

Formation of a bird community on a new island, Surtsey, Iceland

AEVAR PETERSEN

Icelandic Institute of Natural History,
Hlemmur 3, P.O. Box 5320, 125 Reykjavik, Iceland
E-mail: aevan@ni.is

ABSTRACT

The present paper summarizes bird observations from Surtsey, Iceland since the formation of the island in 1963 until 2008. Continuous observations were maintained in the early years of the island; in spring and autumn 1967–1971 and summers 1970–1973. Since then much of the bird observations are incidental by various scientists and bird watchers visiting the island for a limited period.

Different aspects of the bird fauna are examined, the at-sea bird community, vagrants, migrant species, and winter birds, while emphasis is placed on the formation of the breeding bird community. With increasing numbers of breeding species and size of breeding populations as the years passed more structured census of the breeders was needed. Hence whole island censuses were organized in 1990 and 2003. Ringing has been carried out on five occasions. In total 91 bird species have been recorded on or offshore from the island.

The first birds started breeding in 1970, Black Guillemot *Cepphus grylle* and Fulmar *Fulmarus glacialis*. A total of fourteen species have since bred on the island. Four species of large gulls breed (mostly in one colony); Great Black-backed Gull *Larus marinus* (bred first in 1974), Herring Gull *Larus argentatus* (1981), Lesser Black-backed Gull *Larus fuscus* (~1985), and Glaucous Gull *Larus hyperboreus* (1993). The colony, starting to form in 1984, has been particularly important for furthering the development of plant and invertebrate communities. Through the fertilizing agency complete vegetation cover is now found in the oldest part of the gull colony. This development has paved the way for terrestrial birds to start breeding; Snow Bunting *Plectrophenax nivalis* (1996), Greylag Goose *Anser anser* (~2001) and Meadow Pipit *Anthus pratensis* (~2003). Other breeding species are Kittiwake *Rissa tridactyla* (1975) and White Wagtail *Motacilla alba* (~2003), but Arctic Tern *Sterna paradisaea* (1975) has not bred since 1978. In 1990 the island had 316 breeding pairs of six species. In 2003 eleven species bred on the island with a total of about 850 breeding pairs. After 2003 two more species have started breeding, Common Puffin *Fratercula arctica* (2004) and Raven *Corvus corax* (2008).

Surtsey Island was entered on the UNESCO World Heritage list in 2008, not the least for the long history of research and monitoring of various aspects of the island's natural history. As the breeding bird fauna develops a structured bird monitoring program becomes the more important. Recommendations on how this should be carried out are presented in the paper.

INTRODUCTION

Surtsey Island had just risen above the ocean surface when the first birds made their landfall. On 1st December 1963 only two weeks after the eruption began gulls were seen touching down on

the island in between eruption bursts (Fridriks-son 1964, Gudmundsson 1966). A number of bird species have since been recorded on or near the island. Some are on feeding trips from breeding colonies on neighbouring islands in the Westman

Islands group. Others are transient migrants *en route* between breeding areas elsewhere in Iceland or the Arctic and wintering areas in Europe or Africa. Some are immature birds or non-breeders on feeding excursions from other parts of Iceland. Still others are incidental vagrants from either side of the North Atlantic. Some of these species have successively colonized the island and now form the developing breeding bird community.

Gudmundsson (1966) predicted that birds would quickly start breeding on the new island. Proven right he further noted birds would be of considerable ecological importance. Over the years an increasing number of species has colonized Surtsey, contributing increasingly to the young developing ecosystem. Some of the species, gulls in particular, have demonstrated their importance to the ecosystem development, by contributing nutrients to plant and invertebrate communities (Magnússon & Magnússon 2000, Magnússon & Ólafsson 2003).

Through the years bird studies on Surtsey have concentrated on six aspects; (1) recording the bird species seen, (2) observing migration, (3) collecting scientific specimens to augment various research, (4) studying the role of birds in the development of plant and invertebrate communities, (5) registering the breeding species, numbers and distribution, and (6) bird ringing. In the beginning significant importance was attached to birds carrying seeds of pioneering plants to the island, reported in many publications. A detailed overview of the development of the Surtsey bird community has however not been reported in recent years, or since the breeding birds became more than just a few pairs. Censuses were carried out of the entire breeding bird fauna in 1990 and 2003. A structured monitoring program is becoming more and more needed as the bird fauna develops, with increasing numbers of species and breeding pairs. The purpose of the present study is among others to suggest the structure of such a program.

In 2008 Surtsey was entered on the UNESCO World Heritage list (Baldursson & Ingadóttir (eds) 2007). One of the main arguments for its acceptance was the history of various research and monitoring since the island was formed. The nomination makes further demands on keeping the island as free of human influences as possible, while continuing to collect scientific information on the natural environment. The present paper brings together the information that has been collected on birds since the creation of Surtsey. Emphasis is placed on the breeding bird fauna. For general texts on Surtsey, including the bird life, see e.g., Fridriksson (1968, 1975, 1989, 1994), Petersen (1993, 2004), Magnússon & Ólafsson (2003), and Baldursson & Ingadóttir (eds) (2007).

MATERIALS AND METHODS

Materials

Regular bird observations were maintained on Surtsey from 1966 to 1971 during spring and autumn. Observations were primarily directed at staging migrants, recording vagrant species, looking for indications of breeding, and collecting specimens for the scientific collection of the Icelandic Museum of Natural History (now the Icelandic Institute of Natural History). During 1970–1973 wardens were also stationed on the island during the summer months and one of the aims was to record any breeding attempts. Frequent coverage was made of the island and all birds observed on land carefully recorded. Unfortunately regular sustained bird observations could not be maintained after the very early years of the island.

Ever since people first stepped on the island it has been visited annually by scientists, biologists and other natural history scientists alike, as well as students and amateur bird-observers for various studies. These visitors have provided irregular records of new or other bird species, and partial counts of breeders. Together these records document reasonably well new breeding species and to some extent the development of the breeding bird community. These materials were compiled and form part the datasets available here. Much of the bird observations are found in diaries of previous wardens and other visitors, unpublished reports, newspaper reports from expeditions, websites, emails, and records in the log book at the Pálsbaer research hut. This unpublished material is too much for individual inclusion in the bibliography and not referred to in the text.

Some population estimates are available at irregular intervals through the years but more concentrated and systematic efforts were clearly necessary as the breeding populations increased and complete coverage became more challenging and time-consuming. Therefore, in 1990 the island was visited on 5–7 June to map the distribution of the breeding birds and census their numbers. To follow the changes an entire island census was repeated on 27–30 June 2003. It is important to monitor and map all the breeding populations carefully at regular intervals. Besides its own value such observations will assist scientists, who examine the importance of birds in the formation of vegetation and invertebrate communities on Surtsey, and helps to fulfil the requirements placed upon Icelandic authorities by the UNESCO listing.

Census methods in 1990 and 2003

Different methods have to be employed to estimate breeding population size of the various bird species. The passerine species, Snow Bunting *Plec-*

Table 1. Counts and calculations of correction factors in the Surtsey gull colony on 29 June 2003.

	Pairs	Single adults	Correction factors	
			Birds	Pairs
Great Black-backed Gull	48	38	1.28	0.64
Lesser Black-backed Gull	117	58	1.20	0.60
Herring Gull	29	8	1.12	0.56

trophenax nivalis, Meadow Pipit *Anthus pratensis*, and White Wagtail *Motacilla alba*, were mapped using „the territory“ as the census unit, mostly based on locating singing males and nests. Repeated visits were needed to separate territory holders and obtain an idea of the rough size of the territories. Kittiwakes *Rissa tridactyla* and Fulmars *Fulmarus glacialis* were counted using the „Apparently Occupied Nest-site“, as the counting unit (cf. Nettleship 1976). Kittiwakes are confined to the sea-cliffs and the counting unit was a nest considered able to hold eggs or young. Fulmars do not build nests, hence sitting birds that looked like incubating or brooding a chick, was the counting unit. The numbers of gulls, which nest on level ground mostly in one large colony, were counted with a telescope at a distance from the higher grounds at the middle of the island (the Surtur crater). Black Guillemots *Cepphus grylle* were counted on the water, in the early evening period when the largest numbers of birds are present at colonies (cf. Petersen 1981). Greylag Geese *Anser anser* had already hatched their young at the time of fieldwork. Therefore the number of families i.e. pairs with young, were used to estimate the number of breeding pairs.

