Breeding ecology of some seabirds on Handa Island, Sutherland, with particular reference to the use of seabirds as indicators of food availability.

Ingrid A. Baber

Presented in candidature for the degree of Master of Science to the Faculty of Science, University of Glasgow

April 1992.

Candidate's Declaration

I declare that the work recorded in this thesis is entirely my own, unless otherwise stated, and that it is of my own composition. No part of this work has been submitted for any other degree.

April 1992

Acknowledgements

I would like to thank Professor R.S. Phillips for making available facilities within the Department of Zoology. I would also like to thank Bob Furness for his supervision of this work and many helpful comments. Thanks also to David Thompson, Sharon Lewis and Keith Hamer for taking me up to Handa and for various discussions, and also to Nick Klomp for many helpful hints. For help with various graphs in this thesis I would like to thank Kenny Ensor, and Richard Caldow was kind enough to provide me with some of his data collected on Foula in 1987.

This work was carried out on a Royal Society for the Protection of Birds reserve and I would like to thank the RSPB for allowing me to work there. Many thanks go to Iain, Barry, Judy and several others who kept me sane while on Handa. William and Dorothy MacRae were very helpful with the boat journeys across to Handa, keeping me supplied with mail and odd cups of tea. I would also like to thank my parents for providing me with shower facilities and much improved accommodation during my second summer on the island. Most of all I would like to thank Kenny Jack for help with field work, much moral support and his continued patience and trust.

Contents

Summary

The breeding success of kittiwakes *Rissa tridactyla*, guillemots *Uria aalge*, razorbills *Alca torda*, fulmars *Fulmarus glacialis*, great skuas *Catharacta skua* and Arctic skuas *Stercorarius parasiticus* was monitored on Handa Island during the 1989 and 1990 breeding seasons. In 1989 kittiwakes fledged 1.53 young per well built nest and 1.35 young in 1990. Guillemots had a breeding success rate of 0.69 young fledged per occupied site in 1989 and 0.62 young in 1990. Razorbills fledged 0.73 young per occupied site in 1989 and 0.65 young in 1990. There were 0.62 large fulmar chicks per total pairs monitored in 1989 and 0.61 large chicks in 1990. Great skuas produced a mean of 0.68 young per egg in 1989 and 0.64 young in 1990, and Arctic skuas produced 0.66 young and 0.61 young in 1989 and 1990 respectively.

Data on the diets of nonbreeding, breeding and juvenile skuas were collected in both years. The diet of nonbreeders consisted of 83% bird meat, 11% whitefish, 5% sandeel and 1% other items between 1 and 15 July 1989 (n=156 pellets) and of 78% bird meat, 17% whitefish, 5% sandeel and 1% other items between 1 and 15 July 1990 (n=194). Between 1 and 15 July 1990, the diet of breeders consisted of 75% bird meat, 17% whitefish, 7% sandeel and 1% other items (n=173). Both nonbreeders and breeders on Handa took a much larger percentage of bird meat than birds on Foula. Regurgitates from great skua chicks for both years combined showed that their diet was 77% sandeel, 15% bird meat

and 8% whitefish (n=13).

Attendance levels of breeding great skuas were examined in 1989 and 1990, and attendance of nesting kittiwakes was monitored in 1990. Attendance levels for great skuas were similar in both years and decreased as the season progressed. During the later part of the breeding season about 2% of monitored nests were being left unattended. In 1989 the amount of rain was found to have a significant effect on average daily attendance of great skuas. In 1990 some kittiwake chicks were being left unattended within a week of hatching. The percentages of broods of one, two and three kittiwake chicks left unattended were 14.3%, 28.5% and 75.0% respectively.

Great skua chick weights of chicks aged between 13 and 34 days showed that they were growing well in both years.

The results of this study together with data on fish stocks in the Minch area indicate that there was sufficient food for seabirds on Handa in 1989 and 1990. The biology of the breeding seabirds on Handa did not indicate the same shortages of sandeels as recently observed in Shetland.

Chapter 1

Introduction

Introduction

The idea that seabirds may be used as monitors of the marine environment is becoming increasingly popular (Batty 1989, Cairns 1987, Furness 1987a). Many seabirds are upper trophic level consumers and are easier to study than most other top marine predators such as whales, seals and fish. They are numerous, conspicuous and generally aggregate during the breeding season which facilitates sampling. Seabirds have been used to monitor pollutants such as heavy metals, organochlorines and oil in the oceans (Bourne 1976, Thompson et al. 1991, Walsh 1990) and are more recently being exploited as indicators of changes in fish stocks and other important marine resources (e.g., Anderson and Gress 1984, Boersma 1978, Crawford and Shelton 1978). The relationship between food availability and seabird reproduction, growth and feeding patterns is not always a straightforward one and can vary widely (Springer et al. 1986, Vader et al. 1990).

There are numerous seabird parameters that may indicate food levels, but to know which one best indicates varying food conditions can be difficult. Breeding success, breeding numbers and the timing of breeding may all vary depending on prey availability (Anderson et al. 1982, Birkhead and Nettleship 1982, Schaffner 1986, Springer et al. 1984), as may adult survivorship and egg and clutch size (Duffy 1983, Hunt and Butler 1980, Schreiber and Schreiber 1984). Other parameters that can be useful indicators are chick growth and adult body weight (Coulson et al. 1983, Ewins 1985, Ricklefs et al. 1984).

Foraging patterns, colony attendance, diet and guano yields have also been shown to vary with prey availability (Crawford and Shelton 1978, Gaston and Nettleship 1982, Hamer et al. 1991, Springer et al. 1984, Vermeer and Westrheim 1984). These seabird parameters may also vary due to predation (Coulson 1968, Hunt and Hunt 1976a), weather conditions (Barrett and Runde 1980, Ewins 1985) and quality of parental care (Coulson 1968) which need to be taken into account when establishing the relationship between the parameters and food availability. Each seabird parameter acts on a different time scale and may only show changes under certain levels of food availability, making the whole relationship a complex one.

Data on fish stocks most commonly come from commercial and research vessel catches and from acoustic surveys. Fish catch data are used to assess and predict fish stock levels using Virtual-Population-Analysis (VPA). Catch-at-age data, an index of stock abundance (usually determined from catch per unit effort (CPUE) of commercial fisheries) and natural mortality rates are used in the VPA technique to forecast the stock status for the following year. The most recent predictions for the size and age structure of stocks can be inaccurate but are improved as consequent data become available. There are limitations to each of the methods used in assessing fish stocks. Data from commercial fisheries are limited to several species and the CPUE may not be a good measure of stock abundance as only those areas are fished that are economically viable (Goodlad 1989, Kunzlik 1989). Information on the distribution and abundance of juvenile fish is also difficult to obtain using conventional fishing methods. Some of these problems may be overcome by additional research vessel catches, but these are very expensive and hence often limited. Acoustic surveys give a direct measure of biomass but samples need to be taken to confirm the species, size and age structure of fish stocks. This method has been used successfully to determine food conditions in local areas (Anderson et al. 1982). However, acoustic survey is not suitable to assess benthic fish stocks (including sandeels).

Cairns (1987) has suggested which seabird parameters may be best suited for indicating high, medium and low food availability. At high to moderate food availability activity budgets are likely to be the best indicators, whereas at moderate to poor levels he predicted that breeding success, chick growth and colony attendance would provide better measures. When food is extremely scarce, adult survivorship may indicate food availability. Several seabird studies have tried to determine the relationship between various parameters and the levels of food availability.

It is difficult to define food availability as high, medium or low as the scale is a continuous one, but generally it is possible to determine whether or not food is plentiful for a given species. Boersma (1978) found that the breeding patterns of Galapagos penguins Spheniscus mendiculus can be used as an indicator of oceanographic conditions. El Nino is an influx of warm water along the western coast of South America and is associated with a decrease in availability of fish stocks to seabirds which stop breeding and die in large numbers. Prior to

El Nino events, which occur roughly every five to ten years, there is a band of cool water which is much more productive than warmer waters. Boersma found that Galapagos penguin chicks grew faster in 1971 than in 1972 because this was during a period of higher oceanic productivity prior to an El Nino event. She concluded that the timing of breeding of Galapagos penguins coincides with the presence of a band of cool water and that chick growth and breeding success are consistent with increased upwelling, and therefore higher food availability, prior to an El Nino.

Ricklefs, Duffy and Coulter (1984) examined Blue-footed booby Sula nebouxii chicks at 13 localities in the Galapagos Archipelago during July 1981. At the time of the study, water temperatures off the southern and western coasts were several degrees cooler than off the eastern part of the archipelago. Chicks were reweighed and remeasured after five days and most of the chicks in the western cold-water region had gained substantial amounts of weight whereas most of those in the southeastern region had lost weight. Blue-footed boobies fed close to the colonies so the rapid growth associated with cold, productive waters probably reflects only the close inshore food conditions. In Boersma's study chick growth was an indicator of food availability over time whereas in this case it indicated geographical differences in food availability. In both instances though, fast chick growth was associated with cold, productive waters.

