tuff proving the most resistant. Since 1967, surf has eaten away about half the island, above all loose tephra and lava. For the first few years, 3–20 hectares disappeared annually, while recent years have seen an annual average of approximately one hectare washed away.

An attempt has been made to model the future of Surtsey by using the curve of cumulative areal change of Surtsey from 1967 to 2004. These models indicate that 120 years from now, only the core of palagonite tuff will be left. Surrounded at that point by steep palagonite cliffs, Surtsey will be fairly resistant to further erosion and remain standing for thousands of years, like its neighbours in the archipelago.

A series of nine bathymetric maps compiled between 1964 and 2000 on the Surtsey environs reveal that the underwater remnants of the islets Syrtlingur and Jólnir have suffered continuous, rapid submarine erosion, caused probably by both wave action and bottom currents. Since the data indicate that the rate of erosion is gradually decreasing, these submarine hills should survive for a long time. The data on submarine erosion at Surtsey is a unique scientific resource, as no comparable measurements are available on any volcanic islands elsewhere.

### **Ecological laboratory**

From its inception, the Surtsey island has been strictly protected, with human presence limited to a few scientists for a short period each summer. Rarely have the flora and fauna of an entire, intact and undisturbed island been recorded as they naturally accumulated, which means that Surtsey provides an exceptional opportunity to further our understanding of colonisation, extinction and the carrying capacity of an isolated, single-island ecosystem. Added to this are the prospects of studying species numbers declining as the island erodes and shrinks. The opportunity for direct testing of classic island biogeography concepts is invaluable and certainly seldom on offer. Already, monitoring individual plants during their colonisation of Surtsey has provided an extensive record of natural invasion processes and species dynamics; in future, this demographic data provides a foundation for further investigations, e.g. exploring secondary dispersal from the species that are now established.

Surtsey has already allowed the scientific world to gain insights into the interaction of species and how it affects ecological succession. The establishment of a gull colony in the mid-1980s, with its resulting nutrient input, altered primary succession in dramatic ways. The evolving sharp contrast between the lush, species-rich plant community inside the colony and the sparse vegetation outside has been better documented at Surtsey than at any other primary succession site in the world.

The pristine volcanic island of Surtsey is no mere scenario or model, but an actual, natural laboratory and a globally outstanding example of ongoing geological, geomorphological and ecological processes in the development of land-



The ongoing marine erosion of the coastline is a major natural force shaping Surtsey. (Photo: Torgny Nordin 2003).

forms and biological communities. Therefore, it is hereby proposed that this scientifically unique site be recognised through the award of World Heritage Site status.

### 3.c Comparative analysis

Most recorded events of submarine eruptions have resulted in very short-lived islands, which frequently submerged quickly and became submarine volcanic shoals, although these could periodically re-emerge through repeated eruptions. When a more substantial island has resulted, as in Krakatau in Indonesia, human activity has soon affected development of the plant and animal communities, spoiling their usefulness for detailed, long-term research into the establishment and evolution of ecosystems in pristine island systems. Surtsey is therefore unique in both its persistence and its undisturbed environment, allowing a detailed record of geological development to be compiled along with biological surveys of ecosystem development.

Since its settlement around AD 870, 14 submarine volcanic eruptions are known to have occurred off Iceland, prior to the Surtsey eruption.

Ten of these eruptions took place along the submarine Reykjanes Ridge, an extension of the Reykjanes peninsula in Southwest Iceland (Fig 2.3). Three of the eruptions there, i.e. in 1211, 1422 and 1783, are known to have built up islands. No eyewitness descriptions remain, other than for the island first observed in May 1783, which was called Nýey (“New Island”). Reaching a diameter of at least 0.9 km, Nýey was apparently composed of tephra formed in a hydromagmatic eruption exactly like the first phase of the Surtsey eruption. Since no lava flowed, Nýey disappeared by autumn of the same year. It is considered likely that the Vestmannaeyjar area had a submarine eruption in 1896. Four submarine eruptions have been documented off the north coast of Iceland (Sigurður Þórarinnsson 1965).

Currently, thirteen sites are inscribed on the World Heritage List on account of their volcanic character, in addition to nine sites in which evidence of volcanism (usually extinct) is present (Fig. 3.1). Some of the listed sites, including Heard and McDonal Islands in the Southern Ocean, the Galapagos Islands in the Pacific Ocean, Aeolian Islands in the Mediterranean, Pitons Management Area on Saint Lucia in the Eastern Caribbean, and Hawaii Volcanoes





The succession of plants on the sterile surface of Surtsey has been closely monitored from the very beginning. (Photo: Torgny Nordin 2002).

National Park in the Pacific Ocean, are volcanic islands. However, with the exception of Krakatau, which lies within the World Heritage Site of Ujung Kulon National Park, none of these islands have appeared in recent historical times.

On 27 August 1883, the island of Krakatau in the Sunda Straits of Indonesia exploded with enormous force, so that all previous life is generally believed to have been extinguished, leaving a clean slate or *tabula rasa*. Just as in the case of Surtsey, the surviving islands were reshaped by the action of sea, wind and rain and were progressively re-colonised by plants and animals. The volcanology of Krakatau is well known, not least through pioneering work by the Dutch mining engineer R. D. M. Verbeekm, who undertook a series of investigations on the islands six weeks after the eruption. However, as there were no on-site witnesses of the Krakatau eruption, its basic features were only gradually clarified. Three years after the event, the first botanist arrived on Krakatau and collected 30 species of vascular plants that were already growing there. Within ten years, the islands were clothed with low-growing vegetation and today are covered with tropical rain forest, whose tallest trees are over 35 m high. This location is near the equator, in humid tropics with a mean annual temperature of 26.4° C, while Surtsey is in the



Lichens and mosses were early colonisers of the Surtseyjan lava. (Photo: Hervé Jezequel 2005).

cold-temperate North Atlantic. Furthermore, the reservoir of potential colonists in Java and Sumatra was much greater than in Iceland, which is itself still being colonised after the most recent Pleistocene glaciation (Thornton 1996).

Going farther back in time to 1831, the year that Darwin sailed from England, a submarine eruption in the Mediterranean Sea created a new island south of Sicily. In fact, the volcano there was surfacing for the fourth time since first being noticed during the Punic Wars (ca. 250 BC). As the first to go ashore, the British named the new site Graham Island, but not long afterwards the

Italians landed and named it Ferdinanda. The French then named it Giulia, while the Spanish also showed an interest in claiming the new land. Fortunately, any further diplomatic wrangling was averted when the fragile island disappeared a year later through storm erosion. Graham Shoal is now a dormant submarine volcano lying about 10 m below sea level.

In 1927, a new submarine volcano raised itself above sea level within the Krakatau caldera. Named Anak, the resulting island grew quickly, due to repeated eruptions, and today stands over 300 m above sea level, with regular annual eruptions that produce mostly basaltic lava and scoria. Anak is not only of similar size, it has numerous other similarities as well to the island of Surtsey. However, significant differences exist respecting levels of investigation and the type of protection. While the geological, geomorphological and ecological development of Surtsey has been documented systematically and with great regularity, the formation and growth, erosion, biological colonisation and further aspects of Anak have been documented much more sporadically. In addition, while Surtsey has been effectively and totally isolated from casual visitors, tourism and development, Anak has experienced a steady stream of tourists, and local fishermen have set up camps there. Thus, unlike Surtsey, Anak is by no means a pristine laboratory for studying biological colonisation (Sturla Friðriksson and Borgþór Magnússon 1992; Thornton 1996).

In 1957 a volcanic eruption in shallow water began off the west tip of Fayal, an island in the Azores. Quite soon after the new island of Capelinhos appeared, it joined with the main island, and remained active until 1958. The volcanic process was very similar to that of Surtsey, but the geological formation and development as well as the biological colonisation of Capelinhos were poorly documented. Moreover, its biological isolation was broken as soon as it united with the larger island of Fayal.

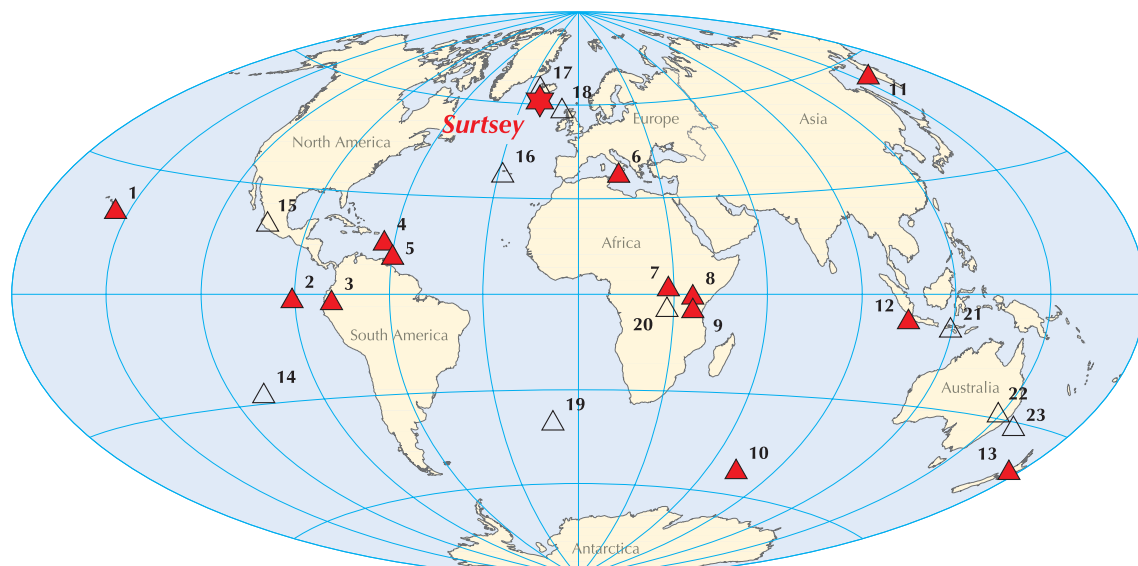
Comparing Surtsey with the two other recent volcanic islands demonstrates its uniqueness (Table 3.1).

A large number of the Earth's other submarine volcanoes are close to the stage of forming new islands; nevertheless, none of them have yet made the dramatic, permanent entry to the world above sea level that Surtsey managed in 1963. A few examples of ready-to-emerge volcanoes are given below:

- First noted by seafarers in 1851, Metis Shoal in the Tonga Islands of the South Pacific erupted in 1969 and built up a short-lived island. This island reappeared during another eruption in 1995. So far, volcanism has failed to establish a permanent island at Metis Shoal.
- Kavachi in the nearby Solomon Islands is the South Pacific's most active submarine volcano. While some of its eruptions, such as in 1939, have produced short-lived islands, its crater remains submarine to this day.

Name (eruptions)	Location and climate	Current attributes and status
Anak, Krakatau (1930–present day)	Sunda Strait of Indonesia at 6°S; humid tropical climate	Volcanic island (some 2 km <sup>2</sup> ); repeated eruptions with interrupted ecological succession; limited scientific study; marked human influence; open to tourism; fishery camps present
Capelinhos, Fayal, Azores (1957–1958)	North Atlantic at 40°N; humid subtropical climate	Began as a volcanic island (2.4 km <sup>2</sup> ), but joined with a larger island (Fayal) and thereby lost isolation; designated as a national refuge; controlled tourism; no systematic scientific studies
Surtsey, Iceland (1963–1967)	North Atlantic at 63°N; humid subarctic climate	Stable but eroding volcanic island (1.4 km <sup>2</sup> ) in a pristine condition, strictly protected; eruption, erosion and ecological succession thoroughly documented; ongoing, detailed geological and biological research

Table 3.1. Recent volcanic islands and their status.



- |   |  |
|---|--|
| ▲ Sites inscribed because of their volcanic character | △ Sites inscribed for other values than their volcanic character         |
| 1 Hawaii Volcanoes N. P. (USA)                        | 14 Rapa Nui N. P. (Chile)  |
| 2 Galápagos Islands (Ecuador)                         | 15 Agave Landscape and Ancient Industrial Facilities of Tequila (Mexico) |
| 3 Sangay N. P. (Ecuador)                              | 16 Landscape of the Pico Island Vineyard Culture (Portugal)              |
| 4 Morne Trois Pitons N. P. (Dominica)                 | 17 Pingvellir N. P. (Iceland)  |
| 5 Pitons Management Area (Saint Lucia)                | 18 St Kilda (United Kingdom)   |
| 6 Isole Eolie (Aeolian Islands) (Italy)               | 19 Gough and Inaccessible Islands (United Kingdom)                       |
| 7 Virunga N. P. (Democratic Republic of the Congo)    | 20 Kahuzi-Biega N. P. (Democratic Rep. of the Congo)                     |
| 8 Mount Kenya N. P./Natural Forest (Kenya)            | 21 Komodo N. P. (Indonesia)  |
| 9 Kilimanjaro N. P. (United Republic of Tanzania)     | 22 Central Eastern Rainforest Reserves (Australia)                       |
| 10 Heard and McDonald Islands (Australia)             | 23 Lord Howe Island Group (Australia)                                    |
| 11 Volcanoes of Kamchatka (Russian Federation)        |  |
| 12 Ujung Kulon N. P. (Indonesia)                      |  |
| 13 Tongariro N. P. (New Zealand)                      | ★ Evaluation Site Surtsey  |

Base map geometric data: ESRI

Fig. 3.1. A world map relating the nominated area of Surtsey nature reserve (red star) to World Heritage Sites, which are primarily inscribed for their volcanic character (filled red triangles) and sites where volcanism is present, although not the main reason for inscription (black, open triangles).

- Near Grenada in the Caribbean, the Kick'em Jenny submarine volcano, whose last eruption in 2000 brought it yet closer to the surface, still remains about 150 m below sea level.
- Loihi seamount in the Hawaiian Islands, considered by many as the next potential for an island in this volcanic chain, has a long way left before reaching the surface, as the crater still lies 1000 m below sea level.
- Ruby submarine volcano near Saipan in the Marianas Islands has now risen to within 230 m of the sea surface. First detected in 1966, Ruby erupted again in 1995.
- About thirteen active submarine volcanoes in the Izu and Volcano Islands of Japan are at a stage allowing them to form new islands. As an example, Fukutoku-Okanoba submarine volcano erupted last in 1992 and is now only 15 m below sea level.

maintained on primary succession (Kristín Svavarsdóttir and Walker 2006). Others include volcanic surfaces on Krakatau, Indonesia (since 1908); glacial moraines at Glacier Bay, Alaska, USA (since 1923); and sand dunes in Cooloolo, Australia (since 1962) (see Walker and del Moral 2003). On Surtsey, it is expected that stable communities will take several hundred to several thousand years to develop, based on similar histories of nearby islands in the Vestmannaeyjar archipelago.

The record of ecological research on Surtsey, which spans 40 years of regular measurements, is exceptional for many reasons, among which are the pristine condition maintained on the island, the data obtained by monitoring individual plant species, and the thorough surveys conducted on the island in its entirety (Sturla Friðriksson 2005).

In addition to the research already carried out at Surtsey, there are many potential, non-destructive measurements which would continue to further our understanding of primary succession.

In terms of ecology, Surtsey is one of few study areas, worldwide, where long-term data has been

These include, to name but a few: studies of nutrient dynamics (particularly of nitrogen and phosphorus); the links between nutrient fluxes and changes in both vascular plant and underground invertebrate populations; carbon accumulation by species and location; the roles of herbivores and mycorrhizae in succession and the ramifications of escaping from mainland herbivores; the microhabitats which plants colonise and how these are partitioned among functional groups; and the role of spatial aggregation of plants during succession (Kristín Svavarsdóttir and Walker 2006).

### 3.d Authenticity/Integrity

The boundaries of the nominated area, Surtsey, have been drawn such that they secure the integrity of the site, show the interdependent and interrelated elements of the Surtsey volcano and its magmatic series, and ensure that all relevant biophysical and ecological processes are included and protected. The protective designation of the Surtsey Nature Reserve will guarantee that the integrity of the nominated area is preserved from any negative future effects through human activities (Chapter 7b).

The nominated area represents the entire, intact Surtsey volcano, including Surtsey island; the submarine remnants of the temporary tephra islands, Syrtlingur and Jólnir; remnants of the submarine volcanic ridge, Surtla; and submarine lava fields. The two primary geological units formed during the Surtsey eruption, tephra and lava, which have since undergone abrasion or modification through geomorphological and geological processes, are both represented within the nominated area. The same applies to the three secondary geological units formed subsequent to the eruption: palagonite tuff, eolian and talus sediments, and coastal sediments. Thus the nominated area includes every element necessary to demonstrate the area's outstanding universal value, while its size is considered adequate to ensure the wholeness, integrity and intactness of factors in the site's natural heritage.

Surtsey island and its littoral and sub-littoral zones contain ecological features and biophysical processes that have come into being and developed since the eruption without any



Sturla Friðriksson and Ian Thornton, two well known island ecologists, on Surtsey in 1990. Ian Thornton (1926 – 2002) was a professor of zoology at La Trobe University, Melbourne, Australia and a leader of ecological research on Krakatau for a number of years. (Photo: Borgþór Magnússon).

discernible human influence. From its very beginnings, the island has been strictly protected and closed to the general public, with access restricted to only a few scientists and nature journalists per year. All species recorded in the field have colonised the island and its littoral zones on their own initiative, so that the island's flora and fauna contains no established exotic or alien species. Species establishment and community development and succession have also proceeded entirely without human interference. There are only three man-made structures on the island, and other physical human disturbance is negligible. It may therefore be justifiably claimed that Surtsey island and its littoral zones represent a pristine natural phenomenon.

The seas immediately surrounding the Surtsey volcano have in the past been utilised for small-scale fishing. However, fishery activity with towed bottom gear has been banned since January 2006 within the nominated area that encompasses the complete magmatic series.

As described in previous chapters, the Surtsey volcano is subject to ongoing geomorphological, geological and ecological processes that are constantly shaping, eroding and remoulding the young island. These natural processes and their documentation in a pristine setting provide support and fulfil major criteria for the nomination.



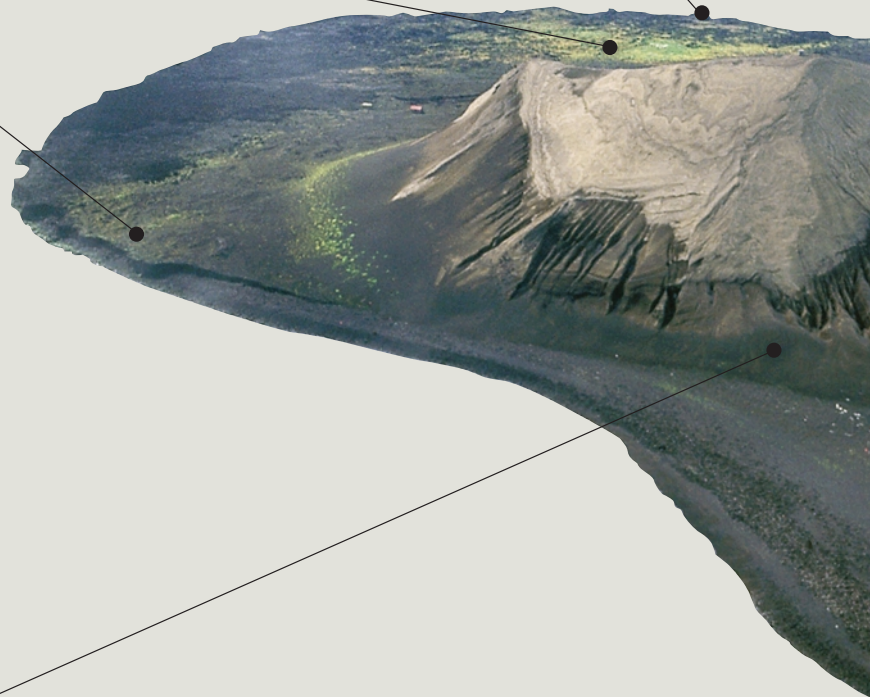
Dense and diverse vegetation has developed within the seagull colony on the lava plain. (Photo: María Ingimarsdóttir 2005).



The surf is constantly abrading the lava, creating high sea-cliffs. (Photo: Borgþór Magnússon 2005).



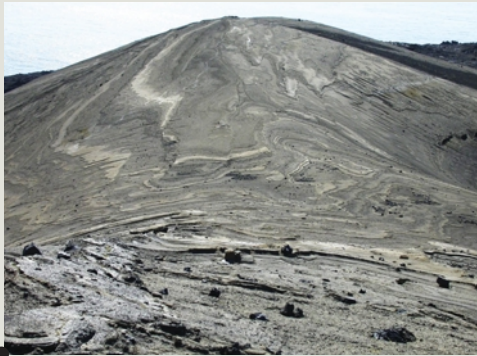
Seagulls have been an important catalyst of ecosystem development on Surtsey through the transport of nutrients from the sea onto the island. (Photo: Borgþór Magnússon 2005).



Running water has eroded the cones and formed small gullies. (Photo: Erling Ólafsson 2004).



Boulders on the shore of the northern spit derived from break-up of lava at the other side of the island (Photo: Borgþór Magnússon 2002).



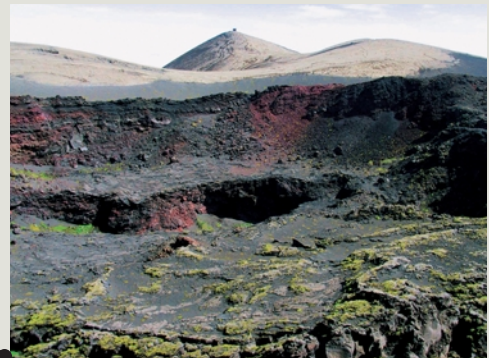
The tephra cones have been converted into dense palagonite tuff, which is very resistant to further erosion. (Photo: María Ingimarsdóttir 2005).



Steaming fissures reflect the existence of a hydrothermal system underneath. (Photo: Árni Bragason 2004).



(Photo: Snævarr Guðmundsson 2005).



Surtungur, the main lava crater of the volcano, with the palagonite tuff hills in the background. (Photo: Sigmar Metúsalemsson 2001).



Driftwood on the northern shore provides a shelter for plants and animals. (Photo: Borgþór Magnússon 2005).



The lowland northern spit seen from the pass between the two tuff cones. (Photo: Erling Ólafsson 2004).



Surtsey has offered a rare opportunity to record the flora and fauna of an entire, intact and undisturbed island. (Photo: María Ingimarsdóttir 2005).

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# 4

## State of conservation and factors affecting the property

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### 4.a Present state of conservation

The conservation status of Surtsey island is excellent and the marks of humans minimal. The infrastructure is limited to one field hut, a helicopter pad and an abandoned lighthouse, which will be removed in the summer of 2007.

Surtsey itself, as well as the island's flora and fauna, are still fast developing, as ever-increasing numbers of species colonise the island and existing species expand their ranges. As tourism and the exploitation or disturbance of wildlife and vegetation is strictly prohibited, trampling, pillaging or disruption are not conservation issues. No population trends have been observed on the island that can be attributed to local anthropogenic factors.

The conservation status of the marine part of the nominated area is less well known, but is considered good as fisheries have been of a small scale (see below).

### 4.b Factors affecting the property

The emerging terrestrial and marine ecosystems of Surtsey are vulnerable to disturbance, natural as well as anthropogenic. The main natural disturbances are the ongoing marine erosion of the coastline and wind erosion of the land surface, both of which should be considered part of the island's past and future natural history. Anthropogenic disturbance is regarded as minimal.



Sandstorm at Austurbunki in 1985. Such sandstorms were common before the tephra cones converted into palagonite tuff. (Photo: Sveinn P. Jakobsson).

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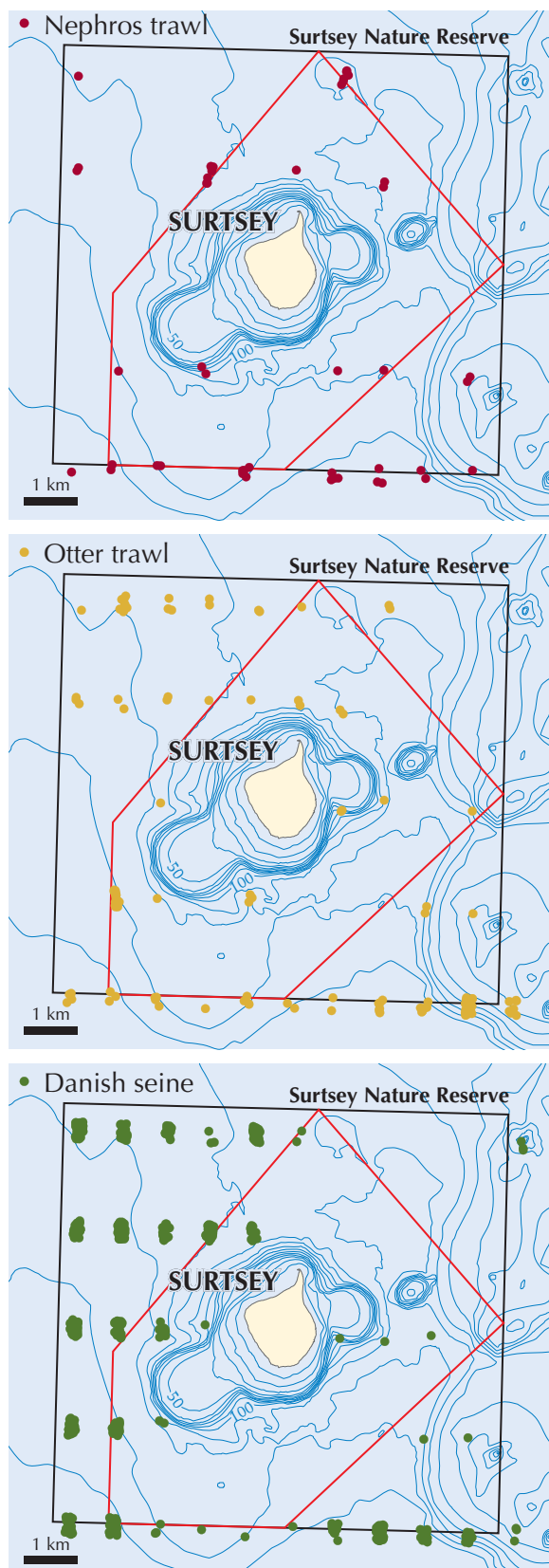


Fig. 4.1. Fishing activities using towed bottom gear in the waters off Surtsey during the period 1987 to 2005. The points refer to the tow starting positions. (Source: Marine Research Institute).

### (i) Development pressures

Surtsey has never been inhabited. Construction work is prohibited unless exempted by the Environment and Food Agency. The current Declaration of Surtsey Nature Reserve (Chapter 7b) also prohibits mining within the ocean section of the reserve and restricts fishing with towed bottom gear to the outer buffer zone.

Historically, i.e. between 1965 and 2005, there has been some fishing inside the nature reserve. Most of this activity has been concentrated to the west of Surtsey (Fig 4.1). In the period from 1987 to 2005, 25 species were registered in catches in the area of Surtsey Nature Reserve (Fig 4.2; Appendix 9c). The area's total yearly catches of demersal species amount to about 45 tonnes. The largest catches are of ling *Molva molva*; an average of 12 tonnes per year. Other important species include the cod *Gadus morhua*, haddock *Melanogrammus aeglefinus*, saithe *Pollachius virens* and witch *Glyptocephalus cynoglossus*, all with more than five tonnes average catch per year.

Three types of towed bottom gear have been used: the Nephrops trawl, otter trawl and Danish seine. The Danish seine is the most common gear; the average number of sets per year within the nominated area has been about 20 and the yearly catch some 17 tonnes, mainly witch, dab *Limanda limanda* and plaice *Pleuronectes*



Long-line fishing boat southeast of Surtsey. Tusk, ling and cod are the primary species taken by long-line in the area. (Photo: Karl Gunnarsson 1996).

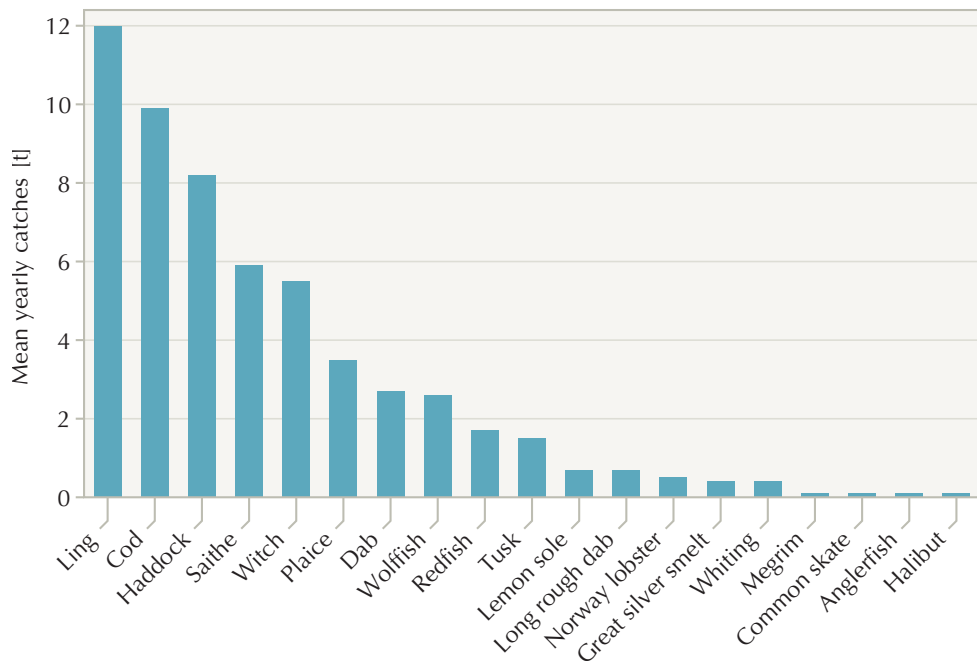


Fig. 4.2. Mean yearly catches of fish and Norway lobster in the Surtsey Nature Reserve. The figures are averages for the period 1987 to 2005. (Source: Marine Research Institute).

*platessa*. On average, otter trawl boats have caught some 14 tonnes annually within the Surtsey Nature Reserve, mainly haddock but also saithe and cod. Boats with the Nephrops trawl have taken some 0.8 tonnes, of which 0.5 tonnes is Norway lobster *Nephros norvegicus* (Fig 4.2). Fishing with towed bottom gear has been prohibited within the nominated area since January 2006.

On average, gill nets bring in about 8 tonnes per year within the reserve, primarily the ling and cod. Other gear types used are the longline and handline. Fishing with gill nets, lines and traps will be allowed within the nominated area.

Currently there are three visible man-made facilities on Surtsey island. In 1967, the Surtsey Research Society erected the research field hut "Pálsbær" close to the shore on the northern part of the island. That site was gradually destroyed by ocean erosion. A new hut was erected on the eastern part of the island in 1985 and has been maintained by the Society ever since. Also, a helicopter pad was built close to the hut in 1993. In the late 1980s the Icelandic Maritime Administration decided to erect a lighthouse on top of the eastern tuff crater, Austurbunki. Although the lighthouse became inoperative after a few years, the concrete foundation is still in place. Responding to a request by the Icelandic World Heritage Committee, the Ministry of Transport

and Communications has agreed to decommission and remove the remnants of the lighthouse and its foundation from Surtsey. The Icelandic Maritime Administration will oversee this removal, which will occur no later than spring or summer of 2007.

Apart from normal maintenance of the field hut Pálsbær and the helicopter pad, there are no plans for additional infrastructures on Surtsey.

## (ii) Environmental pressures

Viewed in a broader context, there are no discernible environmental pressures on Surtsey apart from those operating on a larger regional or global scale, such as climate change and atmospheric pollution.

No heavy industry or other activities that handle or produce environmentally hazardous materials are located within a 50-km radius from Surtsey. The dumping of waste at sea, including damaged nets, fishing gear, containers or household garbage, is an issue of concern, as significant quantities of litter wash up on Surtsey's shores every year. This problem is common along the entire Icelandic coastline.

Large vessels sail along the southern coast of Iceland south of Surtsey. These pose a potential pollution hazard, both now and in the future.



The Pálsbær field hut is the only house on Surtsey. The foundation of an abandoned lighthouse is also visible on the top of the hill in the background. The foundation will be dismantled and removed from the island. (Photo: Árni Bragason 2004).

The major shipping lane from Europe runs close to the mainland coast, making landfall off Dyrhólaey headland, then lying between the mainland and the Vestmannaeyjar archipelago towards the Reykjanes peninsula. This is the most common route, at least among those familiar with the conditions near land. Another, less frequented shipping lane lies farther south, with landfall at Vestmannaeyjar. This lane then leads south of Surtsey, at a distance of four to ten nautical miles from the island, before heading for the Reykjanes peninsula (Fig 4.3).

Between 1999 and 2001, the Icelandic Maritime Administration proposed to delimit a zone that would stretch from Dyrhólaey to the south of Vestmannaeyjar, then from there south and west of Fuglasker to Garðskagi, following the limits of the twelve-mile jurisdiction. This zone was to be defined as an “Area to be Avoided”, conforming to the rules of the International Maritime Organisation and having the purpose of providing protection by directing oil tanker traffic beyond the area, away from Iceland's coast and the spawning grounds on Selvogsbanki fishing banks. The proposal encountered protests from stakeholders and was not implemented at that time.