Certain problems are encountered on Surtsey when estimating the populations of various species, resulting in different accuracies to the estimates. Fulmars and Kittiwakes breed dispersed on the sea-cliffs, and in some situations their nests cannot easily be viewed from land. For Kittiwakes this related primarily to the highest cliffs on the west side (Vesturbúnki), and also to some extent to Fulmars. There the cliff is made of tuff, the cliff surface smooth but does not offer the same possibilities for the birds to nest compared to the lava cliffs so nests are few and dispersed. The sea-cliffs from Vesturbúnki in the southwest, around the southern parts towards the cliffs and southeast from the research hut, cannot be fully viewed from land but offers much greater possibilities for birds to breed. These cliff areas were scanned from a helicopter and a rough estimate made of the birds not seen during land censuses. Some Fulmars nest on level ground on the lava fields inland. They are sometimes difficult to spot due to roughness of the terrain, such as one bird which was found nesting in a closed lava trench in 2003.

Correction factors for gull counts

The large gulls – Great Black-backed Gull *L. marinus*, Lesser Black-backed Gull *L. fuscus*, Herring Gull *L. argentatus*, Glaucous Gull *L. hyperboreus* – present a special challenge in estimating their populations. Sometimes a pair was obviously standing guard by their nest while also many birds were seen standing singly in the colony. A few birds were in flight during the census period while an unknown proportion of the breeders are away from the colony at any one time. The value of counting from a distance is that the colony birds are mostly tranquil and the counts not influenced by the observers. Since the lava field in the colony area is rough in many places many incubating birds could not be seen. The partner however was perching on guard, if not away from the colony on a feeding trip. This applies above all to the Lesser Black-backed Gulls, which tend to conceal their nest rather than place it clearly visible like do the Great Black-backed Gulls. Problems of estimating the size of large gull colonies are discussed in Barbraud & Gélinaud (2005). The best counting unit for comparing figures between censuses is „Numbers of birds“. Methodological baseline studies from elsewhere could potentially be used to estimate of the proportion of birds away from the colony at any one time and to achieve corrections from numbers of birds to numbers of pairs. However, such studies do not seem to be available, although dividing bird numbers by two for converting to breeding pairs has been applied (Lloyd *et al.* 1991). That method clearly underestimates the numbers of pairs since often only one of the pairs is present during counts.

The proportion of single adults present against a pair was estimated in 2003 and correction factors worked out. The gull colony was counted on 29 June 2003 (at 2045–2115) and figures for pairs and single adults kept separate. The details are given in Table 1 for three the most common gull species. All correction factors were similar, i.e. around 60% of the adult breeding birds were present in the colony during counts. These results are similar as previously obtained elsewhere in Iceland for Black-headed Gulls *Larus ridibundus* (0.61; Petersen & Thorstensen 1993). Further counts, at different times of summer and day, are needed to substantiate these results, but for the time being they are

used here to calculate the numbers of breeding pairs in the Surtsey gull colony.

RESULTS

General composition of the bird fauna

Altogether 91 bird species have been recorded on or near Surtsey since the island was formed (Appendix 1). Half (47) of these species are waterbirds while the other half (44) are terrestrial birds. Six different categories can be recognized; (a) regular breeders elsewhere in Iceland make up over half of the species (58); (b) regular transient migrants which breed in Greenland-Canada and overwinter in Europe (5), (c) regular winter visitors (6), (d) vagrants (12), (e) primarily vagrants but also rare or incidental breeders in Iceland (9), and (f) escapes (1). Of the 21 vagrant species most (19) are of European origin, the others Holarctic (1) and North-American (1).

The breeding species

Fourteen species of birds had been confirmed breeding on the island by 2008. Twelve of them are now annual breeders. One has not been found nesting since 1978, while one first bred in 2008 so it remains to be seen if that species will continue to nest every year. Already in 1966 certain species, particularly Kittiwake and Black Guillemot started prospecting for nest sites. They were probably prevented from nesting by the volcanic activity of the nearby temporary crater islands, Syrtlingur and Jólnir, which discharged ash over Surtsey (Gudmundsson 1967). In 1968, Fulmars began attending ledges (Gudmundsson 1970).

The first birds were discovered breeding in 1970, three years after the cessation of volcanic activity. The first nests were those of Black Guillemot (two) and Fulmar (one) (Ólafsson 1971). Another 12 spe-

cies have since then been confirmed breeding on the island; Great Black-backed Gull (Fig. 1) were recorded first in 1974; Kittiwake and Arctic Tern *Sterna paradisaea* in 1975; Herring Gull in 1981; Lesser Black-backed Gull ~1985; Glaucous Gull in 1993; Snow Bunting in 1996; Greylag Goose in ~2001; White Wagtail and Meadow Pipit in ~2003; Puffin *Fratercula arctica* in 2004. The latest addition is Raven *Corvus corax* that nested in 2008.

The year of first breeding is not accurately known for some species. In other cases the first nesting attempt had a long prologue. Greylag Goose probably nested in 1999 but was first confirmed in 2001. Similarly White Wagtail probably bred in 2001 and Meadow Pipit in 2002 but both first confirmed in 2003. The Puffin was first suspected to breed in 2001 when apparently produced scrapes, although first landfall was observed as early as 1978 (Fridriksson 1979). In 2003 behaviour indicated nesting, although this could not be confirmed, while in 2004 food-carrying adults were seen entering nesting burrows on the sea-cliff face on three occasions. Several more birds were seen attending that part of the island. Several birds were seen in the same area every year since 2005. In 2006 burrowing attempts suspected due to Puffins were noticed in the grassy inner parts of the island. Lastly, Ravens have built nest (or attempted to do so) intermittently since 1986 without laying eggs until 2008 when three young were raised.

Development of breeding populations

In the 1990 census six breeding species were encountered on the island. Fulmar and the Lesser Black-backed Gull were the most common breeders, each with over 120 pairs. Other species were

Table 2. Population sizes of breeding birds on Surtsey during whole island censuses in 1990 and 2003. The estimates for the gulls have been recalculated from previous publications (Petersen 1993, 2004) using the correction factors in Table 1.

	1990	2003
Black Guillemot	15	35–40
Fulmar	120	350–400
Kittiwake	4	130
Great Black-backed Gull	31	86
Lesser Black-backed Gull	126	175
Herring Gull	20	37
Glaucous Gull		3
Snow Bunting		11
Greylag Goose		2
Meadow Pipit		2
White Wagtail		1
Total	316	832–887



Fig. 1. An adult Great Black-backed Gull on Surtsey. Photo: Erling Ólafsson, July 9, 2007.

Table 3. Population figures for the breeding species on Surtsey Island from first colonization in 1970 to 2008. The information is compiled from various sources published and unpublished. Shading indicates first year of confirmed breeding. In many cases breeding was confirmed (+) but no estimate was available for the island population. Parentheses indicate possible breeding.

	Black Guillemot	Northern Fulmar	Great Black-b. Gull	Kittiwake	Arctic Tern	Herring Gull	Lesser Black-b. Gull	Glaucous Gull	Snow Bunting	White Wagtail	Greylag Goose	Meadow Pipit	Common Puffin	Raven
1970	2	1												
1971	7	11												
1972	6-8	13												
1973	2+	8												
1974	4	7+	1											
1975	4	17	1	8	1									
1976	6	13	3	0	4									
1977	10+	13-15	3	7	0									
1978	11-12	26	7	2	1									
1979		+	4	+	0									
1980		3	4	+	0									
1981	15-16	6	5	0	0	1								
1982														
1983														
1984		20-30	7	+	0	1								
1985			6											
1986		+				+	+							
1987		13+	15		0	11	+							
1988														
1989														
1990	15	120	31	4	0	20	126							
1991														
1992							+							
1993	+	+	+	+	0	+	+	1						
1994														
1995	+	+	+	+	0	+	+	+						
1996	+	+	+	+	0	+	+	+	1					
1997	+	140+	50	20	0	45	95-100	5	1					
1998									+					
1999	+	+	+	+	0	+	+	+	1		(1)			
2000		+	+	+	0	+	+	+	+		(1)			
2001		+	+	+	0	+	+	+	1	1	1			
2002	25	140+	35	30+	0	35	65+	1	2+	1	1	(2)		
2003	35-40	350-400	86	130	0	37	175	3	11	1	2	2		
2004	+	+	+	+	0	+	+	+	+	+	+	+		
2005	+	+	+	+	0	+	+	+	+	0	+	+	2	
2006	+	+	+	+	0	+	+	+	+	1	+	+	+	
2007	+	+	+	+	0	+	+	+	+				+	
2008	+	+	+	+	0	+	+	+	+	0	0	+	+	1

less common, in declining order, Great Black-backed Gull, Herring Gull, Black Guillemot, and Kittiwake (Table 2).