The relationship between Cape gannets Sula capensis, jackass penguins Spheniscus demersus and Cape cormorants

Phalacrocorax capensis and the pelagic fish stock sizes around South and South West Africa have been examined by Crawford and Shelton (Crawford and Shelton 1978). Interactions between the seabird and fish populations were examined by comparing guano production on certain islands with catches in the vicinity or other estimates of fish stock abundance. The populations of seabirds in this area were shown to be largely dependent on the abundance and availability of their food sources, so during years of high food availability there were large numbers of breeding birds. Guano yields from the islands are related to the temporal changes in fish abundance and therefore provide reliable estimates of bird population size. The breeding numbers of these seabirds could be monitored as indicators of fish stock sizes and their abundance. Cape gannets have a wide foraging range and diet which may make them more reliable as indicators of biomass of fish stocks over a large area, whereas jackass penguins with their limited flight range would be more useful as indicators of local fish abundance. The Cape cormorant has a large maximum clutch size of five, reaches maturity at a young age and has the ability to move readily between breeding areas or to desert nests at any stage. These qualities may make it more suitable in indicating the short term variability of the fish stocks (Crawford *et al.* 1983).

Brown pelicans *Pelecanus occidentalis californicus* have been studied in the Southern California Bight together with northern anchovies *Engraulis mordax* from 1970 through 1979 (Anderson *et al.* 1980, Anderson *et al.* 1982). The levels of anchovies present were mostly determined using acoustic surveys, although this was supplemented with trawl samples and indices of abundance based on commercial "fish spotter" logbook data. The number of breeding pairs increased in 1974 which was associated with a three year period of very high anchovy abundance indices throughout the study site. High numbers of breeders in 1979 and 1980 at one site were linked with locally abundant anchovies. From 1976 to 1978 there was a decline in anchovy abundance as well as low pelican breeding effort and low productivity. Northern anchovies are the major food source for breeding brown pelicans, and it was found that the availability of this food source was the most important determinant of fledging success. When food availability was very high, breeding numbers rose to indicate this but when the availability decreased, fledging success was the best indicator.

A number of studies have examined seabird diets in order to determine the use of these as indicators of fish stock levels. Hislop and Harris (1985) found that recent changes in the food of young puffins Fratercula arctica on the Isle of May, Scotland can be related to the changes in fish stock levels of several species. Puffins in the North Sea feed their young mainly on sandeels Ammodytidae and clupeoids (Harris and Hislop 1978), but in recent years sprats Sprattus sprattus have been replaced by herring Clupea harengus. Data from commercial fisheries, research trawling and acoustic surveys show a decline in the total North Sea sprat population and an increase in the number of young herring. The changes in the diet of young puffins appear to reflect both the decline of sprats and the increase of herring in the North Sea and may be a useful indicator of general trends occurring in specific fish populations.

The diet of nestling Rhinoceros auklets *Cerorhinca monocerata* has also been shown to be useful in providing a means of sampling fish populations and monitoring age classes of juvenile fish (Vermeer and Westrheim 1984). Although no independent measures of fish stock levels were used, the predominance of certain fish species in bird meals appears to reflect their occurrence near auklet colonies. Rhinoceros auklet meals were collected from three islands on the British Columbia coast and the proportions of fish taken at each island reflect the availability of certain fish species. The Pacific saury *Cololabis saira* is an abundant warm water and offshore species and was only found in the diet of birds on the offshore island, whereas the birds on inshore islands were taking predominantly herring and no sauries. Changes in diet may be useful in monitoring these fish populations, especially juvenile fish which are difficult to study using conventional methods.

Northern gannets *Sula bassanus* in Newfoundland, Canada were found to feed on surface schooling pelagic prey that move inshore at different times throughout the season (Montevecchi *et al.* 1988). Sampling occurred during July and August at which time gannets fed predominantly on mackerel *Scomber scombrus* as well as herring, squid *Illex illecebrosus* and capelin *Mallotus villosus*. Annual catches of mackerel and squid by gannets and humans were compared over a ten year period and showed that extreme reductions of dominant prey in the birds' diet were directly associated with subsequent local pelagic fishery failures. The diet of gannets provides a useful indicator of stock levels currently exploited, but may also be useful in providing information on species not commercially fished.

In some cases birds may change their diet without any deleterious effect to their reproductive success, but sometimes a change in diet is accompanied by a decrease in reproductive performance. The diets of thick-billed murres Uria lomvia, common murres Uria aalge and black-legged kittiwakes were examined at two breeding colonies in the eastern Chukchi Sea betweeen 1976 and 1980 (Springer et al. 1984). An increase in fish biomass in the diets of thick-billed murres corresponding to a decrease in the importance of invertebrates and an increase in the proportions of sand lance Ammodytes hexapterus and capelin in diets of murres and kittiwakes were noted during this time period. This is consistent with the authors' hypothesis that the availability of fish biomass to seabirds was fairly low in 1976 due to climatic cooling in the early 1970's followed by warming thereafter causing annual differences in the extent and duration of the sea ice. In addition to the changing diet, reproductive success was markedly different as well. In 1976 the breeding success of kittiwakes was very low. Few birds developed brood patches, few eggs were laid, egg laying occurred late in the breeding season and most of the chicks that hatched died. The reproductive success in consequent years improved as the diet changed. The variations seen in the diets of murres and kittiwakes corresponded in time to differences in the reproductive success of the birds and to interannual changes in water temperature and sea ice cover.

Western gulls Larus occidentalis and Xantus' murrelets Endomychura hypoleuca were studied on Santa Barbara Island, California with slightly differing results (Hunt and Butler 1980). The species of fish taken by Western gulls during the study varied, but the most important change seemed to be the decline in the amount of northern anchovies from a high of 42% of the diet in 1972 to a low of 18% in 1977. Alternative species taken included Pacific saury and market squid Loligo opalescens, and only in 1976 when there were no alternative species did the gulls resort to using sea lion Zalophus californicus placentae and garbage. The percentage of anchovies fed to gull chicks decreased over the course of the study as did the number of nesting birds. Both of these were correlated to the reduced availability of anchovies as determined by commercial fish spotters. The timing of egg laying may have been expected to be sensitive to food availabilty, but there was no difference in the mean date of egg laying for any of the four years studied. The study shows that Western gulls can make use of alternative food sources with little effect on their reproductive success but once food availability drops below a certain level chick growth rates and breeding success decrease. Hunt and Hunt (1976b) have suggested that the persistence of this gull colony through time and the colony size reflects food availability since the availability of schooling fish is needed for the gulls to feed their young adequately. Xantus' murrelets feed on larval fish, especially larval anchovies, and in 1978 larval anchovies failed to survive until late in the season. Murrelets responded to this by delaying egg laying for five to six weeks and the number of birds nesting was also reduced. This delay during times of food shortage may be due to the murrelets' large egg size in relation to their adult body weight.

A number of studies have shown reproductive success to be very low in various seabirds due to a very low food availability. As mentioned before, Anderson et al. (1982) found that during periods of low anchovy abundance, the breeding effort and productivity of Brown pelicans was very low as well.

The reproductive success of kittiwakes at offshore breeding colonies in the southeastern Bering Sea was found to be related to the abundance of juvenile Walleye pollock Theragra chalcogramma (Springer et al. 1986). Persistent kittiwake breeding failures between 1981 and 1984 are attributed to poor pollock recruitment before and during those years as determined by fisheries surveys. The low breeding success resulted from small average clutch sizes and high chick mortality.

British kittiwakes in the northern North Sea have also shown low breeding success due to food shortages (Harris and Wanless 1990). Greatly reduced breeding success was first recorded in Shetland in 1985 and breeding success has been very low since. The trend seems to have spread to several colonies further south and most breeding failures occurred during the chick stage. Kittiwakes in Britain appear to rely mostly on small to medium sized sandeels Ammodytes marinus and independent results from the commercial sandeel fishery show that a series of poor recruiting year classes had caused a decline in the

Shetland stock of sandeels.

Great skuas on Foula, Shetland have also had greatly reduced breeding success since 1987 due to the decline in the availability of sandeels (Hamer et al. 1991). This decrease in breeding success has been accompanied by a change in diet, reduced territorial attendance by adults and a very slight decrease in egg size. The proportion of sandeel in the diet declined and was made up for by an increase in the amount of whitefish taken. As the foraging effort of adults increased, territorial attendance decreased and many chicks were left unattended. These changes are correlated with annual recruitment of sandeels in Shetland waters.