Significant quantities of litter wash up on Surtsey's shores every year. (Photo: Hervé Jezequel 2005).

The climate of Iceland is expected to warm by 2 to 3° C during this century and precipitation to increase by 10–20% (ACIA 2004). If this proves to be the case, the climate of Iceland will resemble that of the Faroe Islands and northern Scotland by the end of this century. Warming of this magnitude would undoubtedly facilitate vegetation and soil development on Surtsey.

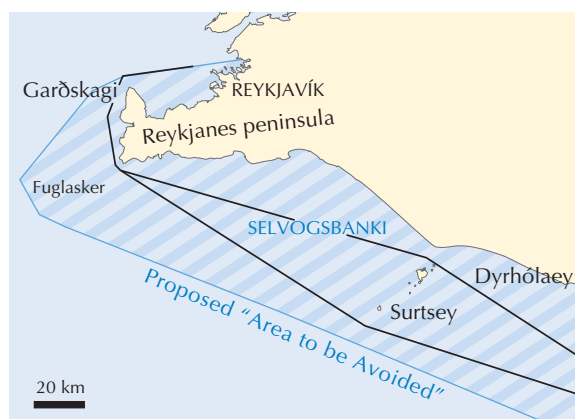


Fig. 4.3. Main shipping routes off the southern coast of Iceland. Hatched area represents a proposed “Area to be Avoided”. (Source: Icelandic Maritime Administration).

### (iii) Natural disasters and preparing for risk

Surtsey is the product of a spectacular natural event, a submarine eruption that lasted for four years, from 1963 to 1967. The new island belongs to the Vestmannaeyjar archipelago, which constitutes a separate volcanic system at the southern end of the Eastern Volcanic Zone of Iceland (Fig. 2.4). As noted above, this is a young volcanic system with its epicentre around Heimaey. There are indications that the Vestmannaeyjar system is approaching a new volcanic episode with the reported submarine eruption in 1896, followed by the Surtsey eruption and the Eldfell eruption 1973. Therefore, a volcanic eruption within the system within the next few decades can not be excluded.

With 1–2 earthquakes per year on the average in the magnitude range 2.0–3.5 on the Richter scale, Surtsey is seismically active. During the time period 1991–2005, 5–6 earthquakes have been recorded annually. No destructive earthquakes are known to have occurred within the Vestmannaeyjar system in historical time.

### (iv) Visitor/tourism pressures

No tourists are allowed on Surtsey and human presence and influence has been minimal. Since the early 1980s visits to the island have been confined to 6–10 scientists, nature journalists and photographers for one to two weeks each year. Any garbage is brought back to the mainland at the end of each visit. The Vestmannaeyjar Rescue Team travels to Surtsey approximately once a year to look after the field hut, Pálsbær, and a maintenance crew of craftsmen from the Surtsey Research Society visits the island every third or fourth year to repair the hut as needed.

Hence, Surtsey is mainly seen by tourists from the air or sea from sight-seeing flights, tourist boats or cruisers.

Strictly speaking, any visit to Surtsey causes some disruption to the island, including trampling and the possible introduction of species. Researchers and visitors alike can also unwittingly affect how the community of breeding birds develops. Fulmars and gulls are particularly vulnerable in this respect. There have been occasional reports of illegal entry onto the island by people on pleasure boats. However, the current rigorous control of human access,



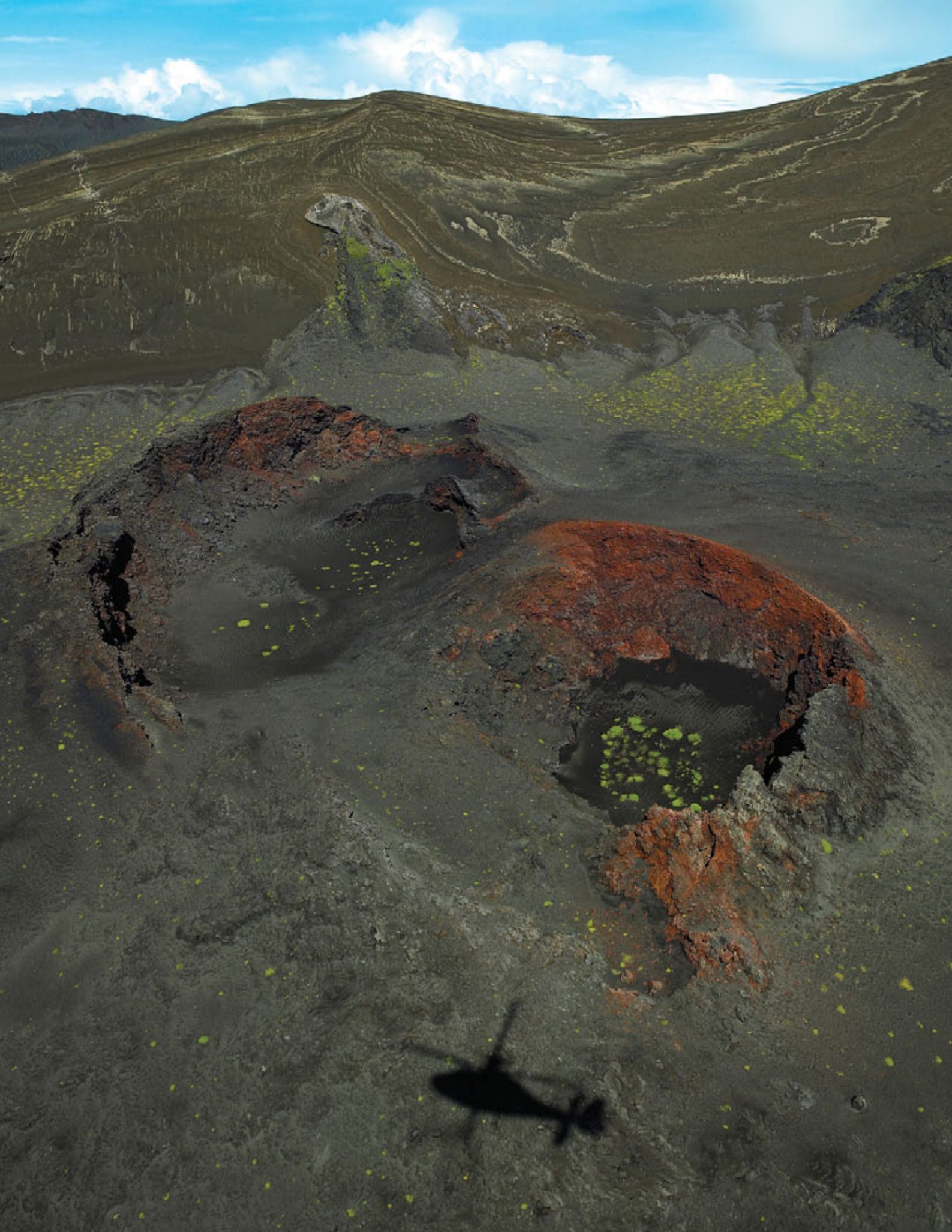
Several foreign cruise liners sail by Surtsey every summer, allowing thousands of tourists to observe the island from a distance. (Photo: Sigmar Metúsalemsson 2001).

together with the strict protection regime on the island, ensures that human disturbance is minimal.

In spring 2005, a local parliamentary representative formally asked the Minister for the Environment whether there were plans to allow tourist access to Surtsey. On that occasion the Minister declared that there are no plans to change the management regime or access restrictions on Surtsey.

### (v) Number of inhabitants within the property and the buffer zone

There are no inhabitants inside the nominated area of Surtsey and never have been. The only inhabited island among the 18 islands in the Vestmannaeyjar archipelago is Heimaey, 18 km NE from Surtsey, with some 4,200 residents.



Aerial view of the crater Surtur.  
(Photo: Ragnar Th. Sigurðsson 2005).

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### 5.a Ownership

The nominated area is owned by the Icelandic State. The nominated area is protected as a nature reserve according to the Act on Nature Conservation, No. 44/1999, which applies in Iceland and throughout its territorial waters and exclusive economic zone. The municipality of Vestmannaeyjar serves as the physical planning authority for the area.

### 5.b Protective designation

In 1965 the Nature Conservation Council (now Environment and Food Agency of Iceland) recommended to the Minister of Education that Surtsey be declared a nature reserve. The intention was to protect and ensure its colonisation and the succession of life under minimal human influence, and to protect its fragile surface and landscape (Appendix 1a). The protection criteria were slightly revised in 1974, in accordance with a new Act on Nature Conservation that entered into force in 1971 (Appendix 1b). However, the island has *de facto* been managed under IUCN category 1a since 1965, i.e. as a *Strict Nature Reserve: protected area managed mainly for science*.

In January 2006, the boundaries of Surtsey Nature Reserve were expanded to their current outlines (see Chapter 1) and a new and revised Declaration of Surtsey Nature Reserve was issued (Chapter 7b). This was done in order to ensure the protection of the entire Surtsey volcanic system, both above and below the sea surface, including the transient islets Jólnir and Syrtlingur as well as the submarine ridge Surtla.

The Surtsey Nature Reserve is protected by the Act on nature conservation, No. 44/1999, as subsequently amended. The objectives of the Act are defined in Article 1 as follows:

*“The purpose of this Act is to direct the interaction of man with his environment so that it harms neither the biosphere nor the geosphere,*

*nor pollutes the air, sea or water.... The Act is intended to ensure, to the extent possible, that Icelandic nature can develop according to its own laws and to ensure the conservation of its exceptional or historical aspects... The Act shall facilitate the nation's access to and knowledge of Icelandic nature and cultural heritage and encourage the conservation and utilisation of resources based on sustainable development.”*

Other articles of the Act on Nature Conservation which relate to the protection of Surtsey include the following:

- Article 37, which confers special protection *inter alia* to volcanic craters, pseudocraters (rootless vents) and lava fields
- Article 38, which calls for the authorisation of projects by the Environment and Food Agency of Iceland if there is any risk of damage to protected sites of natural interest
- Article 53, which defines nature reserves as “areas which it is important to preserve because of their special landscape or biosphere.”

Regulation No. 148/1998, based on Act No. 79/1997 on fishing within the Icelandic Fisheries Jurisdiction, further restricts fisheries within the Surtsey Nature Reserve by banning towed bottom gear within the eastern part of the reserve.



Surtsey with Geirfuglasker in the foreground. (Photo: Erling Ólafsson 2005).

## 5.c Means of implementing protective measures

The Act on Nature Conservation (No. 44/1999, in Article 37) grants special protection to certain landscape and habitat types, including volcanic craters, pseudocraters (rootless vents) and lava fields. No one is allowed to alter, damage or destroy features that fall under Article 37 without prior consent by the Environment and Food Agency of Iceland and the relevant municipality.

The Declaration of Surtsey Nature Reserve states that violating the protective regulations will result in a fine or imprisonment of up to two years. This provision is based on Article 76 in the Act on Nature Conservation (No. 44/1999), which reads as follows: *“Anyone who violates the provisions of this Act or rules adopted by virtue thereof shall be subject to fines or imprisonment of up to two years. Fines shall be paid to the State Treasury. Cases under this Article shall be prosecuted in accordance with provisions for criminal proceedings, cf. the Criminal Proceedings Act, No. 19/1991.”*

The Environment and Food Agency of Iceland is responsible for implementing the protective measures of Surtsey. A visitors' centre with a permanent warden will be established in Vestmannaeyjar town. The management plan under preparation (Appendix 10) will further specify implementation measures for the Surtsey Nature Reserve.

## 5.d Existing plans related to the municipality and region in which the proposed property is located

A *Nature Conservation Strategy, 2004–2008*, was confirmed by the Icelandic Parliament in 2004. This Strategy, to be renewed every five years, is meant to ensure the protection of a representative sample of Iceland's biological and geological diversity, as well as sites of outstanding natural beauty or of cultural or historic significance. A large part of the Vestmannaeyjar archipelago is one of the areas scheduled for protection in the

Nature Conservation Strategy, 2004–2008. The reasons given include the characteristic and spectacular landscape of the Vestmannaeyjar archipelago and their scientific and educational value in terms of geomorphology; however, their rich birdlife is the foremost reason. For example, Vestmannaeyjar is home to Europe's largest breeding colony of the leach's petrel *Oceanodroma leucorhoa* and to the only breeding colony of the Manx shearwater *Puffinus puffinus* in Iceland. Over one-third of the Icelandic puffin *Fratercula arctica* population breeds in Vestmannaeyjar, and these islands are of general international importance regarding areas with seabird populations of over one million pairs (Ólafur Einarsson et al. 2002).

The entire country is subject to planning requirements, according to Iceland's Planning and Building Act, No. 73/1997, No. 135/1997 and No. 58/1999. A municipal plan is a development plan for a specific municipality, detailing the local authority's policy regarding land use, transportation and service systems, environmental matters, and the development of settlement in the municipality over a period of at least 12 years. The *Municipal plan for Vestmannaeyjar archipelago, 2002–2014*, was confirmed by the local government and ratified by the Minister for the Environment on 4 March 2005.

The *Municipal plan for Vestmannaeyjar archipelago* confirms the government's intention to protect the entire archipelago as a managed nature reserve, while allowing sustainable use of its natural resources.

## 5.e Property management plan or other management system

A Draft Management Plan for Surtsey Nature Reserve, 2007–2017, is attached (Appendix 10). The primary aim of this plan is to ensure the continued protection and management of the reserve.

The Surtsey Research Society, besides coordinating and enhancing scientific work on Surtsey, has functioned since 1965 as an official guardian of the island. In the 1974 Declaration of Surtsey Nature Reserve (Appendix 1b), the Nature Conservation Council (now the Environ-



“A room with a view.” (Photo from within Pálsbær: Borgþór Magnússon 2005).

ment and Food Agency of Iceland) bestowed supervision of the island upon the Society.

Supervision includes *inter alia* maintenance of the field hut, keeping track of scientific missions and other visits to the island, informing people about the conservation regime on the island and reviewing applications for permission to go ashore on the island. More or less all scientists and researchers that have formally applied for permission to conduct scientific research on Surtsey have been granted such permission. Natural history journalists and photographers have also, with few exceptions, been granted permission to visit Surtsey, while most other applications have been turned down.

The Society's Rules on Pálsbær remind guests of the hut not being a mere shelter for the shipwrecked, but also a centre for important scientific research. Therefore, it is highly important that every rule be strictly adhered to, such as avoiding bringing any soil traces, organisms or pollutants to the island, or leaving any organic waste on the island.

The current Declaration of Surtsey Nature Reserve (2006) states that the Environment and Food Agency of Iceland has overall responsibility for the reserve. The Surtsey Research Society coordinates and promotes scientific research on Surtsey. The Icelandic Institute of Natural History



Scientists boarding a helicopter from the Icelandic Coast Guard after a successful expedition to Surtsey in 2004. (Photo: Erling Ólafsson).

is engaged in scientific research and responsible for monitoring activities, carried out in cooperation with the Marine Research Institute and the Surtsey Research Society (Chapter 7b). The roles of these four key players will be further specified in the above mentioned management plan.

## 5.f Sources and levels of finance

The Surtsey Research Society receives a small yearly allocation (some 7,000 EUR) through the State Treasury budget, which is used to publish the periodical *Surtsey Research*, update the Society's homepage ([www.surtsey.is](http://www.surtsey.is)) and maintain the field hut Pálsbær. All work conducted by the Society's members is voluntary.

The Icelandic Institute of Natural History and the Marine Research Institute provide significant in-kind support by financing scientific research and the monitoring of Surtsey. Previously this also applied to the Agricultural Research Institute, which participated actively in field work on Surtsey until the 1990s. The Icelandic Coast Guard also provides significant in-kind support by transporting scientists and their crews to the island.



## 5.g Sources of expertise and training in conservation and management techniques

The Environment and Food Agency of Iceland has staff trained in conservation management, including wardens in the national parks and nature reserves managed by the Agency.

The Icelandic Institute of Natural History and the Marine Research Institute, which are now the two main institutes engaged in research on Surtsey, have experts in the fields of geology, geomorphology, volcanology, geography, petrography, oceanography, zoology, botany and ecology. These experts are active in basic nature research, environmental monitoring and resource management at national, Nordic, European and international levels and have the necessary expertise to underpin the long-term protection and management of the area.

On a local level, the Vestmannaeyjar Research Centre and the South Iceland Nature Research Centre in Vestmannaeyjar town employ several geologists and biologists who are mainly engaged in local research and monitoring.

## 5.h Visitor facilities and statistics

The town of Vestmannaeyjar can be reached by air or by ferry from the mainland. Accommodation is available at hotels, hostels and campsites. There are several visitor attractions on the island, including a folk museum, art museum, photography museum and aquarium. The latest star attraction is the *Pompei of the North* project – excavation of houses that were buried under tephra during the volcanic eruption on Heimaey in 1973, which was the first eruption in a densely populated area in Iceland's history and a major economic disaster. The objective of this project is to give visitors the opportunity to see what actually happened.

Surtsey is protected as a strict nature reserve and closed to the general public. Although tourists are not allowed to visit Surtsey, they can view it from the air and from the sea. Aerial sightseeing tours are available from Reykjavik and the town

of Vestmannaeyjar and provide an excellent view of the island. Boat trips are also available from the Vestmannaeyjar harbour. The duration of a round trip by boat is about 4–5 hours.

Scientists have accessed the island by boat and rubber rafts, small planes and helicopters. A small airstrip was in operation until 1976, but is no longer usable or visible. Since then, the only air transportation has been by helicopter. The field hut Pálsbær has all the necessary facilities and can easily accommodate 8–10 people.

## 5.i Policies and programmes related to the presentation and promotion of the property

The Surtsey Research Society has been instrumental in providing information and promoting Surtsey from the very beginning.

The Surtsey Research Society maintains a website ([www.surtsey.is](http://www.surtsey.is)) with information on the Society, the origin and development of Surtsey and its ecosystem, scientific work on Surtsey, and the protection of the island as a nature reserve. The Society publishes *Surtsey Research* (formerly the *Surtsey Research Progress Report*), which is now available on the website. The series includes eleven issues, with the first one published in 1965 and the twelfth issue being prepared for publication. The reports to date contain 201 papers by scientists who have worked or are working on Surtsey. These reports are the most reliable and comprehensive information available on the island's development and on scientific findings concerning the island. The full Surtseyan bibliography is extensive: over 900 papers and books have been published on the island's development. The full bibliography can be accessed at the Surtsey website.

Other sources of information about Surtsey and its environs include the following: the Environment and Food Agency of Iceland ([www.ust.is](http://www.ust.is)), Icelandic Institute of Natural History ([www.ni.is](http://www.ni.is)), Vestmannaeyjar Research Centre ([www.setur.is](http://www.setur.is)), South Iceland Nature Research Centre ([www.nattsud.is](http://www.nattsud.is)), Vestmannaeyjar municipality ([www.vestmannaeyjar.is](http://www.vestmannaeyjar.is)) and Heimaslóð – Vestmannaeyjar ([www.heimaslod.is](http://www.heimaslod.is)).



Scientists are among the few allowed to visit Surtsey; here is an entomologist at work in the seemingly lifeless desert. (Photo: Erling Ólafsson 2005).

The Surtsey Research Society has coordinated several national and international conferences and meetings focusing on various aspects of Surtsey. The *Surtsey Biology Conference* was held in Reykjavik in April 1965 with 38 participants: 22 from Iceland and 16 from abroad. A Biological Outline for research on and around Surtsey was presented, “evaluated, scrutinised and accepted”, as stated in the minutes from the conference. A second conference, the *Surtsey Research Conference*, was held in Reykjavik in June 1967, with a total of 76 participants: 36 from Iceland and 40 from abroad. The thirty- and forty-year anniversaries of the Surtsey eruption have been commemorated by open seminars in Reykjavik. In the autumn of 2005, a workshop, *Surtsey and its management*, was held in the town of Vestmannaeyjar. At this workshop, scientists outlined the geological and ecological development of the island and participants discussed its significance and future.

## 5.j Staffing levels

All areas in Iceland which are protected according to the Act on nature conservation are overseen by the Nature Conservation and Outdoor Recreation Division at the Environment and Food Agency of Iceland. The Division employs staff trained in the conservation and management of protected areas. During the summer months, several wardens are employed at protected areas. Every warden must attend a special training course in environmental law, conservation and outdoor recreation, and the duties of the warden are to aid and guide visitors and to interpret the locality's natural and cultural phenomena. A permanent warden will be stationed at the planned Surtsey visitors centre in the town of Vestmannaeyjar.



The small crater Bjallan.  
(Photo: Hervé Jezequel 2005).

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# 6

## Monitoring

### 6.a Key indicators for measuring the state of conservation

As explained in Chapter 4, there are few discernible environmental pressures at work on Surtsey, and its conservation status is considered excellent. Under the current regime of strict protection, the Surtsey island essentially protects itself. Hence there has been no direct monitoring of its conservation status in the past. However, several natural parameters have been regularly monitored since the island's conception (Table 6.1). Various long-term aspects of vegetation will in particular provide important baselines and indicators concerning the response of a young island system to disturbances such as climatic change.

The management plan under preparation (Appendix 10) will further address the issue of indicators to measure the natural state of Surtsey and its conservation status.

There are no plans to use the island for tourism in the near future. Outside pressures include litter, which the sea washes up on the beach every year and may be potentially

hazardous for birds. Shipping accidents and oil spills that would affect Surtsey are considered unlikely. However, an emergency procedure and response plan for potential oil spills will be developed as part of the management plan under preparation (Appendix 10).

### 6.b Administrative arrangements for monitoring property

The following agencies are responsible for the monitoring referenced in Table 6.1:

Icelandic Institute of Natural History  
Hlemmur 3–5  
IS-105 Reykjavík  
Iceland  
ni@ni.is

Marine Research Institute  
Skúlagata 4  
IS-121 Reykjavík  
Iceland  
hafro@hafro.is

Parameter monitored	Periodicity	Location of record
Influx and colonisation of new species of vascular plants, mosses, lichens, insects and birds	Annually	Icelandic Institute of Natural History
Vegetation development within permanent plots	Bi-annually	Icelandic Institute of Natural History
Ecosystem parameters (plant biomass, soil respiration, soil chemistry, etc.) within permanent plots	Every few years	Icelandic Institute of Natural History
Thorough bird surveys	Every ten years	Icelandic Institute of Natural History
Erosion (size and outline) of the island, as shown by aerial photographs	Bi-annually	Icelandic Institute of Natural History
Development and extent of the palagonite tuff	Bi-annually	Icelandic Institute of Natural History
Development of the hydrothermal area through temperature measurements	Bi-annually	Icelandic Institute of Natural History
Survey of coastal and submarine biota	Every ten years	Marine Research Institute
Offshore wave measurements at a depth of 130 m	Continuously since 1988	Icelandic Maritime Administration
Record of climate (wind speed, temperature, precipitation) at Stórhöfði, some 19 km northeast of Surtsey	Continuously	The Icelandic Meteorological Office

Table 6.1. Natural parameters monitored on and around Surtsey.



A team of ecologists sampling vegetation in one of the permanent study plots on Surtsey. (Photo: Erling Ólafsson 2003).

The Icelandic Meteorological Office  
Bústaðavegur 9  
IS-150 Reykjavík  
Iceland  
skrifstofa@vedur.is

ey, both because it would jeopardise its value as a laboratory of nature and also because transport to and from the island, whether by boat or air, is unsafe. The seminar recommended that a *Surtsey Centre* be established in the town, with the mission of informing people about Surtsey and its development.

## 6.c Results of previous reporting exercises

Although several hundred scientific papers have been published on Surtsey's natural history and development, this report represents the first comprehensive assessment of the island's natural state and conservation.

In September 2005, an open seminar was held in the town of Vestmannaeyjar on the subject *Surtsey and its management*. On this occasion, scientists and representatives of the local community discussed the island's future management, including whether to allow controlled tourism on the island. The seminar concluded, however, that it would be unwise to lift the tourist ban on Surts-



Participants at the workshop, Surtsey and its management, in the town of Vestmannaeyjar, September 2005. (Photo: Ómar Garðarsson 2005).

## 7.a Supplementary material

This nomination report is supplemented by the following audiovisual and printed material:

- A videotape with three films by Ósvaldur Knudsen (1965, 1967 and 1973): Birth of an island; Sequel to Surtsey; and Land out of the ocean. Additional filming and editing by Villi Knudsen.
- A Videotape/DVD by Páll Steingrímsson (1993): Surtsey 30-years of age [in German].
- A DVD by Helga Brekkan and Torgny Nordin (2003): The black island.
- A book by Sturla Friðriksson (2005): Surtsey, ecosystems formed. Varði, The Surtsey Research Society, Reykjavík, 112 pages.
- Surtsey Research Progress Reports No. IX (1982), X (1992) and XI (2000). The Surtsey Research Society, Reykjavík.
- A set of slides.

## 7.b Declaration of Surtsey Nature Reserve, 2006

### ADVERTISEMENT

#### Of a nature reserve on Surtsey island

##### Art. 1

###### *Declaration of conservation*

The Minister for the Environment has, in consultation with the Minister of Fisheries and in accord with the proposal of the Environment and Food Agency and the Icelandic Institute of Natural History, as well as with the consent of the municipality of Vestmannaeyjar [the Westman Islands], decided to renew the declared conservation of Surtsey in such manner that the declaration of conservation shall apply to the entire volcano, whether above the surface of the sea or underwater, including the craters of Jólnir, Syrtlingur and Surtla, together with a specified area of ocean around the island. The protected area is conserved as a nature reserve in accord with

Subparagraph 1 of the first paragraph of Art. 53 of the Act on Nature Conservation, No. 44/1999.

##### Art. 2

###### *Objective of conservation*

The objective of declaring Surtsey a protected area is to ensure that development of the island will be in keeping with the principles of nature itself, as provided in Art. 1 of the Act on Nature Conservation. The purpose of conservation is to ensure that colonisation by plants and animals, biotic succession and the shaping of geological formations will be as natural as possible, and that human disruption will be minimised.

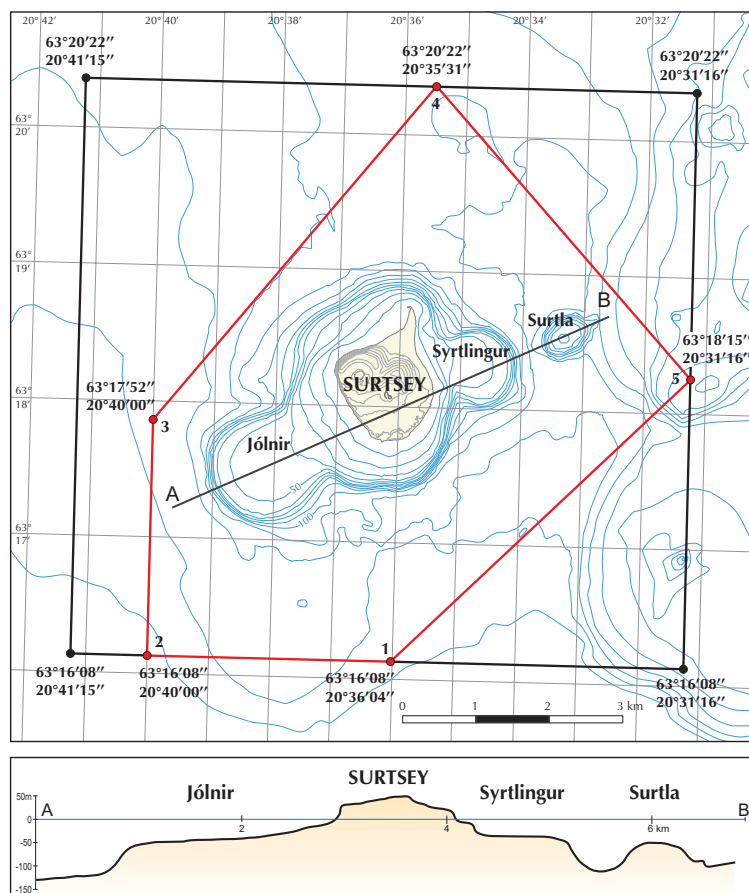
The declaration of conservation is based *inter alia* upon the great value of the area in scientific and nature conservation terms, both for Iceland and internationally; the area has complete and undisturbed natural features which reflect the developmental processes of nature, and which are highly sensitive to disruption.

##### Art. 3

###### *Boundaries of the nature reserve*

The nature reserve includes Surtsey above sea level and down to the sea floor, together with an area of ocean around the island which is demarcated by a line drawn between four corner points; see the accompanying table. The coordinates of the points are designated by the ISNET93 system and by longitude and latitude (degrees, minutes and seconds). The boundaries of the area are shown on the accompanying map.

Table Point	ISNET93		Degrees	
	X coordinate	Y coordinate	Longitude	Latitude
1	415350	315875	20°41'15"	63°16'08"
2	423700	315875	20°41'15"	63°20'22"
3	423700	308020	20°31'16"	63°20'22"
4	415350	308020	20°31'16"	63°16'08"



**Art. 4**

*Supervision of the nature reserve, etc.*

The Environment and Food Agency conducts the supervision of the nature reserve. A six-member advisory committee shall be appointed to advise the Environment and Food Agency on matters of the nature reserve and shall include one representative of the Surtsey Research Society, of the Icelandic Institute of Natural History, of the Marine Research Institute and of the Environment and Food Agency and two representatives of the municipality of the Westman Islands. The representative of the Environment and Food Agency shall be the committee chairperson. This committee shall be appointed to a term of four years.

The Surtsey Research Society coordinates and seeks to further scientific research on Surtsey and inside the nature reserve boundaries. A special agreement shall be concluded in this regard, to be approved by the Minister for the Environment.

The Icelandic Institute of Natural History conducts research and the regular monitoring of natural conditions in the nature reserve, in cooperation with the Marine Research Institute and Surtsey Research Society.

**Art. 5**

*Access to the nature reserve*

It is prohibited to go ashore on Surtsey or to dive by the island except for research purposes and related activities and with the written permission of the Environment and Food Agency.

Vessels are permitted to travel within the reserve around Surtsey.

**Art. 6**

*Conservation of vegetation, animal life and geological formations*

It is prohibited to disturb vegetation, animal life or geological formations or other natural features within the reserve.

It is prohibited to transport to the island live animals, plants, seeds or plant parts, or other organisms. Transporting minerals and soil to the island is also prohibited.

**Art. 7**

*Land use and construction*

Construction, disturbing the earth, extracting materials and otherwise altering the land or the sea floor within the nature reserve are prohibited,

except by permission of the Environment and Food Agency and the Westman Islands municipal council, upon their receiving the opinion of the Surtsey Research Society. It is permissible to maintain such structures as the Surtsey Research Society's hut (Pálsbær) and the helicopter landing facilities on the island, as hitherto and as is described in the conservation plan.

It is prohibited to bury waste or leave it on the island or within the boundaries of the nature reserve.

#### **Art. 8**

##### *Fishing and use of firearms*

Fishing with fishing gear which is dragged along the sea floor, for instance bottom trawls, Danish seines or dredges, is prohibited in the nature reserve within the area bounded by the following points: 1) 20°36'04" W and 63°16'08" N  
2) 20°40'00" W and 63°16'08" N  
3) 20°40'00" W and 63°17'52" N  
4) 20°35'31" W and 63°20'22" N  
5) 20°31'16" W and 63°18'15" N.

The use of firearms is prohibited within the nature reserve, both on land and at sea.

#### **Art. 9**

##### *Exemptions*

Upon receiving the opinion of the Environment and Food Agency and the municipality of the Westman Islands, the Minister for the Environment may authorise departures from these rules in particular circumstances, and may provide in more detail for the conservation of the area.

#### **Art. 10**

##### *Penalties*

Violation of the declared protection entails fines or imprisonment for up to two years.

#### **Art. 11**

##### *Entry into force*

This declaration of protection shall take effect immediately. At the same time, the advertised Declaration No. 122/1974, of Surtsey as a reserve, expires.

*Ministry for the Environment, 27 January 2006*

*Sigríður Anna Þórðardóttir*

*Magnús Jóhannesson*

[Translation: Lingua / Norðan Jökuls ehf.]

## 7.c Form and date of recent records

The Surtsey island and volcano has attracted the interest of a large number of scientists. Thus detailed information exists on its natural history in numerous scientific publications, many of which are cited in this nomination report or presented with it as supplementary material (a full bibliography is also provided at: [www.surtsey.is](http://www.surtsey.is)). Sturla Friðriksson's recent book from 2005 *Surtsey, ecosystems formed* provides a general overview of the island's nature. A geological map, prepared by Sveinn P. Jakobsson in January 2006 (attached), provides the most recent reference to the geology of Surtsey.

## 7.d Agencies holding important records

Icelandic Institute of Natural History  
Hlemmur 3–5  
IS-105 Reykjavík

Surtsey Research Society  
Hlemmur 3–5  
IS-105 Reykjavík

Marine Research Institute  
Skúlagata 4  
IS-121 Reykjavík

University of Iceland  
Suðurgata 1  
IS-101 Reykjavík

National Land Survey of Iceland  
Stillholti 16–18  
IS-300 Akranes

Loftmyndir  
Laugavegi 13  
IS-101 Reykjavík

Icelandic Maritime Administration  
Vesturvör 2  
IS-200 Kópavogur



The Icelandic Meteorological Office  
Bústaðavegi 9  
IS-150 Reykjavík

National and University Library of Iceland  
Arngrímögötu 3  
IS-107 Reykjavík

Environment and Food Agency of Iceland  
Suðurlandsbraut 24  
IS-108 Reykjavík

Agricultural University of Iceland  
Keldnaholt  
IS-112 Reykjavík

Ministry for the Environment  
Skuggasund 1  
IS-150 Reykjavík

Ministry of Education, Science and Culture  
Sölvhólgötu 4  
IS-150 Reykjavík

## 7.e Bibliography

A full bibliography of scientific publications relevant to Surtsey (1963–2006) is provided on a separate CD, attached to this nomination report, and can be found as well at: [www.surtsey.is](http://www.surtsey.is)

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The western sea-cliffs of Surtsey.  
(Photo: Ragnar Th. Sigurðsson 2005).