At the 2003 census five new species had started breeding since 1990 and all of the previous ones were still present (Table 2). The total numbers of breeding pairs had increased from 316 to around 850. In both years Fulmar was the most common species, with 350–400 nests in 2003 and Lesser

Black-backed Gull second with 175 pairs. Kittiwake had increased considerably, as had Great Black-backed Gull, Herring Gull, and Black Guillemot. The Snow Bunting, which started breeding in 1996, had reached 11 pairs by 2003. Glaucous Gull had three pairs, and there were two pairs each of Greylag Goose and Meadow Pipit. White Wagtail was represented by only a single pair. One mixed pair of Glaucous Gull and Herring Gull was found in 2003,

but these species commonly hybridize (Ingólfsson 1970, Vigfúsdóttir, Pálsson & Ingólfsson 2008).

Available population estimates for the breeders since birds started breeding in 1970 are presented in Table 3. On the whole the populations have increased slowly since starting to breed. The main exception is the Arctic Tern that was found breeding in 1975, 1976 and 1978 but never thereafter. Arctic Tern colonies are often unstable, especially small ones (Petersen 1998). The Glaucous Gull has maintained its number of breeding pairs, with 5 pairs in 1997 to 4–5 in 2003. One White Wagtail pair was present in at least 2001–2003 and 2006. The Great Black-backed Gull has more or less held its breeding population from 1990 and the Herring Gull since 1997. The Kittiwake and Snow Bunting have increased in numbers. The Fulmar and Lesser Black-backed Gull greatly increased until 2003, in line with the general population development elsewhere in Iceland (Petersen 1998). The rarest species did not seem to be fully annual; White Wagtails were at least not present in 2004 and 2008, nor were Greylag Geese in 2008 but data are not complete for every year.

Breeding distribution

Distribution of the breeding species in 2003 is shown in Fig. 2. Notable changes had taken place since 1990. In 2003 Fulmars had started nesting on level ground in the gull colony, but were earlier confined to the sea cliffs and several inland slopes on the craters. The gull colony had expanded in all directions, except north. The reason is probably unsuitable habitat of unstable sand dunes in the centre of the island. In 2003 the Great Black-backed Gulls nested primarily where the colony was formed in 1986 and which is now densely vegetated. The Lesser Black-backed Gulls showed the widest distribution, flanking the Great Black-backed Gulls towards southwest, south and east, extending eastwards all the way to the seaward side of the research hut. Herring Gulls showed much the same distribution as the Lesser Black-backed Gull but were much less common. The Glaucous Gulls nested where they started in 1993, at the eastern limit of the gull colony. Distribution of the different gull species did not have clear-cut boundaries but mixed within the colony. Four species of large gulls nesting together is rather uncommon in Iceland but can e.g. be found on the island of Grímsey in Steingrímshöfðum, NW-Iceland (cf. Jóhannsson & Guðjónsdóttir 1995).

Since first breeding in 2003 the Meadow Pipits have nested within the most densely vegetated part of the gull colony (Fig. 3). Individual birds were seen on occasions in 2003 at the centre of the island, near the research hut and the large craters but they were believed to be the breeding birds

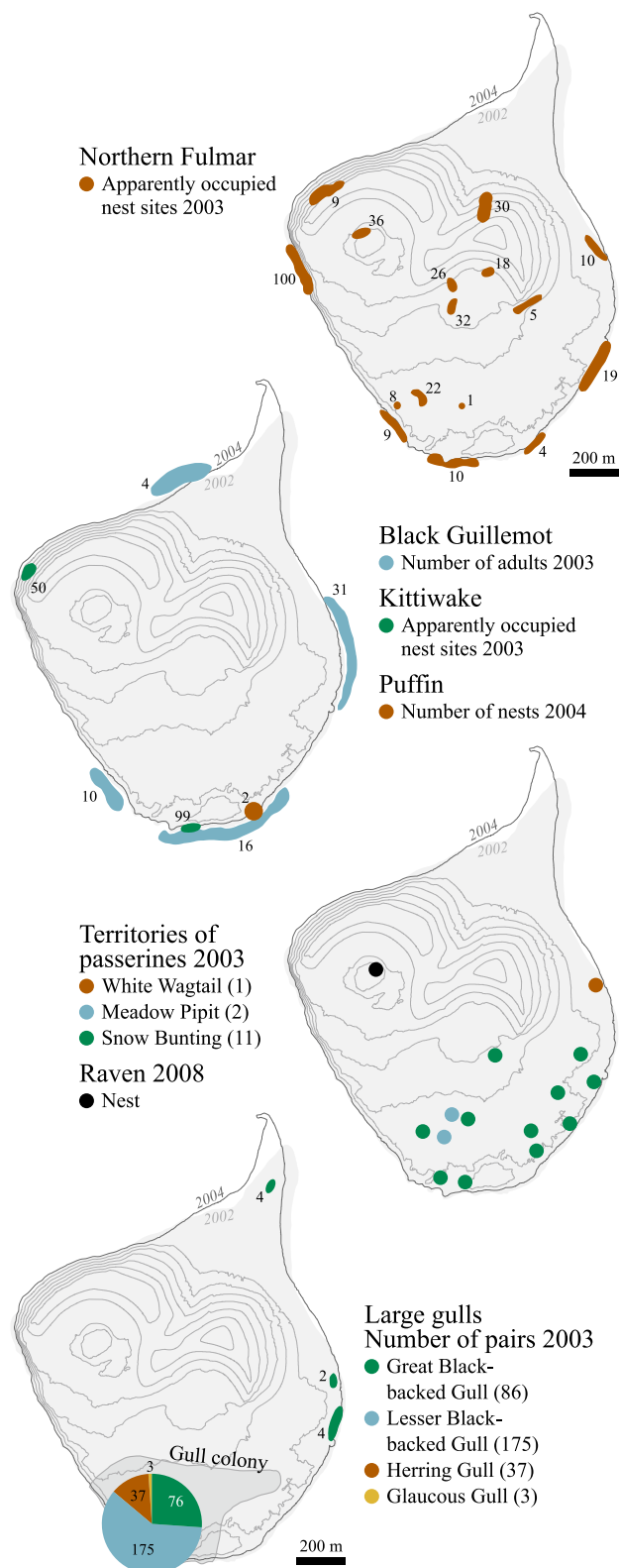


Fig. 2. Breeding distribution of the eleven bird species nesting on Surtsey in 2003 and two species nesting thereafter until 2008. The two years shown indicate the shore line in 2002 and 2004.

from the gull colony on feeding excursions. Similarly in 2003 White Wagtails, which were only found nesting at one place on the eastern sea-cliffs, were



Fig. 3. Meadow Pipit chicks in nest on Surtsey. Photo: Erling Ólafsson, July 9, 2008.

seen on occasions in the centre of island. Snow Buntings were found on their territories mainly towards east from the gull colony in the direction of the research hut. The lava fields are roughest in this southeast part of the island. Three nests were discovered and also adults with fledglings.

One of the two areas frequented by Puffins in 2003 is the same place where they were breeding in 2004. The Ravens nested in 2008 and produced three chicks in the large westernmost carter (Surtungur), where nest-building had been attempted on and off in many years from as early as 1986.

The gull colony

The growth of the gull colony on the southern part of Surtsey has had significant effects on the development of plant and invertebrate communities (Magnússon & Magnússon 2000, Magnússon & Ólafsson 2003). Effects of gulls and other seabirds on the vegetation of their breeding sites are well known (Fridriksson 1979, Sobey & Kenworthy 1979, Stempiewicz 1990, Ellis 2005). Various aspects of gull behaviour contribute to this; the delivery of food ashore, defecation, regurgitation, and nest-building. Soil analyses on Surtsey have showed much higher nutrient values (P, K, NH₃) in gull nests than away from them (Fridriksson 1977a, Magnússon & Magnússon 2000).