Monaghan et al. (1989) compared two Arctic tern *Sterna paradisaea* colonies; a successful breeding colony on Coquet Island and an unsuccessful one on Shetland. At the Shetland colony the breeding success was poor, chicks grew at a slower rate and even though adults foraged at a higher rate, they brought less energy per chick per hour. There was no difference in clutch or egg size, or in the hatching success between the two colonies. The data suggest that Arctic terns at the Shetland colony had difficulty in obtaining intermediate sized sandeels, a size-class which appears to be very important to the chicks.

Barrett et al. (1987) present evidence that suggests a direct relationship between the level of herring stocks and the breeding success of Norwegian puffins (also Vader et al. 1990). The herring stock collapsed in the 1960's causing breeding failure in the 1970's. The food of Norwegian puffin chicks was examined from 1980 to 1983 and it was found that the fledging success and growth of chicks was related to the quality of food brought to the young. The growth rate of chicks at certain colonies was very low in 1981 and 1982 and the timing of mortality corresponded in both years with the period during which the quality and quantity of food dropped markedly. Early in the season puffins brought back reasonable food loads of fish but later provided poor quality food or stopped feeding altogether, resulting in total breeding failures.

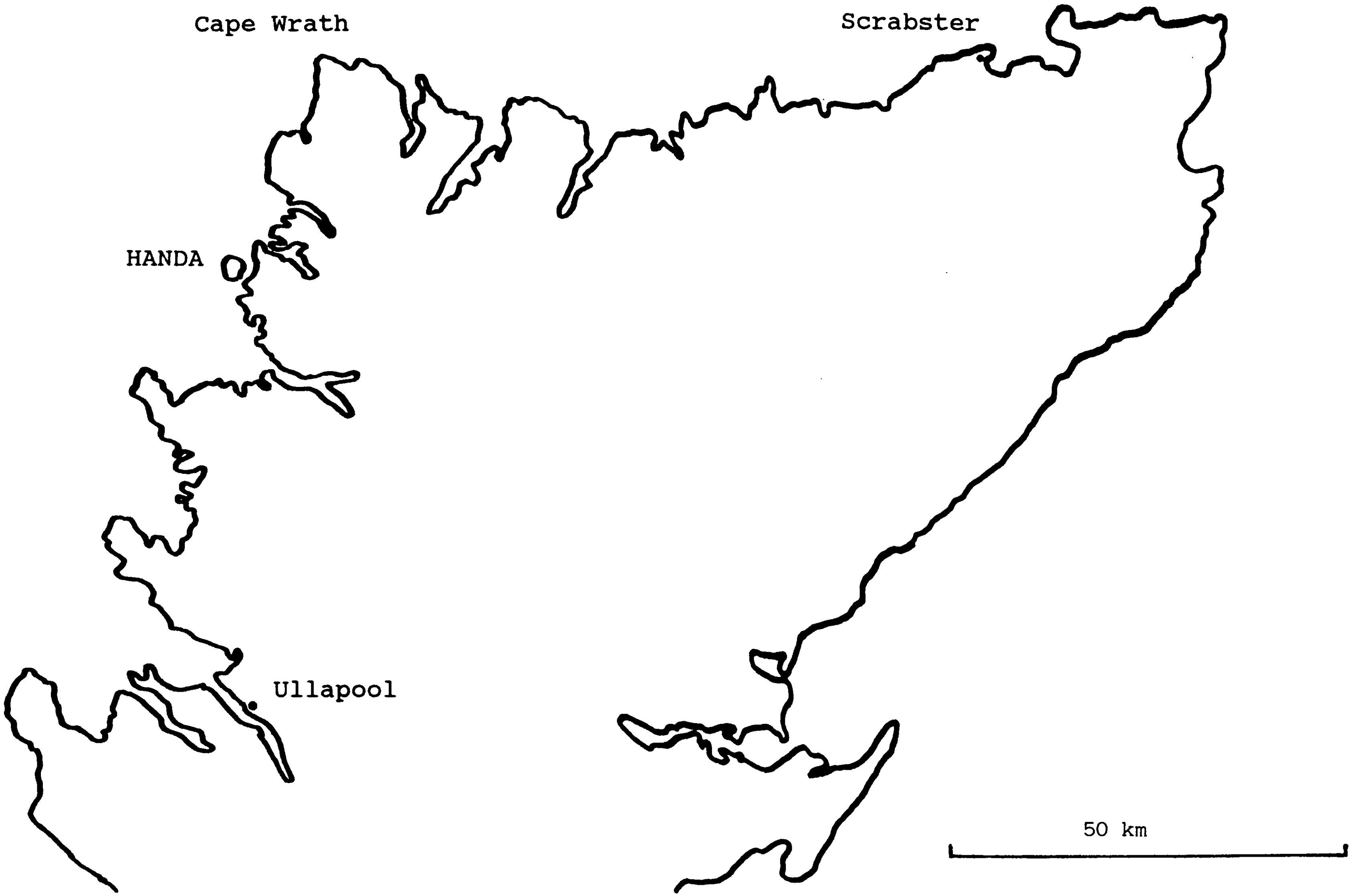
Glaucous-winged gulls Larus glaucescens examined at a colony in British Columbia, Canada were found to respond to low food availability by low chick survival (Hunt and Hunt 1976a). During years of low food availability both territory size and date of hatching were important to chick survival, whereas during years of plentiful food these factors had little relationship to chick survival. Chicks that grew slowly were more likely to be killed by neighbours than fast growing ones, so during food shortages an earlier hatching date and a larger territory provided a better chance for chick survival.

Nonbreeders may also provide useful indicators of food availability. It has been suggested that the number of thick-billed murres in attendance at a colony at any time during the breeding season is determined primarily by the availability of food in surrounding waters (Gaston and Nettleship 1982). Murres do not breed until they are four to five years old, and prebreeding birds probably make up the majority of nonbreeders attending the colony. The nonbreeders appear to be the dominant factor in determining attendance from the start of egg laying to the beginning of fledging. These prospectors are assumed to maximize the amount of time spent at the breeding colony in order to improve their chances of acquiring a breeding site. Therefore when food is abundant, numbers on cliffs will be high because birds have plenty of time to spare, but when food availability is low, numbers on cliffs will be low since the birds spend more time foraging. The nonbreeding population may provide an indication of food availability through their attendance at the colony.

Most seabirds breeding in Shetland rely on sandeels as their major food source (Furness 1989, Furness and Hislop 1981). Since 1983 many of these seabird species have experienced severe breeding difficulties (Hamer et al. 1991, Harris 1989, Harris and Wanless 1990, Heubeck et al. 1987, Monaghan et al. 1988) which is thought to be the result of a shortage or non-availability of sandeels (Heubeck 1989). There has been a series of poor year classes in the Shetland sandeel stock since 1983 (Bailey et al. 1990, Goodlad 1989, Kunzlik 1989) which does not appear to be related to the size of the spawning stock and must therefore be due to factors acting in the first six months of life (Bailey et al. 1990). It has been suggested that environmental factors acting during the egg and larval stages are responsible and not overfishing (Goodlad 1989, Kunzlik 1989), but there is no evidence to prove this.

Plentiful data exist for Shetland seabird colonies, but not much information has been gathered for seabird colonies around the northwest of Scotland. Handa Island lies 28 kilometres to the south of Cape Wrath (see Figure 1.1) and its cliffs are used by well over 100,000 nesting seabirds (RSPB Handa Island warden reports), making it an ideal study site for several seabird species. Six seabird species were studied in detail during the 1989 and 1990 breeding seasons in order to determine whether or not seabirds in this area were experiencing the same breeding difficulties as those in Shetland. The reason for examining the performance of seabirds in north-west Scotland at this time was the suggestion that industrial fishing for sandeels may cause breeding failures of seabirds by having adverse effects on sandeel stocks. There is a local industrial fishery for sandeels in north-west Scotland which has been increasing in scale, but little information was available on seabird performance.

Figure 1.1 Map of north-west Scotland showing the location of Handa Island.


Cape Wrath
Scrabster
HANDA
Ullapool
50 km

Chapter 2

The sandeel fishery in the Minch and around Shetland

2.1 The sandeel fishery in the Minch and around Shetland

In this section the state of the sandeel fishery in the Minch and around Shetland will be briefly described and discussed. There is no by-catch from the sandeel fishery and sandeels are used mainly for fish meal and oil (Goodlad 1989). Fisheries catch and effort data for sandeels are available from the Scottish Office Agriculture and Fisheries Department (SOAFD) and data given in this section are taken from the 'Report of the Industrial Fisheries Working Group, 1989' (Anon. 1989). More recent data are not yet available.