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## Signature on behalf of the State Party

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The Icelandic Government decided in December 2005 to nominate Surtsey for inclusion in the World Heritage List as a natural heritage site.

The nomination is based on extensive scientific research and close observation of the creation and natural history of Surtsey from 1963 to the present time. It is supported by local people, scientists and relevant authorities.

*Signed on behalf of the State Party*

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Place and date

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Þorgerður Katrín Gunnarsdóttir  
Minister of Education, Science and Culture

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Jónína Bjartmarz  
Minister for the Environment

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Lyme grass *Leymus arenarius* against red walls of the crater Surtur. (Photo: Snorri Baldursson 2006).

# Appendices

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## Appendix 1a. Declaration of Surtsey as a Nature Reserve

The protection of Surtsey as a nature reserve entered into force through an announcement in the *Official Gazette* on 19 May 1965; below is the code of conduct for the reserve.

### The Nature Conservation Council of Iceland

#### Makes known:

According to the authority provided in Sub-article C of Article One, and the third paragraph of Art. 12 of Act No. 48/1956, on Nature Conservation, the Nature Conservation Council has determined to declare Surtsey a reserve.

Declaring Surtsey a reserve is done above all for the purpose of ensuring that the colonisation and succession of life on the island in coming years will be as natural as possible and will undergo minimal disturbances caused by man, as this is extremely important from a scientific standpoint. Therefore, it is hereby forbidden to go ashore at Surtsey except with a permit from the Surtsey Research Committee, which, since this committee supervises all scientific investigations at Surtsey, the Nature Conservation Council has decided to entrust with supervision of the island.

It is prohibited to disrupt anything on the island or to transport animals, plants, seeds, or plant parts there, and it is likewise prohibited to leave behind waste of any kind.

Those who might be authorised to go ashore on the island are obliged to adhere in every respect to rules established by the Nature Conservation Council, in consultation with the Surtsey Research Committee, on treatment of the island.

Those violating provisions of this decision will be held responsible in accordance with Art. 33 of Act No. 48/1956 on Nature Conservation.

## Appendix 1 b. Declaration on the nature reserve at Surtsey

The protection of Surtsey was revised through a new Act on Nature Conservation (No. 47/1971), which entered into force in 1971 (and has since been superseded by Act No. 55/1999). Also, the Ministry of Education, Science and Culture announced this revised protection in the *Official Gazette (Law and Ministerial Gazette B, No. 122/1974)*, as appearing below.

### Declaration on the reserve at Surtsey

In accordance with the authorisation in Art. 24 of Act No. 47/1971, on nature conservation, [the Environment and Food Agency] has decided for its part to declare Surtsey a reserve.

The following rules shall apply to this reserve:

2. It is forbidden to go ashore on the island except by permission of the Surtsey Research Society, which supervises scientific research there and which [the Environment and Food Agency] has entrusted with supervising the island.
3. It is prohibited to disrupt anything on the island. Permission from [the Environment and Food Agency] is required to build any lasting man-made structure.
4. It is prohibited to bring any live animals, plants, seeds or plant parts to the island.
5. It is prohibited to leave behind any kind of waste on the island or in its proximity.
6. Shooting is prohibited within 2 km of the island.

Sanctions for violating these rules shall be in accordance with provisions of the Act on Nature Conservation.

Previous provisions on protecting the island are hereby revoked.

The Ministry has approved the declaration of the reserve, and this declaration is hereby published with reference to Art. 32 and 33 of Act No. 47/1971, on nature conservation, and reserve status shall take effect upon publication of this advertisement in the *Law and Ministerial Gazette*.

*In the Ministry of Education, Science and Culture, 3 April 1974*

Magnús T. Ólafsson

Knútur Hallsson

## Appendix 2. Vascular plants on Surtsey

### Species found from 1965 to 2005

		Species status in 2005		
		Alive	Viable population	In permanent plots
<b>Pterydophytes</b>				
<i>Cystopteris fragilis</i> (L.) Bernh.	Brittle bladder-fern	X	X	
<i>Equisetum arvense</i> L.	Field horsetail	X		
<i>Polypodium vulgare</i> L.	Common polypody	X		
<b>Monocots</b>				
<b>Grasses</b>				
<i>Agrostis capillaris</i> L.	Common bent	X	X	X
<i>Agrostis stolonifera</i> L.	Creeping bent	X	X	X
<i>Agrostis vinealis</i> Schreber	Velvet bent			
<i>Alopecurus geniculatus</i> L.	Marsh foxtail	X		
<i>Anthoxanthum odoratum</i> L.	Sweet vernal-grass	X		
<i>Deschampsia beringensis</i> Hult.	Bering's tufted hairgrass	X		
<i>Festuca rubra</i> L. ssp. <i>richardsonii</i> (Hook.) Hultén	Arctic fescue	X	X	X
<i>Leymus arenarius</i> (L.) Hochst.	Lyme-grass	X	X	X
<i>Phleum pratense</i> L.	Timothy	X		
<i>Poa annua</i> L.	Annual meadow-grass	X	X	X
<i>Poa glauca</i> Vahl	Glaucous meadow-grass	X		
<i>Poa pratensis</i> L.	Smooth meadow-grass	X	X	X
<i>Puccinellia capillaris</i> (Lilj.) Jansen	Reflexed saltmarsh-grass	X	X	X
<i>Puccinellia coarctata</i> Fern & Weath	Common saltmarsh-grass			
<b>Sedges and rushes</b>				
<i>Carex maritima</i> Gunnerus	Curved sedge	X	X	X
<i>Eleocharis quinqueflora</i> (F. X. Hartmann) O. Schwarz	Few-flowered spike-rush	X		
<i>Juncus alpinoarticulatus</i> Chaix	Alpine rush	X		X
<i>Juncus arcticus</i> Willd. ssp. <i>intermedius</i> Hyl.	Iceland rush	X		
<i>Luzula multiflora</i> (Retz.) Lej.	Heath wood-rush	X		
<i>Luzula spicata</i> (L.) DC.	Spiked wood-rush			
<b>Orchids</b>				
<i>Platanthera hyperborea</i> (L.) Lindley	Northern green orchid			



Lyme-grass *Leymus arenarius*.  
(Photo: Hervé Jezequel 2005).

	Species status in 2005		
	Alive	Viable population	In permanent plots
<b>Dicots</b>			
<b>Forbs</b>			
<i>Alchemilla filicaulis</i> Buser			
<i>Angelica archangelica</i> L.	X		
<i>Arabidopsis petraea</i> (L.)	X	X	X
<i>Argentina anserina</i> (L.) Rydb.	X	X	
<i>Armeria maritima</i> (Miller) Willd.	X	X	X
<i>Atriplex glabriuscula</i> Edmonston	X		
<i>Cakile arctica</i> Pobed	X	X	
<i>Capsella bursa-pastoris</i> (L.) Medikus			
<i>Cerastium fontanum</i> Baumg.	X	X	X
<i>Cochlearia officinalis</i> L.	X	X	X
<i>Epilobium palustre</i> L.			
<i>Euphrasia wettsteinii</i> Gussarova	X	X	X
<i>Galium normanii</i> O. C. Dahl			
<i>Galium verum</i> L.	X		
<i>Honckenya peploides</i> (L.) Ehrh.	X	X	X
<i>Leontodon autumnalis</i> L.	X	X	
<i>Mertensia maritima</i> (L.) S. F. Gray	X	X	X
<i>Montia fontana</i> L.	X		X
<i>Myosotis arvensis</i> (L.) Hill	X		
<i>Oxyria digyna</i> (L.) Hill	X		
<i>Plantago lanceolata</i> L.	X		
<i>Plantago maritima</i> L.	X		
<i>Polygonum aviculare</i> L.			
<i>Ranunculus acris</i> L.	X	X	X
<i>Rumex acetocella</i> L.	X	X	X
<i>Rumex acetosa</i> L.	X	X	X
<i>Rumex longifolius</i> DC. (Danser) Rech. f.	X	X	
<i>Sagina procumbens</i> L.	X	X	X
<i>Silene uniflora</i> Roth	X	X	X
<i>Stellaria media</i> (L.) Vill.	X	X	X
<i>Taraxacum</i> sp.	X	X	
<i>Tripleurospermum maritimum</i> (L.) W. D. J. Koch	X	X	X
<b>Dwarf shrubs</b>			
<i>Empetrum nigrum</i> L.	X	X	X
<i>Salix herbaceae</i> L.	X	X	
<i>Salix lanata</i> L.	X		
<i>Salix phylicifolia</i> L.	X		
Total: 60 species	51	30	25

English names from:

Hörður Kristinsson. A Guide to the Flowering Plants and Ferns of Iceland. Mál og menning, Reykjavík 1998.



Blooming oysterplant *Mertensia maritima* on Surtsey sand. (Photo: Hervé Jezequel 2005).

## Appendix 3. Bryophyte species recorded on Surtsey

	In permanent plots		In permanent plots
<i>Amblystegium serpens</i> (Hedw.) Schimp.		<i>Fissidens adianthoides</i> Hedw.	
<i>Amphidium lapponicum</i> (Hedw.) Schimp.		<i>Funaria hygrometrica</i> Hedw.	
<i>Anomobryum julaceum</i> (P. Gaertn. et al.) Schimp.		<i>Grimmia torquata</i> Hornsch. ex Grev.	
<i>Aongstroemia longipes</i> (Sommerf.) Bruch et Schimp.		<i>Hypnum lindbergii</i> Mitt.	
<i>Atrichum undulatum</i> (Hedw.) P. Beauv.		<i>Isopterygiopsis pulchella</i> (Hedw.) Z. Iwats.	
<i>Aulacomnium palustre</i> (Hedw.) Schwägr.		<i>Jungermannia pumila</i> With.	
<i>Barbula unguiculata</i> Hedw.		<i>Leptobryum pyriforme</i> (Hedw.) Wilson	
<i>Bartramia ithyphylla</i> Brid.		<i>Lophozia excisa</i> (Dicks.) Dumort.	
<i>Brachythecium albicans</i> (Hedw.) Schimp.	X	<i>Marchantia polymorpha</i> L.	
<i>Brachythecium rivulare</i> Schimp.		<i>Mnium hornum</i> Hedw.	
<i>Brachythecium rutabulum</i> (Hedw.) Schimp.		<i>Oncophorus virens</i> (Hedw.) Brid.	
<i>Brachythecium salebrosum</i> (F. Weber et D. Mohr) Schimp.	X	<i>Philonotis arnellii</i> Husn.	
<i>Brachythecium velutinum</i> (Hedw.) Schimp.		<i>Philonotis tomentella</i> Molendo	
<i>Bryoerythrophyllum recurvirostrum</i> (Hedw.) P. C. Chen		<i>Plagiomnium cuspidatum</i> (Hedw.) T. J. Kop.	
<i>Bryum argenteum</i> Hedw.	X	<i>Pogonatum urnigerum</i> (Hedw.) P. Beauv.	
<i>Bryum dichotomum</i> Hedw.	X	<i>Pohlia annotina</i> (Hedw.) Lindb.	
<i>Bryum imbricatum</i> (Schwägr.) Bruch et Schimp.		<i>Pohlia filum</i> (Schimp.) Mårtensson	
<i>Bryum klinggraeffii</i> Schimp.		<i>Pohlia wahlenbergii</i> (F. Weber et D. Mohr) A. L. Andrews	
<i>Bryum pallens</i> Sw.		<i>Polytrichum alpinum</i> Hedw.	
<i>Bryum pallescens</i> Schleich. ex Schwägr.		<i>Polytrichum longisetum</i> Sw. ex Brid.	
<i>Bryum salinum</i> I. Hagen ex Limpr.		<i>Polytrichum piliferum</i> Hedw.	
<i>Cephaloziella divaricata</i> (Sm.) Schiffn.	X	<i>Polytrichum sphaerothecium</i> (Besch.) Müll. Hal.	
<i>Cephaloziella hampeana</i> (Nees) Schiffn.	X	<i>Psilopilum laevigatum</i> (Wahlenb.) Lindb.	
<i>Ceratodon purpureus</i> (Hedw.) Brid.	X	<i>Racomitrium ericoides</i> (Brid.) Brid.	X
<i>Dichodontium pellucidum</i> (Hedw.) Schimp.		<i>Racomitrium fasciculare</i> (Hedw.) Brid.	X
<i>Dicranella crispa</i> (Hedw.) Schimp.		<i>Racomitrium lanuginosum</i> (Hedw.) Brid.	X
<i>Dicranella schreberiana</i> (Hedw.) Dixon		<i>Reboulia hemisphaerica</i> (L.) Raddi	
<i>Dicranella varia</i> (Hedw.) Schimp.		<i>Rhytidiadelphus squarrosus</i> (Hedw.) Warnst.	
<i>Dicranoweisia crispula</i> (Hedw.) Milde		<i>Sanionia uncinata</i> (Hedw.) Loeske	X
<i>Didymodon fallax</i> (Hedw.) R. H. Zander		<i>Scapania scandica</i> (Arnell et H. Buch) Macvicar	
<i>Didymodon icmadophilus</i> (Schimp. ex Müll. Hal.) K. Saito		<i>Schistidium flexipile</i> (Lindb. ex Broth.) G. Roth	X
<i>Didymodon insulanus</i> (De Not.) M. O. Hill		<i>Schistidium frigidum</i> H. H. Blom	
<i>Distichium capillaceum</i> (Hedw.) Bruch et Schimp.		<i>Schistidium maritimum</i> (Turner) Bruch et Schimp.	X
<i>Ditrichum cylindricum</i> (Hedw.) Grout		<i>Schistidium strictum</i> (Turner) Loeske ex Mårtensson	X
<i>Ditrichum heteromallum</i> (Hedw.) E. Britton		<i>Straminergon stramineum</i> (Brid.) Hedenäs	
<i>Drepanocladus aduncus</i> (Hedw.) Warnst.	X	<i>Trichostomum brachydontium</i> Bruch	
<i>Drepanocladus polygamus</i> (Schimp.) Hedenäs		<i>Ulota phyllantha</i> Brid.	X
<i>Encalypta ciliata</i> Hedw.			



The moss *Racomitrium lanuginosum* growing on lava blocks in the shelter of the Surtungur crater. (Photo: Hervé Jezequel 2005).

## Appendix 4. Lichens species recorded in Surtsey

### Fruticose lichens:

*Cladonia chlorophaea* (Flörke ex Sommerf.) Spreng.  
*Cladonia furcata* (Huds.) Schrad.  
*Cladonia islandica* nom. prov.  
*Cladonia macroceras* (Delise) Hav.  
*Cladonia pocillum* (Ach.) Grognot  
*Cladonia rangiformis* Hoffm.  
*Cladonia symphicarpa* (Flörke) Fr.  
*Cladonia* sp.  
*Stereocaulon alpinum* Laurer  
*Stereocaulon arcticum* Lynge  
*Stereocaulon capitellatum* H. Magn.  
*Stereocaulon condensatum* Hoffm. (?)  
*Stereocaulon depressum* (Frey) I. M. Lamb  
*Stereocaulon glareosum* (L. I. Savicz) H. Magn.  
*Stereocaulon rivulorum* H. Magn.  
*Stereocaulon spathuliferum* Vain.  
*Stereocaulon tomentosum* Fr.  
*Stereocaulon vanoyei* Duv.  
*Stereocaulon vesuvianum* Pers.

### Foliose lichens:

*Collema tenax* (Sw.) Ach. em. Degel.  
*Leptogium lichenoides* (L.) Zahlbr.  
*Leptogium* sp.  
*Peltigera canina* (L.) Willd.  
*Peltigera didactyla* (With.) J. R. Laundon  
*Peltigera neckeri* Hepp. ex Müll. Arg.  
*Peltigera rufescens* (Weiss) Humb. (?)  
*Peltigera venosa* (L.) Hoffm.  
*Xanthoria candelaria* (L.) Th. Fr.  
*Xanthoria parietina* (L.) Th. Fr.

### Crustose lichens:

*Acarospora smaragdula* (Wahlenb.) A. Massal.  
*Acarospora* sp.  
*Arthonia gelidae* R.Sant.  
*Arthonia lapidicola* (Taylor) Branth & Rostr.  
*Caloplaca citrina* (Hoffm.) Th. Fr.  
*Caloplaca verruculifera* (Vain.) Zahlbr.  
*Calvitimela armeniaca* (DC.) Hafellner  
*Candelariella coralliza* (Nyl.) H. Magn.  
*Catillaria chalybeia* (Borrer) A. Massal.  
*Gyalidea fritzei* (Stein) Vězda  
*Hymenelia arctica* (Lynge) Lutzoni  
*Lecania subfuscula* (Nyl.) S. Ekman  
*Lecanora poliophaea* (Wahlenb.) Ach.  
*Lecanora salina* H. Magn.  
*Lecidea lapicida* (Ach.) Ach. var. *pantherina* Ach.  
*Lichenomphalia* sp.  
*Micarea* sp.  
*Pertusaria lactea* (L.) Arnold  
*Pilophorus cereolus* (Ach.) Th. Fr. (?)  
*Pilophorus dovrensis* (Nyl.) Tindal, Hertel & Rambold  
*Placopsis gelida* (L.) Linds.  
*Placopsis lambii* Hertel & V. Wirth  
*Porpidia cinereoatra* (Ach.) Hertel & Knoph  
*Porpidia flavicunda* (Ach.) Gowan (?)  
*Porpidia melinodes* (Körb.) Gowan & Ahti  
*Porpidia soledizodes* (Lamy ex Nyl.) J. R. Laundon  
*Porpidia tuberculosa* (Sm.) Hertel & Knoph  
*Protopannaria pezizoides* (Weber) P. M. Jørgensen & S. Ekman  
*Psilolechia clavulifera* (Nyl.) Coppins  
*Psilolechia leprosa* Coppins & Purvis  
*Pyrenidium hyalosporum* Alstrup, D. Hawksw. & R. Sant.  
*Rhizocarpon expallescens* Th. Fr.  
*Rhizocarpon lavatum* (Fr.) Hazsl.  
*Rinodina gennarii* Bagl.  
*Scoliciosporum umbrinum* (Ach.) Arnold  
*Stereocaulon tornense* (H. Magn.) P. James & Purvis (?)  
*Trapelia coarctata* (Sm.) M. Choisy  
*Trapelia involuta* (Taylor) Hertel  
*Verrucaria aethiobola* Wahlenb.  
*Verrucaria aquatilis* Mudd  
*Verrucaria* sp.



The lichen *Stereocaulon alpinum* growing on a bed of *Racomitrium lanuginosum*.  
 (Photo: Erling Ólafsson 2005).

## Appendix 5. Fungi species recorded on Surtsey

Fungi on Surtsey island, including species that were isolated from the soil and grown in culture media in the research laboratory.

*Absidia corymbifera* (Cohn) Sacc. & Trotter  
*Aphanomyces bacillariacearum* Scherff.  
*Arrhenia rustica* (Fr.) Redhead, Lutzoni, Moncalvo & Vilgalys  
*Cadophora fastigiata* Lagerb. & Melin  
*Cadophora malorum* (Kidd & Beaumont) W. Gams  
*Ceriosporopsis halima* Linder  
*Cladosporium macrocarpum* Preuss  
*Dinemasporium marinum* Sv. Nilsson  
*Entoloma sericeum* (Bull.) Quéf.  
*Epicoccum nigrum* Link  
*Kirschsteiniothelia maritima* (Linder) D. Hawksw.  
*Lamprospora crouanii* (Cooke) Seaver  
*Lecanicillium psalliotae* (Treschow) Zare & W. Gams  
*Lulworthia medusa* (Ellis & Everh.) Cribb & J. W. Cribb  
*Mucor hiemalis* Wehmer  
*Octospora axillaris* (Nees) M.M. Moser  
*Onygena corvina* Alb. & Schwein.  
*Penicillium citrinum* Thom  
*Penicillium palitans* Westling  
*Peziza varia* (Hedw.) Fr.  
*Phoma putaminum* Speng.  
*Trichoderma harzianum* Rifai  
*Trichoderma viride* Pers.: Fr.  
*Ulocladium botrytis* Preuss



An agaric of the genus *Panaeolus* growing in a patch of sea sandwort. (Photo: Erling Ólafsson 2005).

## Appendix 6. Bird species seen on or around Surtsey

Red-throated diver	<i>Gavia stellata</i>	Swallow	<i>Hirundo rustica</i>
Great northern diver	<i>Gavia immer</i>	Meadow pipit*	<i>Anthus pratensis</i>
Northern fulmar*	<i>Fulmarus glacialis</i>	Rock pipit	<i>Anthus petrosus</i>
Manx shearwater	<i>Puffinus puffinus</i>	White wagtail*	<i>Motacilla alba</i>
Storm petrel	<i>Hydrobates pelagicus</i>	European robin	<i>Erithacus rubecula</i>
Leach's petrel	<i>Oceanodroma leucorhoa</i>	Redstart	<i>Phoenicurus phoenicurus</i>
Gannet	<i>Sula bassana</i>	Wheatear	<i>Oenanthe oenanthe</i>
Great cormorant	<i>Phalacrocorax carbo</i>	Ring ouzel	<i>Turdus torquatus</i>
European shag	<i>Phalacrocorax aristotelis</i>	Fieldfare	<i>Turdus pilaris</i>
Squacco heron	<i>Ardeola ralloides</i>	Song thrush	<i>Turdus philomelos</i>
Grey heron	<i>Ardea cinerea</i>	European blackbird	<i>Turdus merula</i>
Whooper swan	<i>Cygnus cygnus</i>	European redwing	<i>Turdus iliacus</i>
Pink-footed goose	<i>Anser brachyrhynchus</i>	Garden warbler	<i>Sylvia borin</i>
Greylag goose*	<i>Anser anser</i>	Chiffchaff	<i>Phylloscopus collybita</i>
Barnacle goose	<i>Branta leucopsis</i>	Willow warbler	<i>Phylloscopus trochilus</i>
Brent goose	<i>Branta bernicla</i>	Jackdaw	<i>Corvus monedula</i>
European widgeon	<i>Anas penelope</i>	Raven (*)	<i>Corvus corax</i>
European teal	<i>Anas crecca</i>	Starling	<i>Sturnus vulgaris</i>
Mallard	<i>Anas platyrhynchos</i>	Chaffinch	<i>Fringilla coelebs</i>
Tufted duck	<i>Aythya fuligula</i>	Brambling	<i>Fringilla montifringilla</i>
Common eider	<i>Somateria mollissima</i>	Redpoll	<i>Carduelis flammea</i>
King eider	<i>Somateria spectabilis</i>	Crossbill	<i>Loxia curvirostra</i>
Harlequin duck	<i>Histrionicus histrionicus</i>	Lapland bunting	<i>Calcarius lapponicus</i>
Long-tailed duck	<i>Clangula hyemalis</i>	Snow bunting*	<i>Plectrophenax nivalis</i>
Common scoter	<i>Melanitta nigra</i>	Northern oriole	<i>Icterus galbula</i>
Red-breasted merganser	<i>Mergus serrator</i>		
Merlin	<i>Falco columbarius</i>		
Gyrfalcon	<i>Falco rusticolus</i>		
Corncrake	<i>Crex crex</i>		
Eurasian oystercatcher	<i>Haematopus ostralegus</i>		
Ringed plover	<i>Charadrius hiaticula</i>		
Golden plover	<i>Pluvialis apricaria</i>		
Knot	<i>Calidris canutus</i>		
Sanderling	<i>Calidris alba</i>		
Purple sandpiper	<i>Calidris maritima</i>		
Dunlin	<i>Calidris alpina</i>		
Common snipe	<i>Gallinago gallinago</i>		
Whimbrel	<i>Numenius phaeopus</i>		
Redshank	<i>Tringa totanus</i>		
Turnstone	<i>Arenaria interpres</i>		
Red-necked phalarope	<i>Phalaropus lobatus</i>		
Grey phalarope	<i>Phalaropus fulicarius</i>		
Arctic skua	<i>Stercorarius parasiticus</i>		
Great skua	<i>Stercorarius skua</i>		
Little gull	<i>Larus minutus</i>		
Black-headed gull	<i>Larus ridibundus</i>		
Common gull	<i>Larus canus</i>		
Lesser black-backed gull*	<i>Larus fuscus</i>		
Herring gull*	<i>Larus argentatus</i>		
Iceland gull	<i>Larus glaucoides</i>		
Glaucous gull*	<i>Larus hyperboreus</i>		
Great black-backed gull*	<i>Larus marinus</i>		
Kittiwake*	<i>Rissa tridactyla</i>		
Arctic tern*	<i>Sterna paradisaea</i>		
Common guillemot	<i>Uria aalge</i>		
Brünnich's guillemot	<i>Uria lomvia</i>		
Razorbill	<i>Alca torda</i>		
Black guillemot*	<i>Cepphus grylle</i>		
Little auk	<i>Alle alle</i>		
Common puffin*	<i>Fratrercula arctica</i>		
Turtle dove	<i>Streptopelia turtur</i>		
Long-eared owl	<i>Asio otus</i>		
Short-eared owl	<i>Asio flammeus</i>		
Skylark	<i>Alauda arvensis</i>		

\* = Have bred on Surtsey

(\*) = Have built nests but never laid eggs

Newly hatched fulmar chick *Fulmarus glacialis* on Surtsey. (Photo: Borgþór Magnússon 2005).





## Appendix 7. Terrestrial invertebrates recorded on Surtsey

**ARTHROPODA** Joint-legged animals**INSECTA****Collembola** Springtails**Hypogastruridae**

- Ceratophysella denticulata* (Bagnall, 1941)  
*Ceratophysella succinea* (Gisin, 1949)  
*Hypogastrura assimilis* (Krausbauer, 1898)  
*Hypogastrura purpureascens* (Lubbock, 1967)

**Neanuridae**

- Anurida granaria* (Nicolet, 1847)  
*Friesea mirabilis* (Tullberg, 1871)

**Onychiuridae**

- Mesaphorura krausbaueri* Börner, 1901  
*Mesaphorura macrochaeta* Rusek, 1976  
*Protaphorura armata* (Tullberg, 1869)  
*Thalassaphorura duplopunctata* (Strenzke, 1954)

**Isotomidae**

- Archisotoma besselsi* (Packard, 1877)  
*Desoria violacea* (Tullberg, 1876)  
*Folsomia brevicauda* Agrell, 1939  
*Folsomia fimetaria* (Linnaeus, 1758)  
*Folsomia quadrioculata* (Tullberg, 1871)  
*Isotoma anglicana* Lubbock, 1862  
*Isotoma maritima* (Tullberg, 1871)  
*Isotomiella minor* (Schaeffer, 1896)  
*Parisotoma notabilis* (Schaeffer, 1896)  
*Proisotoma minuta* (Tullberg, 1871)  
*Pseudisotoma sensibilis* (Tullberg, 1876)  
*Vertagopus arboreus* (Linnaeus, 1758)

**Sminthuridae**

- Sminthuridae indet. sp.

**Neelidae**

- Neelides minutus* (Folsom, 1901)

**Protura** Proturans**Protentomidae**

- Protentomon thienemanni* Strenzke, 1942

**Mallophaga** Lice**Menoponidae**

- Eidmanniella pustulosa* (Nitzsch, 1866)

**Hemiptera** True bugs**Saldidae**

- Salda littoralis* (Linnaeus, 1758)

**Corixidae**

- Arctocoris carinata* (Sahlberg, 1819)

**Drepanociphidae**

- Euceraphis punctipennis* (Zetterstedt, 1828)

**Aphididae**

- Acyrtociphon auctum* (Walker, 1849)  
*Brachycaudus helichrysi* (Kaltenbach, 1843)  
Aphididae indet. spp.

**Orthezidae**

- Arctorthezia cataphracta* (Olafsen, 1772)

**Thysanoptera** Thrips**Thripidae**

- Apterothrips secticornis* (Trybom, 1896)  
*Aptinothrips rufus* (Gmelin, 1788)  
*Taenipthrips atratus* (Haliday, 1836)

**Neuroptera** Lacewings**Hemerobiidae**

- Wesmaelius nervosus* (Fabricius, 1793)

**Trichoptera** Caddis flies**Limnephilidae**

- Limnephilus affinis* Curtis, 1834  
*Limnephilus elegans* Curtis, 1834  
*Limnephilus fenestratus* (Zetterstedt, 1840)  
*Limnephilus griseus* (Linnaeus, 1758)

**Lepidoptera** Butterflies and moths**Plutellidae**

- Plutella xylostella* (Linnaeus, 1758)  
*Rhigognostis senilella* (Zetterstedt, 1839)

**Gelechiidae**

- Bryotropha similis* (Stainton, 1854)

**Tortricidae**

- Eana osseana* (Scopoli, 1763)

**Pyralidae**

- Matilella fusca* (Haworth, 1811)  
*Crambus pascuella* (Linnaeus, 1758)  
*Nomophila noctuella* (Denis & Schiffermüller, 1775)

**Nymphalidae**

- Vanessa atalanta* (Linnaeus, 1758)  
*Vanessa cardui* (Linnaeus, 1758)

**Geometridae**

- Epirrhoe alternata* (Müller, 1764)  
*Xanthorhoe decoloraria* (Esper, 1806)  
*Xanthorhoe designata* (Hufnagel, 1767)

**Noctuidae**

- Agrotis ipsilon* (Hufnagel, 1766)  
*Autographa gamma* (Linnaeus, 1758)  
*Cerapteryx graminis* (Linnaeus, 1758)  
*Chortodes stigmatica* (Eversmann, 1855)  
*Diarsia mendica* (Fabricius, 1775)  
*Euxoa ochrogaster* (Guenée, 1852)  
*Noctua pronuba* (Linnaeus, 1758)  
*Peridroma saucia* (Hübner, 1808)  
*Phlogophora meticulosa* (Linnaeus, 1758)

**Coleoptera** Beetles**Carabidae**

- Amara quenseli* (Schönherr, 1806)  
*Bembidion bipunctatum* (Linnaeus, 1761)  
*Nebria rufescens* (Ström, 1768)  
*Notiophilus biguttatus* (Fabricius, 1779)  
*Patrobus septentrionis* (Dejean, 1828)  
*Trichocellus cognatus* (Gyllenhal, 1827)

**Dytiscidae**

- Agabus bipustulatus* (Linnaeus, 1767)

**Staphylinidae**

- Amischa analis* (Gravenhorst, 1802)  
*Atheta amicula* (Stephens, 1832)  
*Atheta atramentaria* (Gyllenhal, 1810)  
*Atheta excellens* (Kraatz, 1856)  
*Atheta fungi* (Gravenhorst, 1806)  
*Atheta graminicola* (Gravenhorst, 1806)  
*Atheta vestita* (Gravenhorst, 1806)  
*Omalium excavatum* Stephens, 1834  
*Oxyopoda islandica* Kraatz, 1857  
*Parocysa rubicunda* (Erichson, 1837)

**Lathridiidae**

- Lathridius minutus* (Linnaeus, 1767)