Gulls are omnivores; they feed on natural foods (fish, eggs), scavenge, take offal and discards from fishing vessels while predated on other birds, even kleptoparasitize other birds. Most of their foods are of marine origin and some carried on land, some eaten by chicks, later regurgitating the indigestible remains as pellets. Some foods get partially eaten and others left untouched to decay, becoming food for micro organisms and invertebrates. The adult gulls as well as the chicks defecate all over the colony area. Food remains and pellets

found at gulls' nests on Surtsey have included a leg of gull and unidentified bones, adult Razorbill *Alca torda* head, and legs of alcid young (possibly Razorbill) taken at sea or nearby colonies. In 2003 food remains found included several Puffin and guillemot *Uria* eggs (originating from neighbouring islands), predated gull chick, and fish remains, e.g. small Redfish *Sebastes* and relatively large (10–20 cm) unidentified fish lying around in the colony. In 2003 a fish tag (Isl. Hafr. 62014) was found in the gull colony, the fish was most likely carried on land as food for gull chicks. The Marine Research Institute confirmed that it came from a Pollock *Pollachius virens* fry tagged ca 20 km away a year before then 40 mm long. Herring Gulls on Surtsey were in 1990 seen prospecting Fulmar eggs, which are particularly vulnerable if the birds are off duty, being snow white against the black lava and sand. Eaten Fulmar eggs were found near predated nests in the gull colony on human disturbance. Gulls also predate on land birds. Snipe *Gallinago gallinago*, unidentified wader leg, and a female Crossbill *Loxia curvirostra* have been found by gulls' nests. Bones and wings of Golden Plover *Pluvialis apricaria* were found in a nest (Fridriksson 1977b).

In the early years of the island concern was expressed that the gulls were having negative influence on the vegetation development. They tore colonizing plants, at that time mainly Sea Sandwort *Honckenya peploides*, for use as nest material, possibly setting back their expansion but also dispersing seeds. Plant growth took rapid steps forward after the gulls formed a colony in 1984 but previously they had only nested dispersed. In 1990 an analysis was made of the nest material in gulls' nests (Table 4). There was a clear difference in nest material selection between the gull species. Great Black-backed Gulls choose primarily Sea Sandwort, while Lesser Black-backed and Herring Gulls selected mosses. The timing of breeding differed between the gull species, as shown in 1990 (Table 5). Great

Table 4. Nest material in gulls' nests on Surtsey 1990. Numbers of nests are given. The gull species are Great Black-backed Gull (GBBG), Lesser Black-backed Gull (LBBG) and Herring Gull (HG).

	GBBG	LBBG	HG
Lymegrass	1		
Grasses	1		
Sea Sandwort	14	2	
Mosses	1	25	5
Mosses and grasses		6	3
Mosses and Sea Sandwort		6	3

Table 5. Difference in the timing of breeding of three gull species nesting on Surtsey in 1990. No. of nests with % in parentheses is shown.

	Eggs	Chicks
Great Black-backed Gull	4 (23)	12 (77)
Herring Gull	10 (91)	1 (9)
Lesser Black-backed Gull	39 (100)	0 (0)

Black-backed Gulls nest earliest then Herring Gull and Lesser Black-backed Gull was the latest.

Sea watches

In order to obtain an idea of the use of the sea areas around Surtsey, sea watches were conducted in three sessions on 6–7 June 1990 using a fixed telescope at a preset location. Each session consisted of three 10-minute observation stints but all the data were combined on analysis. The results are summarized in Table 6. Altogether 466 birds were seen, of which 118 (25%) were unidentified. The great majority of the birds were in flight (448; 96%), the rest on the water. Fulmar was the most common species, then Puffin and Kittiwake, but all others with less than 10% frequency.

On the whole these frequencies reflect the commonness of the species in this general region but not quite. Fulmar (Fig. 4), Puffin and Common Guillemot *Uria aalge* are the most common breeding species on the Westman Islands. The last species should have been in greater frequency except it usually feeds further offshore. Arctic Tern and Arctic Skua *Stercorarius parasiticus* do not breed on the island but are commonly found feeding in the region. Oystercatchers *Haematopus ostralegus* nest

Table 6. Birds seen offshore from Surtsey and their numbers during three observation sessions on 6–7 June 1990.

	Total	%
Fulmar	144	41
Puffin	62	18
Gannet	44	13
Kittiwake	34	10
Common Guillemot	33	9
Arctic Tern	18	5
Oystercatcher	5	1
Great Black-backed Gull	4	1
Lesser Black-backed Gull	2	1
Black Guillemot	1	<1
Arctic Skua	1	<
Unidentified*	118	

* Mainly birds, which were flying too near and rapidly across the telescope field of view, while some were too far away.



Fig. 4. Fulmars are common breeders on the Westmann Islands, including Surtsey. They were the first bird species to start breeding on Surtsey (in 1970) together with Black Guillemots. Photo: Erling Ólafsson, July 10, 2007.

on nearby Heimaey Island, while the three gull species nest on Surtsey, Black Guillemots and Fulmars. They most likely feed in the sea areas in the vicinity of the island.

Vagrants

The numbers of straggling species (vagrants) recorded depend heavily on the length of period and time of year studies are carried out. Regular observations were only maintained during the migration periods (spring, autumn) in the early years of the island. Therefore most of the vagrant records are from those years. In the last three decades greater emphasis has been placed on recording new species for the island and following the development of the breeding bird fauna, with visits mainly concentrated in the summer (June–July). Food availability, e.g. the type of plants and extent of vegetation, availability of insects and beached food, etc., also governs the length of stay of many of these vagrants.

Two vagrant species very rare to Iceland have been recorded on Surtsey, the European Squacco Heron *Ardeola ralloides* (1969) and the North-American Northern Oriole *Icterus galbula* (1971). The former is the only record for Iceland while the last was the third. The other vagrant species mostly include the commonest and most regular vagrants in Iceland, such as Little Gull *Larus minutus*, Turtle Dove *Streptopelia turtur*, Long-eared Owl *Asio otus*, Swallow *Hirundo rustica*, European Robin *Erithacus rubecula*, Song Thrush *Turdus philomelos*, Garden Warbler *Sylvia borin*, Chiffchaff *Phylloscopus collybita*, Willow Warbler *P. trochilus*, Jackdaw *Corvus monedula*, Chaffinch *Fringilla coelebs*, Brambling *F. montifringilla*, Crossbill *Loxia curvirostra*, and Lapland Bunting *Calcarius lapponicus*. Several addition-

al, but are generally not as common, vagrants in Iceland have been recorded, e.g. Corncrake *Crex crex*, Sky Lark *Alauda arvensis*, Rock Pipit *Anthus spinoletta*, Redstart *Phoenicurus phoenicurus*, and Ring Ouzel *Turdus torquatus*.

Several bird species do not breed but are regular and common visitors in Iceland, mostly as winter visitors. Some of those have been seen on or near Surtsey, such as Grey Heron *Ardea cinerea*, King Eider *Somateria spectabilis*, Iceland Gull *Larus glaucooides*, Little Auk *Alle alle*, and Fieldfare *Turdus pilaris*.

In addition to vagrants that have been seen on land, some have only been observed at sea in the vicinity of the island. This includes Sooty Shearwater *Puffinus griseus*, Common Tern *Sterna hirundo*, and Blackcap *Sylvia atricapilla*. Much greater numbers of vagrant species have been observed on Heimaey Island 20 km from Surtsey. This results from a permanent year-round human settlement, more feeding possibilities due to more diverse habitats, and considerable bird interest.

Migrants

Surtsey is ideally situated for the study of migration. It is the southernmost land in Iceland, and right on the migratory flyway between the High Arctic of Greenland – Canada and wintering areas in Europe – Africa. Migrating land-birds and waders are therefore likely to stop over on the island, although their length of stay depends on the food availability. The spring return of some Icelandic migrant breeders, which mostly travel southeast for winter, is more concentrated at the south-east parts of Iceland. Surtsey may hence not seem suited for studies of these migrants, depending on the species in question.

During 1966 to 1971 bird observers were stationed on the island to monitor various activities, including the bird migration, mainly during spring but also in the autumn (Gudmundsson 1966, 1967, 1968, 1970, 1972). From these studies a reasonably good overview is available of the migratory land-birds in the early years of the island, summarized here. The migration observations from Surtsey are interesting to compare to results elsewhere in Iceland, but a detailed analysis is outside the scope of this text.

The insect-feeding species, such as Wheatear *Oenanthe oenanthe*, Meadow Pipit, and White Wagtail were among the most common migrants. Insects were over the whole island, although patches of vegetation and the coastline are best suited (Ólafsson & Ingimarsdóttir 2009). These are passerines and common breeders in Iceland. The last two are undoubtedly of Icelandic origin but birds of the first belonged also to the population breeding in Greenland.