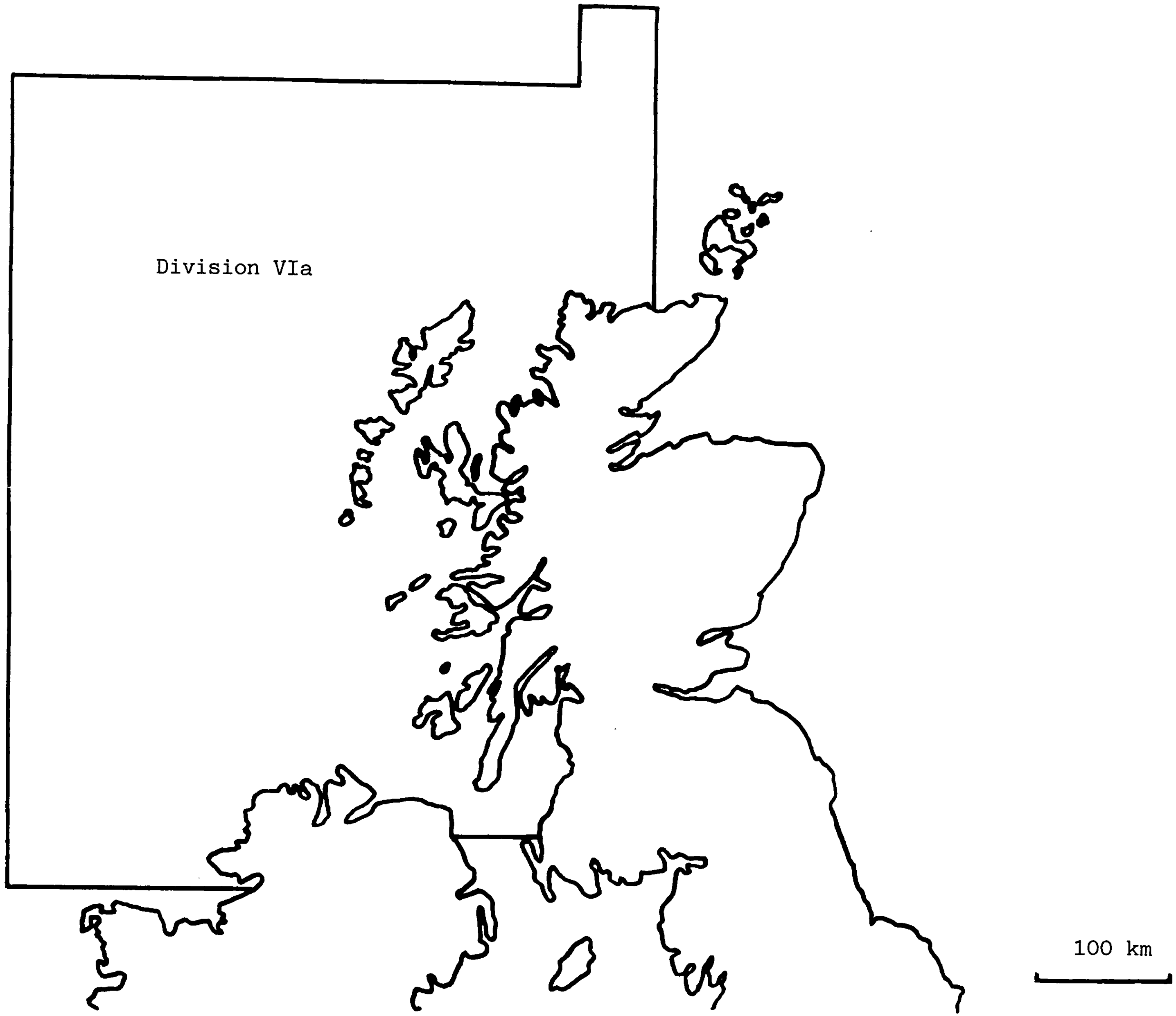
Much of the Minch is covered by the area referred to as Division VIa in the report and is shown in Figure 2.1. Complete records of sandeel catches and effort for Division VIa date back to 1980 whereas they go back to 1974 for the Shetland area.

Table 2.1 gives the total sandeel catch in tonnes for Division VIa, standardised effort in days absent from port, the total biomass (TBM), the spawning stock biomass (SSB), the catch per unit effort (CPUE) and the total catch/TBM x 100.

Table 2.1 Sandeel catch (tonnes) in Division VIa for 1980-1988.

Year	Catch	Effort	TBM	SSB	CPUE	Catch/TBMx100
1980	211	26	43233	14468	8.12	0.5
1981	5972	303	55918	30040	19.71	10.7
1982	10873	588	66486	37150	18.49	16.4
1983	13051	447	94492	39414	29.20	13.8
1984	14166	446	117019	59967	31.76	12.1
1985	18586	475	90545	74766	39.13	20.5
1986	24469	530	103449	56981	46.17	23.7
1987	14479	290	131728	53947	49.93	11.0
1988	24465	439	99579	81053	55.73	24.6

Figure 2.1 Map showing the area defined as Division VIa by the International Council for the Exploration of the Sea (ICES).


Division VIa
100 km

The TBM and SSB of sandeels in Division VIa are figures estimated by SOAFD using virtual population analysis (VPA) and become less reliable for recent years due to the method used for estimating population size. The total sandeel catch increased to 24,465 t in 1988 compared to 14,479 t in 1987 and has only been higher in 1986. Fishing effort has remained reasonably constant since 1983 and the catch per unit effort has consistently increased to a high of 55.73 in 1988. For Division VIa in 1988, the majority of fish caught (49%) were 2-group sandeels (see Table 2.2) which is the result of a strong 1986 year class. VPA shows that both the 1987 and 1988 year classes appear to be below average for this area which means that the spawning stock might fall in 1989 and continue to fall in 1990 as those year classes enter the spawning stock as 2-group fish (Anon. 1989). The SOAFD urge caution in the interpretation of these results and at present there are no limitations on the sandeel fishery in Division VIa.

Table 2.2. Catch of sandeels at age in numbers (millions) in Division VIa for 1980-1988.

Year	Age group of majority caught	No. at that age group	Total nos. caught	%age of sandeels caught at majority age group
1980	0	27	52.5	51.4
1981	0	462	1007.5	45.9
1982	0	885	1944	45.5
1983	0	2644	3722	71.0
1984	0	1937	3624	53.4
1985	0	3260	4652	70.1
1986	0	3070	5795	53.0
1987	1	1197	2310	51.8
1988	2	1764	3579	49.3

The total sandeel catch, TBM, SSB, CPUE and catch/TBM x 100 for the Shetland area are shown in Table 2.3 (Anon. 1989, Bailey et al. 1991).

Table 2.3. Sandeel catch (tonnes) in Shetland for 1974-1988.

Year	Catch	Effort	TBM	SSB	CPUE	Catch/TBMx100
1974	7400	-	-	-	-	-
1975	12900	847	-	-	15.23	-
1976	20200	1188	-	-	17.00	-
1977	21500	1351	66954	22529	15.91	32.1
1978	28100	1397	78845	28140	20.11	35.6
1979	13400	592	65389	29322	22.64	20.5
1980	25400	1006	68725	33159	25.25	37.0
1981	46700	1846	77151	35250	25.30	60.5
1982	52000	1937	102117	30651	26.85	50.9
1983	37000	1538	109895	37698	24.06	33.7
1984	32600	1624	138177	53788	20.07	23.6
1985	17200	792	99893	72151	21.72	17.2
1986	14000	623	86755	63842	22.47	16.1
1987	7200	434	72421	50596	16.59	9.9
1988	4700	281	47301	45276	16.73	9.9

The total landings fell to 4,700 t in 1988, the lowest on record since the fishery started in 1974. A peak was reached in 1982 when the total catch amounted to 52,000 t; ever since the landings have decreased. Both the total stock biomass and the spawning stock biomass have fallen in recent years in the Shetland area due to low levels of recruitment. In 1988 the majority (58%) of the sandeel catch by numbers of fish consisted of 0-group fish (see Table 2.4). The fishing of sandeels has been banned in Shetland between July and October in 1989 and 1990 and altogether in 1991 in order to let the sandeel population recover.

Table 2.4. Catch of sandeels at age in numbers (millions) in Shetland for 1977-1988.