- Coccinellidae**  
*Coccinella undecimpunctata* Linnaeus, 1758
- Curculionidae**  
*Barynotus squamosus* Germar, 1824  
*Ceutorhynchus insularis* Dieckmann, 1971  
*Otiorhynchus arcticus* (Fabricius, 1780)
- Hymenoptera** Hymenopterans
- Ichneumonidae**  
*Aclastus gracilis* (Thomson, 1884)  
*Atractodes ambiguus* Ruthe, 1859  
*Campoletis* sp.  
*Diadegma boreale* Horstmann, 1980  
*Enizemum ornatum* (Gravenhorst, 1829)  
*Nepiera collector* (Thunberg, 1822)  
*Ophion nigricans* Ruthe, 1859  
*Pimpla arctica* Zetterstedt, 1838  
*Pimpla sodalis* Ruthe, 1859  
*Stilpnus tenebricosus* (Gravenhorst, 1829)  
*Sussaba pulchella* (Holmgren, 1858)
- Braconidae**  
*Alysia manducator* (Panzer, 1799)  
*Chorebus cf. cytherea* (Nixon, 1837)  
*Chorebus* sp.  
*Dacnusa* sp.  
*Meteorus rubens* (Nees, 1811)
- Aphidiidae**  
*Monoctonus caricis* (Haliday, 1833)  
Aphidiidae indet. spp.
- Cynipidae**  
*Alloxysta* sp.
- Eucoilidae**  
*Trybliographa* sp.
- Pteromalidae**  
*Cyrtogaster vulgaris* Walker, 1833  
*Eupteromalus fucicola* (Walker, 1835)  
Pteromalidae indet. spp.
- Diapriidae**  
*Polypeza ciliata* (Thomson, 1859)
- Scelionidae**  
*Trimorus* sp.
- Platygastridae**  
*Platygaster splendidulus* Ruthe, 1859
- Megaspilidae**  
*Dendrocerus bifoveatus* (Kieffer, 1907)
- Diptera** True flies
- Tipulidae**  
*Prionocera turcica* (Fabricius, 1794)  
*Tipula marmorata* Meigen, 1818  
*Tipula rufina* Meigen, 1818
- Limoniidae**  
*Limonia autumnalis* (Staeger, 1840)  
*Erioptera hybrida* (Meigen, 1804)
- Anisopodidae**  
*Sylvicola fenestralis* (Scopoli, 1763)
- Trichoceridae**  
*Trichocera maculipennis* Meigen, 1818
- Bibionidae**  
*Bibio nigriventris* Haliday, 1833  
*Dilophus femoratus* Meigen, 1804
- Scatopsidae**  
*Scatopse notata* (Linnaeus, 1758)
- Sciaridae**  
*Bradysia cf. nitidicollis* (Meigen, 1818)  
*Lycoriella conspicua* (Winnertz, 1867)  
Sciaridae indet. spp.
- Mycetophilidae**  
*Brevicornu* sp.  
*Exechia frigida* (Boheman, 1865)  
*Exechia nigra* (Edwards, 1925)  
*Exechia micans* Lastovka & Matile, 1974
- Chironomidae**  
*Chironomus* spp.  
*Cricotopus* sp.  
*Diamesa bertrami* Edwards, 1935  
*Diamesa bohemani* Goetghebuer, 1932  
*Diamesa incallida* (Walker, 1856)  
*Diamesa zernii* Edwards, 1933  
*Eukiefferiella minor* (Edwards, 1929)  
*Halocladus variabilis* (Staeger, 1839)  
*Metricnemus eurynotus* (Holmgren, 1883)  
*Micropsectra atrofasciata* Kieffer, 1911  
*Micropsectra lindrothi* Goetghebuer, 1931  
*Paracladopelma laminata* (Kieffer, 1921)  
*Procladius islandicus* Goetghebuer, 1931  
*Psectrocladius limbatellus* (Holmgren, 1869)  
*Smitthia* sp.  
*Tanytarsus gracilentus* (Holmgren, 1883)  
*Telmatogeton japonicus* Tokunaga, 1933  
*Oliverida tricornis* (Oliver, 1976)
- Ceratopogonidae**  
Ceratopogonidae indet. sp.
- Simuliidae**  
*Simulium aureum* (Fries, 1824)  
*Simulium vittatum* Zetterstedt, 1838
- Empididae**  
*Clinocera stagnalis* (Haliday, 1833)
- Dolichopodidae**  
*Dolichopus plumipes* (Scopoli, 1763)  
*Hydrophorus viridis* (Meigen, 1824)  
*Syntomon pallipes* (Fabricius, 1794)
- Lonchopteridae**  
*Lonchoptera furcata* (Fallén, 1823)
- Syrphidae**  
*Eupeodes corollae* (Fabricius, 1794)  
*Eupeodes lundbecki* (Soot-Ryen, 1946)  
*Eupeodes punctifer* (Frey, 1934)  
*Helophilus pendulus* (Linnaeus, 1758)  
*Melangyna lasiophthalma* (Zetterstedt, 1843)  
*Melanostoma mellinum* (Linnaeus, 1758)  
*Parasyrphus tarsatus* (Zetterstedt, 1838)  
*Platycheirus albimanus* (Fabricius, 1781)  
*Platycheirus clypeatus* (Meigen, 1822)  
*Platycheirus manicatus* (Meigen, 1822)  
*Platycheirus peltatus* (Meigen, 1822)  
*Syrphus torvus* Osten-Sacken, 1875
- Phoridae**  
*Megaselia pumila* (Meigen, 1830)  
*Megaselia sordida* (Zetterstedt, 1838)
- Piophilidae**  
*Piophila vulgaris* Fallén, 1820
- Sciomyzidae**  
*Pherbellia ventralis* (Fallén, 1820)  
*Tetanocera robusta* Loew, 1847
- Helcomyzidae**  
*Heterocheila buccata* (Fallén, 1820)
- Sepsidae**  
*Themira dampfi* Becker, 1915  
*Themira pusilla* (Zetterstedt, 1847)
- Coelopidae**  
*Coelopa frigida* (Fabricius, 1805)

**Anthomyzidae***Anthomyza socculata* (Zetterstedt, 1847)**Carniidae***Meaneura lamellata* Collin, 1930**Heleomyzidae***Heleomyza borealis* (Bohemann, 1866)*Heleomyza serrata* (Linnaeus, 1758)*Neoleria prominens* (Becker, 1897)*Tephrochlaena oraria* Collin, 1943**Drosophilidae***Drosophila funebris* (Fabricius, 1787)*Scaptomyza graminum* (Fallén, 1823)*Scaptomyza pallida* (Zetterstedt, 1847)**Sphaeroceridae***Copromyza equina* Fallén, 1820*Copromyza nigrina* (Gimmerthal, 1847)*Crumomyia nigra* (Meigen, 1830)*Kimosina empirica* (Hutton, 1901)*Leptocera lutosa* (Stenhammar, 1855)*Minilimosina fungicola* (Haliday, 1836)*Spelobia clunipes* (Meigen, 1830)*Spelobia luteilabris* (Rondani, 1880)*Spelobia pseudosetaria* (Duda, 1918)*Spelobia rufilabris* (Stenhammar, 1855)*Thoracochaeta zosteræ* (Haliday, 1833)**Ephydriidae***Discocerina bohemanii* (Becker, 1896)*Hydrellia griseola* (Fallén, 1823)*Parydra pusilla* (Meigen, 1830)*Philygria vittipennis* (Zetterstedt, 1838)*Scatella stagnalis* (Fallén, 1823)*Scatella tenuicosta* Collin, 1930**Scathophagidae***Chaetosa punctipes* (Meigen, 1826)*Scathophaga calida* Curtis, 1832*Scathophaga furcata* (Say, 1823)*Scathophaga litorea* Fallén, 1819*Scathophaga stercoraria* (Linnaeus, 1758)**Anthomyiidae***Botanophila betarum* (Lintner, 1883)*Botanophila fugax* (Meigen, 1826)*Botanophila rubrigena* (Schnabl, 1815)*Delia angustifrons* (Meigen, 1826)*Delia echinata* (Séguy, 1923)*Delia fabricii* (Holmgren, 1873)*Delia platura* (Meigen, 1826)*Delia radicum* (Linnaeus, 1758)*Delia setigera* (Stein, 1920)*Fucellia fucorum* (Fallén, 1819)*Fucellia maritima* (Haliday, 1838)*Lasiomma picipes* (Meigen, 1826)*Pegoplata infirma* (Meigen, 1826)*Zaphne brunneifrons* (Zetterstedt, 1838)*Zaphne divisa* (Meigen, 1826)*Zaphne frontata* (Zetterstedt, 1838)**Muscidae***Coenosia pumila* (Fallén, 1825)*Graphomyia maculata* (Scopoli, 1763)*Helina annosa* (Zetterstedt, 1838)*Hydrotaea armipes* (Fallén, 1825)*Hydrotaea dentipes* (Fabricius, 1805)*Limnophora pandellei* Séguy, 1923*Limnophora sinuata* Collin, 1930*Musca domestica* Linnaeus, 1758*Mydaea palpalis* Stein, 1916*Myospila mediatubunda* (Fabricius, 1781)*Spilogona baltica* (Ringdahl, 1918)*Spilogona micans* (Ringdahl, 1918)*Spilogona pacifica* (Meigen, 1826)*Thricops rostratus* (Meade, 1882)**Fanniidae***Fannia canicularis* (Linnaeus, 1761)*Fannia glaucescens* (Zetterstedt, 1845)**Calliphoridae***Calliphora uralensis* Villeneuve, 1922*Calliphora vicina* Robineau-Desvoidy, 1830*Cynomya mortuorum* (Linnaeus, 1761)*Phormia terraenovae* Robineau-Desvoidy, 1830**Hippoboscidae***Ornithomyia avicularia* (Linnaeus, 1758)*Ornithomyia chloropus* Bergroth, 1901**Siphonaptera Fleas****Ceratophyllidae***Dasypsyllus gallinulae* (Dale, 1878)**ARACHNIDA Arachnids****Araneae Spiders****Linyphiidae***Agyneta nigripes* (Simon, 1884)*Allomengea scopigera* (Grube, 1859)*Erigone arctica* (White, 1852)*Erigone atra* Blackwall, 1833*Erigone tirolensis* L. Koch, 1872*Islandiana princeps* Brændegaard, 1932*Lepthyphantes complicatus* (Emerton, 1882)*Lepthyphantes mengei* Kulczynski, 1887*Lepthyphantes zimmermanni* Bertkau, 1890*Leptotrix hardyi* (Blackwall, 1850)*Savignya frontata* (Blackwall, 1833)*Walckenaeria clavicornis* (Emerton, 1882)*Walckenaeria nudipalpis* (Westring, 1851)**Acari Mites and ticks****Gammasina***Dendrolaelaps oudemansi* Halbert, 1915*Haemogamasus nidi* Michael, 1892*Macrocheles matrius* Hull, 1925*Rhodacarus roseus* Oudemans, 1902*Thinoseius spinosus* Willmann, 1930*Eviphis ostrinus* (C. L. Koch, 1836)*Zercon triangularis* C. L. Koch, 1836*Arctoseius* sp.*Eugamasus kraepelina* (nomen dubium)*Halolaelaps suecicus* (Sellnick, 1957)*Halolaelaps* sp.*Parasitus halophilus* Sellnick, 1957**Ixodida***Ixodes ricinus* (Linnaeus, 1758)*Ceratixodes uriae* (White, 1852)**Actinedida***Cocceupodes clavifrons* (Canestrini, 1886)*Ereynetes agilis* (Berlese, 1923)*Pedeculaster mesembrinae* (Canestrini, 1881)*Tarsonemus fusarii* Cooreman, 1941*Nanorchestes arboriger* (Berlese, 1904)*Rhagidia mordax* Oudemans, 1906*Rhagidia* sp.*Penthalodes ovalis* (Dugès, 1834)*Petrobia apicalis* (Banks, 1917)*Bdella* sp.

*Neomolgus littoralis* (Linnaeus)  
*Anystis* sp.  
*Bakerdalia* sp.

**Acaridida**

*Caloglyphus reglei*  
*Myianoetus digiferus*  
*Myianoetus vesparum*  
*Tyrophagus similis*  
*Tyrophagus dimidiatus*  
*Schwiebia cavernicola*  
*Histiostoma feroniarum*  
*Histiostoma* (hypopus)

**Oribatida**

*Lauroppia falcata* (Paoli, 1908)  
*Oribotritia faeroensis* (Sellnick, 1923)  
*Hypochthonius rufulus* C. L. Koch, 1836  
*Liochthonius lapponicus* (Trägårdh, 1910)  
*Liochthonius muscorum* Forsslund, 1964  
*Liochthonius propinquus* Niedbala, 1972  
*Eniochthonius minutissimus* (Berlese, 1903)  
*Hermannia* sp.  
*Tectocephus velatus* (Michael, 1880)  
*Suctobelbella subcornigera* (Forsslund, 1941)  
*Suctobelbella sarekensis* (Forsslund, 1941)  
*Suctobelbella acutidens* (Forsslund, 1941)  
*Quadroppia quadricarinata* (Michael, 1885)  
*Quadroppia* sp.  
*Oppiella nova* (Oudemans, 1902)  
*Oppiella splendens* (C. L. Koch, 1841)  
*Medioppia subpectinata* (Oudemans, 1900)  
*Autogneta longilamellata* (Michael, 1885)  
*Ameronothrus lineatus* (Thorell, 1871)  
*Ameronothrus nigrofemoratus* (C. L. Koch, 1879)  
*Zygoribatula exilis* (Nicolet, 1855)  
*Chamobates cuspidatus* (Michael, 1884)  
*Ophidiotrichus connexus* (Berlese, 1904)  
*Achipteria coleoptrata* (Linnaeus, 1758)

**ANNELIDA** Segmented worms**Oligochaeta** Earthworms**Lumbricidae**

*Lumbricus castaneus* (Savigny, 1826)

**Enchytraeidae**

*Enchytraeidae* indet. spp.

**MOLLUSCA** Molluscs**Gastropoda** Snails and slugs**Agriolimacidae**

*Deroceras agreste* (Linnaeus, 1758)

**Vitrinidae**

*Vittrina pellucida* (O. F. Müller, 1774)

**NEMATODA** Roundworms**Rhabditina****Cephalobidae**

*Acrobeloides nanus* (de Man, 1884)

**Monhysterida****Monhysteridae**

*Monhystera* sp.

**ROTATORIA** Rotifers**Eurotalaria****Philodinidae**

*Philodina acuticornis odiosa* Milne, 1916

**Habrotrochidae****Habrotrocha**

*Habrotrocha constricta* (Dujardin, 1841)  
*Habrotrocha* sp.

**Ploima****Euchlandidae**

*Euchlanis dilatata* Ehrenberg, 1832

**Notommatidae**

*Cephalodella gibba* (Ehrenberg, 1832)  
*Cephalodella gracilis* (Ehrenberg, 1832)

The muscid fly *Tricops rostratus* visiting an autumn hawkbit *Leontodon autumnalis*. (Photo: Erling Ólafsson 2005).



## Appendix 8. Seaweed species recorded at Surtsey

## Green algae

*Acrochaete viridis* (Reinke) R. Nielsen  
*Acrochaete wittrockii* (Wille) R. Nielsen  
*Acrosiphonia arcta* (Dillwyn) J. Agardh  
*Blidingia minima* (Nägeli ex Kützing) Kylin  
*Bryopsis plumosa* (Hudson) C. Agardh  
*Derbesia marina* (Lyngbye) Solier  
*Endodictyon infestans* H. Gran  
*Enteromorpha compressa* (Linnaeus) Nees  
*Enteromorpha flexuosa* (Wulfen) J. Agardh  
*Enteromorpha intestinalis* (Linnaeus) Nees  
*Enteromorpha linza* (Linnaeus) J. Agardh  
*Enteromorpha prolifera* (O. F. Müller) J. Agardh  
*Epicladia flustrae* Reinke  
*Sahlingia subintegra* (Rosenvinge) Kornmann  
*Monostroma grevillei* (Thuret) Wittrock  
*Omphalophyllum ulvaceum* Rosenvinge  
*Pseudentoclonium submarinum* Wille  
*Spongomorpha aeruginosa* (Linnaeus) van den Hoek  
*Ulothrix speciosa* (Carmichael ex Harvey in Hooker) Kützing  
*Ulothrix flacca* (Dillwyn) Thuret in Le Jolis  
*Ulothrix subflaccida* Wille  
*Ulva lactuca* Linnaeus  
*Ulvaria fusca* (Postels & Ruprecht) Ruprecht  
*Urospora bangioides* (Harvey) Holmes & Batters  
*Urospora penicilliformis* (Roth) Areschoug  
*Urospora wormskioldii* (Mertens in Hornemann) Rosenvinge

## Brown algae

*Alaria esculenta* (Linnaeus) Greville  
*Chorda filum* (Linnaeus) Stackhouse  
*Desmarestia aculeata* (Linnaeus) Lamouroux  
*Desmarestia ligulata* (Lightfoot) Lamouroux  
*Desmarestia viridis* (O. F. Müller) Lamouroux  
*Ectocarpus fasciculatus* Harvey  
*Ectocarpus siliculosus* (Dillwyn) Lyngbye  
*Fucus spiralis* Linnaeus  
*Halosiphon tomentosum* (Lyngbye) Jaasund  
*Haplospora globosa* Kjellman  
*Hincksia granulosa* (J. E. Smith) P. Silva  
*Hincksia hincksiae* (Harvey) P. Silva  
*Hincksia ovata* (Kjellman) P. Silva  
*Hincksia recurvata* (Kuckuck) unpublished combination  
*Hincksia secunda* (Kützing) P. Silva  
*Laminaria digitata* (Hudson) Lamouroux  
*Laminaria hyperborea* (Gunnerus) Foslie  
*Leptonematella fasciculata* (Reinke) Silva  
*Petalonia fascia* (O. F. Müller) Kuntze  
*Petalonia zosterifolia* (Reinke) Kuntze  
*Petroderma maculiforme* (Wollny) Kuckuck  
*Phaeostroma pustulosum* Kuckuck  
*Protectocarpus speciosus* (Børgesen) Kornmann in Kuckuck  
*Pylaiella littoralis* (Linnaeus) Kjellman  
*Scytosiphon lomentarius* (Lyngbye) Link  
*Sphacelaria caespitula* Lyngbye

## Red algae

*Achrochaetium secundatum* (Lyngbye) Nägeli  
*Antithamnionella floccosa* (O. F. Müller) Whittick  
*Audouinella membranacea* (Magnus) Papenfuss  
*Audouinella pectinata* (Kylin) Papenfuss  
*Bangia artropurpurea* (Roth) C. Agardh  
*Callophyllis cristata* (C. Agardh) Kützing  
*Delesseria sanguinea* (Hudson) Lamouroux  
*Lomentaria clavellosa* (Turner) Gaillon  
*Lomentaria orcadensis* (Harvey) Collins ex W. R. Taylor  
*Meiodiscus spetzbergensis*  
 (Kjellm) G. W. Saunders & McLachlan  
*Membranoptera alata* (Hudson) Stackhouse  
*Phycodrys rubens* (Linnaeus) Batters  
*Erythrodermis traillii* (Holmes ex Batters) Guiry & Garbary  
*Plocamium cartilagineum* (Linnaeus) Dixon  
*Polysiphonia stricta* (Dillwyn) Greville  
*Porphyra miniata* (C. Agardh) C. Agardh  
*Porphyra purpurea* (Roth) C. Agardh  
*Porphyra umbilicalis* (Linnaeus) Kützing  
*Porphyropsis coccinea* (J. Agardh ex Areschoug) Rosenvinge  
*Rhodochorton purpureum* (Lightfoot) Rosenvinge  
*Rhodophysema elegans* (P. Crouan & H. Crouan) Dixon  
*Scagelothamnion pusillum* (Ruprecht) Athanasiadis in Maggs  
 & Hommersand



*Alaria esculenta* growing at 5 m depth in Surtsey.  
 (Photo: Karl Gunnarsson 1997).

## Appendix 9a. Marine zoobenthos found on hard substrate at 0 to 40 m depth at Surtsey

The following animal species were collected in the littoral and sublittoral zones down to depths of 40 m.

### Porifera sponges

- Grantia compressa* (Fabricius, 1780)
- Halichondria panicea* (Pallas, 1766)
- Sycon ciliatum* (Fabricius, 1780)

### Scyphozoa stalked jellyfish

- Haliclystus octoradiatus* (Lamarck, 1816)

### Hydrozoa hydroids

- Aequorea forskalea* (Forsskal, 1775)
- Bougainvillia ramosa* (Van Beneden, 1844)
- Callycella syringa* (Linnaeus, 1767)
- Campanularia integra* Macgillivray, 1842
- Clytia hemisphaerica* (Linnaeus, 1758)
- Clytia sarsi* Cornelius, 1982
- Corymorpha nutans* M. Sars, 1835
- Cuspidella humilis* (Alder, 1862)
- Diphasia rosacea* (Linnaeus, 1758)
- Dulichia porrecta* (Bate, 1857)
- Eudendrium capillare* Alder, 1856
- Eudendrium rameum* (Pallas, 1766)
- Filellum serpens* (Hassall, 1848)
- Halecium curvicaule* Lorenz, 1886
- Halecium halecium* (Linnaeus, 1758)
- Halecium labrosum* Alder, 1859
- Halecium muricatum* (Ellis et Solander, 1786)
- Hydractinia carica* Bergh, 1887
- Lafoeina tenuis* Van Beneden, 1847
- Obelia hyalina* Clarke, 1879
- Obelia longissima* (Pallas, 1766)
- Perigonimus roseus* Jäderholm, 1909
- Phialella quadrata* (Forbes, 1848)
- Tubularia larynx* Ellis et Solander, 1786

### Alcyonacea soft coral

- Alcyonium digitatum* Linnaeus, 1758

### Actinaria sea anemone

- Urticina felina* (Linnaeus, 1761)

### Polycheta bristle worms

- Hydroides norvegica* (Gunnerus, 1768)
- Pomatoceros triquetter* (Linnaeus, 1767)

### Gastropoda gastropods

- Aporrhais pespelicanis* Linnaeus, 1758
- Buccinum undatum* Linnaeus, 1758
- Cryptonatica affinis* (Gmelin, 1791)
- Gibbula tumida* (Montagu, 1803)
- Hinia incrassata* (Ström, 1768)
- Lacuna pallidula* (E. M. da Costa, 1778)
- Lacuna vincta* (Montagu, 1803)
- Limacina helicina* (Phipps, 1774) Pteropod
- Margarites groenlandicus* (Gmelin, 1791)
- Margarites helycinus* (Phipps, 1774)
- Margarites olivaceus* (T. Brown, 1827)
- Neptunea despecta* (Linnaeus, 1758)
- Odostomia unidentata* (Montagu, 1803)
- Omalogyra atomus* (Philippi, 1841)
- Onoba semicostata* (Montagu, 1803)
- Patina pellucida* (Linnaeus, 1758)
- Skeneopsis planorbis* (Fabricius, 1780)
- Tectura testudinalis* (O. F. Müller, 1776)

- Tectura virginea* (O. F. Müller, 1776)
- Velutina velutina* (O. F. Müller, 1776)

### Bivalvia bivalves

- Abra nitida* (O. F. Müller, 1776)
- Abra prismatica* (Montagu, 1803)
- Chlamys distorta* (da Costa, 1778)
- Chlamys islandica* (O. F. Müller, 1776)
- Crassadoma pusio* (Linnaeus, 1758)
- Heteranomia squamula* (Linnaeus, 1758)
- Hiatella arctica* (Linnaeus, 1767)
- Kellia suborbicularis* (Montagu, 1803)
- Lyonsia norvegica* (Gmelin, 1791)
- Modiolula phaseolina* (Philippi, 1844)
- Musculus discors* (Linnaeus, 1767)
- Mya truncata* Linnaeus, 1758
- Mytilus edulis* Linnaeus, 1758
- Palliolium tigrinum* (O. F. Müller, 1776)
- Parvicardium pinnulatum* (Conrad, 1831)
- Spisula solida* (Linnaeus, 1758)

### Nudibranchia sea slugs

- Acanthodoris pilosa* (Abildgaard in O. F. Müller, 1789)
- Adalaria proxima* (Alder et Hancock, 1854)
- Aeolidia papillosa* (Linnaeus, 1761)
- Ancula gibbosa* (Risso, 1818)
- Archidoris pseudoargus* (Rapp, 1827)
- Catronia aurantia* (Alder et Hancock, 1854)
- Dentronodus frondosus* (Ascanius, 1774)
- Doto coronata* (Gmelin, 1791)
- Doto pinnatifida* (Montagu, 1804)
- Eubranchus pallidus* (Alder et Hancock, 1842)
- Flabellina verrucosa* (M. Sars, 1829)
- Onchidoris bilamellata* (Linnaeus, 1767)
- Onchidoris muricata* (O. F. Müller, 1776)
- Tergipes tergipes* (Forsskal, 1775)

### Crustacea/Amphipoda amphipods

- Ampithoe rubricata* (Montagu, 1808)
- Apherusa jurinei* H. Milne-Edwards, 1830
- Calliopius laeviusculus* Krøyer, 1838
- Caprella linearis* Linnaeus, 1767
- Caprella septentrionalis* Krøyer, 1838
- Gammarellus angulosus* (Rathke, 1843)
- Gammarellus homari* Fabricius, 1779
- Gammaropsis nitida* Stimpson, 1853
- Hyperia galba* (Montagu, 1813)
- Hyperoche medusarum* (Krøyer, 1838)
- Ischyrocerus anguipes* Krøyer, 1838
- Jassa falcata* (Montagu, 1808)
- Metopa alderi* (Bate, 1857)
- Metopa borealis* G. O. Sars, 1882
- Metopa bruzeli* (Goes, 1866)
- Metopa pusilla* G. O. Sars, 1892
- Metopa rubrovittata* G. O. Sars
- Metopa solbergi* Schneider, 1884
- Obelia geniculata* (Linnaeus, 1758)
- Parapleustes bicuspis* (Krøyer, 1838)
- Pleusymtes glaber* (Boeck, 1861)
- Stenothoe monoculoides* (Montagu, 1813)

### Crustacea/Isopoda isopods

- Idotea granulosa* Rathke, 1843
- Idotea neglecta* G. O. Sars, 1897
- Idotea pelagica* Leach, 1815

*Janira maculosa* Leach, 1814  
*Janiropsis breviremis* G. O. Sars, 1899  
*Munna krøyeri* Goodsir, 1842

**Crustacea/Cirripedia** acorn barnacles

*Balanus balanus* (Linnaeus, 1758)  
*Chirona hameri* (Asciandus, 1767)  
*Semibalanus balanoides* (Linnaeus, 1766)  
*Verruca stroemia* O. F. Müller, 1776

**Crustacea/Natantia** shrimps

*Crangon allmanii* Kinahan, 1857  
*Eualus pusiolus* (Krøyer, 1841)

**Crustacea/Anomura** squat lobster

*Galathea nexa* Embleton, 1834

**Crustacea/Brachyura** crabs

*Hyas coarctatus* Leach, 1815  
*Pagurus bernhardus* (Linnaeus, 1758)  
*Pandalus montagui* Leach, 1814  
*Polybius holsatus* (Fabricius, 1798)

**Crustacea/Copopoda** copepod

*Harpacticus arcticus* Poppe, 1884

**Pyconogonida** sea spider

*Nymphon hirtum* Krøyer, 1844

**Bryozoa** bryozoans

*Alcyonidium albidum* Alder, 1857  
*Alcyonidium mamillatum* Alder, 1857  
*Alcyonidium mytili* Dalyell, 1847  
*Alcyonidium parasiticum* (Fleming, 1828)  
*Alcyonidium polyoum* Hassall  
*Amphiblestrum flemingi* (Busk, 1854)  
*Arachnidium fibrosum* Hincks, 1880  
*Bartensia gracilis* (M. Sars)  
*Buskia nitens* Alder, 1857  
*Callopora craticula* (Alder, 1857)  
*Callopora dumerilii* (Audouin, 1826)  
*Callopora lineata* (Linnaeus, 1767)  
*Celleporella hyalina* (Linnaeus, 1767)  
*Celleporina hassallii* (Johnston, 1847)  
*Cribrilina annulata* (Fabricius, 1780)  
*Cribrilina cryptoecium* Norman, 1903  
*Cribrilina punctata* Hassall, 1841  
*Cylindroporella tubulosa* (Norman, 1868)  
*Diplosolen obelia* (Johnston, 1838)  
*Electra pilosa* (Linnaeus, 1768)  
*Escharella immersa* (Fleming, 1828)  
*Flustra foliacea* Linnaeus, 1758  
*Lichenopora hispida* (Fleming, 1828)  
*Lichenopora verrucaria* (Fabricius, 1780)  
*Membranipora membranacea* (Linnaeus, 1767)  
*Membraniporella nitida* (Johnston, 1838)  
*Microporella ciliata* (Pallas, 1766)  
*Parasmittina trispinosa* (Johnston, 1838)  
*Plagioecia patina* (Lamarck, 1816)  
*Porella alba* Noordgard, 1906  
*Porella minuta* (Norman, 1868)  
*Porella smitti* Kluge, 1907  
*Scizomavella linearis* (Hassall)  
*Scruparia ambigua* (d'Orbigny, 1841)  
*Scruparia chelata* (Linnaeus, 1758)  
*Scrupocellaria elongata* (Smitt, 1868)  
*Scrupocellaria scruposa* (Linnaeus, 1758)  
*Tegella arctica* (d'Orbigny, 1851)  
*Tegella unicornis* (Fleming, 1828)

*Tricellaria ternata* (Ellis et Solander, 1786)  
*Tubulipora liliacea* (Pallas, 1766)  
*Umbonula littoralis* Hastings, 1944

**Echinodermata/Asteroidea** starfish

*Hippasteria phrygiana* (Parelius, 1768)  
*Asterias rubens* Linnaeus, 1758

**Echinodermata/Echinoidea** sea urchins

*Echinus esculentus* Linnaeus, 1758  
*Strongylocentrotus droebachiensis* (O. F. Müller, 1776)

**Echinodermata/Ophiuroidea** brittle star

*Ophiopholis aculeata* (Linnaeus, 1767)

**Echinodermata/Holothurioidea** sea cucumber

*Cucumaria frondosa* (Gunnerus, 1767)

**Ascidacea** tunicates

*Ascidia callosa* Stimpson, 1852  
*Ascidia obliqua* Alder, 1863  
*Boltenia echinata* (Linnaeus, 1767)  
*Halocynthia pyriformis* (Rathke in O. F. Müller, 1806)  
*Styela rustica* (Linnaeus, 1767)

**Pisces** fish

*Ammodytes tobianus* Linnaeus, 1758 Sand eel  
*Cyclopterus lumpus* Linnaeus, 1758 Lump sucker  
*Limanda limanda* (Linnaeus, 1758) Dab  
*Liparis montagui* (Donovan, 1804) Montagu's sea snail  
*Lophius piscatorius* Linnaeus, 1758 Anglerfish  
*Microstomus kitt* (Walbaum, 1792) Lemon sole

**Appendix 9b.**

Animals found in the sand at 16 to 125 m depths on the underwater slope of the volcano at Surtsey. *Nephrops norvegicus*\* was fished at 140 to 160 m around Surtsey

**Polychaeta** bristle worms

*Ammotrypane aulogaster* Rathke, 1843  
*Anaitides groenlandica* Oersted  
*Capitella capitata* (Fabricius, 1780)  
*Diplocirrus glaucus* (Malmgren, 1867)  
*Ditrupe arietina* (O. F. Müller, 1776)  
*Sthenelais filamentosa* Ditlevsen, 1917  
*Goniada maculata* Oersted, 1843  
*Kefersteinia cirrata* (Keferstein, 1862)  
*Nephtys hombergii* Savigny, 1818  
*Owenia fusiformis* delle Chiaje, 1841  
*Pectinaria koreni* (Malmgren, 1866)  
*Pholoe minuta* (Fabricius, 1780)  
*Scoloplos armiger* (O. F. Müller, 1776)  
*Spio filicornis* (O. F. Müller, 1766)  
*Spiophanes bombyx* (Claparède, 1870)  
*Castalia punctata* (O. F. Müller, 1788)  
*Eteone longa* (Fabricius, 1780)  
*Lanice conchilega* (Pallas, 1766)  
*Nephtys longisetosa* Örsted, 1882  
*Scolecopsis squamata* (O. F. Müller, 1789)  
*Pseudopolydora antennata* (Claparède, 1870)  
*Thelepus cincinnatus* (Fabricius, 1780)

**Crustacea/Amphipoda** amphipod*Hippomedon denticulatus* (Bate, 1857)**Crustacea/Brachyura** crabs*Eurynome aspera* (Pennant, 1777)*Nephrops norvegicus*\* (Linnaeus, 1758)*Philocheras bispinosus* (Hailstone, 1835)**Bivalvia** bivalves*Abra nitida* (O. F. Müller, 1776)*Abra prismatica* (Montagu, 1808)*Acanthocardium echinatum* (Linnaeus, 1758)*Arctica islandica* (Linnaeus, 1767)*Macoma calcaria* (Gmelin, 1791)*Spisula elleptica* (Brown, 1827)**Echinodermata/Ophiuroidea** brittle stars*Amphiura filiformis* (O.F. Müller, 1776)*Ophiacten affinis* (Lütken, 1858)**Echinodermata/Echinoidea** sea urchin*Echinocardium flavescens* (O. F. Müller, 1776)

Common starfish, *Asterias rubens* in the shallow sublittoral at Surtsey. (Photo: Karl Gunnarsson 1997).

### Appendix 9c. Fish species found in the sea around Surtsey

Starry ray	<i>Amblyraja radiata</i> (Donovan, 1808)
Sand eel*	<i>Ammodytes tobianus</i> Linnaeus, 1758
Wolffish	<i>Anarhichas lupus</i> (Linnaeus, 1758)
Spotted catfish	<i>Anarhichas minor</i> Ólafsson, 1772
Greater silver smelt	<i>Argentina silus</i> (Ascanius, 1775)
Tusk	<i>Brosme brosme</i> (Ascanius, 1772)
Basking shark	<i>Cetorhinus maximus</i> (Gunnerus, 1765)
Herring	<i>Clupea harengus</i> Linnaeus, 1758
Roundnose grenadier	<i>Coryphaenoides rupestris</i> Gunnerus, 1765
Lumpsucker*	<i>Cyclopterus lumpus</i> Linnaeus, 1758
Common skate	<i>Dipturus batis</i> (Linnaeus, 1758)
Cod	<i>Gadus morhua</i> Linnaeus, 1758
Witch	<i>Glyptocephalus cynoglossus</i> (Linnaeus, 1758)
Long rough dab	<i>Hippoglossoides platessoides</i> (Fabricius, 1780)
Halibut	<i>Hippoglossus hippoglossus</i> (Linnaeus, 1758)
Megrim	<i>Lepidorhombus whiffiagonis</i> (Walbaum, 1792)
Dab**	<i>Limanda limanda</i> (Linnaeus, 1758)
Montagu's sea snail*	<i>Liparis montagui</i> (Donovan, 1804)
Anglerfish*	<i>Lophius piscatorius</i> Linnaeus, 1758
Capelin	<i>Mallotus villosus</i> (Müller, 1776)
Haddock	<i>Melanogrammus aeglefinus</i> Linnaeus, 1758
Whiting	<i>Merlangius merlangus</i> Linnaeus, 1758
Lemon sole*	<i>Microstomus kitt</i> (Walbaum, 1792)
Blue ling	<i>Molva dypterygia</i> (Pennant, 1784)
Ling	<i>Molva molva</i> (Linnaeus, 1758)
Plaice	<i>Pleuronectes platessa</i> Linnaeus, 1758
Saithe	<i>Pollachius virens</i> (Linnaeus, 1758)
Redfish	<i>Sebastes marinus</i> (Linnaeus, 1758)
Deep-sea rosefish	<i>Sebastes mentella</i> (Travin, 1951)

\* Found sublittorally; listed also in App. 9a.