Other High-Arctic migrants included Turnstone *Arenaria interpres* and Snow Bunting. In these early years of the island these two species did not have opportunities for foraging except along the tide-line, the first feeding on drifted small crustaceans (euphausids) and Goose Barnacles *Lepas* spp. The Snow Bunting is mainly a seed-eater and its food on the island is likely to have consisted mainly of drifted seeds when vegetation was still sparse. With ever increasing vegetation their feeding possibilities have dramatically changed, finally leading to the species starting to breed. Migratory Snow Buntings were also found to have grit (mineral stones) in the stomachs of such origin that they must have migrated from the British Isles (Fridriksson 1964, 1970, Fridriksson & Sigurdsson 1968, 1969).

The most frequent staging wader species was Oystercatcher, while others showed up e.g. Ringed Plover *Charadrius hiaticula*, Redshank *Tringa totanus*, and Dunlin *Calidris alpina*. These are all common Icelandic breeders, while the last could also be birds continuing to High-Arctic breeding grounds. These birds were mostly seen feeding on the coast, hence the length of their stay was dependent on what brought in by the tide. Other High-Arctic wader breeders, the Knot *Calidris canutus* and the Sanderling *C. alba*, have been observed on the island but only in small numbers. They regularly stage in Iceland in large numbers, especially the south-west and west. The habitat and food situations for these birds were most likely unfavourable on Surtsey. Same for three other waders, which are common breeders in Iceland, Golden Plover *Pluvialis apricaria*, Snipe *Gallinago gallinago*, and Whimbrel *Numenius phaeopus*. They did not find the right habitat or feeding conditions on Surtsey, not even nowadays. They have been recorded occasionally on land but not in the relative large numbers that are likely to pass the island during migration.

During the observation years around 1970 geese were often seen in flight on migration off the island. As they are vegetative feeders the island did not offer proper feeding conditions, although they were seen stopping in small numbers for short periods of time. Three species of geese have been recorded, Greylag Goose, Pink-footed Goose *Anser brachyrhynchus*, and Barnacle Goose *Branta leucopsis*. They all breed in Iceland, and the last two also in the High-Arctic. With increased vegetation staging by geese may have become more frequent, finally leading to Greylag Geese starting to breed, probably as early as 1999.

The most detailed studies on the migratory birds were made on the Meadow Pipit and the Wheatear. Information was gathered on the timing of arrival in spring (late April into May) and the body condition of the birds. Comparison of the two species

Table 7. Species and numbers of birds ringed on Surtsey in 1975, 1990, 1993, 1997 and 2003.

	Adults on nests					Unfledged chicks					Total
	1975	1990	1993	1997	2003	1975	1990	1993	1997	2003	
Fulmar					118		1				119
Lesser Black-backed Gull				5				14	10	25	54
Great Black-backed Gull						1	3	38	40	164	246
Glaucous Gull								1		6	7
Herring Gull								18	10		28
Meadow Pipit										1	1
Snow Bunting										3	3
				5	118	1	4	71	60	199	458

showed an interesting dichotomy in these related passerines in spring. Meadow Pipits were generally emaciated, as if they had used up most of their fat reserves during the flight from Europe. Recoveries of the Meadow Pipits have shown Icelandic birds overwinter in SW-Europe, while the Wheatear travel further, to W-Africa (Petersen 1998). Contrary to the pipits the Wheatears were in excellent body condition upon arrival on Surtsey. They needed this for travelling to the High-Arctic, while the pipits do not migrate further than Iceland.

As is apparent from above the combination of species stopping over on Surtsey, and their frequency in numbers, are likely to have changed since the early years of the island, when hardly any vegetation had colonized it. Therefore it would be of interest to repeat the earlier migration observations from around 35 years ago.

Winter visitors

The wintering birds are less well known than the situation in summer, or during the migration periods in spring and autumn. Only fragmentary observations exist but of the terrestrial birds Purple Sandpipers *Calidris maritima* and Ravens have been recorded in mid winter (31 January). European Redwings *Turdus iliacus* have been seen as late as 25 November, probably late migrants. Gulls of various species have also made landfall on Surtsey, for resting or scavenging for tide-line food. However, as expected seabirds dominate such as Kittiwake, Fulmar, gulls, and auks, mainly on the seas around the island.

The winter bird fauna is presumably similar to that registered on the nearby Heimaey during the annual Icelandic Christmas Bird Counts (Petersen 1983, Petersen & Hjartarson 1989, 1991, 1993). Besides the birds mentioned above, other common species include Great Cormorant *Phalacrocorax carbo*, Common Eider *Somateria mollissima*, and Snow Bunting.

Ringling

Bird ringling, by attaching a metal ring to a leg, is the traditional method of studying the travels of migratory birds. During the period of migration studies on Surtsey emphasis was placed on collecting museum specimens. Ringling has not been used much as a tool to study birds on Surtsey, but could add considerable knowledge to the birds' migratory habits, on the location of their wintering grounds, body condition, origin of their breeding place, etc.

Only on five occasions have ringling been undertaken on Surtsey, in 1975, 1990, 1993, 1997 and 2003, in all 458 birds of six species (Table 7). Recoveries of Surtsey-ringed birds have been few away from the island. By the end of 2008 these were nine; Lesser Black-backed Gull (3), Great Black-backed Gull (5), and Herring Gull (1). One Lesser Black-backed Gull was recovered nearly five years later in the Faeroes in spring, presumably on its way back to Iceland from the wintering grounds. One was sighted on the wintering grounds in Spain during height of winter half a year old. The third bird was sighted twice soon after fledging on fishing boats off the Westman Islands. Two Great Black-backed Gulls were recovered in the Faeroes in their first autumn, presumably southbound. A third bird of similar age over-wintered in Iceland and was shot near Reykjavik. The fourth bird was also shot near Reykjavik three years after ringling. The fifth bird was found dead three years old in the Heimaey harbour, the only inhabited island in the Westman Islands group. The only recovered Herring Gull was found dead at Breidamerkur-sundur, SE-Iceland two months after ringling on Surtsey. Then one bird, ringed outside Surtsey has been recovered there. A Redshank *Tringa totanus* was ringed in England as a full-grown bird and recovered on Surtsey two years later during the migration period in spring. Undoubtedly this was an Icelandic bird returning from the wintering grounds for the summer.



Fig. 5. Great Black-backed Gull chicks on Surtsey. When big enough the chicks wander from the colony area towards the sea cliffs on disturbance. Photo: Erling Ólafsson, July 8, 2008.

All the recoveries are in accordance with the general migratory behaviour of gulls from elsewhere in Iceland, also the appearance of the Redshank (cf. Petersen 1998). Despite relatively many Fulmars having been ringed on Surtsey none has been recovered to date. This species is among the largest bird populations in Iceland and adults not harvested, which normally increases the chances of recovery. On the other hand the ringed adults can be expected to show up on the nesting sites on Surtsey in many years to come as they are one of the most long-lived bird species.

The gull colony on Surtsey is in some ways ideal for ringing studies, as it contains four species of large gulls (Fig. 5), three of which are in relatively large numbers, and is relatively undisturbed from humans contrary to elsewhere in Iceland. But there are also drawbacks to such a dense colony, as discovered in 2003. Gulls are omnivorous and also predatory if opportunities arise, both inter-specifically and cannibalistic. If the parents are flushed away on human approach and the chicks wander off their parents' territory, they are likely to get killed by other gulls. In July 2003, about a month after ringing, eight (of 195) gull chicks (and a number of unringed chicks) were found dead. Chick deaths were in general higher than in 2002 (E. Ólafsson, pers. comm.). Although poor feeding conditions in 2003 cannot be ruled out, it seems likely that disturbance in the colony resulted in unusually heavy chick mortality. Surtsey is a proclaimed nature reserve which is closed to visitors and where nature should take its own course and human influences be kept at a minimum. Bearing this in mind caution is therefore needed when approaching the gull colony and rules are clearly needed for visits.

DISCUSSION

Ecological relationships – development of a bird community

The development of a new breeding bird community is dependent upon many factors, both physical and biological. Different sectors of such a community depend upon different scenarios, which govern the rate at which the community develops. The birds, firstly, need to reach the island, and this in turn is dependent upon a host of factors such as population size, feeding habits, travelling capabilities, the distance to breeding sources, etc. On reaching the island another suite of factors influence the rate at which individual species colonize the island, e.g. time of year, feeding conditions, breeding habits, available habitats, etc. The sea has important influences, in that organic matter is brought on land in different forms by birds. Sea spray also brings minerals onto land and the terrestrial communities develop through interaction between the developing vegetation and its associated invertebrate fauna, which are food resources for the birds.