Year	Age group of majority caught	No. at that age group	Total nos. caught	%age of sandeels caught at majority age group
1977	0	5970	10360.5	57.6
1978	0	5453	11740	46.4
1979	1	2665	4509	59.1
1980	0	6432	8242	78.0
1981	0	13243	18043	73.4
1982	0	16851	24710.5	68.2
1983	0	5604	10217.5	54.8
1984	0	6773	10968	61.8
1985	0	2192	4354.5	50.3
1986	0	2226	3805	58.5
1987	1	984	1592.5	61.8
1988	0	544	939.5	57.9

The sandeel stock in the north-west of Scotland appears to be doing fine at the moment but the situation in Shetland is quite different. Although recruitment has been below average in Division VIa in 1987 and 1988, the population is not declining as rapidly as in Shetland and the total catches for Division VIa have never reached the high levels of those in Shetland. The percentage of the total biomass which has been landed (catch/TBM x 100) went as high as 60.5% in Shetland in 1981 whereas the highest in Division VIa was 24.6% in 1988. In Shetland the catch per unit effort has remained reasonably stable compared to the continually increasing CPUE seen in Division VIa, but the largest catch recorded for Division VIa (24,469 t in 1986) is less than half that for Shetland (52,000 t in 1982). Division VIa is much larger than the Shetland area so one might expect the CPUE to be lower if sandeels were evenly distributed. The high CPUE achieved in Division VIa in recent years suggests that either the sandeels are more clumped than around Shetland, or their movements may be more predictable making it easier for the fishermen to catch sandeels. The high CPUE in a large area does not suggest a shortage of sandeels in Division VIa.

Although there is currently no evidence that controls are needed on the sandeel fishery in Division VIa, care needs to be taken in order to prevent a situation occurring similar to that in Shetland.

Chapter 3

Breeding success of various seabird species

3.1 Introduction

The breeding success of kittiwakes, guillemots, razorbills, fulmars, great skuas and Arctic skuas was monitored on Handa Island during the 1989 and 1990 breeding seasons. The methods used for surveying these species will be described and the results discussed. There are approximately 10,000 pairs of kittiwakes, 98,000 pairs of guillemots, 8,000 pairs of razorbills, 3,000 pairs of fulmars, 80 pairs of great skuas and 30 pairs of Arctic skuas present on Handa Island (RSPB Handa Island warden reports).

3.2 Methods

For all the cliff nesting seabirds monitored (kittiwakes, guillemots, razorbills and fulmars), the standard Nature Conservancy Council survey methods (as described in a report to NCC by M.P. Harris) were used in order to ease the comparison of results betweeen colonies. Study plots were chosen at various positions over the island where visibility of the birds was good, in order to obtain accurate results. Where possible, an attempt was made to have several study plots for each species in a variety of places, such as dense and sparse areas, high up and low on cliff faces or large and small ledges. This will reduce the bias of accidentally choosing an area with an unusually high or low breeding success for the colony. Black and white prints of the study sites were made and transparent overlays placed on top. Each bird or nest was numbered on the overlay using a permanent marker and checked at regular intervals using 10 x 50 binoculars. The same study plots were monitored over the two year period (see Figure 3.1).

Kittiwakes were monitored at five different sites to give a total of 255 pairs in 1989 and 315 pairs in 1990. I recorded how many nests had eggs, numbers of other nests occupied and other sites that were regularly visited. For each nest the number of young that fledged was also recorded.

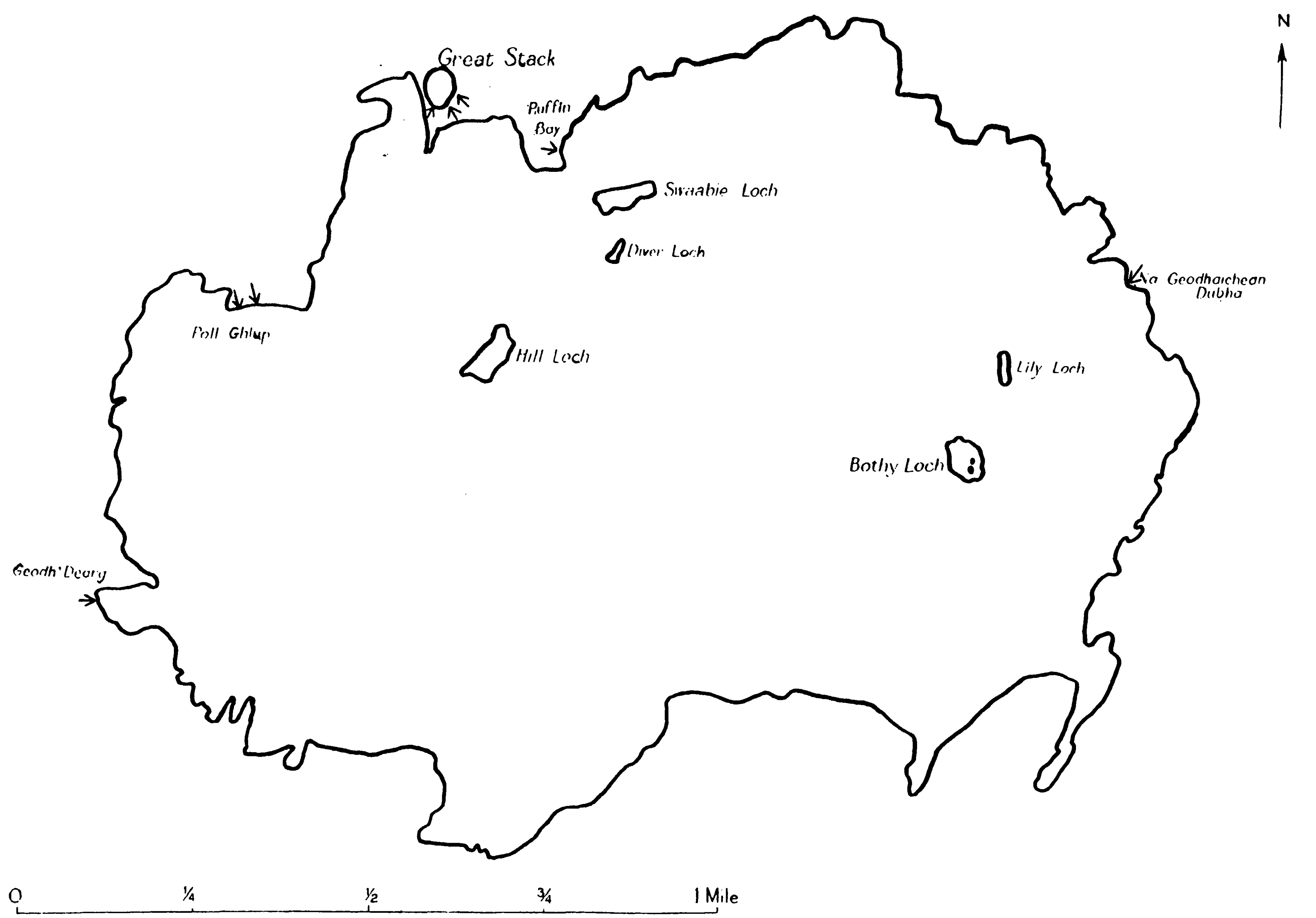
Four different sites were chosen at which to monitor guillemots. A total of 220 pairs of guillemots were followed in 1989 and 223 pairs in 1990. The numbers of breeders and nonbreeders (or failed breeders) at each site were noted, as were the number of eggs taken by predators or failed eggs, number of young taken by predators or lost and the number of young thought to have fledged. As guillemot chicks leave the cliffs before they are fully grown, any young leaving when aged 15 days or more old and/or well feathered were considered as having been reared successfully (NCC survey method).

Most razorbills were not clearly visible so only two different sites were chosen. In 1989 86 pairs were monitored and in 1990 82 pairs. The same data as for guillemots were collected.

A total of 169 and 186 pairs of fulmars were monitored in 1989 and 1990 respectively at two different sites. I noted the number of pairs that laid, the number of chicks that were lost, the number of eggs not hatched and the number of large chicks that were assumed to have fledged.

Most of the island was searched for skua nests but due to a pair of red-throated divers Gavia stellata breeding on one of

Figure 3.1 Map of Handa showing the monitoring sites for kittiwakes, guillemots, razorbills and fulmars. The arrows point to the monitored sites. Na Geodhaichean Dubha is referred to as Goose Green in the text.