\*\* Found both in the shallow sublittoral and deeper than 100 m; listed also in App. 9a.



## Appendix 10: Draft Management Plan for the Surtsey Nature Reserve, 2007–2017

### Introduction

Surtsey island has been managed for conservation ever since the original Declaration of the Surtsey Nature Reserve by the Minister of Education, Science and Culture on 19 May 1965, in the Icelandic *Official Gazette*. A new declaration came into force in 1974, pursuant to the revised Act on Nature Conservation, No. 47/1971. The third Declaration of the Surtsey Nature Reserve was issued by the Minister for the Environment in January 2006. At that time the Reserve was enlarged to incorporate the entire Surtsey volcano as it stands on the sea floor, together with a significant area of the surrounding seas. The codes of conduct and conservation provisions of the Declaration are based on the Act on Nature Conservation, No. 44/1999.

The Environment and Food Agency of Iceland is responsible for the conservation, protection and management of the Surtsey Nature Reserve. To advise the Agency on matters regarding the Reserve, a special Advisory Committee was appointed in January 2006, composed of two members from the Municipality of Vestmannaeyjar and one representative from the Surtsey Research Society, the Icelandic Institute of Natural History, the Marine Research Institute and the Environment and Food Agency.

This draft Management Plan for the Surtsey Nature Reserve, 2007–2017, provides a long-term vision for Reserve management, along with a series of more detailed goals and objectives that include the necessary measures for integrated conservation, research, monitoring and interpretation. During the first quarter of 2007, the draft plan will be subject to review by the Municipality of Vestmannaeyjar, the Surtsey Research Society, Icelandic Institute of Natural History, Marine Research Institute, South Iceland Research Centre and Vestmannaeyjar Research Centre. A final plan will then be prepared and confirmed by the Minister for the Environment.

### Vision

The vision of Surtsey Nature Reserve management is to establish the Reserve as an internationally renowned site for the integrated conservation, study, monitoring and interpretation of a globally significant natural phenomenon. The island's terrestrial component will be conserved through restricted access and the highest protection and conservation standards. A buffer zone around the island will serve to safeguard its marine features from threats posed by tanker and other shipping traffic, over-fishing and offshore energy development. A World Heritage Site status will strengthen the long-term conservation of Surtsey as a pristine nature reserve.

### Guiding principle and management goals

The guiding principle behind the Declaration of the Surtsey Nature Reserve was ensuring that development of the island and its submerged components remain in keeping with natural evolutionary processes, free of human intervention. Measures have been taken to guarantee that biotic succession, geomorphological processes and colonisation by plants and animals follow natural pathways and undergo minimal human disruption. This has reinforced the value of Surtsey for science and nature conservation, both within Iceland and on a global basis.

The management of the Surtsey Nature Reserve, 2007–2017, will be founded on this guiding principle, as well as on the

goals listed below; they provide the long-term framework for management and a basis for selecting and assessing objectives.

**Conservation:** The principal land use in the Surtsey Nature Reserve comprises conservation. The island and surrounding seas will be managed towards conserving the natural heritage, so as to maintain key features and provide a model of best practice. Conservation management measures will aim at ensuring to the greatest possible extent that natural features and processes remain undisturbed by man. Intervention, however, may occur when called for to protect any more significant natural features from deterioration or hazard. In such cases, decisions will be made on a case-by-case basis, allowing for the reversibility of any actions taken and for minimum disturbance to other natural features and processes.

**Research:** Such scientific research shall be encouraged as will improve understanding of natural features in the Surtsey Nature Reserve, or will assist in protecting and managing its globally outstanding qualities. The Environment and Food Agency will commission such research on a case-by-case basis, in cooperation with the Surtsey Research Society. Research will only be permitted if it is in keeping with the Declaration of the Surtsey Nature Reserve and leads to no damage to nature in the Reserve.

The Surtsey Nature Reserve is to be a model of integrated conservation management, whereby nature conservation and research interests are considered together. Where there is a potential conflict of interests between research and nature conservation, decisions will be made with reference to the Declaration of the Surtsey Nature Reserve and provisions of the Act on Nature Conservation, No. 44/1999, following consultation with the Advisory Committee.

**Access:** It is prohibited to go ashore on Surtsey or to dive by the island except when carrying out research purposes and related activities and bearing written permission from the Environment and Food Agency. Vessels are however permitted to travel through the Reserve around Surtsey.

**Education and interpretation:** There is a wealth of primary and secondary information sources on Surtsey and its eruption and development; these are kept by several agencies and organisations as well as by individuals. The Environment and Food Agency, in cooperation with the Surtsey Research Society, is to work towards collating this material. Education and interpretation programmes will be developed, in partnership with those maintaining the information, in order to instill a long-lasting appreciation for Surtsey Nature Reserve characteristics and for the importance of sustainable conservation management at this unique site. Interpretation facilities will be established in the town of Vestmannaeyjar on Heimaey, the only inhabited island in the archipelago.

**Development:** It is recognized that some development activities are inevitable concerning operations for monitoring, research and conservation within the Surtsey Nature Reserve. No new construction or renovation may proceed until it has undergone an environmental impact assessment and the determination has been made of its meeting the following criteria: it is considered essential, temporary and reversible; its evaluated effects are judged to have minimal detrimental

effects on natural features, landscape or the wilderness quality of the Reserve; and it does not conflict with statutory stipulations.

**Man-made hazards and risks:** The main sailing routes between Iceland and Europe pass through the vicinity of the Surtsey Nature Reserve. However, larger ships do not usually come close to the Reserve, due to sea conditions and limited water depth. Automatic identification systems cover Icelandic territorial waters, and every vessel that carries cargo oil and/or other hazardous cargo within the Icelandic pollution prevention zone is required to report to the Icelandic Coast Guard Maritime Traffic Service.

The Surtsey Nature Reserve is included in the Icelandic contingency plan for oil pollution incidents. Strong currents, high wave energy and the island's shore types (cliffs, coarse-grained pebble beaches) are considered in the island's favour, since they limit the risk of long-term effects on the biota by oil spills. Equipment to combat oil pollution is kept ready in Heimaey, with supplements in Reykjavík. According to the Icelandic Marine Pollution Act, No. 33/2004, a ship-owner is obliged to remove any shipwreck on beaches, and the Environment and Food Agency can order the removal of sunken ships.



From the very beginning human influence on Surtsey has been minimal. (Photo: Hervé Jezequel 2005).



# Bibliography of Surtsey 1963-2006

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This bibliography of scientific publications relevant to Surtsey (1963–2006) was compiled by the Icelandic Institute of Natural History in relation to the Nomination of Surtsey for the UNESCO World Heritage List in January 2007.\* The bibliography can also be found at: [www.surtsey.is](http://www.surtsey.is) where it is regularly updated.

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\* Snorri Baldursson and Álfheiður Ingadóttir (eds.) 2007. Nomination of Surtsey for the UNESCO World Heritage List. Icelandic Institute of Natural History, Reykjavík, 123 pages.

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# Supplementary Material to the Nomination of Surtsey for the UNESCO World Heritage List\*

## Books, Reports and Maps:

Sturla Friðriksson (2005): Surtsey, ecosystems formed. Varði, The Surtsey Research Society, Reykjavík, 112 pages.

Surtsey Research Progress Reports No. IX (1982). Surtsey Research Society, Reykjavík, 154 pages.

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Geological map of Surtsey by Sveinn P. Jakobsson 2000, scale 1:5000. Icelandic Institute of Natural History and the Surtsey Research Society, Reykjavík.

Geological map of Surtsey by Sveinn P. Jakobsson 2006, scale 1:5000. Icelandic Institute of Natural History Reykjavík.

## Videotapes/DVDs:

<i>Id. No. and Caption</i>	<i>Date/Year</i>	<i>Director Copyright owner</i>	<i>Copyright if other than director</i>	<i>Contact details of copyright owner</i>
1 <u>The Surtsey Eruption 1963–1967</u> (Incl. three films; <i>Birth of an island</i> ; <i>Sequel to Surtsey</i> and <i>Land out of the ocean</i> )	1965; 1967; 1973	Ósvaldur Knudsen (Additional filming and editing by Villi Knudsen)	Vilhjálmur Knudsen	The Red Rock Cinema, Hellusund 6A IS-101 Reykjavík, Iceland + 354 8459548
2 <u>Surtsey eine Insel aus Magma geboren</u>	1993	Páll Steingrímsson		Súðarvogi 18, IS-104 Reykjavík, Iceland + 354 5624730
3 <u>The Black Island</u>	2003	Helga Brekkan and Torgny Nordin		SEE-Film Krukmakargatan 31 SE-11858 Stockholm, Sweden + 46 739813692 and Seylan Ltd. Mýrargötu 2, IS-101 Reykjavík, Iceland + 354 5519898

\* The materials listed here were already sent in January 2006 as supplements accompanying the nomination report.

## Slides

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1 Aerial photograph of Surtsey	12 August 2004	Loftmyndir Ltd.		Laugavegi 13, IS-101 Reykjavík, Iceland + 354 5402500	X
2 Surtsey Eroded hills	August 2005	Sigurður H. Magnússon sigurdur@ni.is		Icelandic Institute of Natural History Hlemmur 3, IS-125 Reykjavík, Iceland	
3 Surtsey Roby lava	August 2005	Borgþór Magnússon borgthor@ni.is		Icelandic Institute of Natural History Hlemmur 3, IS-125 Reykjavík, Iceland	
4 Surtsey Shore vegetation	August 2005	Borgþór Magnússon borgthor@ni.is		Icelandic Institute of Natural History Hlemmur 3, IS-125 Reykjavík, Iceland	
5 Surtsey View from SW	July 2002	Torgny Nordin		Lotsgatan 3D 414 58 Göteborg, Sweden + 46 0709-606161	X
6 Surtsey Pioneer plants	July 2002	Torgny Nordin		Lotsgatan 3D 414 58 Göteborg, Sweden + 46 0709-606161	
7 Surtsey Gull colony	August 2005	Borgþór Magnússon borgthor@ni.is		Icelandic Institute of Natural History Hlemmur 3, IS-125 Reykjavík, Iceland	
8 Surtsey Tuff sea cliffs	August 1982	Sveinn P. Jakobsson sjak@ni.is		Icelandic Institute of Natural History Hlemmur 3, IS-125 Reykjavík, Iceland	
9 Surtsey Tuff crest	August 1998	Sveinn P. Jakobsson sjak@ni.is		Icelandic Institute of Natural History Hlemmur 3, IS-125 Reykjavík, Iceland	
10 Surtsey Grey seals	October 1998	Karl Gunnarsson karl@hafro.is		Marine Research Institute Skúlagötu 4, IS-121 Reykjavík, Iceland	
11 Surtsey Sublittoral community	August 1997	Karl Gunnarsson karl@hafro.is		Marine Research Institute Skúlagötu 4, IS-121 Reykjavík, Iceland	



12	Surtsey Aerial view of the new Island	30 Nov. 1963	Sigurður Þórarinnsson	Sven Þ. Sigurðsson	Hæðargarði 21 IS-108 Reykjavík, Iceland + 354 5813791	X
13	Sky above Surtsey view from Heimaey	1965	Anonymus	Sólarfilma Ltd.	Sóltúni 20 IS-105 Reykjavík, Iceland + 354 5529333	X
14	Aerial view of Surtsey	April 1964	Snorri Snorrason	Sólarfilma Ltd.	Sóltúni 20 IS-105 Reykjavík, Iceland + 354 5529333	X
15	Lava plunges down a cliff in Surtsey	Autumn 1966	Snorri Snorrason	Sólarfilma Ltd.	Sóltúni 20 IS-105 Reykjavík, Iceland + 354 552933	X

A CD containing the  
nomination report and  
Bibliography of Surtsey 1963-2006

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Nomination of

# SURTSEY

for the UNESCO World Heritage List

SUPPLEMENTARY INFORMATION I



2007

Prepared as supplementary information to the Nomination of Surtsey  
for the UNESCO World Heritage List.

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MINISTRY FOR THE ENVIRONMENT 2007.

## Appendix XI: Supplementary information

This appendix to the Nomination of Surtsey for the UNESCO World Heritage List contains supplementary information compiled in response to letter from IUCN dated 31 August sent following the field evaluation mission undertaken by Dr. Chris Woods from 12-16 August 2007.

This document has been prepared by the Ministry for the Environment in cooperation with the Icelandic Institute of Natural History, The Environment and Food Agency and the local authorities in Vestmann islands. Professor Roger del Moral contributed also to the chapter on biological comparison as referred to in the paper.

### 1. Comparative analysis (Section 3.c of the nomination dossier)

#### Surtsey as the type locality of *Surtseyan tephra* and one of the best preserved submarine tuyas

The Surtsey eruption was monitored in detail and is considered one of the best documented eruption of its kind in the world (Sigurður Þórarinnsson 1966, 1967)<sup>1</sup>. The first phase of the eruption was characterized by hydromagmatic (syn.: phreatomagmatic) eruptions. This type of explosive activity involving mafic magmas, is now termed *Surtseyan* (Fisher & Schmincke, 1984 and Heiken & Wohletz, 1985).

The material produced during an explosive volcanic eruption is called *tephra* (syn.: hyaloclastite) (Fisher & Schmincke 1984). Surtsey, therefore, may be considered as the type locality of *Surtseyan tephra*. The interpretation of significant depositional structures of the Surtsey tephra is facilitated through the detailed description of the eruption. These structures of the tephra have been described by Sheridan (1971, 1972) and Heiken & Wohletz (1985). Analysis of the reworked tephra, or sediments, of Surtsey has been carried out by Ingólfsson (1982).

Surtsey has been described as a submarine *tuya* (syn.: table mountain), i.e. a volcano formed by an eruption into water or ice and capped by subaerial lava (Chapman et al. 2000). Tuyas formed by subglacial volcanic eruptions have been described from Iceland, Antarctica and British Columbia. Submarine tuyas are, however, rare (Chapman et al. 2000) and it can be stated that Surtsey is one of best preserved submarine tuyas in the world.

#### Comparison with other type localities and tuff cones

Surtseyan tephra is easily altered and consolidated to *tuff*. This is a temperature sensitive process which, on Surtsey, has been greatly facilitated by the formation of a hydrothermal system in 1967. The process of alteration and consolidation of the Surtsey tephra has been followed ever since.

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#### <sup>1</sup> References:

- Chapman, M., C. C. Allen, M. T. Gudmundsson, V. G. Gulick, S. P. Jakobsson, B. K. Luchitta, I. P. Skilling and R. B. Waitt 2000. Volcanism and ice interactions on Earth and Mars. In: J. Zimbelmann & T. Gregg (eds.), Environmental Effects on Volcanic Eruption: From the Deep Oceans to Deep Space, Kluwer Academic/Plenum Publishers, New York, 39 - 74, Chapter 3, 39-73.
- Fisher, R. V. & H.-U. Schmincke 1984. Pyroclastic rocks. Springer Verlag, Berlin, 472 p.
- Heiken, G. & K. Wohletz 1985. Volcanic ash. University of California Press, Berkeley, 245 p.
- Ólafur Ingólfsson 1982. Some observations on the sediments of Surtsey. Surtsey Research Progress Report 9, 133-141.
- Pichler, H. 1981. Italienische Vulkan-Gebiete III. Sammlung Geologischer Führer 69. Gebr. Borntraeger, 270 p.
- Sheridan, M. F. 1971. Particle-size characteristics of pyroclastic tuff. Journ. Geophys. Res. 76, 5627-5634.
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- Sigurður Þórarinnsson 1944. Tefrokronologiska studier på Island. Thjórsárdalur och dess förödelse. Geogr. Ann. 26, 1-217. .
- Sigurður Þórarinnsson 1966. Some facts about the Surtsey eruption. Natturfraedingurinn 35, 153-181.
- Sigurður Þórarinnsson 1967. Surtsey. The new island in the North Atlantic. Viking Press Inc., New York, 115 p.

Two tuff cones developed on Surtsey. Tuff cones are quite common in volcanic areas throughout the world. In Iceland alone, probably several hundred tuff cones are wholly or partly exposed, but few display their internal structures in the same degree as Surtsey. The development of the two tuff cones in Surtsey by erosional forces has been closely monitored, e.g. by a unique 54 vertical air photo sets taken by the Icelandic Geodetic Survey since 1964.

On Jeju (Cheju) Island, South Korea, tuff rings and tuff cones are numerous (Kim et al. 1986)<sup>2</sup>. The Seongsan Ilchulbong cone, which was included on the World Heritage List in 2007, is of Middle Pleistocene age and was formed by Surtseyan hydromagmatic eruptions. A tuff cone was developed but the eruption ceased before subaerial lava was erupted (Sohn & Chough 1992, Sohn 1996). Depositional processes at the Seongsan Ilchulbong tuff cone have been studied in detail (Sohn & Chough 1992). Tephrae have formed by Surtseyan eruptions in the Aeolian Islands, but tuff cones have not been described (Pichler 1981).

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<sup>2</sup> References:

- Kim, D. H., J. H. Hwang, , S. K. Hwang, M. F. Howells & A. J. Reedman 1986. Tuff rings and cones on Jeju Island, Korea. Journ. Geolog. Soc. Korea 22, 1-9.
- Sohn, Y. K. 1996. Hydrovolcanic processes forming basaltic tuff rings and cones on Cheju Island, Korea. GSA Bulletin 108, 1199-1211.
- Sohn, Y. K. & S. K. Chough 1992. The Ilchulbong tuff cone, Cheju Island, South Korea: depositional processes and evolution of an emergent, Surtseyan-type tuff cone. Sedimentology 39, 523-644.

**Table I.** Summary of Geological Comparative Analysis of Surtsey with five other volcanic type localities on the World Heritage List, as well as one site not on the World Heritage List.

Volcanic islands/ W H Sites	State	Area (ha)	Age (yr)	Climate	Volcanic Activity and Type	Volcanic Features	Notes	Criteria
Surtsey	Iceland	3,370 (140 land)	44	Sub-arctic	Active tectonic basaltic magma	Surtseyan, tuff cone, lava shield, significant depositional structures	Type locality for Surtseyan tephra; best preserved submarine tuya in the world; 'geological textbook'	viii
Anak Krakatau (Ujung Kulon)	Indonesia: part of site	±300 growing	77 (ongoing)	Tropical	Very active tectonic silicic magma	Tuff cone in formation	Since 1927 continually re-erupting: 1972, 1992-7, 2004	vii
Aeolian islands	Italy	1,216	Late Pleistocene to Recent	Warm temperate	Very active tectonic basaltic to intermed. magmas	Vulcanian & Strombolian	Three volcanoes active for 200 years: 'geological textbook'	viii
Jeju Island + Ilbuchong cone	S. Korea	9,475	0.1 Ma	Temperate	Dormant shield basaltic magma	Tubes, tuff speleothem	Fixed hotspot. Unusually long lava tube cave complex	vii, viii
Subantarctic Islands	N. Zealand S. Ocean	76,458 5 groups	Tertiary to Recent	Sub-antarctic	Remnant volcanoes	Tuff cone		vii, viii, ix, x
Volcanic islands/ Not WH Sites								
Capelinhos, Fayal Island	Azores		50	Sub-tropical	Remnant volcano basaltic magma	Tuff cone	Now part of the island of Fayal.	

## Biological comparison

New, less isolated volcanic terrains which have contributed significant studies of colonisation (e.g. Mt St Helens).

Similar to Surtsey, ecological studies have been carried out on Mt St. Helens every year following its eruption in 1980. Hence, data series extending over 25 years are available from this inland volcano. The most comprehensive studies have been in the field of plant ecology and soil development. Compared to Surtsey, less emphasis has been placed on colonisation and development of animal life and its interaction with the vegetation development.

In 2007, Professor Roger del Moral, plant ecologist and leading scientist in terms of ecological research on Mt. St Helens, visited Surtsey for the first time when he took part in the biological expedition to the island. Following the expedition he gave his view of the universal ecological value of Surtsey as it compares to Mt. St Helens and other similar and important volcanic sites (see enclosed letter). In his letter Roger del Moral states:

*"My studies on Mount St. Helens are focused on colonization and vegetation development in several habitats. None of these habitats is nearly as isolated as is Surtsey, yet there are several commonalities. On Mount St. Helens, initial colonists were generally wind dispersed. This was true even though other species were shown to establish and grow better when planted. Dispersal limitations were a major factor in dictating which species colonized initially. Though dispersal mechanisms differ greatly on Surtsey compared to Mount St. Helens, both sites demonstrate the importance of chance events. On both, the accumulating species form novel communities (not previously described). On Mount St. Helens, succession has proceeded to a greater degree than on Surtsey, and vegetation is beginning to develop into recognizable communities. This has yet to occur on Surtsey, and owing to its extreme isolation, it may never occur.*

*On Mount St. Helens, the importance of nutrient import from intact systems was an early theme. This is parallel to the importance of seabirds adding nutrients to the upland lavas. The Surtsey situation forcefully demonstrates the specific links among birds, insects, plants and the sea. On Mount St. Helens, the relationships are tenuous and general.*

*On Mount St. Helens, the crucial importance of safe-sites has been a central theme. Early establishment was dictated by especially favorable sites. On Surtsey, safe-sites provide the mechanism for establishment outside the gull colony. The importance of safe-sites in the two different habitats demonstrates the global importance of safe-sites in early succession.*

*On Mount St. Helens, we have demonstrated local species turnover, where uncommon early colonists are lost from permanent plots (or specific quadrats). These losses fall primarily on species with excellent dispersal ability, but poor competitive ability. It will be very interesting to document the pattern of species turnover on Surtsey. Comparisons here could also be to data from Krakatau.*

*The comparisons between Surtsey and Mount St. Helens help to clarify the importance of isolation in the development of vegetation, despite the obvious differences in climate, dominant substrate and nature of the isolation. Comparisons of the rate of succession help to determine relative importance of fertility and isolation in succession in general.*

*For your information, Mount St. Helens is nominally protected in the Mount St. Helens National Volcanic Monument. The public has virtually unrestricted access to the entire Monument (permits needed to climb to the crater edge, but this easy climb is completed by several hundred people each summer). No camping is permitted in areas devastated by the blast, and most of the interesting areas are accessible only to hikers. Certain trails are open to mountain bikes.*

*The theory of island biogeography is a major concept, with broad application. Surtsey provides the opportunity for a carefully documented analysis of patterns of colonization and extinction. The theory normally deals with equilibriums which have not yet been reached (as far as I can tell), but predictions based on the theory can be tested on Surtsey in ways not possible elsewhere. New lavas (e.g. on Hawaii) may be tracked, but they are not isolated from colonists. There is an infrastructure in place to follow the biota on Surtsey in a detailed manner. These data may eventually lead to extensions of the theory.*

.....

*Finally, I would like to comment on the Aeolian Islands, which I see are on the World Heritage list. I visited the islands of Lipari, Vulcano and Stomboli in 2001. The latter two contain active volcanoes. Each of these islands has important and interesting histories that date from the 8<sup>th</sup> Century (BCE). However, none matches Surtsey in terms of their biological importance. All have been heavily grazed and cut over the centuries. All have substantial resident and large tourist populations. I am not aware that any significant study of plant ecology is being conducted on any of these islands, and I am reasonably certain that no permanent plot studies are being conducted on the latter two. This topic was discussed with Prof. Emilia Poli Marchese during my 4 months in Catania (to study Mt. Etna). She is the leading ecologist who studies succession on Mt. Etna, and never indicated any detailed studies in the Aeolian Islands.*

*Thank you for the opportunity to comment on the biological importance of Surtsey. To me, it is a Mecca, which ecologists who study succession should honor and hope to visit. I was very impressed with the place and with the people working to understand its biology. I have experienced primary succession on young volcanoes in Hawaii (3), California (2), Washington (5), Japan (about 10 on three islands), Kamchatka (4) and Italy (5). None compares with Surtsey."*

**Other islands or isolated sites rated as biological laboratories, particularly in the contribution they make to the theory of island ecology.**

Iceland was glaciated during the last ice age and, therefore, has a relatively young biota which has colonised the island during the last 11.000 years. Most of the species are common to the neighbouring countries and endemic species are hardly found. The distance from Iceland to the nearest islands and landmasses is relatively short and measured in hundreds of kilometres rather than thousands as is the case with many of the more remote oceanic islands in the Southern hemisphere, e.g. Galapagos and Hawaii. These southern islands have highly evolved and diversified endemic biota which is millions of years old and provide textbook examples of evolution, island isolation and adaptive radiation, which have had profound importance in biology.

In contrast, the young island of Surtsey provides a unique opportunity to study the short term colonisation, development and stabilisation of an island ecosystem under natural conditions. In the 44 years since its formation, the number of species on the island has been increasing steadily, with colonisation events exceeding extinctions. This trend will probably continue over the next few decades followed by a decline in species number due to the ongoing oceanic erosion and shrinking of the island until all the outer lava has been washed away, leaving only the palagonite tuff core (p 56 in the Nomination report). Surtsey is one of 18 islands in the Vestmannaeyjar archipelago and the second largest. Comparison with the other much older islands makes a very interesting opportunity to test various aspects of island ecological theory.

Roger del Moral also discusses this point (see attached letter):

*"The theory of island biogeography is a major concept, with broad application. Surtsey provides the opportunity for a carefully documented*



analysis of patterns of colonization and extinction. The theory normally deals with equilibriums which have not yet been reached (as far as I can tell), but predictions based on the theory can be tested on Surtsey in ways not possible elsewhere. New lavas (e.g. on Hawaii) may be tracked, but they are not isolated from colonists. There is an infrastructure in place to follow the biota on Surtsey in a detailed manner. These data may eventually lead to extensions of the theory.”

## 2. Environmental pressures (Section 4.b.ii and iii)

According to Icelandic laws, the Environment and Food Agency is responsible for preventive measures as well as combating pollution incidents at sea and along the coast line. In this task, the agency cooperates with the Icelandic Coast Guard and the Icelandic Maritime Administration, among others. Ships carrying harmful substances are required to report their entrance into Icelandic Exclusive Economic Zone, and location on-route to harbour to the Maritime Traffic Service. The Coast Guard can intervene with the assigned route according to international laws if the ship and its cargo are deemed to pose a threat to the environment and, furthermore, if the ship's master does not obey orders given, the Coast Guard has the right to intercept and take over the control of the ship.

The Environment and Food Agency has counter-pollution equipment on stock in Reykjavik, ready to be flown to areas where needed. A smaller batch is available in the Harbour of Vestmanna island. According to the contingency plan, equipment and manpower is expected to control small to medium-sized incidents (tenths to hundreds of tons of oil). In more severe cases, Iceland relies on the Copenhagen agreement between the Nordic countries on mutual assistance in case of marine pollution incidents, and the cooperation between countries within the European Union, Iceland and Norway, under the umbrella of the European Maritime Safety Agency (EMSA).

The southern coast of Iceland and the adjacent seas in general are considered of highest importance to the nation's economy and its natural heritage. The Spawning areas for large part of commercially exploited fish species are along the coastline (ref. Fig. 1). Furthermore,

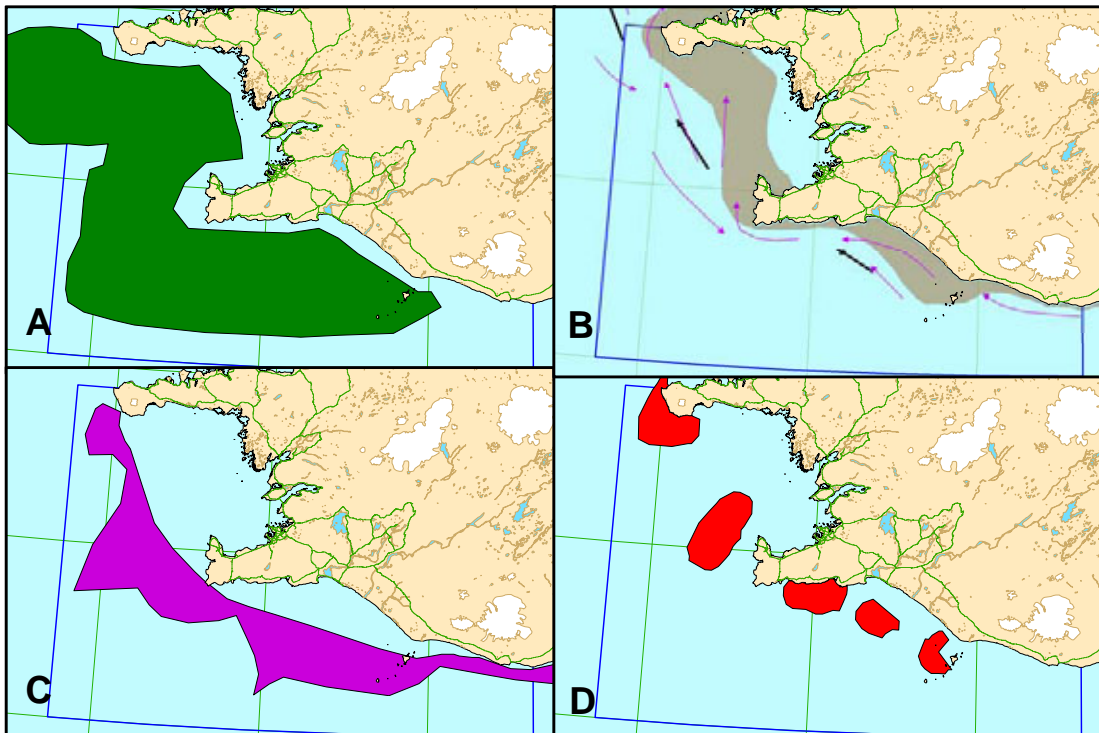


Fig. 1. Main spawning areas of: A Haddock (*Melanogrammus aeglefinus*), B Capelin (*Mallotus villosus*), C Plaice (*Pleuronectes platessa*) and D Atlantic herring (*Clupea harengus*) along the shoreline of South and Southwest Iceland. Blue line demarcates the area covered by the combined sensitivity map and contingency plan (Vákort).

the area is important for fishing, especially for the fishing villages on the Reykjanes Peninsula and the Vestmanna islands. The main sailing route between Iceland and Europe is through the area, where more than 80% of all goods to and from the island are freighted (Fig. 2). This contradiction has resulted in that in the Icelandic national contingency plan, most emphasises has been put into preventing and preparing for a pollution incident in this area.

A combined sensitivity map and contingency plan (Icel. „vákort“) for the area from Vik i Myrdal in the East and westward to the tip of the Snæfellsnes peninsula has been available since 2004 (see area demarcated with a blue line in Fig. 1). This GIS-based map/database/plan holds comprehensive information on items that could be at risk if an oil pollution incident would occur in the area, e.g. fish spawning, nursing, and exploitation; bird colonies (summer, winter and migration routes and areas), aquaculture and other activities. Furthermore, items that could cause such an event are situated (e.g. sailing routes, industry, oil depots, sewage outlets), and finally, items that are considered beneficial for the organisation and execution of responses (e.g. roads, airfields, coastal currents, direct connection to weather stations, harbours; names, phone number and E-mail of harbour managers, and other people related to the necessary activities). This system was for the first time tested in actual events in the grounding of Wilson Muuga on the Reykjanes Peninsula on December 19, 2006, where it was found to be essential in detecting the most important sensitive areas, gaining information about the conditions on the grounding site, and preparing for clean-up - which fortunately was not needed as things turned out.

Finally, Iceland put forward a proposal to the International Maritime Organization (IMO) to declare the area south of Iceland, demarcated from Dyrholaey, south off Surtsey, south off Eldey on the Reykjanes ridge and the coastal area off Reykjanes peninsula, as an Area To Be Avoided, as elaborated in attached documents submitted to the NAV subcommittee of IMO. This proposal has now been accepted by the Maritime Safety Committee (MSC) at its meeting in Copenhagen 3-12 October 2007. The aforementioned measures will come into effect on July 1<sup>st</sup> 2008.

Accordingly ships carrying oil or other hazardous or noxious substances in bulk, and larger freight ships are required to sail at least 7-10 Nautical Miles south of Surtsey, thus diminishing the risk of oil pollution event in the area. Iceland considers, in light of the aforementioned that everything possible has been done in order to minimize the risk of an oil pollution incident on Surtsey island, and has adequate measures available for combating oil pollution incidents likely to happen in its Exclusive Economic Zone.