Bird communities are usually made up of species with different life styles; the complexity depends on the environmental conditions available at each location. In the beginning, all the breeding species on Surtsey relied on the ocean for their food. Such was the situation in the summer of 1990, but a decade later the island had become much more vegetated with increased insect life, making it possible for terrestrial birds to maintain themselves and breed. Currently Snow Buntings, which are seed and insect eaters, Greylag Geese which are grazers, and the insect-feeding White Wagtails and Meadow Pipits have successfully colonised the island. Ravens, which subsist on eggs, birds or by scaveng-

ing, have long been able to sustain themselves on the island, but the general feeding conditions were presumably still too poor for breeding and raising young until 2008. The large gull colony of around 300 pairs in 2003 could presumably supply enough energy for a breeding pair of Ravens. However, the gulls that breed on Surtsey are large, hardy birds, which by their sheer numbers are likely to keep the Ravens away. On the other hand Fulmars are vulnerable with its large and very visible white egg, although they spit stomach oil and partially digested food if provoked to keep predators at a distance.

The gull situation on Surtsey makes an interesting study, both the development of this multi-species community and the interactions with vegetation and the terrestrial invertebrate fauna. This is a colony which is largely unaffected by man, but gulls are generally harassed in Iceland if not killed, as they are looked upon as pests. Therefore many gull colonies are rather unstable and often difficult to separate natural influences from human-induced ones. Although the gulls on Surtsey have not been left fully undisturbed this colony provides excellent study opportunities, comparing species and comparing with different situations elsewhere.

The breeding birds so far have been largely seabirds although one could question why Arctic Terns, which still commonly feed offshore, have not bred for so long. Until rather recently feeding conditions have not been available for terrestrial birds. Greylag Geese and Meadow Pipits did not start breeding until the vegetation cover in the gull colony had become sufficient. Snow Buntings started earlier since they feed on seeds, which both drift ashore or stem from the developing plant community, complete vegetation cover was not needed since they nest in holes in the lava, unlike Meadow Pipits which usually place their nest in the side of grassy knolls.

The breeding birds are obviously very important in the formation of soil on the island, as well as in the development of the plant and insect communities. This is especially true for the seabirds, which actively transport nutrients from the ocean onto land. This is particularly noticeable in the gull colony in the southern part of the island, where full vegetation cover has developed on the oldest colony area from 1984 as a result of their breeding and nutrient-transfer activities.

The extensive organic matter carried by seabirds onto land in the form of excreta, food and nest material can lead to a species-few plant community as found in dense seabird colonies elsewhere. Nutrient enrichment has positive effects on various other organisms, such as fungi, algae, bacteria and the invertebrate community that feeds on these. The compilation of nest materials, dead bodies, pellets, food remains, excreta, etc. have positive effects on

both flora and small fauna development (cf. Ólafsson 1982, Gjelstrup 2000). For instance, nests can serve as sites for seed colonization, and dead tissue as food for small animals (Ólafsson 1982). Grass-pulling for nest-building, in itself a destructive exercise can in the end be positive for the development of the ecosystem by dispersing plant seeds. On the negative side trampling and nest-scraping of birds can slow down vegetation development, but undoubtedly these factors are minor compared to the positive aspects of gull behaviour.

Since the geese and the Meadow Pipits nest within the gull colony predation can easily slow down the rate of their population development. On the other hand the gulls are likely to act as protectors against marauding Ravens. The delicate balance between predation and protection will decide if these terrestrial birds continue to breed in the long run. Ravens, as top predators, did not seem to be able to breed and successfully raise chicks until the seabird population had reached a certain size. Yet they are also able to seek food (eggs and dead birds) on nearby islands, or scavenge on bird corpses or marine biota washed up on the Surtsey beach.

Surtsey is subject to much erosion from ocean wave action and the island becomes constantly smaller (Jakobsson & Gudmundsson 2003). This creates instability for cliff-nesting birds, which are primarily Fulmars, Kittiwakes and Black Guillemots. The last two species breed exclusively on sea-cliff faces, while Fulmars are able to go inland for breeding, thus avoiding the effects of habitat destruction. Through the years Kittiwakes have changed breeding sites on the cliffs presumably as a result of the physical changes in the cliff faces that have taken place from one breeding season to another, unlike in more stable situations elsewhere. Black Guillemots are more likely to find appropriate fissures to breed on the same island section although the cliff has changed by erosion since the year before. But in the end it is likely that most of the flat lava fields on Surtsey will erode away but the more resilient tuff mountains will persist. Similar processes have taken place in the past to most of the twenty stacks which now form the Westman Islands group. Species like Greylag Goose and Meadow Pipits, and most of the gull colony, will likely disappear with time, after decades or a few centuries.

Candidate breeders

While the bird fauna is still developing, several species can be mentioned as likely breeding candidates in years to come. A Rock Pipit *Anthus petrosus* was seen in mid summer of 2002. The Oystercatcher and the Ringed Plover are also possible colonizers, while the Arctic Tern may well begin to

breed again. Two petrel species, which nest on the other Westman Islands, the Storm Petrel *Hydrobates pelagicus* and Leach's Petrel *Oceanodroma leucorhoa*, have been considered potentials for breeding but have so far evaded discovery. In 2007 Razorbill *Alca torda* was seen on the sea near the cliffs showing behaviour which pointed to breeding but this was not confirmed. No freshwater is found on the island and this will greatly influence the species likely to colonize Surtsey in years to come. Species that are attracted to freshwater, such as many waders and ducks are not likely to start breeding.

Potential human influence

Researchers and visitors alike can affect the development of the breeding bird community on the island albeit indirectly or unwittingly. The Fulmar and the gulls are particularly vulnerable in this respect. When scared Fulmars often throw their egg from the nest bowl which means breeding is over for them that season. Gulls are scavengers as well as predators and unguarded eggs and young are liable to predation by conspecifics or other species. So if humans stay unduly long in or very near the colony, this can result in heavy predation. Fulmars have also started nesting within the boundaries of the gull colony. If they are flushed off their eggs considerable time can last until they return and their large white egg, so visible against the black lava or sand on the island, is an easy catch for gulls, or perhaps Ravens. This became clear in 2003 when ringing of gull chicks was carried out and 21 Fulmar eggs were present in the epicentre of the gull colony in the beginning. The day after only 13 were left but 4 were found broken and the gulls probably removed the rest. In light of these facts, it is important to establish some code of conduct in the colonies of these birds, especially during the egg stage and when chicks are small from May to early July.

More alarming than unintended effects, are the actions by man which wittingly are affecting the breeding bird fauna. On one occasion at least gulls were found dead in numbers on land in the main breeding colony, also freshly fired patrons. Although any use of firearms is by regulation illegal they had obviously been shot by people who had landed on the island without permit. Surtsey has been sat aside for nature to develop on its own principles and direct influence of man prohibited. It is therefore sad that someone is prepared to jeopardize this unique opportunity for studying the development of a new ecosystem.

RECOMMENDATIONS FOR FUTURE MONITORING

It is important to maintain regular observations on the birdlife on Surtsey to obtain reliable data on

the changes in the bird fauna. The following bird monitoring aspects are recommended for Surtsey: (a) breeding bird surveys, (b) registration of visitors and other incidental observations, (c) recording seabirds at sea, and (d) bird ringing. Detailed descriptions of methods used for each of these aspects are outside the scope of this paper. Some can be found in the general monitoring literature, such as Walsh & Harris (1995) and Gilbert, Gibbons & Evans (1998).

Breeding birds surveys

It is recommended that complete coverage of the breeding birds takes place at least every 3rd year. This involves censuses of the numbers breeding of each species and their breeding distribution. Mapping on aerial photographs is recommended. Different census techniques are needed depending on species. From land the gull colony is best surveyed by telescope from the slopes of the nearby crater (Surtur). The colony should also be surveyed by vertical aerial photography for comparison with ground truth. Ground transects for nests are also possible since many nests are invisible from air although the partners to incubating birds may show up on photographs. Disturbance may however be too severe. Only partial counts can be made on the sea cliffs from land. Hence counts from a boat or helicopter (Fulmar, Kittiwake, Black Guillemot), are desirable for complete coverage.

Registration of visitors and other incidental observations

New or rare bird species can be expected to show up on Surtsey virtually any time, and it is important that such records be noted and made available. Compilation of such records is one form of monitoring, giving an indication of the origin and frequency of potential settlers. A number of scientists visit Surtsey every year and many of them have a good knowledge of birds and can therefore contribute with their, albeit incidental, observations. Till now these observations are scattered in diaries and even not recorded. It is recommended that these observations be compiled in a common database so that they will become available for future consideration as part of the monitoring program for the island.