Great Stack
Puffin Bay
Swaabie Loch
Diver Loch
Poll Ghlup
Hill Loch
Na Geodhaichean Dubha
Lily Loch
Bothy Loch
Geodh' Deary
N
0
¼
½
¾
1 Mile

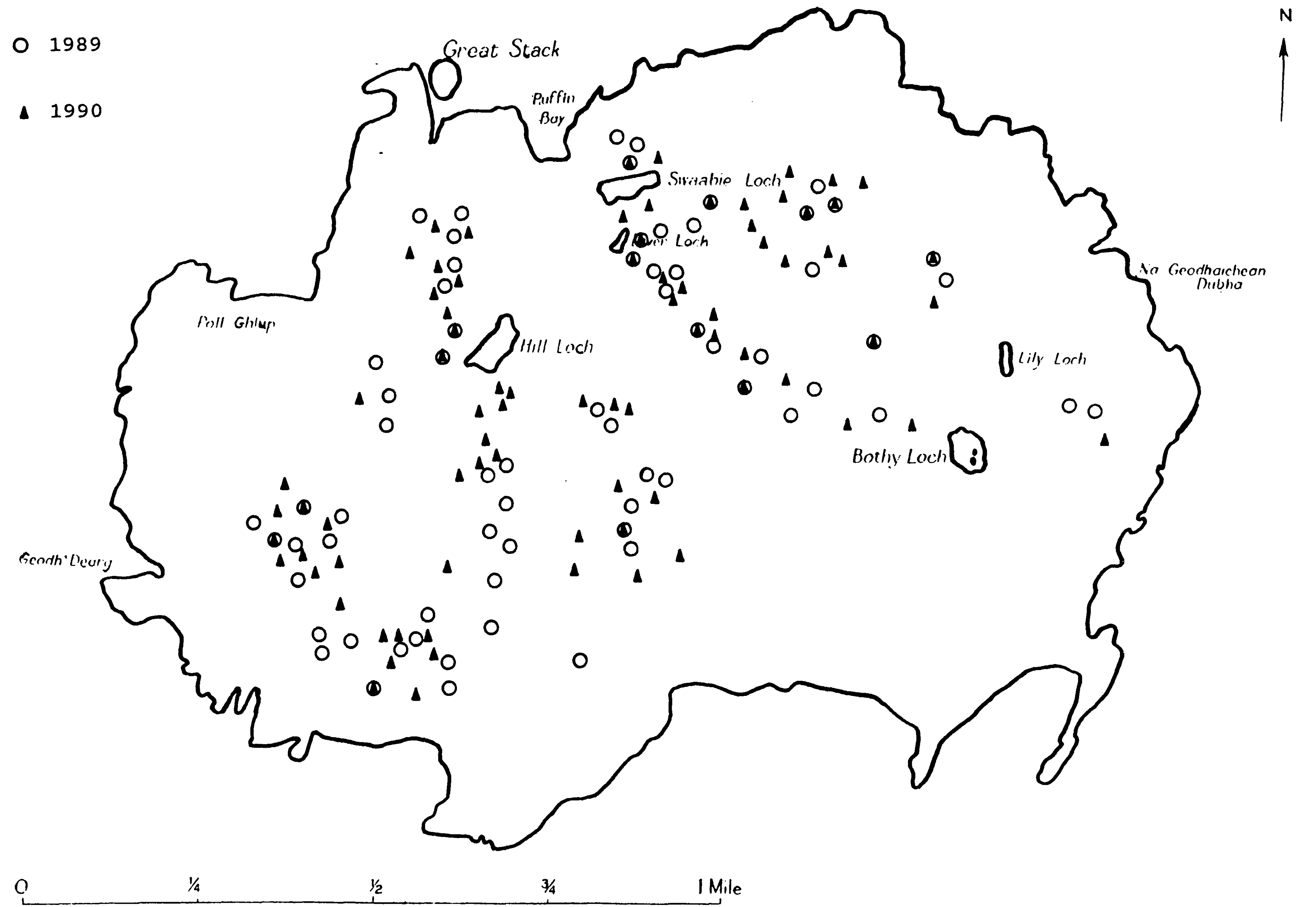
the lochs, a number of Arctic skua nests could not be marked or monitored. All nests found were marked with bamboo canes and checked every few days for egg predation, hatching, chick predation and fledging. In 1989 69 great skua nests and 20 Arctic skua nests were followed, and in 1990 80 great skua nests and 21 Arctic skua nests were found (see Figures 3.2 and 3.3 for positions of nests).

3.3 Results

In 1989 255 pairs of kittiwakes were monitored at five different sites (see Table 3.1). 242 pairs laid, 26 pairs fledged zero young, 69 pairs fledged one young and 160 pairs fledged two young. For all well built nests combined, 22 pairs fledged zero young, 69 pairs fledged one young and 160 pairs fledged two young to give a total of 389. The mean number of young fledged per well built nest was 1.53. In 1990 315 pairs were monitored at the same sites (see Table 3.2). For all well built nests, 47 pairs fledged zero young, 97 pairs fledged one young, 156 pairs fledged two young and one pair fledged three young to give a total of 412. The mean number of young fledged per well built nest monitored was 1.35. Kittiwakes hatched almost one week later in 1990 than in 1989, the majority hatching around 24 June in 1990.

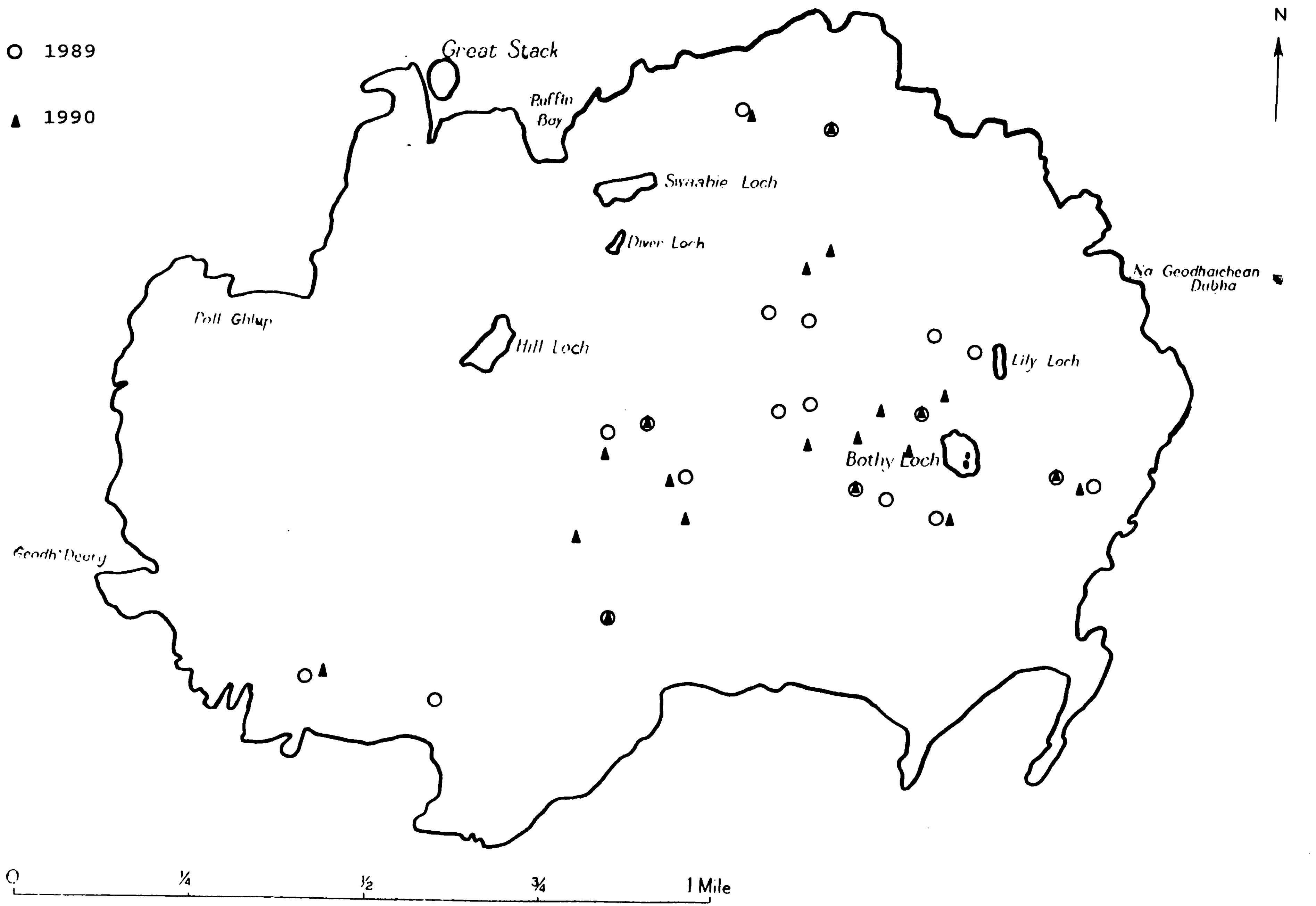
Guillemots were monitored at four sites and results for 1989 are given in Table 3.3. Of the 220 pairs monitored, 211 pairs bred, 15 eggs were lost or failed, 45 young were lost and 151 young were assumed to have fledged. Overall the number of young fledged per pair laying was 0.72 and the number fledged

Figure 3.2 Map of Handa showing the positions of great skua nests in 1989 and 1990.



1989
1990
Great Stack
Puffin Bay
Swaabie Loch
Hill Loch
Poll Ghlup
Geodh' Deurg
Na Geodhaichean Dubha
Lily Loch
Bothy Loch
N
0
¼
½
¾
1 Mile

Figure 3.3 Map of Handa showing the positions of Arctic skua nests in 1989 and 1990.