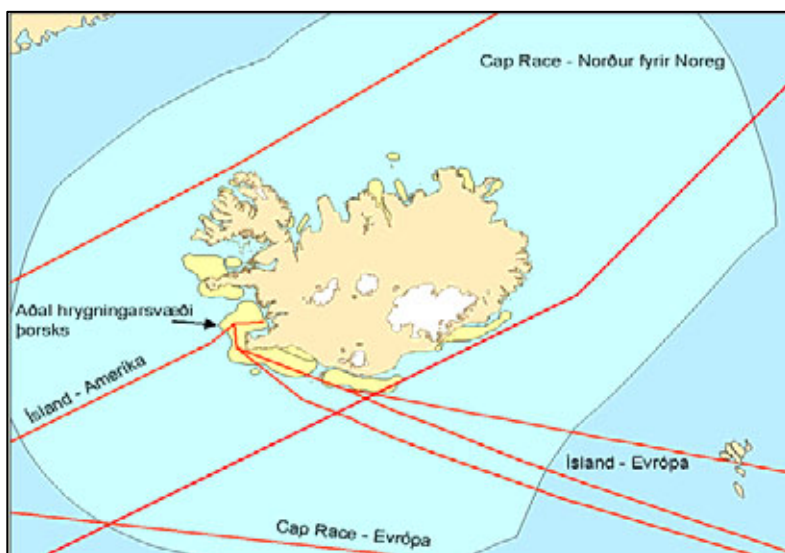


Fig. 2. Main spawning area of the Atlantic Cod (*Gadus horhua*) in Icelandic waters, and the main sailing routes within the Icelandic Exclusive Economic Zone, before the protective measures off S- and SW coast come into effect (see Fig. 3).

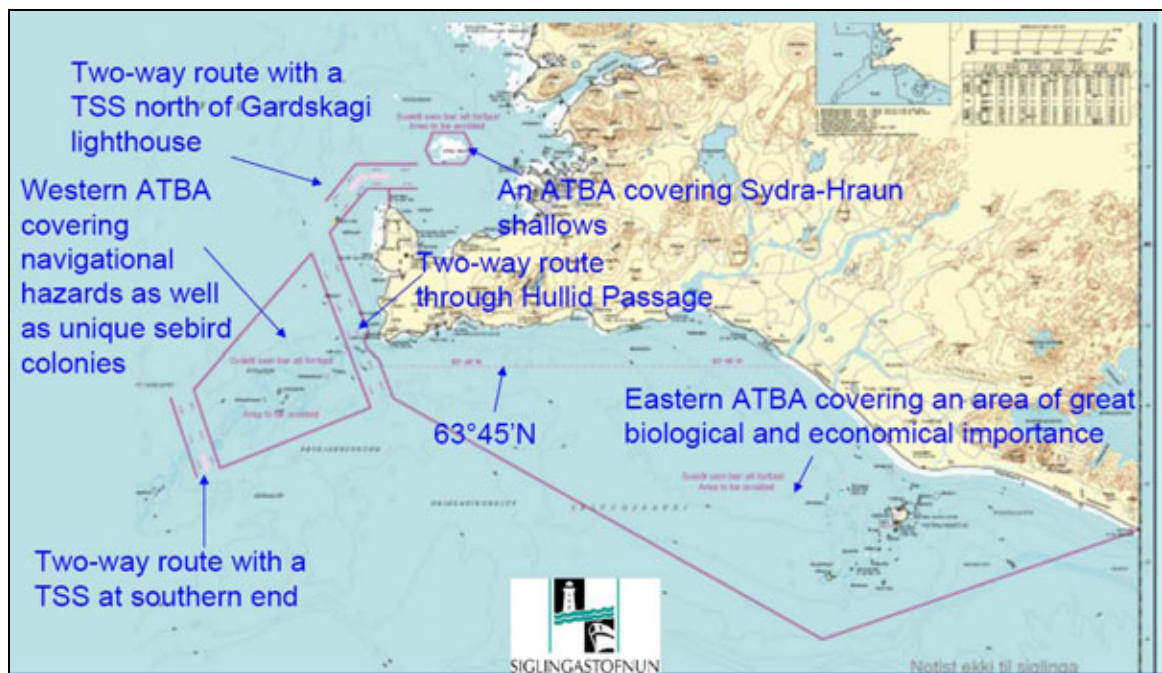


Fig 3. The newly accepted routing measures and three sensitive areas to be avoided (ATBA) off the S- and SW coast of Iceland (from the Icelandic Maritime Administration).

### 3. Vestmannaeyjar Local Plan (Section 5.d)

The Physical Master Plan for Vestmannaeyjar community for the period 2002-2014 was adopted by the local government at 10 January 2005 and approved by the Minister for the Environment on 4 March 2005. The Master Plan, *Aðalskipulag Vestmannaeyja 2002-2014*, is accessible, in Icelandic only, on the internet at the local government website:

<http://www.xtreme.is/vestmannaeyjar.is/index.php?p=100&i=483>

The Master Plan acknowledges and confirms the protection status of Surtsey. The Master Plan dates before the enlargement of the Surtsey Nature Reserve in January 2006 and therefore does not adequately reflect the current size and the protection status of the Surtsey volcanic system within the protected area. This does however not affect the protection status of the nature reserve as stipulated in the advertisement of the nature reserve on Surtsey island from 2006.

Section 4.13.3, of the Master Plan titled "Areas on Heimaey not mentioned in other sections" describes land-use in the Vestmann islands which are, all but Surtsey, leased by associations of local people for traditional land-use, i.e. sheep grazing and sea-bird hunting. The following text at the end of the section "Surtsey is protected and all excursions to the island are subject to a permission by the Surtsey Research Society which has a hut on the island." confirms the protection status of Surtsey. Since 2006 the Environment and Food Agency is however responsible for permitting research excursions to Surtsey. Section 4.19, called "Nature Conservation Areas", specifically deals with conservation areas and protected areas as classified in the Nature Conservation Act. All of the Vestmann islands are conservation areas according to the Nature Conservation Registry of the Ministry for the Environment and adequately identified as such in the Master Plan. The main objectives of the Master Plan for these areas are to promote traditional and sustainable use in bird hunting and egg collecting and that appropriate conservation status, to retain uniqueness, nature and traditions of the islands and to retain natural features, landscape and biota on Heimaey and to protect areas identified by the Nature Conservation Registry, which are according to section 4.19.3.2 in the Master Plan, Elliðaey, Ystiklettur, Hellisey, Súlnasker Helgafell and Eldfell. Other islands are covered by local conservation plan and the Ministries Nature Conservation Plan for 2004-2008 which covers all of the islands as indicated on the Master Plan Map by a

blue circle (Map 1. Aðalskipulag Vestmannaeyja 2002-2014, Vestmannaeyjar, Sveitafélagsuppráttur 1:50.000).

#### 4. Management Plan (Section 5.e)

A draft Management Plan for the Surtsey Nature Reserve is attached as a separate document. The Management Plan has not been finished and needs to be discussed and approved by the Surtsey advisory committee and the Environment and Food Agency and then adopted and signed by the Minister for the Environment. It is anticipated that the Management Plan can be adopted in the spring of 2008.

#### 5. Funding and staffing (Section 5.f)

The Surtsey World Heritage project will be financed by the state and the local government. The initial funding plan is based on a total of 1,5 staff units divided between three main projects. First is the general project management of the Surtsey visitor centre, the second is the necessary environmental research and monitoring in Surtsey and the third is a ranger position during the summer to guide and inform tourists in the Vestmann islands about the protected area Surtsey Nature Reserve and its relationship with the other Vestmann islands.

The relevant funding agencies are the Environment and Food Agency, The Icelandic Institute of Natural History and the Vestmannaeyjar municipality. The funding model is two fold. First is the base funding for housing, exhibition and equipment and secondly, the annual management cost for salaries, renting and general overheads. The Vestmannaeyjar municipality will build a house to accommodate the visitor centre as a part of a much larger project initiated to restore the cultural, social and scientific activities in the community. Hence, the building will harbour various interlinked activities which will have a great beneficial effect for the whole operation located in the building.

There will be no entrance fee to the visitor centre as it is mainly set up as an information and education centre. Annual revenues will only come from sales of various goods. However, estimations indicate that a visitor centre has a great potential of being a tourist attraction giving the local community revenues.

**Table II.** Summary showing staffing and funding for the Surtsey Visitor Centre for the first four years of operation. Funding is indicated in US\$.

	2007	2008	2009	2010	2011
<b>Staff and housing</b>					
Permanent position		50%	100%	100%	100%
Exhibit and sci. material 25%		X	X	X	X
Assistant posit. 25%			X	X	X
Surtsey exhibition	567,000				
Housing			100,000	100,000	100,000
<b>Funding</b>					
Environment and Food Agency	117,000	200,000	200,000	200,000	200,000
Icelandic Institute of Natural History	284,000	20,000	20,000	20,000	20,000
Ministry for the Environment	83,000				
Ministry of education, Culture and Science	83,000				
Local Authorities			25,000	25,000	25,000
<b>Summary</b>	<b>567,000</b>	<b>245,000</b>	<b>245,000</b>	<b>245,000</b>	<b>245,000</b>

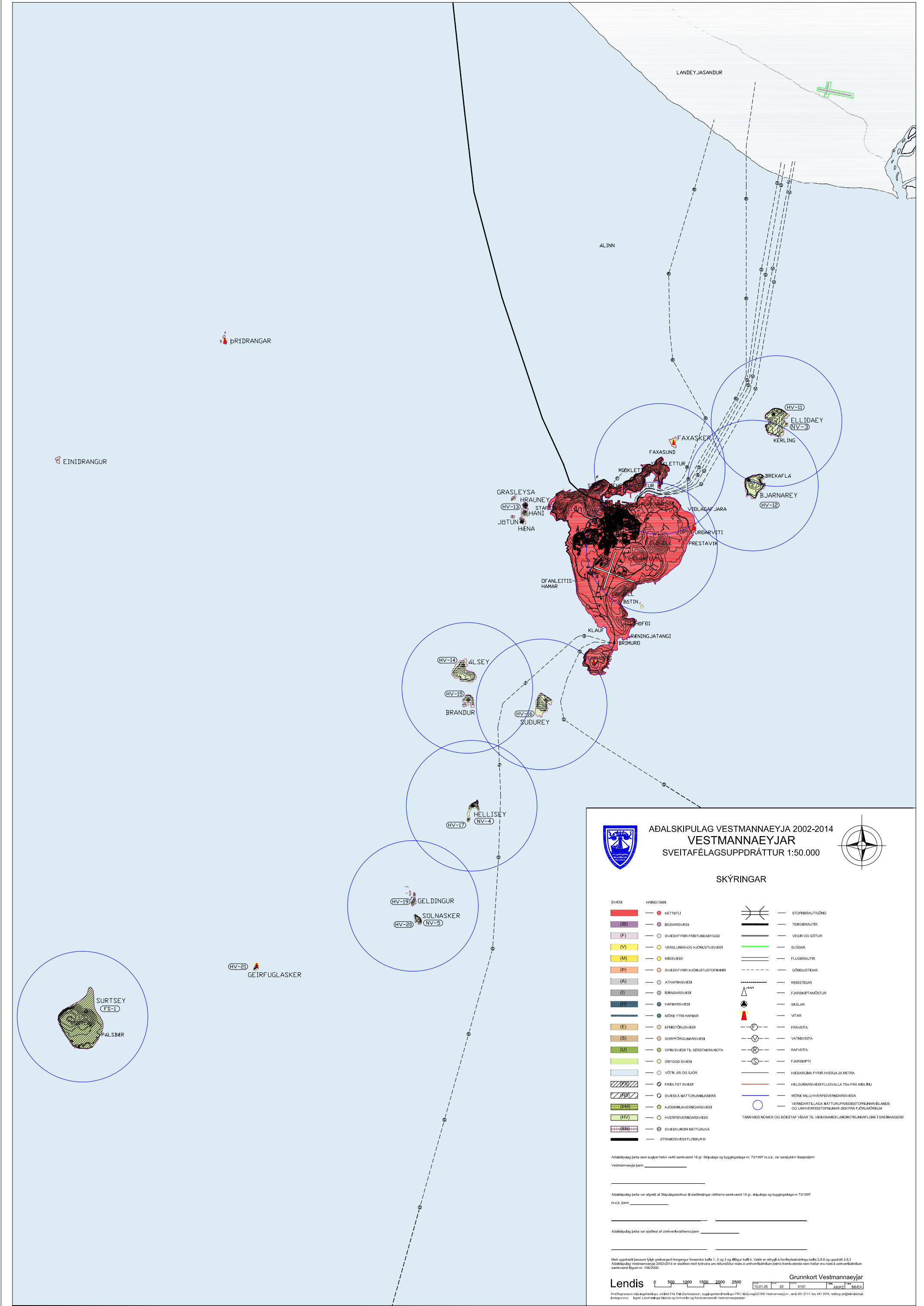
#### **6. Visitor numbers and facilities (sections 5.h, and 5.i)**

Approximately 50.000 tourists visit the Vestmann Islands/Heimaey every year. Through the years, excursions around Surtsey (flights and boat trips around the island) have not been the number one choice for tourists. However, this has changed in the past few years. Since Surtsey was listed on the Icelandic Tentative list as a possible nomination to the World Heritage List there has been a growing interest in excursions to Surtsey. Last year about 300 people went on an extra tour around Surtsey. Travel agencies in the Vestmann Islands claim they have never had as many requests for excursions to Surtsey as last year. The Surtsey Visitor Centre in Heimaey will definitely promote Surtsey and awaken people's interest in learning more about the island and its development and unique geographic history. The Surtsey exhibit in the Icelandic Culture House in Reykjavík has been very popular amount tourists and will definitely be a valuable addition to tourist activities in the Vestmann islands when the exhibition will be transferred to the Surtsey Visitor Centre in Heimaey in 2009.

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ÞRÍDRANGAR

EINIDRANGUR

GRASLEYSA  
HRAUNEY  
STAFHANI  
JÖTUN  
HÉNA

DFANLEITIS-  
HAMAR

HV-14  
ALSEY

HV-15  
BRANDUR

HV-16  
SUBUREY

HV-17  
HELLISEY  
(NV-4)

HV-18  
GELDINGUR

HV-20  
SÖLNASKER  
(NV-5)

HV-21  
GEIRFLUGLASKER

SURTSEY  
(FS-1)

PÁLSBÆR



ADALSKIPULAG VESTMANNAEYJA 2002-2014  
VESTMANNAEYJAR  
SVEITAFÉLAGSUPPDRÁTTUR 1:50.000



SKÝRINGAR

SVEIÐI	HRINGTÆNI	SKÝRINGAR
(R)	●	STORBRAUTGÖNG
(IB)	○	TENGBRAUTIR
(F)	○	VEGR OG GÖTUR
(V)	○	SLÓÐAR
(M)	○	FLUGBRAUTIR
(B)	○	GÖNGUSTEGAR
(A)	○	REIÐSTIGAR
(I)	○	FJARSKIPTAMÖSTUR
(H)	○	SKÁLAR
(E)	○	VITAR
(S)	○	FRÁVEITA
(U)	○	VATNSVEITA
(O)	○	RAFVEITA
(N)	○	FJARSKIPTI
(P)	○	HEDARLINA FYRIR HVERJA 20 METRA
(Q)	○	HELGUNARSVEIÐI FLUGVALLA 75m FRÁ MIÐLINU
(R)	○	MÖRK MELLI HVÆRISVEIÐARSVEIÐA
(S)	○	VERNDARTELLAGA NÁTTURLIFRÆÐISSTOFNANNA-ILANDS OG UMHVÆRISSTOFNANNA 20M FRÁ FJÖRUMÖRKUM
(T)	○	TÆKI MÍÐ NÚMÉR OG BÓKSTAF VÍSAR TIL VIÐKOMANDI LANDMÖRKUNARFLÖKKI I GREINARGERÐ
(U)	○	
(V)	○	
(W)	○	
(X)	○	
(Y)	○	
(Z)	○	

Adalskipulag þetta sem auglýst hefur verið samkvæmt 18 gr. Skulpslags og byggingarlaga nr. 73/1997 m.s.b. var samþykkt í Bjarstjórn Vestmannaeyja þann \_\_\_\_\_

Adalskipulag þetta var afgreitt af Skulpslagstjórnunni til staðfestingar ráðherra samkvæmt 19 gr. skulpslags og byggingarlaga nr. 73/1997 m.s.b. þann \_\_\_\_\_

Adalskipulag þetta var staðfest af Umhverfisstofnun þann \_\_\_\_\_

# Nature Reserve Surtsey

(Proposed World Heritage Site)



Management Plan  
2007 - 2017

# SURTSEY NATURE RESERVE – DRAFT MANAGEMENT PLAN

Surtsey Nature Reserve, (Proposed World Heritage Site) Management Plan 2007-2017

Project management:

Authors:

Maps:

Photographs: Source is given at individual photograph

Front cover photographs:

Back cover photographs:

Drawings:

Maps and graphics:

Cover and lay-out:



# SURTSEY NATURE RESERVE – DRAFT MANAGEMENT PLAN

Language assistance:

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## **Preface**

## **Acknowledgments**

# SURTSEY NATURE RESERVE – DRAFT MANAGEMENT PLAN

## 1 INTRODUCTION

Surtsey is completely natural site, a designated Nature Reserve and therefore being a national and international Protected Area of considerable conservation significance, its development and evolution will be strictly governed by the principles of natural succession. Therefore any colonisation by plants and animals, all biotic succession and the shaping of any geological formations will be allowed to evolve without human influence in as natural a manner as is possible and the area will always be an exemplary example of assemblage of natural features which have evolved on an emergent maritime landmass.

The Declaration of Conservation for Surtsey *inter alia* recognises not only these circumstances but also the outstanding scientific values and unique nature conservation values of the area, both in a national Icelandic and international context.

The Surtsey Nature Reserve was established in 1965, with the sole intention of protecting its geological and biological features. The Nature Conservation Council, now the Environment (and Food) Agency of Iceland, recommended that the island was declared as a Nature Reserve by the Minister of Education, Science and Culture during and after the eruption stage (November 1963 - June 1967).

Following changes in the environmental legislation in 1971, the protection criteria for the Nature Reserve were slightly amended. In January 2006, a new and revised Declaration for the Surtsey Nature Reserve was issued. The boundaries of the area were expanded to ensure that the protection of the entire Surtsey volcanic system, both above and below the sea surface could be achieved. (See the Notification of the Nature Reserve on Surtsey island, No.50/2006).

The Surtsey Nature Reserve since its inception in 1965, has *de facto* been managed in conformity with the requirements of an IUCN category 1a Strict Nature Reserve, i.e. a Protected Area managed exclusively for science.

### **The purpose of this Management Plan**

The Surtsey Nature Reserve Management Plan 2007 - 2017 not only details what is unique and of outstanding universal significance about Surtsey, but also sets out a long term Vision for integrated conservation management of the area and its key features.

The statement also sets out a management framework for the site through a series of Principles which will be guide the management of the site in conformity with the requirements of the World Heritage Convention. These are supported by other more specific Management Objectives and the rationale for them, which will be implemented over the ten-year period of this Management Plan. Collectively these will achieve the desired management outcomes and the longer term Vision for the island.

To help understand the context for the management of the property, a description of the site is included along with a summary of the current legislation associated with its protection. In addition a further commentary demonstrates how the Management Authorities will respond to any risks which could threaten the integrity of the natural features and / or character of the proposed World Heritage Site.

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Collectively these elements of the Plan define the basis for monitoring the State of Conservation of the property and the process for the site's Periodic Monitoring should it be inscribed.

### Key elements of the Management Plan

The island of Surtsey has been managed solely for nature conservation purposes ever since the land emerged from the sea. This has been reinforced in a legal sense since the adoption of the Surtsey Nature Reserve Declaration by the Minister of Education, Science and Culture on 19<sup>th</sup> May 1965.

A new Declaration came into force in 1974, pursuant to the revised Act on Nature Conservation, No 47/1971. A third Surtsey Nature Reserve Declaration was issued by the Minister for the Environment in January 2006. Following this latter Declaration, the Reserve was enlarged to incorporate the entire Surtsey volcano, to include its entire geomorphologic mass upwards from the sea bed, together with a significant marine area which surrounds it. The Codes of Conduct and conservation provisions within the Declaration are based on the Nature Reserve Act, No. 44/1999.

This Management Plan for the Surtsey Nature Reserve, 2007-2017 provides a long-term vision for management of the Reserve, along with a comprehensive statement of the detailed management goals and objectives for the site. These include in particular those measures which are necessary to achieve the effective and integrated conservation of the site, the programmes of research and monitoring which will be required to ensure that its scientific value is fully understood and finally the approach which will be adopted to enable its values to be more fully appreciated, interpreted and understood by those who visit the island.

The following themes therefore provide the guiding principles for this Management Plan:

- In accordance with the Surtsey Nature Reserve designation, the use of the island will be restricted to the conservation of its natural biological and geomorphological values and the retention of the long term integrity of its natural values.
- The Surtsey Nature Reserve will be managed as an exemplar of conservation management, with the needs of natural conservation and research viewed and undertaken in an integrated manner.
- The site's natural heritage values and natural processes will remain protected from external and human intervention to ensure that its natural values are safeguarded and can evolve naturally.
- The conservation of the marine environment along with any features in it; will be afforded equal status and the same degree of protection as their adjacent land areas.
- Any development or works undertaken on the island will only be permissible if the effect of it on area's natural significance, are fully and properly evaluated and it is proven that they will not to have any detrimental or unacceptable impact or effect upon the natural features, landscape or the qualities of wildness associated with the island and its surroundings.

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- Any scientific research that increases the understanding of the heritage features of the Reserve or guides their improved management so that its outstanding universal values are more effectively protected will be encouraged.
- Collaborative education and interpretation programmes will be developed to instil a long term appreciation of not only the qualities of this unique site but also the increase the public's awareness of the importance of its sustainable conservation management.

### The World Heritage Convention in Iceland

The World Heritage Convention was adopted by the General Conference of UNESCO at its Seventeenth session in November 1972. This Convention introduced to the world the concept of '*Outstanding Universal Value*' and the need to conserve such values as part of the World Heritage of Mankind.

The Convention also imposed the duty on the World Heritage Committee to establish and maintain a list of *World Heritage* properties of Outstanding Universal Value, which are representative of the global inheritance of the planet's cultural and natural values.

The World Heritage Convention came into force in 1974 with Iceland ratifying it in December 1995 and submitting its first nomination in 2003. In the Summer 2004, Þingvellir National Park was inscribed onto the World Heritage List as a cultural landscape under Criteria 24(a) iii and vi of UNESCO's Operational Guidelines (July 2002).

Although the Þingvellir National Park is currently the only Icelandic site included on the World Heritage List, the Icelandic Government subsequently nominated the Surtsey Nature Reserve for inclusion on the World Heritage List in 2005. The Surtsey Nature Reserve was proposed for inclusion on the World Heritage list under Criterion viii as

*" an outstanding example which represents a major stage of earth's history, a record of life, an example of a significant ongoing geological process in the development of landforms, and a significant geomorphic or physiographic features."*

The site is also nominated under Criterion ix because it represents

*"... an outstanding example of the significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals."*

In accordance with the criteria outlined in the World Heritage Operational Guidelines, the Government acknowledged that any such nomination should include an effective management framework which demonstrates that there is an appropriate legal protection framework to secure the long-term protection and conservation of World Heritage Sites.

This Management Plan statement demonstrates how the Island of Surtsey will be managed in perpetuity to fulfil the requirements of both the criteria of Article 11.5 of the Convention and

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the requirements of paragraph 77 of the Operational Guidelines thereby protecting the unique and outstanding universal natural values of the site

### *The Surtsey World Heritage Site*

The Surtsey Nature Reserve was proposed for inscription as a natural World Heritage site having been included on Iceland's World Heritage sites tentative list following a decision of the Icelandic Government in December 2005.

The justification for its nomination, stem from the principles of sound scientific observation and research associated with the evolution of its natural and biological values since the creation of the island in 1963 and its subsequent evolution to date.

### *The need for and role of this Management plan*

The Nature Conservation Act became effective in July 1999 (No. 44/1999) and outlines the conservation role of the Environment (and Food) Agency of Iceland. Amongst its duties the Agency is responsible for overseeing the preparation of Management plans for nature conservation areas. Nature Conservation area as defined in Article 3 of the Nature Conservation Act include:

- Protected Areas, i.e. national parks, nature reserves, country parks, and natural monuments.
- Other areas and natural phenomena on Iceland's Nature Conservation Registry.
- Areas demarcated on land or at sea which are protected by other Acts because of the importance their landscape or nature features.

Article 7 of the Declaration, (i.e. the Notification of Surtsey Island as a Nature reserve), also highlights the fact that it is permissible for certain structures to be allowed on the island<sup>1</sup>

This statement therefore represents the first Management Plan for the Surtsey Nature Reserve. It specifies how the outstanding universal value of the island will be preserved and indicates how the current management systems and approach will be enhanced to ensure that the island will be effectively protected for present and future generations.

The primary purpose of this Plan is to ensure that the natural heritage of the island and its surroundings are protected in a balanced, sustainable and integrated way. The Authorities responsible for this Plan and its implementation will therefore build and maintain effective partnership arrangements. In so doing they recognise the need for all the relevant stakeholders to support the aims and objectives of this document.

The Environment (and Food) Agency of Iceland has used the evidence and data in the UNESCO WORLD Heritage Nomination dossier for Surtsey as a primary source of information for this Management Plan.

This Management Plan was approved by the Nature Reserve Advisory Committee for Surtsey Nature Reserve and the Minister for the Environment at its meeting in **December 2007**.

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<sup>1</sup> A hut and the helicopter landing platform are permissible.

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### ***Other Plans of relevance to the management of Surtsey***

In addition to this Management Plan, the other plans which are of relevant to the management of the Surtsey Nature Reserve are the Municipal Plan for Vestmannaeyjar Archipelago, published in accordance to the Planning and Building Act, (4 March 2005) the Nature Conservation Strategy, published in (Parliamentary year 2003-2004) in accordance with the Nature Conservation Act no 44/1999 and the Icelandic Contingency Plan for Oil Pollution Incidents (October 2007).

### **The Municipal Plan for the Vestmannaeyjar Archipelago**

The entire Country within which Surtsey is located is subject to provisions and requirements of Iceland's Planning and Building Act, no. 73/1997, no. 135/1997 and no. 58/1999. A Municipal Plan is the Development Plan for a specific municipality and details a Local Authority's policies in respect of land use, the development of settlements in the municipality over a period of at least 12 years, as well the transportation, service systems and infrastructure and environmental matters anticipated during this period.

The *Municipal Plan for the Vestmannaeyjar Archipelago*, 2002-2014, was confirmed by the relevant Local Government and ratified by the Minister for the Environment on 4 March 2005. The *Municipal Plan for the Vestmannaeyjar Archipelago* confirms the Government's intention to protect the entire archipelago as a managed nature reserve, while allowing sustainable use of its natural resources where these two issues are compatible.

### **The Nature Conservation Strategy, 2004-2008**

A *Nature Conservation Strategy, 2004-2008*, was confirmed by the Icelandic Parliament in 2004. This Strategy, (reviewed every five years), is meant to ensure the protection of a representative sample of Iceland's biological and geological diversity, as well as sites of outstanding natural beauty or of cultural or historic significance.

A significant part of the Vestmannaeyjar archipelago is scheduled for protection under the provisions of the Nature Conservation Strategy, 2004-2008. The foremost reason for this is to ensure that the rich birdlife of the Vestmannaeyjar archipelago, along with its characteristic and spectacular landscape, are protected and the profile and importance of the scientific and educational value of their geomorphology are increased. A Declaration on Vestmannaeyjar habitat nature reserve will be published in the near future.

### **The Icelandic Contingency Plan for Oil Pollution Incidents**

The Surtsey Nature Reserve is an area specifically included as a vulnerable area in the Icelandic Contingency Plan for oil pollution incidents. An automatic notification / identification system covers all Icelandic territorial waters and every vessel that carries a cargo of oil and/or any other hazardous cargo, within the Icelandic Pollution Prevention Zone is required to register and report to the Icelandic Coast Guard Maritime Traffic Service.

To enlarge the area classified as vulnerable a new proposal was put forward to the International Maritime Organization (IMO) to declare the area south of Icelandic, demarcated from Dyrhólaey, south of Surtsey, south of Eldey on Reykjanes peninsula, as an Area To Be Avoided.

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This proposal has now been accepted by the Maritime Safety Committee (MSC) at its meeting in Copenhagen 3-12 October 2007, and will come into effect 1 July 2008.

### **Other Regulations affecting the Site**

A temporary ban on towed bottom fishing gear was introduced by the Ministry of Fisheries in March 1998 (Article 3, Regulation no. 148/1998.)

## 2 Description of the Reserve

The Plan area is located in the Municipality of Vestmannaeyjar and is bounded by latitudes 63°16'N and 63°20'N and longitudes 20°31'W and 20°41'W. (See the accompanying location map). It also coincides with the strictly protected part of the nationally designated Surtsey Nature Reserve.

The 33.7 km<sup>2</sup> of the property comprises and encompasses the entire Surtsey volcano, of which 1.4 km<sup>2</sup> is above the sea's surface, 13.2 km<sup>2</sup> which is submerged and an area of 19.1 km<sup>2</sup> of surrounding ocean. An additional 31.9 km<sup>2</sup> of the Surtsey nature Reserve has been defined as the buffer zone for this property for the purposes of this Plan.

### *Introduction to the Reserve*

The island of Surtsey is a part of the Vestmannaeyjar archipelago located south of Iceland's southern coast. The archipelago consists of 18 islands and a number of skerries situated on the submarine shelf off the south central coast of Iceland.

Heimaey is the largest island (13.6 km<sup>2</sup>) and the only one inhabited with a population of 4,200. There is a single town named Vestmannaeyjar, the most important fishing harbour along the south coast of Iceland.

*Here will be the complete description of the Nature Reserve's topography, geology, climate, terrestrial life, vegetation, birds, marine life is included in Chapter 2, of the nomination dossier.*

### *The Socio-Economic Context and tourism at the Site*

Tourism is an important element of the economy of the Vestmannaeyjar archipelago. In addition to the tourist attractions on Heimaey, it is anticipated that a new visitor centre on Surtsey in the town of Heimaey will increase the attractiveness of the islands to visitors.

Local entrepreneurs have previously indicated their desire to increase tourism to and on the island. This interest arose when a local Parliamentary representative formally asked in Parliament whether there were any plans to allow further tourist access on Surtsey. In response, the Minister for the Environment stated quite clearly that there were no plans to alter the existing access restrictions on Surtsey.

Accordingly there are no existing or proposed tourist facilities on Surtsey and there are no plans to erect tourist facilities in the Nature Reserve. The Surtsey Nature Reserve Declaration clearly states that it is prohibited to go ashore on the island or to dive near the island except for research or related activities. These arrangements will continue.

### **Access to the Property**

In accordance with the Nature Reserve Declaration, access to Surtsey is only permitted for scientific research, the maintenance of properties and for licensed documentary filming or photography.



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Although tourists are prohibited from going ashore, it is possible to view the island from the air as aerial sightseeing tours are organised from Reykjavík and the town of Vestmannaeyjar. Aerial sightseeing when undertaken in a controlled and responsible manner provides an excellent means of viewing the island, its geological formation and bird life. There are opportunities for boat trips from the harbour of Vestmannaeyjar around the islands.

Access and transportation for those permitted to go ashore for research purposes or for maintaining of properties such as Pálsbær, travel by helicopter or by boat to the island but the again is strictly regulated through a licensing procedure. To enable such trips to take place a helicopter platform exists on the island but there is no harbour.

All individuals and/or parties visiting Surtsey Nature Reserve, wanting to go ashore or to dive in the Nature reserve, must possess an official permit from the Environment (and Food) Agency of Iceland prior to their visit.

### Interpretation and Education

At present all interpretation and education relating to Surtsey Nature Reserve take place outwith the Nature Reserve. Any future education and interpretation plans and programmes will continue to be delivered in this way, the focus for their delivery being through a proposed new visitor centre in the offices of the Environment (and Food) Agency in the town of Heimaey, on the island of Heimaey. These programmes will aim to increase awareness of the importance of the Nature Reserve and the approaches which are being promoted to protect and enhance its natural heritage values.

To ensure that the centre is adequately serviced, staff from the Environment (and Food) Agency will work in close collaboration with the local Municipality and Research institutions including the South Iceland Nature Centre and the Vestmannaeyjar Research Centre. The Agency has prioritised resources to ensure that the proposed centre is adequately staffed and facilities provided which support the conservation messages relating to the Nature reserve.

During 2008, the Agency will in cooperation with the local Municipality, commence work on the design of the visitor centre and its associated office facilities. In due course the *Surtsey-Genesis* exhibition currently exhibited at the Culture House in the National Centre for Cultural Heritage in Reykjavík, will be transferred to the proposed new visitor centre on Heimaey by 2009.

The *Surtsey Genesis* exhibition traces the emergence and evolution of the island Surtsey up to the present day and predicts its geographical and ecological development over the next 120 years. The latest multimedia techniques are used to convey the invaluable findings of scientific research in Surtsey.

The 1963 - 1967 oceanic eruptions were the longest period of volcanic activity in Iceland in historic times and the genesis and emergence of a new land mass sparked worldwide attention by scientists and the public alike. Surtsey was declared a Nature reserve in 1965 and has from its creation has provided as a living laboratory for scientists to study volcanology, tuff formation, land formation and its erosion, the colonisation of virgin land by plants and animals and the processes of ecological succession.