Recording seabirds at sea

The seabird community at-sea in the vicinity of Surtsey can be studied by three principal methods, sea-watching from land, transects from boats, and transects from aeroplanes. Such studies give the species composition, frequency of individual species, and how they use the sea areas around the island. It is recommended that such a distribution-at-sea aspect is added to the overall monitoring program for the island. Each of the three methods

has their shortcomings, hence a combination of methods is recommended.

Bird ringing

It is suggested that bird ringing be a part of the bird monitoring effort on the island. Emphasis should be given to the breeding birds and the regular staging visitors in spring and autumn. Such studies broaden the knowledge of the birds visiting Surtsey and their travels, towards breeding regions elsewhere in Iceland or in the Arctic and the wintering areas, elsewhere in Iceland or at more southerly latitudes. New technologies, such as geo-locators, can also be employed for this purpose.

ACKNOWLEDGEMENTS

This overview has benefited from the observations of numerous people, who have visited Surtsey since the island was formed. Thanks to all these individuals. In the early years of the island, a number of observers were stationed on the island for longer or shorter periods, such as Hálfván Björnsson and Erling Ólafsson before and after 1970. Borgthór Magnússon and Sigurdur H. Magnússon have visited the island for decades and contributed many bird observations, as well as important papers on bird-vegetation interactions. In 1990 the island was visited by Jóhann Ó. Hilmarsson, who produced a short report on his visit, as did Hallgrímur Gunnarsson in 1997. Thanks to all these individuals, as well as the Surtsey research pioneers, to name but Sturla Fridriksson and Finnur Gudmundsson from the biological side. Thanks to my fellow travellers on recent Surtsey visits for their help and support, Gudmundur A. Gudmundsson (1993), Sverrir Thorstensen, Thórey Ketilsdóttir, and Magnús Magnússon (2003). Erling Ólafsson contributed the bird photographs from Surtsey, for which I am grateful. Lastly, Borgthór Magnússon and Tom Barry read a draft of the paper and their comments are greatly appreciated.

References

Anon 1966. Fugl seztur að í Surtsey. (Birds colonize Surtsey.) Althýðublaðið 13.7., 47(155): 1, (in Icelandic).
Baldursson, S. & Á. Ingadóttir (eds) 2007. Nomination of Surtsey for the UNESCO World Heritage List. Náttúrufræðistofnun Íslands/Icelandic Institute of Natural History. 123 pp. + map.
Barbraud C. & G. Gélineau 2005. Estimating the sizes of large gull colonies taking into account nest detection probability. *Waterbirds* 28: 53–60.
Ellis, J.C. 2005. Marine birds on land: a review of plant biomass, species richness, and community composition in seabird colonies. *Plant Ecol.* 181: 227–241.
Fridriksson, S. 1964. Um aðflutning lífvera til Surtseyjar. (The colonization of the dryland biota on the island of Surtsey off the coast of Iceland). *Náttúrufræðingurinn* 34: 83–89, (in Icelandic with an English summary).

Fridriksson, S. 1970. Seed dispersal by Snow Buntings in 1968. *Surtsey Res. Progr. Rep.* V: 18–19.
Fridriksson, S. 1975. Surtsey. Evolution of life on a volcanic island. Butterworths, London. 198 pp.
Fridriksson, S. 1977a. The Black-backed Seagull's nest on Surtsey, Appendix X, 2 pages, *in*: Technical Progress Report of biological research on the volcanic island Surtsey and environment for the year 1976. Report to Div. of Biomedical and Environmental research, U.S. Energy Research and Development Administration, Washington 25, D.C. Contract no. EY-76-C-02-3531. 4 pp. + 12 appendices.
Fridriksson, S. 1977b. Bird-watching on the island of Surtsey summer 1976, Appendix IX, 7 pages, *in*: Technical Progress Report of biological research on the volcanic island Surtsey and environment for the year 1976. Report to Div. of Biomedical and Environmental research, U.S. Energy Research and Development Administration, Washington 25, D.C. Contract no. EY-76-C-02-3531. 4 pp. + 12 appendices.
Fridriksson, S. 1979. Observations of birds on Surtsey summer 1977. Pp. 61–68 *in*: Surtsey. Technical Progress Report of biological research on the volcanic island Surtsey and its environs for the period 1965–1978. Report to Dept. of Energy, Washington D.C. Contract no. EY-76-C-02-3531. 113 p.
Fridriksson, S. 1989. The volcanic island of Surtsey, Iceland, a quarter-century after it 'rose from the sea'. *Environmental Conservation* 16: 157–162.
Fridriksson, S. 1994. Surtsey. Lífríki í mótun. (Surtsey. Ecosystem formed). Hid íslenska náttúrufræðifélag og Surtseyjarfélagid, Reykjavík. 112 pp., (in Icelandic).
Fridriksson, S. & H. Sigurdsson 1968. Dispersal of seed by Snow Buntings to Surtsey in 1967. *Surtsey Res. Progr. Rep.* IV: 43–49.
Fridriksson, S. & H. Sigurdsson 1969. Snjótittlingar hugsanlegir frædreifendur. (The possible dispersal of seed by Snow Buntings to Surtsey in 1967.) *Náttúrufræðingurinn* 39: 32–40, (in Icelandic with an English summary).
Gilbert, G., D.W. Gibbons & J. Evans 1998. Bird Monitoring Methods – a manual of techniques for key UK species. RSPB, Sandy.
Gjelstrup, P. 2000. Soil mites and collembolans on Surtsey, Iceland, 32 years after the eruption. *Surtsey Research* 11: 43–50.
Gudmundsson, F. 1966. Birds observed on Surtsey. *Surtsey Res. Progr. Rep.* II: 23–28.
Gudmundsson, F. 1967. Bird observations on Surtsey in 1966. *Surtsey Res. Progr. Rep.* III: 37–41.
Gudmundsson, F. 1968. Ornithological work on Surtsey in 1967. *Surtsey Res. Progr. Rep.* IV: 51–55.
Gudmundsson, F. 1970. Bird migration studies on Surtsey in the spring of 1968. *Surtsey Res. Progr. Rep.* V: 30–39.
Gudmundsson, F. 1972. Ornithological work on Surtsey in 1969 and 1970. *Surtsey Res. Progr. Rep.* VI: 64–65.
Ingólfsson, A. 1970. Hybridization of Glaucous Gulls *Larus hyperboreus* and Herring Gulls *L. argentatus* in Iceland. *Ibis* 112: 340–362.
Jakobsson, S.P. & G. Gudmundsson 2003. Rof Surtseyjar. Maelingar 1967–2002 og framtíðarspá. (The marine abrasion of Surtsey, Iceland: areal changes 1967–2002 and future development). *Náttúrufræðingurinn* 71: 138–144, (in Icelandic with an English summary).
Jóhannsson, J.H. & B. Guðjónsdóttir 1995. Varpfuglar í Steingrímsfirði og nágrenni. Könnun 1987–1994. (Atlas of breeding birds in Steingrímsfjörður and vicinity, NW-Iceland: a survey 1987–1994.) *Fjölrit Náttúrufræðistofnunar* 28, 76 pp., (in Icelandic with an English summary).
Lloyd, C.S., M.L. Tasker & K. Partridge 1991. The Status of Seabirds in Britain and Ireland. T. & A.D. Poyser, Calton. xviii+355 pp.