O 1989
▲ 1990
N
Great Stack
Puffin Bay
Swaabie Loch
Diver Loch
Na Geodhaichean Dubha
Poll Ghlup
Hill Loch
Lily Loch
Bothy Loch
Geodh' Deary
0
¼
½
¾
1 Mile

TABLE 3.1 Breeding success of kittiwakes on Handa in 1989

Site	No. of pairs monitored	Pairs laid	Other nests	Trace nests	No. of nests not hatched	No. of nests hatched but zero fledged	No. of pairs hatching of those laid	Fledging success of all pairs monitored				Mean no. of young fledged per:		
								0	1	2	total no. of fledged	pair laying	pair with nest	total pairs monitored
Great Stack A	70	64	4	2	4	0	60 (94%)	10	16	44	104	1.63	1.53	1.49
Great Stack B	50	48	2	0	0	0	48 (100%)	2	13	35	83	1.73	1.66	1.66
Inside Great Stack	34	32	2	0	2	2	30 (94%)	6	12	16	44	1.38	1.29	1.29
Phol Ghlup A	52	50	1	1	0	2	50 (100%)	4	13	35	83	1.66	1.63	1.60
Phol Ghlup B	49	48	0	1	2	1	46 (96%)	4	15	30	75	1.56	1.56	1.53
Totals	255	242	9	4	8	5	234 (97%)	26	69	160	389	1.61	1.55	1.53
Mean ± SE												1.59 ±0.06	1.53 ±0.07	1.51 ±0.06

TABLE 3.2 Breeding success of kittiwakes on Handa in 1990

Site	No. of pairs monitored	Pairs laid	Other nests	Trace nests	No. of nests not hatched	No. of nests hatched but zero fledged	No. of pairs hatching of those laid	Fledging success of all pairs monitored				Mean no. of young fledged per:		
								0	1	2(3)	total no. of fledged	pair laying	pair with nest	total pairs monitored
Great Stack A	104	94	5	5	5	2	89 (95%)	17	34	52(1)	141	1.50	1.42	1.36
Great Stack B	52	49	2	1	1	2	48 (98%)	6	14	32	78	1.59	1.53	1.50
Inside Great Stack	32	28	2	2	1	6	27 (96%)	11	7	14	35	1.25	1.17	1.09
Phol Ghlup A	66	58	5	3	2	5	56 (97%)	15	19	32	83	1.43	1.32	1.26
Phol Ghlup B	61	55	3	3	2	4	53 (96%)	12	23	26	75	1.36	1.29	1.23
Totals	315	284	17	14	11	19	273 (96%)	61	97	156(1)	412	1.45	1.37	1.31
Mean ± SE												1.43 ±0.06	1.35 ±0.06	1.29 ±0.07

TABLE 3.3 Breeding success of guillemots on Handa in 1989

Site	Total pairs	Breeders	Nonbreeders	Predated / failed eggs	Predated young	Assumed no. of young fledged	No. of young fledged per: pair laying	occupied site
Great Stack	80	77	3	7	23	47	0.61	0.59
Phol Ghlup A	84	82	2	6	13	63	0.77	0.75
Phol Ghlup B	27	27	0	0	3	24	0.89	0.89
Geodh' Dearg	29	25	4	2	6	17	0.68	0.59
Totals	220	211	9	15	45	151	0.72	0.69
Mean ± SE							0.74 ±0.06	0.70 ±0.07

TABLE 3.4 Breeding success of guillemots on Handa in 1990

Site	Total pairs	Breeders	Nonbreeders	Predated / failed eggs	Predated young	Assumed no. of young fledged	No. of young fledged per:	
							pair laying	occupied site
Great Stack	85	84	1	12	23	49	0.58	0.58
Phol Ghlup A	86	82	4	11	15	56	0.68	0.65
Phol Ghlup B	30	30	0	4	6	20	0.67	0.67
Geodh' Dearg	22	21	1	3	5	13	0.62	0.59
Totals	223	217	6	30	49	138	0.64	0.62
Mean ± SE							0.64 ±0.02	0.62 ±0.02

TABLE 3.5 Breeding success of razorbills on Handa in 1989

Site	Total pairs	Breeders	Nonbreeders	Predated / failed eggs	Predated young	Assumed no. of young fledged	No. of young fledged per:	
							pair laying	occupied site
Phol Ghlup A	39	36	3	3	4	29	0.81	0.74
Phol Ghlup B	47	46	1	1	11	34	0.74	0.72
Totals	86	82	4	4	15	63	0.77	0.73
Mean ± SE							0.78 ±0.04	0.73 ±0.01

TABLE 3.6 Breeding success of razorbills on Handa in 1990

Site	Total pairs	Breeders	Nonbreeders	Predated / failed eggs	Predated young	Assumed no. of young fledged	No. of young fledged per:	
							pair laying	occupied site
Phol Ghlup A	37	34	3	5	7	22	0.65	0.59
Phol Ghlup B	45	44	1	5	8	31	0.70	0.69
Totals	82	78	4	10	15	53	0.68	0.65
Mean ± SE							0.68 ±0.03	0.64 ±0.05

TABLE 3.7 Breeding success of fulmars on Handa in 1989

Site	No. of pairs monitored	Pairs laid	Apparently occupied sites	No. of pulli predated	No. of eggs not hatched and/or young predated	No. of eggs not hatched	Total failed sites of those laid	No. of large pulli	No. of large pulli per: pair laying	No. of large pulli per: total no. of pairs
Puffin Bay	102	98	4	4	12	3	19	79	0.81	0.77
Goose Green	67	59	8	3	27	3	33	26	0.44	0.39
Totals	169	157	12	7	39	6	52	105	0.67	0.62
Mean ± SE									0.63 ±0.19	0.58 ±0.19

TABLE 3.8 Breeding success of fulmars on Handa in 1990

Site	No. of pairs monitored	Pairs laid	Apparently occupied sites	No. of pulli predated	No. of eggs not hatched and/or young predated	No. of eggs not hatched	Total failed sites of those laid	No. of large pulli	No. of large pulli per: pair laying	No. of large pulli per: total no. of pairs
Puffin Bay	133	126	7	8	23	4	35	91	0.72	0.68
Goose Green	53	43	10	5	11	4	20	23	0.53	0.43
Totals	186	169	17	13	34	8	55	114	0.67	0.61
Mean ± SE									0.63 ±0.10	0.56 ±0.13

per occupied site was 0.69. In 1990 217 pairs bred of the 223 pairs monitored, 30 eggs were lost or failed, 49 young were lost and 138 young were assumed to have fledged (see Table 3.4). The number of young fledged per pair laying was 0.64 and number fledged per occupied site was 0.62. The majority of guillemots hatched within a few days of 26 June in 1990 which is a week later than in 1989.

For razorbills the same data as for guillemots were collected and are shown in Tables 3.5 and 3.6 for 1989 and 1990 respectively. In 1989 the productivity was 0.77 young fledged per pair laying and 0.73 fledged per occupied site. In 1990 0.68 young were fledged per pair laying and 0.65 fledged per occupied site. The majority of young hatched around 28 June in 1990 which is again a week later than in the summer of 1989.

In 1989 a total of 169 fulmar sites were monitored (see Table 3.7) at which 157 pairs laid and 12 were apparently occupied sites. In seven nests chicks were lost and in 39 cases it is not known whether the eggs did not hatch or the young were lost. Six eggs definitely did not hatch. By 23 July there were 105 large chicks per total pairs monitored to give an overall productivity of 0.67 large chicks per pair laying and 0.62 large chicks per total number of pairs monitored. A total of 186 fulmar pairs were monitored in 1990 (see Table 3.8). 169 pairs laid and 17 were apparently occupied sites. In 13 nests chicks were lost, in 34 cases it is not known whether the eggs did not hatch or the young were lost and eight eggs definitely did not hatch. By the beginning of August there were 114 large chicks which gives a breeding success of 0.67 large chicks per pair laying and 0.61 large chicks per total number of pairs monitored. The majority of young hatched towards the end of July in 1990 which is about 1.5 weeks later than in 1989.