The exhibition explains also explains the reason and decisions taken by the Icelandic Authorities for

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nominating Surtsey as a candidate for inclusion on the UNESCO's World Heritage List as a natural phenomenon. It also explores why Icelandic scientists believe the site is unique amongst the earth's volcanic islands.

[www.thjodmenning.is](http://www.thjodmenning.is)

### Data sources and information about Surtsey.

The Surtsey Research Society has collected and collated information on Surtsey ever since its creation. The Society maintains a website [www.surtsey.is](http://www.surtsey.is) on the origin and development of Surtsey and its associated ecosystem. The website also contains information about the Society, its scientific work and the scientific reports that it has published relating to the island. Other sources of information on Surtsey and its environs include:

The Environment (and Food) Agency of Iceland	<a href="http://www.ust.is">www.ust.is</a>
The Icelandic Institute of Natural History	<a href="http://www.ni.i">www.ni.i</a>
The Vestmannaeyjar Research Centre	<a href="http://www.setur.is">www.setur.is</a>
The South Iceland Nature Research Centre	<a href="http://www.nattsud.is">www.nattsud.is</a>
The Vestmannaeyjar Municipality	<a href="http://www.vestmannaeyjar.is">www.vestmannaeyjar.is</a>
Heimaslóð - Vestmannaeyjar	<a href="http://www.heimaslod.is">www.heimaslod.is</a>

### *Buffer zone*

In January 2006, the Surtsey Nature Reserve boundary was amended to include a large buffer zone, covering 65.6 km<sup>2</sup> in total.

Fishing is permitted within the buffer zone, but construction, mining and the use of firearms are prohibited.

### *Zoning of the site*

Following the Declaration of Surtsey as a Nature Reserve, the area is now delineated into three distinct management zones,

- The area of Surtsey island above the sea (1.4 km<sup>2</sup>),
- The submerged part of the Surtsey volcano and the ocean which surrounds it (32.3 km<sup>2</sup>)
- The buffer zone of the Surtsey Nature Reserve (31.9 km<sup>2</sup>).

### *Land use*

No human activity or the permanent imprint of man exists on the Surtsey Nature Reserve. The island is therefore characterised by its wild, natural and untouched appearance. The land and its surrounding seas are actively managed to conserve this character and the important natural heritage values of the site. This regime of management provides the best way to maintain the property's key features and as well as providing a model of best practice conservation management of a naturally evolving ecosystem.

All management measures will seek to ensure as far as is possible that the prevailing natural processes and the associated features they create remain undisturbed by man. Positive intervention will only occur when it is necessary to protect any critical or significant natural features from unacceptable alteration or deterioration. In such cases, decisions will be made

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on a case-by-case basis and in a manner which ensures that any action which could create disturbance to other natural features and processes, can be reversed.

### 3 OWNERSHIP, MANAGEMENT AND PLANNING

#### *Ownership of the Site*

The Surtsey Nature Reserve is owned by the Icelandic State and protected according to the Nature Conservation Act, No. 44/1999, which applies to Iceland, throughout its territorial waters and also to its exclusive economic zone. The Municipality of Vestmannaeyjar is the physical Planning Authority for the area.

#### *Agencies with an active interest in the Site*

In addition to the Icelandic State, the owner of the property, the following have an interest in the Nature reserve.

#### **The Environment (and Food Agency) of Iceland;**

This Agency has the duty to protect and supervise the Nature Reserve. A six-member Executive Committee advises the Agency on matters relating to the management of the Nature reserve. Its members include representatives of the Surtsey Research Society, the Icelandic Institute of Natural History, the Marine Research Institute, the Environment (and Food) Agency of Iceland and the Municipality of the Westman Islands.

#### **The Icelandic Institute of Natural History:**

This Institute in accordance with the Declaration conducts research and regular monitoring of the natural conditions in the Nature Reserve.

#### **The Marine Research Institute:**

This Institute conducts research and regular monitoring of the natural conditions in the marine environment.

#### **The Surtsey Research Society:**

This Society coordinates research and furthers scientific knowledge about the Surtsey Nature Reserve.

#### **The Municipality of the Westman Islands:**

The Municipality is the Unitary Planning Authority for the island archipelago and is responsible for all local planning within the Westman Islands.

Other agencies with an interest but with no statutory duties or responsibilities under the Declaration include,

- The Vestmannaeyjar Research Centre ([www.setur.is](http://www.setur.is)).
- The South Iceland Nature Research Centre ([www.nattsud.is](http://www.nattsud.is)).
- Vestmannaeyjar Museum of Natural History.
- Vestmannaeyjar Tourist Office ([www.vestmannaeyjar.is](http://www.vestmannaeyjar.is)).
- The Icelandic Maritime Administration ([www.sigling.is](http://www.sigling.is)).

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### *Protective designations on the site*

In 1965 the Nature Conservation Council (now The Environment (and Food) Agency of Iceland) recommended to the Minister of Education that Surtsey was declared as a Nature Reserve. The reasons for its request and the justification for its future management are to protect the island and its fragile surfaces and landscape and to ensure that any colonisation and succession of life and ecosystems which occur on them do so, under conditions of minimal human influence.

The protection criteria were slightly revised in 1974, in accordance with the new Nature Conservation Act of 1971. However, the island has *de facto* been managed as a Strict Nature Reserve and as a Protected Area primarily for scientific study strictly in accordance with the principles of an IUCN category Ia Protected Area.

### *The current Surtsey Nature Reserve Declaration*

In January 2006, the boundaries of the nature reserve were expanded to their current limits and a new and revised Declaration of a Nature reserve was issued. The decision to do so, was taken to ensure that the entire Surtsey volcanic system, both above and below the sea surface, including the transient islets Jólnir and Syrtlingur as well as the submarine ridge Surtla, were safeguarded.

The text of the complete Surtsey Nature Reserve Declaration, 26 January 2006 reads as follows:

## ADVERTISEMENT of Nature reserve on Surtsey island

### Art. 1

#### *Declaration of conservation*

The Minister for the Environment has, in consultation with the Minister of Fisheries and in accordance with the proposal of the Environment and Food Agency and the Icelandic Institute of Natural History, as well as with the consent of the municipality of Vestmannaeyjar [the Westman Islands], decided to renew the declared conservation of Surtsey in such a manner that the declaration of conservation shall apply to the entire volcano, whether above the surface of the sea or underwater, including the craters of Jólnir, Syrtlingur and Surtla, together with a specified area of ocean around the island. The protected area is conserved as a nature reserve in accord with Subparagraph 1 of the first paragraph of Art. 53 of the Act on nature conservation, No. 44/1999.

### Art. 2

#### *Objective of conservation*

The objective of declaring Surtsey a protected area is to ensure that development of the island will be in keeping with the principles of nature itself, as provided in Art. 1 of the Act on nature conservation. The purpose of conservation is to ensure that colonisation by plants and animals, biotic succession and the shaping of geological formations will be as natural as possible, and that human disruption will be minimised.

The declaration of conservation is based inter alia upon the great value of the area in scientific and nature conservation terms, both for Iceland and internationally; the area has complete and undisturbed natural features which reflect the developmental processes of nature, and which are highly sensitive to disruption.

### Art. 3

#### *Boundaries of the nature reserve*

The nature reserve includes Surtsey above sea level and down to the sea floor, together with an area of ocean around the island which is demarcated by a line drawn between four corner points; see the accompanying table. The coordinates of the points are designated by the ISN93 system and by longitude and latitude (degrees, minutes and seconds). The boundaries of the area are shown on the accompanying map.

Table Point	ISN93		Degrees	
	X coordinate	Y coordinate	Longitude	Latitude
1	415350	315875	20°41'15"	63°16'08"
2	423700	315875	20°41'15"	63°20'22"
3	423700	308020	20°31'16"	63°20'22"
4	415350	308020	20°31'16"	63°16'08"

### Art. 4

#### *Supervision of the nature reserve, etc.*

The Environment and Food Agency conducts the supervision of the nature reserve. A six-member advisory committee shall be appointed to advise the Environment and Food Agency on matters of the nature reserve and shall include one representative of the Surtsey Research Society, of the Icelandic Institute of Natural History, of the Marine Research Institute and of the Environment and Food Agency and two representatives of the municipality of the Westman Islands. The representative of the Environment and Food Agency shall be the committee chairperson. This committee shall be appointed to a term of four years.

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The Surtsey Research Society coordinates and seeks to further scientific research on Surtsey and inside the nature reserve boundaries. A special agreement shall be concluded in this regard, to be approved by the Minister for the Environment.

The Icelandic Institute of Natural History conducts research and the regular monitoring of natural conditions in the nature reserve, in cooperation with the Marine Research Institute and Surtsey Research Society.

### Art. 5

#### *Access to the nature reserve*

It is prohibited to go ashore on Surtsey or to dive by the island except for research purposes and related activities and with the written permission of the Environment and Food Agency.

Vessels are permitted to travel within the reserve around Surtsey.

### Art. 6

#### *Conservation of vegetation, animal life and geological formations*

It is prohibited to disturb vegetation, animal life or geological formations or other natural features within the reserve.

It is prohibited to transport to the island live animals, plants, seeds or plant parts, or other organisms. Transporting minerals and soil to the island is also prohibited.

### Art. 7

#### *Land use and construction*

Construction, disturbing the earth, extracting materials and otherwise altering the land or the sea floor within the nature reserve are prohibited, except by permission of the Environment and Food Agency and the Westman Islands municipal council, upon their receiving the opinion of the Surtsey Research Society. It is permissible to maintain such structures as the Surtsey Research Society's hut (Pálsbær) and the helicopter landing facilities on the island, as hitherto and as is described in the conservation plan.

It is prohibited to bury waste or leave it on the island or within the boundaries of the nature reserve.

### Art. 8

#### *Fishing and use of firearms*

Fishing with fishing gear which is dragged along the sea floor, for instance bottom trawls, Danish seines or dredges, is prohibited in the nature reserve within the area bounded by the following points: 1) 20° 36'04" W and 63° 16'08" N 2) 20° 40'00" W and 63° 16'08" N 3) 20° 40'00" W and 63° 17'52" N 4) 20° 35'31" W and 63° 20'22" N 5) 20° 31'16" W and 63° 18'15" N. The use of firearms is prohibited within the nature reserve, both on land and at sea.

### Art. 9

#### *Exemptions*

Upon receiving the opinion of the Environment and Food Agency and the municipality of the Westman Islands, the Minister for the Environment may authorise departures from these rules in particular circumstances, and may provide in more detail for the conservation of the area.

### Art. 10

#### *Penalties*

Violation of the declared protection entails fines or imprisonment for up to two years.

### Art. 11

#### *Entry into force*

This declaration of protection shall take effect immediately. At the same time, the advertised Declaration No. 122/1974, of Surtsey as a reserve, expires.

*Ministry for the Environment, 27 January 2006*

*Sigríður Anna Þórðardóttir*

*Magnús Jóhannesson*

[Translation: Lingua / Norðan Jökuls ehf.]

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### *Additional protection afforded by the Nature Conservation Act.*

The Surtsey Nature Reserve is protected by the Nature Conservation Act, No. 44/1999 and as subsequently amended. The objectives of the Act are defined in Article 1 as:

*“The purpose of this Act is to direct the interaction of man with his environment so that it harms neither the biosphere nor the geosphere, nor pollutes the air, sea or water....*

*...The Act is intended to ensure, to the extent possible, that Icelandic nature can develop according to its own laws and to ensure the conservation of its exceptional or historical aspects...*

*...The Act shall facilitate the nation's access to and knowledge of Icelandic nature and cultural heritage and encourage the conservation and utilisation of resources based on sustainable development.”*

Other articles of the Nature Conservation Act which relate to the protection of Surtsey include:

- Article 37, which confers special protection *inter alia* to volcanic craters, pseudo craters (rootless vents) and lava fields.
- Article 38, which requires the authorisation of projects by the Environment (and Food) Agency of Iceland if there is any risk of damage to protected sites of natural interest.
- Article 53, which defines nature reserves as “*areas which it is important to preserve because of their special landscape or biosphere.*”

### **Regulations on fisheries within Surtsey Nature Reserve**

Regulation No. 148/1998 of Act No. 79/1997 relating to fishing within the Icelandic Fisheries jurisdiction, further restricts fisheries within the Surtsey Nature Reserve, by banning the use of bottom towed fishing gear in the defined buffer zone of the Reserve.

## 4 MANAGEMENT PRINCIPLES, ISSUES AND OBJECTIVES

### *Introduction*

This section defines the values of the property and explores the management issues and challenges facing the Nature Reserve. In addition it outlines a series of principles and broad management objectives which will guide and direct the long term management of the Nature reserve to ensure that its outstanding universal values are maintained.

The Plan in its entirety therefore provides a clear and comprehensive statement of the policies which will guide the future decision about the management of the island.

It would also be useful to include a statement here to make it clear that the process of natural evolution will occur and hence likewise so could the management principles need to be reviewed over time. E.g. The dynamic way in which the site changes cannot be totally predicted and hence this Plan will itself need to reflect a degree of flexibility to account for this fact.

### Overview of the current “State of Conservation” of the Reserve

The Surtsey Nature Reserve is a globally significant geological and ecological site. Since the eruptions created it, Surtsey has played an important role in the development of geological thinking, in particular in the science of volcanology.

The Surtsey Nature Reserve is globally unique and is of outstanding global scientific significance because of the combination of ecological features and biophysical processes that now exist since the island’s creation. The fact that these processes have not been affected by any discernible human influence means that no other maritime site exists in the world where these circumstances are replicated.

There needs to be a Section added in here which makes two things clear

1. What are the outstanding universal values of the sites which make it so important as identified in the nomination dossier
2. A statement which summarises the overall condition of the conservation value of these special qualities.

From the point of view of cross referencing and reinforcing the nomination dossier, it would be best to indicate which particular species, ecosystems or aspects of the site are truly unique in a global sense and a short synopsis of those aspects of the site which are in a “favourable condition” and those which are not.

The policies which follow in this Plan can then demonstrate not only what overall management approaches are needed to safeguard the site but also the priorities which you have to get those asset which are not in favourable condition, into such a state.

You may also want to move this section about the State of Conservation forward in the text to the Section which describes the site. It is always helpful for the reader to know exactly why the site is important as soon as possible in the document



## **Our ten year VISION for the Surtsey Nature Reserve**

*Sensitive management of the Surtsey Nature Reserve will ensure that it is a globally significant natural phenomenon, internationally recognised for its natural values and high standards of the conservation management, scientific research and monitoring.*

*The island of Surtsey will remain a wild and remote place, protected, undisturbed and inaccessible to humans but increasing used by wildlife.*

*Its marine features will be protected from any threats from shipping, fishing, marine exploration and offshore energy development, through effective surveillance in and of the buffer zone around the island.*

### ***Principles for the management of Surtsey.***

To achieve this Vision, a set of principles will guide the actions and decisions of the relevant Management Authorities, agencies and organisations charged with caring for the future of the island.

These management principles are deliberately long term thereby providing management continuity and an informed means to make important decisions about the site. The suite of management principles are derived from the Surtsey Nature Reserve Declaration and tailored to reflect the present issues and future challenges facing this Protected Area. Individually and collectively the implementation of these principles will ensure that the evolution of the island's form and character including its submerged components will continue to remain in keeping with the natural evolutionary processes which affect it and in a manner which is free from human intervention.

#### ***Principle 1:***

***The outstanding universal value of Surtsey's unique geology, geological processes and landscape will be conserved and sustained.***

The principle places the conservation of the geological, geomorphological and landscape and seascape values of the Surtsey nature Reserve at the very core of the Management plan.

Its aim is to guarantee that the geomorphological processes follow natural evolutionary processes and pathways and are free from human intervention.

#### ***Principle 2:***

***The biological and ecological values of the nature reserve will be conserved and sustained***

The diversity and wider values of the biological and ecological features of the site are critical and need to be properly understood, conserved and promoted. The importance of these values

## SURTSEY NATURE RESERVE – DRAFT MANAGEMENT PLAN

will be fully accounted for in all decisions which affect the site to ensure that its values are protected and conserved. By so doing, biotic succession and the colonisation of the area by plants and animals again will be able to follow natural evolutionary processes and pathways free from human intervention.

### *Principle 3:*

*The submerged components and marine value of the nature reserve will be conserved and sustained.*

Special recognition and attention will be given to the values of the marine environment whether geological, geomorphological, biological or ecological. As before the importance of these values will be fully accounted for in all decisions which affect the site so as to ensure that the biotic succession and geomorphological processes follow natural pathways free from undue human influence or disruption.

### *Principle 4:*

*The socio-economic benefits of the reserve to local communities will be promoted through sensitive management and appropriate community engagement.*

In managing Surtsey and areas beyond, the needs of local people will be recognised and addressed. Maintaining the pristine conditions of the Nature reserve and promoting it as a high quality and distinctive visitor destination will be the platform for developing appropriate socio economic benefits. The site will be promoted as a repeat destination and visitors will be encouraged to stay longer on Heimaey and make return trip thereby increasing the economic multipliers in the local economy.

### *Principle 5:*

*Appropriate forms of orientation, interpretation and education will be provided to increase the public's understanding and appreciation of importance of the Nature reserve*

The need to embrace and promote the values and relevance of the natural environment, the philosophy of the conservation Declaration in a practical way and the outstanding universal significance of the Surtsey Nature Reserve are crucial. Education programmes will provide the public with a comprehensive overview of the importance of Surtsey and the rationale for managing the nature reserve in a pristine condition.

### *Achieving the effective management of the property.*

Developing an effective and integrated approach to the management of Surtsey is crucial for its future conservation and enjoyment. In addition and in order to ensure that the outcomes of the proposed management approaches are fulfilled, all the proposed management initiatives in this Plan will be monitored systematically, periodically and their objectives reviewed periodically during the operational period 2007-2017. This will be achieved by defining and setting targets for all the proposed management outcomes and reporting on how well they have been achieved using a series of simple, clear, appropriate and time related performance indicators. The Advisory Committee will be responsible for this review and it will take place as part of the Environment (and Food) Agency's Executive Annual reporting arrangements.

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### Management Objectives for the Surtsey Nature Reserve.

For the management of Surtsey to be successful, the Management Principles of this Plan need to be translated into an accompanying suite of more detailed Management Objectives and delivered through a costed and programmed approach. The Action Plan at the end of this document outlines the actual work which will be undertaken during the life of this Plan.

All the Objectives and the management outcomes proposed will be focused on protecting the conservation values of the site and encouraging their continual improvement. Collectively these Objectives will:

- Provide a coordinated framework for the integrated management of the Reserve and ensure that all its natural features and natural processes are maintained in a natural condition.
- Enhance the scientific understanding of the terrestrial environment of the Reserve and its surrounding marine environment.
- Establish effective and regular liaison arrangements with scientific and research agencies, local communities and non governmental organisations.
- Share any new information and knowledge about the island natural features and those of its surrounding waters with the widest possible audience.
- Establish education and interpretation programmes that promote a greater understanding of the Surtsey Nature Reserve and the relevance of its sustainable conservation management practices.
- Provide staffing and support facilities which will achieve the Vision for the island and meet its routine operational needs.
- Introduce appropriate protection and mitigation measures for all real and perceived threats to the island's key values.
- Increase the endowment fund needed to pay for the required level of management of the site.

To ensure that the above Principles are fulfilled, the Advisory Committee will adopt the following suite of Management Objectives.

### *Key Management Objectives*

#### *1. Conserving the values and significance of Surtsey*

The principal land use of the Surtsey Nature Reserve is nature conservation. Accordingly the island and its surrounding seas will be managed to reflect sound science and best possible management practice consistent with the protection and enhancement of the island's natural and heritage values.

All conservation management measures undertaken will seek to ensure that these natural processes and their associated features remain undisturbed by man. Any intervention which is necessary to protect the reserve's significant natural features from any unacceptable deterioration or unwanted hazards will be considered carefully. In such cases, decisions about the acceptability of any intervention will be made on an individual basis and in a manner which enables any management outcomes which are necessary to be reversed so that disturbance to other natural features and processes is minimised in the long term.

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The Icelandic Institute of Natural History in cooperation with the Marine Research institute and Surtsey Research Society will conduct monitoring and research programmes of the natural phenomenon within the Nature reserve. This approach will again reflect the statutory procedures and requirements of Article 4 of the Surtsey Nature Reserve Declaration.

### ***Objective 1.1:***

***Significant damage to the geological and geomorphological features, on either land or underwater will be prevented.***

The island and the surrounding seas will be managed to safeguard the importance and integrity of their natural heritage values. Management will reflect best practice and promoted as examples of international excellence in conservation management, for others to copy.

The only permitted developments and human intervention permitted on Surtsey is the maintenance of the hut Pálsbær and the helicopter platform. Neither the extraction of sand or gravel is permitted, nor any disturbance of the surface, including geological sampling for research purposes. Any such activities which are proposed require consent and an appropriate licence from the Environment (and Food) Agency.

Activities which threaten or damage the underwater geology and geomorphology are likewise not be permitted. In addition no action on the land surface of the island, including any geological sampling or disturbance of the ground will be permitted which will affect the integrity of any geological or geomorphological feature. All scientific research sampling will also be subject to the appropriate consent procedures.

No engineering or extractive works will be permitted in the inter tidal zone or offshore if it is likely to damage any features of the submerged physical environment through disruption, alteration of the current or wave patterns or through increasing the sediment load.

### **Anticipated Management Outcome:**

- *The island and its maritime surroundings remain unaffected by any impacts which threaten the integrity of their natural and geological features or values*

### **Performance Indicator**

- *The number of damaging incidents which occur each year.*

### ***Objective 1.2:***

***The landscape character of Surtsey will be maintained and enhanced.***

Surtsey is a designated nature reserve and its landscape character and natural features are of national and international importance. It is imperative that these outstanding qualities remain undamaged. To ensure that the international conservation status of the site is not compromised, no other land use except the management of nature will be permitted.

Currently there are only three visible man-made structures on the island. In 1967, the Surtsey Research Society erected the research field hut, "Pálsbær" close to the shore on the northern part of Surtsey. This site was gradually destroyed by ocean erosion and a new hut erected on the eastern part of the island in 1985.

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In addition to the hut, a helicopter pad was built near it in 1993. In the late 1980s the Icelandic Maritime Administration decided to erect a lighthouse on the island. After a few years, the lighthouse became obsolete, but its concrete foundation still remains in place. Apart from normal maintenance of the Pálsbær field hut and its eventual replacement, there are no plans for additional infrastructures on Surtsey.

Some development activities may be required for monitoring, research and conservation within the Surtsey Nature Reserve. Any development or renovations which are required will be subject to a full Environmental Impact Assessment in accordance with the Regulations and will be designed and implemented to ensure that they have minimal detrimental impact on the environment of the island.

The assessment of the acceptability of any work will take into account whether the development is essential, temporary and reversible. For any development to be acceptable, it must have minimal detrimental effect on the area's natural features, its landscape or the wilderness qualities of the Surtsey Nature Reserve.

### Anticipated Management Outcome

- *The concrete foundation of the lighthouse will be removed in 2 years.*
- *No new buildings or structures will be erected on Surtsey.*
- *A 5 year maintenance programme for the Pálsbær hut and the helicopter landing pad, including a risk assessment of the works, will be completed by July 2008.*
- *Any programme of coastal erosion measures will be produced by summer 2008 and agreed and costed by the Environment (and Food) Agency working with the Scientific Research Agency.*

### Performance Indicators

- *The extent to which each of these outcomes is achieved*

### **Objective 1.3:**

***Natural plant communities will be maintained in a favourable condition.***

As mentioned previously, natural processes will be allowed to continue without human intervention. Any potentially damaging works will be subject to the statutory consents procedures of the Environment (and Food) Agency before they are undertaken. To ensure the effectiveness of this, monitoring programmes of the vegetation on the island will be undertaken in accordance with the codes of Conduct of the Icelandic Institute of Natural History, as prescribed in the of Surtsey Nature Reserve Declaration (Notification, Art. 4).

As before any human activity which threatens or damage the significant features of the natural plant communities will not be permitted.

### Anticipated Management Outcome:

- *No damaging operations occur.*
- *The frequency and scale appropriate programmes of monitoring the condition of the island's vegetation will be agreed by the relevant Authorities before the end of 2008.*
- *Plant communities, their ecosystems and the process of succession continue to occur in an unhindered manner.*

### Performance Indicators

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- *The number of damaging operations to plant communities recorded each year and the extent to which these impacts are irreversible.*
- *An annual assessment of the extent to which the favourable conservation status of the site has altered.*
- *An assessment every five years of the extent to which natural processes still completely prevail*

### **Objective 1.4:**

*The population trends of breeding terrestrial birds on the Reserve will be determined.*

The first birds made their landfall on Surtsey just after it had risen above the surface of the ocean. The numbers of breeding terrestrial birds now needs to be monitored by establishing a systematic recording programme. Before such a programme can be undertaken, consent will be required from the Environment (and Food) Agency to avoid any elements of it causing potential damage.

In all instances the population trends of breeding birds and the impacts of these programmes will be monitored in accordance to the Icelandic Institute of Natural History Code of conduct as described in the Surtsey Nature Reserve Declaration (Notification, Art. 4).

### **Anticipated Management Outcome:**

- *To establish a breeding bird monitoring programme by 2009*
- *To undertake monitoring of bird populations annually*
- *To establish and maintain a data base of breeding bird types and numbers on Surtsey*

### **Performance Indicators**

- *To report to the Advisory Committee annually on the change in the bird populations on Surtsey*

### **Objective 1.5:**

*Existing breeding bird populations will be maintained in favourable condition.*

Thirteen species of birds were recorded nesting on Surtsey in 2005, of which twelve appear to breed annually. It is important that seabird numbers are monitored both in absolute terms and relative to similar populations elsewhere. The Environment (and Food) Agency in liaison with the Icelandic Institute for Natural History will establish a bird species monitoring programme and its frequency.

Researchers and visitors can unwittingly affect how communities of breeding birds develop. Species such as fulmars and gulls for instance are particularly vulnerable to disturbance. Threats to the breeding bird populations need to be identified, minimised and acted upon before they occur. In particular, unacceptable practices in particular littering from ships and the sounds of motorised vehicles (including disturbance from the over flying of the island by planes and noise of pleasure boats) will be prevented.

Other than essential operational helicopter flights, no other flights to or over the nature reserve will allowed during the breeding season. Discussions will take place with the Civil Aviation Authority to establish a mechanism to achieve this.

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### Anticipated Management Outcome:

- *A monitor programme of the populations of breeding seabirds and their breeding success will be established in 2008 and repeated annually.*
- *Surveillance surveys of marine litter will be undertaken once a month and any impacts on seabirds, particularly entanglement in nets will be documented.*
- *An aviation plan defining acceptable flight paths that all helicopter flights into and out of the landing platform on Surtsey, will be implemented before the end of 2008.*
- *Procedures will be published for all sightseeing flight operators and others to regulate flights close to Surtsey Nature Reserve during the breeding season.*

### Performance Indicators

- *The % increase in the breeding bird population*
- *The amount of litter collected per month above the acceptable threshold*
- *The number of infringements to the aviation plan per year by helicopters or leisure flights*

### Objective 1.6:

*The resting and feeding areas of breeding birds will be maintained in a favourable condition.*

Based on current geological knowledge, it is unlikely that oil or gas exists in sufficient amounts to make its production economically viable within the Nature reserve. Birds are however extremely vulnerable to oil spills, the most likely source being accidental or deliberate discharge of waste oil from passing ships. An Oil spill Response Plan will therefore be prepared for the nature reserve area and focus on preventing any ship carrying hazardous cargoes from sailing close to the Nature reserve.

Commercial fishing also affects the food supply of seabirds both positively and detrimentally. Discards provide food on which several bird species rely, whilst over fishing can potentially deplete fish stocks for prey species. In addition certain fishing techniques can cause accidental mortality of seabirds and damage to the marine environment. Whilst fishing is allowed in a limited zone within the Nature reserve, it is of important to safeguard the resting and feeding areas for birds. To achieve this, a fishing ban will be introduced inside the Nature reserve boundary.

### Anticipated Management Outcome:

- *Areas at sea important for resting and feeding of breeding bird populations, will be identified by summer 2008*
- *The implementation of a total fishing ban within the nature reserve boundary will be introduced by the end of 2008.*
- *The existing Oil Spill Response and Contingency Plans will be reviewed by summer 2008 and its Regulations made more stringent.*
- *The adequacy of the existing Deep Water Route for shipping will be reviewed and as necessary alternative navigation control measures will be introduced.*
- *Amendments to the Common Fisheries Policy will be sought, to ensure that fisheries around the island are managed in a sustainable way and fishing levels do not threaten the populations of breeding birds.*
- *Regulations will be introduced where necessary to prevent the use of damaging fishing methods, particularly fixed nets and long lines.*

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- *A Code of Practice for visiting ships and boats will be introduced by Summer 2008, to minimise any disturbance to breeding and resting birds.*

### Performance Indicators

- *The relevant Codes of practice and Regulations are in place by the prescribed times*
- *The number of infringements of the Regulations per year.*

### **Objective 1.7:**

*The island will be kept free of all alien, invasive or introduced plant or animal species*

It is prohibited to transport live animals, plants, seeds or plant parts, or other organisms to Surtsey. Likewise transporting minerals, gravel or soil to the island is also prohibited. If material is imported to Surtsey, e.g. timber for construction or maintenance purposes, care is required to avoid the importation of species not indigenous to the island. All imported building materials will therefore be screened and washed to ensure that it does not contaminate the natural biodiversity of the island. Likewise all equipment and clothing to be used on the island will be thoroughly cleaned before being taken onto Surtsey.

Introduced species are the main threat to the biodiversity of remote islands and every effort will be made to ensure that this does not occur on Surtsey. If a new non-indigenous plant or animal is observed, then it will be removed before it has chance to spread. The only exception will be where the balance of probability indicates that a plant or animal has arrived naturally and without direct human influence.

Byelaws prohibit the landing of dogs on the island, as they could introduce parasites which would endanger the indigenous animals. To avoid this, the current bylaw that prohibits the introduction of species alien to the archipelago and any landing of dogs or cats on the island will remain and be strictly enforced

### Anticipated Management Outcome:

- *Any species of animal or plant that arrives on the island through human action, either accidentally or intentionally will be removed as soon as it is observed.*

### Performance Indicators

- *The number of incidents of alien, invasive species recorded on the island each year*

### **Objective 1.8:**

*No shore-based activities will impact on the marine environment.*

Particular care is needed to avoid any damage to the natural environment on Surtsey coast or in its surrounding waters. Care will be taken to ensure that relevant Agencies and researchers are aware of the need for vigilance and also of the contingencies expected of them, in case of an incident or accident.

This vigilance is also required by visiting boats and vessels to ensure that oil spills, the discharge of sewage or the disposal of food waste from visiting recreational boats, fishing boats or cruise ships, is prevented and no harm occurs to the marine areas and natural environment surrounding Surtsey.



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### Anticipated Management Outcome:

- *A Code of Practice preventing the discharge of polluting substances (organic waste and pollutant chemicals) into the surrounding seas will be introduced by June 2008*
- *A contingency plan to deal with marine contamination from visiting vessels is operational by June 2008.*

### Performance Indicators

- *The number of pollution incidents recorded each year*
- *The number of times the Contingency plan is put into force*
- *The extent to which any features or habitats have suffered irreversible damage*

### Objective 1.9:

***The internationally important shoreline and underwater habitats will be maintained in a favourable condition.***

The emerging terrestrial and marine ecosystems of Surtsey are vulnerable to disturbance from both natural as well as human processes. The main natural processes which impact on the island are the continual effects of marine erosion of the coastline and wind erosion of the land surface. Both of these are part of the island's natural evolution.

Although direct human disturbance is currently minimal, inappropriate fishing methods, particularly the use of mobile fishing gear can cause damage to fragile organisms. Diving close to the island is prohibited except for research and related activities and can only be undertaken with written consent from the Environment (and Food) Agency. Despite this there have been incidents of fishing inside the Nature reserve mostly to the west of Surtsey.

Monitoring programmes will be undertaken in liaison with the Marine Research Institute to measure these impacts

### Anticipated Management Outcome:

- *Monitoring programmes of qualifying features of the marine environment will be undertaken to ensure that the shoreline and underwater habitats remain in favourable condition.*
- *Regulations will be in place by 2009 banning any fishing methods within the nature reserve which damages the seabed.*
- *A Code of conduct for divers involved in scientific research will be introduced by the summer 2008 to prevent features being removed or disturbance to the sea bed.*
- *A monitoring programme to assess the impact of fishing for crustaceans within the nature reserve will be initiated to assess whether these populations are in favourable condition.*

### Performance Indicators

- *The relevant monitoring programmes are in place by the prescribed times*
- *The relevant Codes of practice and Regulations are in place by the prescribed times*
- *The number of infringements of the Regulations per year.*

### Objective 1.10

***Research undertaken within the Nature reserve will be carried out in accordance with prescribed practices.***

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All research on Surtsey Nature Reserve should contribute to the greater understanding and appreciation of the site. Research will therefore only be permitted when it can be demonstrated that it can not take place anywhere else apart from Surtsey.