- Magnússon, B. & E. Ólafsson 2003. Fuglar og framvinda í Surtsey. (The colonisation of Surtsey volcanic island by birds and plants.) *Fuglar* 2003: 22–29, (in Icelandic with an English summary).
- Magnússon, B. & S.H. Magnússon 2000. Vegetation succession on Surtsey, Iceland, during 1990–1998 under the influence of breeding gulls. *Surtsey Research* 11: 9–20.
- Nettleship, D.N. 1976. Census techniques for seabirds of arctic and eastern Canada. *Canadian Wildlife Serv. Occ. Pap. No. 25*. 33 pp.
- Ólafsson, E. 1971. Bird observations on Surtsey in 1971. Appendix VI, 3 p. *in*: Technical Progress Report of biological research on the volcanic island Surtsey and environment for the year 1975. Report to Div. of Biomedical and Environmental research, U.S. Energy Research and Development Administration, Washington 25, D.C. Contract no. AT(11-1)-3521.
- Ólafsson, E. 1982. The status of the land-arthropod fauna on Surtsey, Iceland, in summer 1981. *Surtsey Res. Progr. Rep. IX*: 68–72.
- Ólafsson, E. & M. Ingimarsdóttir 2009. The land-invertebrate fauna on Surtsey during 2002–2006. *Surtsey Research* 12: 113–128.
- Petersen, A. 1981. Breeding biology and feeding ecology of Black Guillemots. D.Phil. thesis. University of Oxford, England. xiv + 378 pp.
- Petersen, A. 1983. Fuglatalningar ad vetrarlagi: Saga og árangur. (The annual Christmas Counts in Iceland.) *Bliki* 2: 28–42, (in Icelandic with an English summary).
- Petersen, A. 1993. Fuglar. (Birds.), pp. 14 *in*: *Surtsey 30 ára*. Surtseyjarfélagid, Reykjavík. 16 pp., (in Icelandic).
- Petersen, A. 1998. Íslenskir fuglar (Icelandic Birds.) *Vaka-Helgafell*, Reykjavík. 312 pp., (in Icelandic).
- Petersen, A. 2004. The birdlife of Surtsey. Surtsey Research Society home page. (English transl. of the Icelandic text of 1.11.2003). 2 p. http://www.ni.is/surtsey/pp_isl/lifla_5.htm.
- Petersen, A. & G. Hjartarson 1989. Vetrarfuglatalningar: Skipulag og árangur 1987. (The Icelandic Christmas Bird Counts: Some general points, and results for 1987.) *Fjölrit Náttúrufræðistofnunar* 11, 42 pp., (in Icelandic with an English summary).
- Petersen, A. & G. Hjartarson 1991. Vetrarfuglatalningar: Árangur 1988. (The Icelandic Christmas Bird Count: Results for 1988.) *Fjölrit Náttúrufræðistofnunar* 18, 38 pp., (in Icelandic with an English summary).
- Petersen, A. & G. Hjartarson 1993. Vetrarfuglatalningar: Árangur 1989. (The Icelandic Christmas Bird Count: Results for 1989.) *Fjölrit Náttúrufræðistofnunar* 23, 43 pp., (in Icelandic with an English summary).
- Petersen, A. & S. Thorstensen 1993. Hettumásvörp í Eyjafirdi 1990. (The distribution and numbers of Black-headed Gulls in Eyjafjörður 1990.) *Bliki* 13: 45–59, (in Icelandic with an English summary).
- Sobey, D.G. & J.B. Kenworthy 1979. The relationship between Herring Gulls and the vegetation of their breeding colonies. *J. Ecol.* 67: 469–496.
- Stempiewicz, L. 1990. Biomass of Dovekie excreta in the vicinity of a breeding colony. *Colonial Waterbirds* 13: 62–66.
- Vigfúsdóttir, F., S. Pálsson & A. Ingólfsson 2008. Hybridization of Glaucous Gull (*Larus hyperboreus*) and Herring Gull (*Larus argentatus*) in Iceland: mitochondrial and microsatellite data. *Phil. Trans. R. Soc. B*. doi: 10.1098/rstb.2008.0042.
- Walsh, P.M. & M.P. Harris 1995. Seabird Monitoring Handbook for Britain and Ireland: a compilation of methods for survey and monitoring of breeding seabirds. JNCC, Peterborough, RSPB, ITE, The Seabird Group. Loose-leaf folder.

Appendix 1. Bird species seen on or around Surtsey 1963 – 2008. Species that have bred are marked with *.

Red-throated Diver	<i>Gavia stellata</i>	Common Gull	<i>Larus canus</i>
Great Northern Diver	<i>Gavia immer</i>	Lesser Black-backed Gull*	<i>Larus fuscus</i>
Northern Fulmar*	<i>Fulmarus glacialis</i>	Herring Gull*	<i>Larus argentatus</i>
Manx Shearwater	<i>Puffinus puffinus</i>	Iceland Gull	<i>Larus glaucoides</i>
Storm Petrel	<i>Hydrobates pelagicus</i>	Glaucous Gull*	<i>Larus hyperboreus</i>
Leach's Petrel	<i>Oceanodroma leucorhoa</i>	Great Black-backed Gull*	<i>Larus marinus</i>
Gannet	<i>Sula bassana</i>	Kittiwake*	<i>Rissa tridactyla</i>
Great Cormorant	<i>Phalacrocorax carbo</i>	Arctic Tern*	<i>Sterna paradisaea</i>
European Shag	<i>Phalacrocorax aristotelis</i>	Common Tern	<i>Sterna hirundo</i>
Squacco Heron	<i>Ardeola ralloides</i>	Common Guillemot	<i>Uria aalge</i>
Grey Heron	<i>Ardea cinerea</i>	Brünnich's Guillemot	<i>Uria lomvia</i>
Whooper Swan	<i>Cygnus cygnus</i>	Razorbill	<i>Alca torda</i>
Pink-footed Goose	<i>Anser brachyrhynchus</i>	Black Guillemot*	<i>Cepphus grylle</i>
Greylag Goose*	<i>Anser anser</i>	Little Auk	<i>Alle alle</i>
Barnacle Goose	<i>Branta leucopsis</i>	Common Puffin*	<i>Fratercula arctica</i>
Brent Goose	<i>Branta bernicla</i>	Turtle Dove	<i>Streptopelia turtur</i>
European Widgeon	<i>Anas penelope</i>	Domestic (Razing?) Pigeon	<i>Columba livia domestica</i>
European Teal	<i>Anas crecca</i>	Long-eared Owl	<i>Asio otus</i>
Mallard	<i>Anas platyrhynchos</i>	Short-eared Owl	<i>Asio flammeus</i>
Tufted Duck	<i>Aythya fuligula</i>	Sky Lark	<i>Alauda arvensis</i>
Common Eider	<i>Somateria mollissima</i>	Swallow	<i>Hirundo rustica</i>
King Eider	<i>Somateria spectabilis</i>	Meadow Pipit*	<i>Anthus pratensis</i>
Harlequin Duck	<i>Histrionicus histrionicus</i>	Rock Pipit	<i>Anthus spinoletta</i>
Long-tailed Duck	<i>Clangula hyemalis</i>	White Wagtail*	<i>Motacilla alba</i>
Common Scoter	<i>Melanitta nigra</i>	European Robin	<i>Erithacus rubecula</i>
Red-breasted Merganser	<i>Mergus serrator</i>	Redstart	<i>Phoenicurus phoenicurus</i>
Merlin	<i>Falco columbarius</i>	Wheatear	<i>Oenanthe oenanthe</i>
Gyrfalcon	<i>Falco rusticolus</i>	Ring Ouzel	<i>Turdus torquatus</i>
Corncrake	<i>Crex crex</i>	European Blackbird	<i>Turdus merula</i>
Eurasian Oystercatcher	<i>Haematopus ostralegus</i>	Fieldfare	<i>Turdus pilaris</i>
Ringed Plover	<i>Charadrius hiaticula</i>	Song Thrush	<i>Turdus philomelos</i>
Golden Plover	<i>Pluvialis apricaria</i>	European Redwing	<i>Turdus iliacus</i>
Knot	<i>Calidris canutus</i>	Garden Warbler	<i>Sylvia borin</i>
Sanderling	<i>Calidris alba</i>	Chiffchaff	<i>Phylloscopus collybita</i>
Purple Sandpiper	<i>Calidris maritima</i>	Willow Warbler	<i>Phylloscopus trochilus</i>
Dunlin	<i>Calidris alpina</i>	Jackdaw	<i>Corvus monedula</i>
Common Snipe	<i>Gallinago gallinago</i>	Raven*	<i>Corvus corax</i>
Whimbrel	<i>Numenius phaeopus</i>	Starling	<i>Sturnus vulgaris</i>
Redshank	<i>Tringa totanus</i>	Chaffinch	<i>Fringilla coelebs</i>
Turnstone	<i>Arenaria interpres</i>	Brambling	<i>Fringilla montifringilla</i>
Red-necked Phalarope	<i>Phalaropus lobatus</i>	Redpoll	<i>Carduelis flammea</i>
Grey Phalarope	<i>Phalaropus fulicarius</i>	Crossbill	<i>Loxia curvirostra</i>
Arctic Skua	<i>Stercorarius parasiticus</i>	Lapland Bunting	<i>Calcarius lapponicus</i>
Great Skua	<i>Stercorarius skua</i>	Snow Bunting*	<i>Plectrophenax nivalis</i>
Little Gull	<i>Larus minutus</i>	Northern Oriole	<i>Icterus galbula</i>
Black-headed Gull	<i>Larus ridibundus</i>		