Decisions about the acceptability of any research project will be made on an individual basis and in accordance with the terms of the Nature Conservation Act and the obligations of the Nature Reserve Declaration. Where the needs of nature conservation and research are in conflict, then the former will take priority. In all instances no activities will be allowed which threaten or devalue the World Heritage values of the island.

### Anticipated Management Outcome:

- *All research projects will be subject to scrutiny and written consent from the Environment (and Food) Agency a minimum of one month prior to their commencement in the field.*
- *The results of any research undertaken will be provided to the Environment (and Food) Agency and the Surtsey Research Society within six months of the completion of the field work.*

### Performance Indicators

- *The number of research applications which do not reach the required assessment standards*

### Objective 1.11:

*All biological information relating to Surtsey Nature Reserve will be collected, managed and collated in a consistent format.*

Given the range of geological, biological and ecological information which could be produced by research and survey work on Surtsey Nature Reserve, there is a need to ensure that it is collected in a consistent manner and where possible is comparable and easily available. This will improve opportunities for synthesising information over time and hence increase its validity and usefulness for others.

### Anticipated Management Outcome:

- *An agreed ten year programme of biological and geological monitoring will be produced in partnership with the Surtsey Research Society, the Icelandic Institute of Natural History and the Marine Research Institute by 2009.*
- *Protocols for the collection, format and storage of any geological, biological information relating to the Nature Reserve will be produced prior to the publication of the ten year programme.*

### Performance Indicators

- *The relevant monitoring programmes are in place by the prescribed times*

### *2. Managing the visitor experience*

The sense of pride that local people have for the island of Surtsey is important, as it characterises not only part of their local identity but the close relationship that communities have with the natural environment. Sharing the experience of Surtsey is therefore important

The provision of high quality tourist experiences on Heimaey is a way of achieving this and new tourist opportunities need to be achieved sensitively and responsibly. For this reason the main focus for tourism development will be indirect rather than direct and involve the provision of a new visitor centre to interpret the Nature reserve. This will not only explain the environmental importance of the island but provide an important means of generating tourism revenue, creating jobs and helping to change the current tourism patterns in the Westman Islands.

Local staff from the Environment (and Food) Agency's and from its headquarters in Reykjavík will work in close cooperation with the Municipality of the Westman Islands and local agencies and voluntary groups to achieve this. Collaborative projects will also be undertaken to ensure that adequate training and development of local staff is provided in both conservation and tourism management.

#### *Objective 2.1:*

#### *Visitor facilities will only be provided on Heimaey*

Because access to Surtsey is prohibited, all visitor facilities to the Westman Isles will be provided on Heimaey, the only inhabited island in the Vestmannaeyjar archipelago. An Agreement between the Environment (and Food) Agency, the Ministry for the Environment and the Municipality of Vestmannaeyjar will indicate how and what visitor facilities will be provided. It is anticipated that a new Visitor centre for Surtsey Nature Reserve will be opened in the town of Vestmannaeyjar, by mid 2009.

The Surtsey Genesis exhibition currently housed in the Culture House in Reykjavík will also be relocated to the Visitor centre on Heimaey in 2009. In addition the range of primary and secondary information about the Surtsey Nature Reserve and its evolution since its eruption will be housed in this centre. Any such information which forms part of the information material in the centre will be presented bilingual in Icelandic and English and displayed in a way which meets the needs of backgrounds and abilities including those with mobility, hearing or visual difficulties.

To assist visitor management, a Ranger or Warden will be appointed for Surtsey Nature Reserve and based in Heimaey. The Ranger will be responsible for developing a visitor Management plan (for where and by when) should this become necessary and for monitoring the numbers of recreational boat trips to and in the Nature reserve waters

#### **Anticipated Management Outcome:**

- A new fully resourced and staffed Visitor centre will be provided in Heimaey by 2009

#### **Performance Indicators**

- The visitor centre is operational for the summer season of 2009

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### *Objective 2.2*

*Educational and interpretation programmes for Surtsey will be provided and continually improved over the Plan period.*

The production of a combined Interpretation and Education strategy will improve visitor orientation to the area and provide them with a better understanding and appreciation of the importance of the island, its surrounding waters and the reasons why these assets need to be managed in a sustainable manner.

This strategy will include individual formal and informal education programmes tailored, to meet the needs of as wide a range of ages and learning abilities. Emphasis will be focussed in particular on teaching children of school age.

In addition the Environment (and Food) Agency's website, will be used as a publicity and public relations medium and developed so that it becomes the initial point of contact for those wishing to gain information on any aspect of the Surtsey Nature Reserve.

### **Anticipated Management Outcome:**

- *An education and interpretation programme for the Surtsey Nature Reserve will be implemented by 2010*
- *The Environment (and Food) Agency's website will be updated by summer 2008 to provide contemporary information about the Nature reserve, with links to the Surtsey Research Society website [www.surtsey.is](http://www.surtsey.is).*

### **Performance Indicators**

- *The relevant programmes are in place by the prescribed times*

### *Objective 2.3*

*The Surtsey Nature Reserve will be promoted nationally and internationally.*

Surtsey is not just of great scientific importance in Iceland but internationally. It also represents a location offering scientists an opportunity for unique research. The work of the Surtsey Research Society and scientific research agencies will be promoted and their experiences shared. Effective collaboration and the sharing of information and expertise on conservation management and the monitoring of the site will improve the standards of management of Surtsey itself. These links will also enable the Surtsey Nature Reserve to be identified and promoted in its appropriate national and global context.

Adequate funds to enable staff to undertake relevant professional training and development and to participate in national and international conferences, on conservation and management are therefore essential.

Links with other interpretation/education professionals on Heimaey, for instance the local natural history museum, the South Iceland Research Centre and the Vestmannaeyjar Research Centre will also be promoted. In addition the feasibility of locating an additional centre to interpret the Surtsey Nature Reserve, elsewhere in Iceland will be investigated.

A programme of regular community based events on the Western Isles and features in the local newspapers about the Reserve will be promoted to encourage effective liaison with local communities and interested organisations and to maintain Surtsey in the public eye.

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### Anticipated Management Outcome:

- A programme of liaison initiatives and research will be implemented by 2009
- Programmes of staff development will commence in 2009

### Performance Indicators

- The number of research proposals received each year from new scientists and Institutions

## 3. Administering the Reserve

Providing and coordinating an appropriate overall framework for the administration and management for the island is essential if the natural values of the proposed World Heritage site are to be maintained and effectively monitored. Management resources therefore need to be allocated so that the Nature reserve can be managed to the standards which reflect its status and meet the conservation obligations expected of this national and internationally important site.

### *Objective 3.1:*

*The nature reserve will be administered and managed to the highest standards.*

The Environment (and Food) Agency will manage the Nature reserve in an integrated way and the staff appointed to do so, will be appointed in 2008 and located on Heimaey. Employees of the Environment (and Food) Agency will also be responsible for liaison with officials in the local Municipality, scientific research agencies and individuals as appropriate. Negotiations will take place with the Ministry for the Environment to fund two employees to be responsible for conservation and interpretation work.

### Anticipated Management Outcome:

- *The preferred management structure will be in place by 2009*

### Performance Indicators

- *Staff posts are operational by 2009*

### *Objective 3.2*

*A Surtsey Advisory Committee will oversee the conservation management of the Reserve.*

Regular communication between all the parties involved in the scientific research, strategic planning and the day-to-day management of Surtsey Nature Reserve is essential. Therefore the Environment (and Food) Agency and the Advisory Committee will liaise with officials from the local Municipality, the scientific research agencies, and individuals. Regular operational meetings will also be held between the Environment (and Food) Agency, the Nature Reserve Warden and those scientific researchers working on matters associated with the area on a regular basis.

An explanation of the role of the Advisory Committee appears in Appendix 1

### Anticipated Management Outcome:

- *The Surtsey Management Advisory Committee will be established by the end of 2008*

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### Performance Indicators

- *Not relevant*

#### **Objective 3.3:**

*Adequate finance will be secured to manage the Surtsey Nature Reserve*

The Surtsey Nature Reserve is an important internationally recognised research station amongst the scientific community. The Environment (and Food) Agency will make every effort to raise the necessary finance to secure the future viability of the Reserve's management activities through public support and from other national and international organisations and bodies. A public appeal will be initiated to increase the endowment for the property to enable the island to be managed to the standards it deserves.

#### **Anticipated Management Outcome:**

- *Negotiations will be initiated immediately with Ministry for the Environment to secure adequate fund to manage the site in a manner which maintains its unique status.*
- *A high profile public appeal will be launched in 2008 to raise funds to increase the current endowment fund dedicated to the management of the nature reserve.*

#### **Performance measure**

- *To secure an annual fund of xxxxxx by 2011*

#### **Objective 3.4:**

*Adequate logistical support for the management of the nature reserve will be provided.*

Suitable accommodation must be available to visiting staff and specialists, so that the necessary management, research and monitoring of Surtsey, can be undertaken. The only building on Surtsey at present is the Pálsbær hut, owned by the Surtsey Research Society. The Environment (and Food) Agency will negotiate with the Surtsey Society to secure appropriate access to and /or use of suitable accommodation for the proposed Ranger / Warden or other staff when they need to visit the island. In addition the Environment (and Food) Agency in liaison with the Surtsey Research Society will introduce a protocol for booking accommodation and for the transportation of those licensed to visit the island.

#### **Anticipated Management Outcome:**

- *Protocols for booking accommodation and the transportation of staff and specialists visiting the islands will be agreed by 2008.*

#### **Performance Indicators**

- *The number of circumstances when the agreed protocol is not followed.*

### 4. Implementing this Management Plan

For this Management plan to deliver a sustainable future for Surtsey Nature Reserve, it needs to be agreed and endorsed by all the relevant stakeholders and appropriate authorities. Thereafter the management of the island will be undertaken in accordance with the content of this Plan and its objectives will be actively promoted, monitored and the Plan reviewed as necessary over the next five years.

This task will be undertaken by the Reserve's Advisory committee and its success will be measured against the extent to which the anticipated management outcomes have been achieved. The Advisory Committee will produce and publish an progress report on this annually.

#### *Objective 4.1:*

*The performance of this Management Plan will be monitored and reviewed regularly.*

Progress towards the desired long-term management outcomes for the site, may be influenced by the availability of new information and resources. Therefore this Management Plan and the programme of Action associated with it, will be reviewed regularly and updated as required.

Because the Advisory Committee has the expertise, experience and access to resources to assist with this work, it will be responsible for this task. In monitoring the effectiveness of the Management Plan, the Committee will provide guidance to the managers of the Nature reserve, including advising on the issues associated with the provision of visitor facilities on Heimaey.

The Environment (and Food) Agency office on Heimaey will provide the Secretariat for this Committee and be responsible for liaising and advising with it and others as necessary.

#### **Anticipated Management Outcome:**

- *To complete a full review the Management Plan within 5 years*
- *To review the annual programme of work every year*

#### **Performance Indicators**

- *The completion of the reviews by the Advisory Committee in the timescales indicated.*
- *To account for and justify the reasons why the anticipated outcomes have not been achieved*

## **Programme of Action for 2007-2011**

It is the part of the purpose of this Management Plan to establish what work needs to be done to safeguard the future integrity of the site. To do this, priorities must be identified so that the necessary resources and finances can be identified and sourced.

This Management Plan therefore represents not only a statement of principle but a tool to bid for and secure appropriate funds from the relevant agencies.

The following programme of Action identifies the tasks considered necessary at present to achieve the Objectives of this Management plan. The actions are set out as a rolling programme covering periods of three years. This schedule will be updated at the end of each year to reflect the circumstances which prevail and any new ones that have arisen. Those initiatives which have been completed will move from a programme of capital investment into one which reflects the ongoing revenue needed to ensure that their care and maintenance status is maintained.

The individual elements of this programme as prioritised in terms of their importance. Undertaking the work in this way will therefore mean that those activities or projects which need to be done to reduce or minimise the risks to the integrity of the site, are done first. This does not however mean that schemes which are of lesser importance should not be undertaken, but merely that there is more time to implement them without risk that the site's integrity will be threatened.

The Advisory Committee will be responsible for the implementation of this programme of work after it has been endorsed by the Environment and Food Agency. Delivery of the programme will be the responsibility of the local staff of the Agency.



Overview of proposed Action Plan

Theme As set out in the Plan i.e.	Proposed action	Management Objective achieved	Responsibility	Priority and Progress
<p><b>Conserving the reserve</b></p>	<p>List of the name of the proposed schemes and initiatives as identified in the list of Management outcomes. A few words summarising them would be helpful</p>	<p>List the Objectives which each project relates to.  Remember that any individual project can achieve a more than one of the different management outcomes.</p>	<p>Name of the Lead agency/ agencies, organisations and who is responsible for undertaking the work</p>	<p>Indicate in a generalised way if the work proposed is High, Medium or Low priority. This should then cross refer to the next section which is setting out the funds required over the period of the Plan and the what is done first to reduce the degree of risk to the conservation of the assets</p> <p>Indicated the date by which the project is expected to be completed and how progress towards this target will be assessed. I can help you further with this later</p>
<p><b>Managing the Visitor experience</b></p>	<p>As above</p>			
<p><b>Administering the reserve</b></p>	<p>As above</p>			
<p><b>Implementing the Plan</b></p>	<p>As above</p>			

If you are able it would be of additional benefit if you could identify the projected costs for each of these elements of the Plan. As you can see I have included a statement explaining that part of the purpose of this Management Plan and the reason for outlining the programme of Action within it, is to use the overall statement first to get agreement on what is needed and the priorities for the work and then as a way of identifying the financial needs and then as a tool to bid for and secure them with the relevant agencies

## SURTSEY NATURE RESERVE – DRAFT MANAGEMENT PLAN

Summary of predicted estimates to implement the proposed programme of Action

Theme

Annual costs for 2008-2011

	2008-2009	2009-2010	2010-2011	Comment
Conserving the reserve				
Managing the Visitor experience				
Administering the reserve				
Implementing the Plan				

## Appendix 1

### The role of the Advisory Committee

The Advisory Committee will be composed of two members from the Municipality of Vestmannaeyjar and one representative from each of the following; the Surtsey Research Society, the Icelandic Institute of Natural History, the Marine Research Institute and the Icelandic Environment (and Food) Agency.

The Committee role and responsibilities are to advise the Icelandic Environment (and Food) Agency on:

- Reviewing the status, content and effectiveness of the Management plan.
- Co-ordinating and approving the annual programme of work identified in the Plan's programme of Action.
- Securing funds and resources to meet the operational and administrative costs of the Reserve.
- Identifying opportunities for resources and funds to support special projects and new initiatives.
- Determining the acceptability of any application for permissions and consent relating to the Surtsey Nature Reserve
- Deciding the acceptability of any application for the development or renovation of the Pálsbær hut or the helicopter pad.
- Implementing the proposed programmes of interpretation and education relating to the island
- Ensuring that the Management plan is implemented effectively and in liaison with other organisations and institutes
- Promoting the Surtsey Nature Reserve locally, nationally and internationally with other partners.

The Advisory Committee will meet at least three a year, the first meeting of which each year will be to determine and agree the programmes of work and the budget for that year.

At least once a year the Committee will also consider and review the effectiveness of the management work undertaken during that year and whether the outcomes anticipated have been achieved.

## Appendix

### The Icelandic World Heritage Committee

List of members

List of duties

## Appendix


### Contributing authors and advisers

List of contributing participants

# SURTSEY NATURE RESERVE – DRAFT MANAGEMENT PLAN

List of reviewers

29.2.08  
→

Dastain  


pls

• respond *with* Thanks

• To file

• To evaluator + lead panels ↑

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IUCN  
David Sheppard, Head, Programme on  
Protected Areas

Reykjavík February 26, 2008  
Reference: MMR05110259/30.81.10-

Subject: IUCN evaluation of "Surtsey" (Iceland) - Nominated for inclusion on the World Heritage List

Dear Mr. David Sheppard,  
A reference is made to your letter of December 19 2007 regarding IUCN evaluation of "Surtsey" (Iceland) - Nominated for inclusion on the World Heritage List.

Iceland welcomes the opportunity to supply additional information on the nomination of Surtsey for the World Heritage List, especially the relationship of the Surtsey nomination to the potential Mid Atlantic Ridge nomination.

The Icelandic authorities would like to emphasize that the nomination of Surtsey to the World Heritage list is a stand alone nomination based on the outstanding universal value of Surtsey and the spectacular and thoroughly documented Surtsey eruption 1963-1967 as stipulated in the already supplied materials.

The concept of a Transnational Serial Nomination of the Mid Atlantic ridge has been discussed amongst the relevant parties a number of times with the facilitation of the World Heritage Centre in Paris. Iceland has participated and hosted an informal expert meeting in Reykjavík in January 2007 to discuss the Mid Atlantic Ridge. The discussion focused on the concept of the Mid Atlantic Ridge by State Parties concerned.

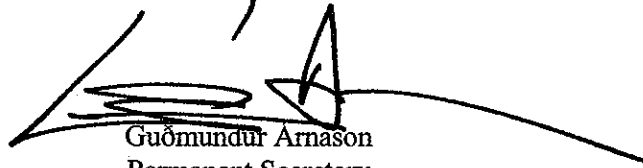
The next stage in the process is an expert workshop that the government of Portugal has generously decided to host at the end of March. The framework concept and components of a possible future Transnational Serial Nomination of the Mid Atlantic Ridge remains to be discussed further, outlined and drafted.

We foresee that the Surtsey World Heritage Site will be incorporated / added as one of the components of a Mid Atlantic Ridge Transnational Serial site, once established.

Thingvellir World Heritage Site is currently on the World Heritage List as a cultural heritage site but is registered on the Icelandic Tentative List as a mixed site. The natural components of the site have been described and mapped, but a nomination of Thingvellir as a natural and mixed site has not been submitted to the World Heritage Centre. It is therefore premature to relate the current World Heritage Site Thingvellir to a possible Mid Atlantic Ridge

nomination. However, this issue will certainly be considered in preparation for a nomination of the natural heritage of Thingvellir National Park on the World Heritage List.

On behalf of the Minister



Guðmundur Arnason  
Permanent Secretary

*Ragnheiður H. Þórarinsdóttir*  
Ragnheiður H. Þórarinsdóttir  
Adviser

Encl.: Mid Atlantic Ridge Expert Workshop, Iceland, 16 January 2007, SYNTHESIS REPORT  
A letter from Mr. Francesco Bandarin, director of UNESCO World Heritage Center, April 15 2007

Cc: World Heritage Center Unesco, Europe and North America Section  
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Minister of Justice, Mr. Björn Bjarnason chair  
Skuggasundi 3, 150 Reykjavík  
Icelandic National Commission for UNESCO  
Ms. Guðný Helgadóttir chair



## Mid Atlantic Ridge Expert Workshop, Iceland

Government of Iceland  
in cooperation with the  
UNESCO World Heritage Centre  
16 January 2007

### SYNTHESIS REPORT

#### Introduction

1. The Mid Atlantic Ridge Expert Workshop was held in Reykjavik, Iceland on 16 January 2007 with the participation of experts from Iceland, Norway and the UNESCO World Heritage Centre<sup>1</sup>.
2. The meeting was **opened and welcomed** by Ms Ragnheidur H. Thorarinsdottir, chair of the Icelandic World Heritage Committee (IWHC), followed by the introduction round of the participants. Sigurður Á. Thráinsson, member of the IWHC and natural focal point of Iceland took over chairing the meeting.

#### Presentations

3. Dr. Mechtild Rössler (UNESCO World Heritage Centre) provided an overview presentation on **the evolution of the World Heritage Convention and serial trans-boundary nominations according to the Operational Guidelines**. She described how the implementation of the Convention evolved since 1972, how cultural and the natural heritage is defined and is linked together in one instrument. In 1992 the categories of cultural landscapes were integrated into the Operational Guidelines, in 1994 the Global Strategy was introduced and over time the concepts transboundary, transnational, serial and large scale nominations evolved. New thinking and terms are now in use such as sustainability, biodiversity and others. New dimensions of serial sites in a thematic framework were discussed including the Ruta Inca/Quapac Nan, Rift Valley, Alpine Arc and Pacific Line Islands. Experts meetings were and are crucial for the evolution of the interpretation of the World Heritage Convention. Underrepresented themes including scientific discoveries, routes, shared heritage or climate change are being explored. Ms. Rössler then described the background of the meeting in

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<sup>1</sup> Experts from the United Kingdom, Portugal and IUCN/WCPA were not able to attend.

Iceland and the idea of serial trans-national nominations along the ridge. In September 2004 the “Earth Heritage-World Heritage” conference at the Dorset- and Devon Coast was held bringing together geological experts from around the world met. A side meeting with experts from Iceland, Norway, the United Kingdom, Portugal as well as IUCN, WCPA and the World Heritage Centre discussed the idea of nominations along the Mid-Atlantic Ridge (MAR) in a joint framework. This meeting was the first meeting on MAR.

Following the meeting Mr Tony Weighell (UK) wrote a paper, outlining a general framework for the Mid-Atlantic ridge with definitions about the project and its key-values. Ms. Rössler underlined that one of the State Parties must take the lead for the nomination for one or more parts (which later could be extended). All countries connected to the MAR have already ratified the Convention. In preparing a serial nomination it is important to specifically define the extent of the MAR, which is the longest rift valley in the world or approx. 16 000 km from north to south. It is therefore important to look into paragraphs 134b, 135, 137-139 in the OG in this connection. Ms Rössler also stressed that the MAR-project would be a pilot project on geological heritage. Finally she emphasised the importance of informing States Parties and experts of the idea of such a serial nomination and pointed out that a co-operation with the Nordic World Heritage Foundation, scientific groups (including IUGS) would be important.

4. **Mr. Snorri Baldursson (Institute of Natural History, Iceland) presented the case of the Surtsey nomination document as “Surtsey, creation and evolution”.** He discussed the formation and development of the island and mentioned that Surtsey was nominated under criterion (viii) as a geological feature. Iceland is the largest land mass of the Mid-Atlantic ridge and Surtsey could be linked to the serial nomination of the MAR.

During the discussion Ms Rössler pointed out that tourists may become interested in Surtsey if it was accepted for World Heritage Listing which could become a management issue. Árni Bragason member of the IWHC mentioned that there will be a visitor centre in the Vestman-Islands established and that it would be possible for the tourists to take boat-cruises around Surtsey. The World Heritage Centre indicated that there are other sites such as St. Kilda (UK) which are not made accessible to visitors, but only to researchers. It is important to carefully look into how the site interpretation at visitor centres and the accessibility to the public. Mr Baldursson mentioned that it is dangerous to get to Surtsey and that one can be stranded there for days because of fog so it is also for practical reasons that it is closed to the public. Mr Sigurður Á. Þráinsson mentioned that the minister of environment does not want the island to be open to the public, just to researchers and instead the visitor centre in the Vestman Islands will serve the public. The National History Institute is making an exhibition about Surtsey which will be moved to the Vestman Islands after being exhibited for a few months in the Culture House – National Centre for cultural Heritage in Reykjavík.



5. **Mr. Gaute Sønstebo (Directorate for Nature Management, Norway)** made a presentation on **Jan Mayen and Bouvet islands** which are the Northern- and Southernmost points of the MAR and both belong to Norway. Jan Mayen is part of the Kingdom of Norway since 1929 and Bouvet Island since 1930. He explained in detail the geological and geomorphological formation and biological diversity of the islands and highlighted current research carried out by his Government at both sites. He stated that Norway only intends to nominate them within the framework of MAR and not on their own. He mentioned that the discussions regarding the nomination of the MAR in Norway have so far been informal, but the islands Jan Mayen and Bouvet Island are now included on the most recent Tentative List of Norway which still has to be accepted.

#### 5. Mid-Atlantic Ridge – a review of a potential serial nomination

Ms. Rössler indicated the five key points to be discussed under this item of the agenda based on the background document:

- (i) *Exchange of information on the nature and distribution of Mid Atlantic Ridge heritage*
  - (ii) *Set limits to the Ridge “phenomenon”- the volcanic features associated with mid oceanic spreading in the Atlantic extended beyond the ridge; where should limits be set for practical and scientific reasons?*
  - (iii) *Review the distribution and function (in terms of heritage protected) of existing World Heritage sites on the Ridge*
  - (iv) *Identify heritage (biological, geological, cultural) that is potentially of Outstanding Universal Value on the Ridge but currently lies outside World Heritage sites*
  - (v) *Produce a report on the above including: review of the issues involved managing such serial sites; the use of serial nominations for capacity building; recommendations for action:*
- i. *Exchange of information on the nature and distribution of Mid Atlantic Ridge heritage (biological, geological, cultural);*

The participants agreed that it would be most important to bring in other countries with territories along the Ridge into the project and spread information about the scheme. It is thus important to have information on the web-page and make a brochure which we could send to the relevant parties. The World Heritage Centre noted that it was going to have a meeting with Mr Tim Badman, site manager of Dorset in February 2007 and would keep him informed.

The importance of specifically defining the MAR and decide about the limits of the phenomenon was stressed. There are two main theories about the limits of the MAR. The narrow one which limits it to the Ridge itself and the second and broader one

where the whole phenomenon of the opening of the Atlantic Ocean is included and thus the Canary Islands (Spain) or the Capverdes Islands would form part. It was suggested to ask two or three scientists to define the limits of the project. It was recommended that Mr Tony Weighell would be asked to steer the definition work and that Mr Helgi Torfason would introduce the project at the IUGS (International Union of Geological Sciences) meeting in Oslo.

*Recommendations:*

- to bring in the other countries into the co-operation concerning potential MAR sites and to encourage the State Parties which sites are related to the MAR to include them in Tentative Lists;
- to encourage considerations of the outstanding universal value of the Ridge;
- to contact research and scientific groups at universities to join in the information gathering;
- to produce a web-page on the project and encourage funding for a brochure;
- Set up a time-frame and report about the progress at the side meeting during the 31<sup>st</sup> session of the World Heritage Committee in New Zealand.

ii. *Set limits to the Ridge "phenomenon"-the volcanic features associated with mid oceanic spreading in the Atlantic extended beyond the ridge; where should limits be set for practical and scientific reasons?*

A first draft of the MAR-project was already written in 2004 and it was suggested to get back to Mr Tony Weighell and ask him to draft the framework text on the ridge and limitations of the ridge and we would bring the draft to the next meeting. This would include specifically: What is the ridge in the scientific terms? Is it just the ridge itself or the opening of the Atlantic Ocean?

It was noted that it is not possible to nominate the MAR as a whole because of the submarine parts outside of the national jurisdictions. We have thus to look at terrestrial features and submarine areas within the national jurisdictions. It was mentioned that it would be wise to form a small group of scientists which would set the limitations for the MAR in relation to this proposal. The key values would be geological and biological features, mainly criteria (viii) and (x).

Furthermore, concerning transboundary properties, adjacent borders, and prepare joint transnational properties the relevant paragraphs of the Operational Guidelines need to be considered. We must also look at serial transnational properties, non contiguous sites of the same geological, geomorphological formations. It was considered that criterion viii<sup>2</sup> to be the most important but that x<sup>3</sup> is also important due to biological diversity. There is also a question about the importance of criteria

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<sup>2</sup> Criteria viii: be outstanding examples representing major stages of earth's history, including the record of life, significant on-going geological processes in the development of landforms, or significant geomorphic or physiographic features.

<sup>3</sup> Criteria x: contain the most important and significant natural habitats for in-situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.

ix<sup>4</sup>. The World Heritage Centre would contact both Mr Weighell and Mr Badman for further advice.

*Recommendations.*

- To work with Universities and specialized research groups to identify the limits of the Ridge and to inquire about research groups in universities from State Parties concerned;
- To encourage students to write their thesis on the ridge phenomenon and the protection of sites along it;
- To review the legal possibilities under the World Heritage Convention and collaborate with the marine programme;
- To collaborate with other relevant international conventions (e.g. CMS) and programmes (IOC).

iii. *Review the distribution and function (in terms of heritage protected) of existing World Heritage sites on the Ridge;*

The meeting noted that a number of sites already exist along the ridge including in Iceland and Portugal, but that these sites may need to be reviewed for other values (e.g. geological).

*Recommendations:*

- To recommend State Parties to review how their existing World heritage sites to the MAR;
- To encourage consideration of potential re-nominations for other values, e.g. Pico Island (Azores, Portugal);
- To prepare a letter to relevant State Parties to inquire whether they would be interested to review their Tentative Lists and existing sites in relation to a MAR nomination; The World Heritage Centre was asked to send this Circular Letter;

iv. *Identify heritage (biological, geological, cultural) that is potentially of Outstanding Universal Value on the Ridge but currently lies outside WH sites;*

So far most of the MAR meetings had been informal or related to other meetings. The Iceland meeting concluded that a stage was reached where those meetings need to be more formal. One or more of the State Parties concerned have to take a leading role in the cooperation and nomination work.

*Recommendations:*

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<sup>4</sup> Criteria ix: be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals.

- To potentially set up a working group, when the interest of State Parties is clear and has been voiced;
  - to set up a drafting group for the framework text;
  - to reiterate that this process is not impacting on existing nominations and that it is not blocking State Parties to nominate sites;
  - to illustrate the two options: to nominate on its own and also as a part of a serial nomination of the MAR phenomenon;
  - to encourage nomination of focal-points for the project and to ask countries to nominate experts to participate in the working group.
- v. *Produce a concise report on the above including: review of the issues involved managing such serial sites; the use of serial nominations for capacity building; recommendations for action:*

The meeting also concluded to make a synthesis report of its findings to be included on the web-pages of the World Heritage Centre.

*Recommendations:*

- To place the report on the WHC- web pages;
- to send the Circular Letter to Brazil (St Paul's Rock), Iceland, Denmark (Faroe Islands), Iceland, Spain (Canary Islands), Portugal, Norway, Cap Verde and the United Kingdom (Gough Island).
- To encourage funding from the EU and other sources;
- To encourage funding from the Nordic Council of Ministers (has to involve three Nordic countries);
- To encourage in terms of managing systems regular meetings of the group;
- To welcome a next meeting in the Azores, in case Portugal wishes to host it;
- to establish a specialist group after the New Zealand side meeting and to start with an informal working group which could be formalized when the limit of the project and the countries involved is clear;

## **6. other issues**

Mr Einar Sæmundsson from Thingvellir National Park/World Heritage site asked about management plans for serial sites. Whether one needs to have the same management plan for all the sites? Ms. Rössler answered that this was an issue that need to be discussed in detail in the working group. The Operational Guidelines would require a Management System – this could be done through an agreed charter. It is important to co-ordinate all issues including name – changes to existing World heritage sites nominated again under the MAR. The purpose of the meeting in Iceland was to formalize the project. Following this meeting an official letter will be sent to the relevant countries.

## **7. Closure of the meeting**

The Chairperson thanked all participants for their presentations and active involvement in the discussions. It was decided that the World Heritage Centre would send the conclusions of the Reykjavík-meeting to the other State Parties involved in the Ridge and inform them about the project.

#### **8. Site visit**

Following the meeting an excursion to the World Heritage site at Thingvellir was carried out, a cultural property located on the Ridge.



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## CULTURE SECTOR / WORLD HERITAGE CENTRE

To the Permanent Delegations of  
Brazil  
Cape Verde  
Denmark  
Iceland  
Norway  
Portugal  
Spain  
United Kingdom

15 March 2007

Ref. : WHC/74/516/CF/MR

**Subject: Follow-up of the Expert meeting on the Mid Atlantic Ridge  
held in Reykjavik, Iceland, 16 January 2007**

Dear Madam/Sir,

I have the pleasure to inform you that an Expert Meeting on the Mid Atlantic Ridge was held in Reykjavik, Iceland, on 16 January 2007 at the invitation by the Icelandic authorities. This meeting took place as a follow-up to the Earth Heritage Meeting (United Kingdom, 2004), and could be considered as a starting point for a potential serial transnational nomination process.

The meeting was organised by the Icelandic World Heritage Committee and the Ministry of the Environment, in collaboration with the World Heritage Centre. The discussions focused on the concept of the Mid Atlantic Ridge and potential nominations of geological and marine sites along the Ridge by States Parties concerned. Please find attached to the letter the results and the main recommendations of this meeting.

The geological features of the Mid Atlantic Ridge, as well as marine, ecological and eventually cultural values, could lead to a potential nomination for the World Heritage List as a transnational serial nomination. Furthermore, the meeting proposed to establish a scientific framework and to create an informal Working Group for this serial nomination, including experts from all States Parties concerned.

A side meeting is foreseen to take place during the World Heritage Committee in New Zealand in June 2007 with delegations or representatives of the State Parties interested. In addition, a meeting on the definition of the Mid Atlantic Ridge's limits is proposed to be held during the International Geological Congress (IUGS) in Oslo in 2008.

We would be pleased if you could inform the World Heritage Centre whether your country is interested in this project. We would also kindly request you to indicate the name of the contact person, or to confirm the name of your existing focal point for natural heritage.


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The meeting also encouraged scientific collaboration between universities, creating a network of specialists linked to the Mid Atlantic Ridge. We would be grateful if you could inform relevant national universities which may have research priorities linked to the ridge phenomenon.

May I take this opportunity to thank you for your cooperation in the implementation of the World Heritage Convention.

Please accept, dear Madam/Sir, the assurances of my highest consideration.

  
Francesco Bandarin  
Director

Cc: National Commissions  
Focal points for natural heritage  
Nordic World Heritage Foundation (NWHF)  
IUCN  
IUGS  
SC/EES  
International Oceanographic Commission (IOC)