The breeding success rate of great skuas on Handa in 1989 and 1990 is shown in Table 3.9. In 1989 for the 68 nests monitored, 125 eggs were laid of which 15 (12%) were lost or addled. Of the remaining 110 eggs which hatched, 25 young (20%) either died or were lost and 85 young (68%) were nearly fledged or had fledged by 26 July. 18 nests were found to have zero young, 15 nests had one young and 35 nests had two young. The mean number of young produced per nest and surviving to at least half-grown was 1.25 and 0.68 per egg. In 1990 for the 80 nests monitored, 151 eggs were laid of which 31 (20.5%) were lost or addled. Of the remaining 120 eggs which hatched, 24 young (15.9%) either died or were lost to predators and 96 young (63.6%) were nearly fledged or had fledged by the end of July. 22 pairs were found to fledge zero young, 20 pairs one young and 38 pairs two young. The mean number of young produced per nest and surviving to at least half-grown was 1.20, and 0.64 per egg. The mean hatching date for great skuas was 19 June in both 1989 and 1990. In 1989 two pairs of territorial nonbreeders were present on the island and in 1990 there was only one pair. Of 32 breeding great skuas colour-ringed in 1989, 29 (or 91%) were seen again in 1990.

Table 3.9. Breeding success of great skuas on Handa in 1989 and 1990.

	1989		1990	
no. of nests:	68		80	
no. of eggs laid:	125		151	
no. of eggs not hatched: (predated/addled)	15	(12%)	31	(21%)
no. of young died/predated:	25	(20%)	24	(16%)
no. of large pulli/fledged:	85	(68%)	96	(64%)
no. of nests with 0 young:	18		22	
no. of nests with 1 young:	15		20	
no. of nests with 2 young:	35		38	
mean no. of young per:				
nest:	1.25		1.20	
eggs laid:	0.68		0.64	

In 1989 20 Arctic skua nests were marked and monitored and there were probably another ten pairs present in the areas not searched. For the nests monitored the breeding success was 1.25 young produced per nest or 0.66 young per egg laid (see Table 3.10). In 1990 21 nests were marked (which is comparable to the previous year's figure of 20) and again another ten pairs were suspected in those areas not searched. There did not appear to be a marked increase in the number of Arctic skua nests on Handa. 1.19 young were produced per nest or 0.61 per egg laid (see Table 3.10). The mean hatching date in 1990 was 22 June which is one day later than the mean for 1989.

Table 3.10. Breeding success of Arctic skuas on Handa in 1989 and 1990.

	1989		1990	
no. of nests:	20		21	
no. of eggs laid:	38		41	
no. of eggs not hatched: (predated/addled)	5	(13%)	8	(20%)
no. of young died/predated:	8	(21%)	8	(20%)
no. of large pulli/fledged:	25	(66%)	25	(61%)
no. of nests with 0 young:	4		5	
no. of nests with 1 young:	7		7	
no. of nests with 2 young:	9		9	
mean no. of young per:				
nest:	1.25		1.19	
eggs laid:	0.66		0.61	

3.4 Discussion

Breeding success data for several seabird species on Handa Island have been collected in the past, but the data are intermittent and not very extensive. It is normal for seabirds to lay lower clutch sizes if they breed late in the season (Furness and Monaghan 1987) which may account for the slightly lower breeding success for some of the species in 1990 compared to 1989. Guillemot eggs which are laid late in the season have been found to have lower success rates (Harris and Wanless 1988) which may account for the slightly lower breeding success in 1990.

Most productivity information that has been collected is on kittiwakes, but different sites have been used each year. In 1985 breeding success was 1.67 young fledged per well built nest (1985 Handa warden report) but no data are given as to how many nests were followed at how many sites. In 1986 286 nests were monitored at four sites and the breeding success was 1.09 fledged per well built nest (1986 Handa warden report). No data were collected in 1987. In 1988 breeding success was 0.69, from 243 nests monitored at four different sites (1988 Handa warden report). Breeding success in 1989 was 1.53 fledged per well built nest and 1.35 in 1990. Generally breeding success has been fairly good for kittiwakes in those years monitored except for 1988 when productivity was 0.69. During this breeding season the main period and stage of loss was late July when the young were large or had just fledged (1988 Handa warden report). There was a significant difference in the mean number of young fledged per well built nest between 1989 and 1990 (Chi-square with two degrees of freedom = 12.6, n=570, $P<0.01$). In 1989 there were more young fledged than expected and in 1990 there were less. This may be because seabirds lay smaller clutch sizes in years when the breeding season is late (Furness and Monaghan 1987), which it was in 1990.

Kittiwake breeding success at British colonies has been examined between 1986 and 1988 (Harris and Wanless 1990). Breeding success varied greatly from zero (several colonies in 1988) to 1.56 young fledged per well built nest (Lowestoft in 1987). At each colony productivity was generally very similar over the three years except in the northern North Sea where many colonies had a very low productivity rate in 1988. Several kittiwake colonies in Shetland have been doing poorly since 1986 (Heubeck et al. 1987). Many kittiwake colonies in the North Sea have continued to do very poorly in recent years (Lloyd et al. 1991), but in marked contrast to this, kittiwakes on Handa have been doing well.

For guillemots and razorbills on Handa, breeding success data were only collected in 1988 and in my study. Three sites were chosen in 1988 at which 171 pairs of guillemots were studied. The breeding success was 0.82 young fledged per occupied site (1988 Handa warden report). 35 razorbills were monitored at one site giving a breeding success of 0.86 young fledged per occupied site (1988 Handa warden report). Productivity rates for both species have declined over the past two years to 0.62 and 0.65 for guillemots and razorbills respectively, but still show fairly successful breeding seasons. The decline in breeding success between 1989 and 1990 was not significant for guillemots ($t=0.91$, d.f.=441, $P>0.05$), nor was it significant for razorbills ($t=0.62$, d.f.=166, $P>0.05$). Other British guillemot colonies have had breeding success rates of 0.69 to 0.85 between 1986 and 1989, except 0.61 on the Farne Isles, Northumberland in 1986 (P.M. Walsh, pers. comm., Harris and Wanless 1988).

Fulmars have not been monitored on Handa before 1989. The breeding success rates of 0.62 and 0.61 large chicks per occupied site in 1989 and 1990 respectively show reasonable breeding success, but there was a considerable difference between the two sites chosen in both years. This suggests that the site at Goose Green is less suitable for fulmars or that poorer birds breed in this location. There was a much smaller number of fulmars breeding in the Goose Green area than at the site at Puffin Bay. The fulmars on Handa were doing as well as or slightly poorer than successful unpredated fulmars in the Clyde area (B. Zonfrillo, pers. comm.). In 1988 fulmar production was lower than in 1987 at five colonies checked around Britain (Harris 1989).

Skuas had successful breeding seasons in both 1989 and 1990. Although the figures for great skuas show a slight decrease in breeding success from 0.68 young produced per egg laid in 1989 to 0.64 in 1990, this does not represent a true decline. In 1990 one great skua nest was found containing a clutch of three and one nest with a clutch of four, both of which are very unusual (Furness 1987b). There was no evidence at either nest that three adults were present at any time. When these nests are excluded from the calculations the breeding success is 0.67 young per egg laid which is very similar to the figure of 0.68 in 1989. The survival rate of the colour-ringed adult birds was also good with 91% being seen again in 1990.

Arctic skuas showed a slight but not significant decrease in breeding success. There was no significant difference in the mean number of young fledged per nest between 1989 and 1990 (Chi-square with two degrees of freedom = 0.09, n=41, P>0.05). In the 1986 Handa warden report a value of 0.56 is mentioned for the breeding success rate of Arctic skuas but no mention is made of how this figure was obtained or how many nests were monitored. The breeding success of skuas in Shetland started decreasing in 1986 and was reduced to almost zero by 1988 (Hamer et al. 1991, Walsh NCC report). In 1989 great skuas had a slightly better breeding season but Arctic skuas still performed very poorly. Skuas on Handa are doing very well compared to other British colonies and there is no indication that breeding success levels are declining.

Although no breeding success data have been collected for skuas on Handa before 1986, an attempt has been made to monitor breeding numbers. Great and Arctic skuas first colonised Handa in 1964 and numbers have been noted since 1970 (see Table 3.11). Great skuas have increased from three breeding pairs in 1970 to 80 breeding pairs in 1990 and do not appear to be levelling off. Arctic skua breeding numbers rose to 35 in 1985 and have stayed around 30 breeding pairs since then.

Table 3.11. Numbers of breeding skua pairs on Handa, 1970-1990 (except 1971-1975).

Year	Great Skuas	Arctic Skuas
1970	3	1
1976	12	3
1977	20	5
1978	8	6
1979	12	6
1980	24	13
1981	28	14
1982	38	19
1983	40	22
1984	46	28
1985	52	35
1986	50-65	30
1987	62	32
1988	69	30
1989	71	30
1990	80	30

Chapter 4

The diet of great skuas

4.1 Introduction

Data on the diets of nonbreeding, breeding and juvenile great skuas were collected in both years. Great skuas regurgitate pellets of indigestible food remains which can easily be collected and identified. Each pellet contains mostly one food type and regular collection of pellets gives accurate information on the composition of the diet (Furness and Hislop 1981). Chicks rarely produce pellets but sometimes regurgitate their last meal which gives an indication of the foods consumed.

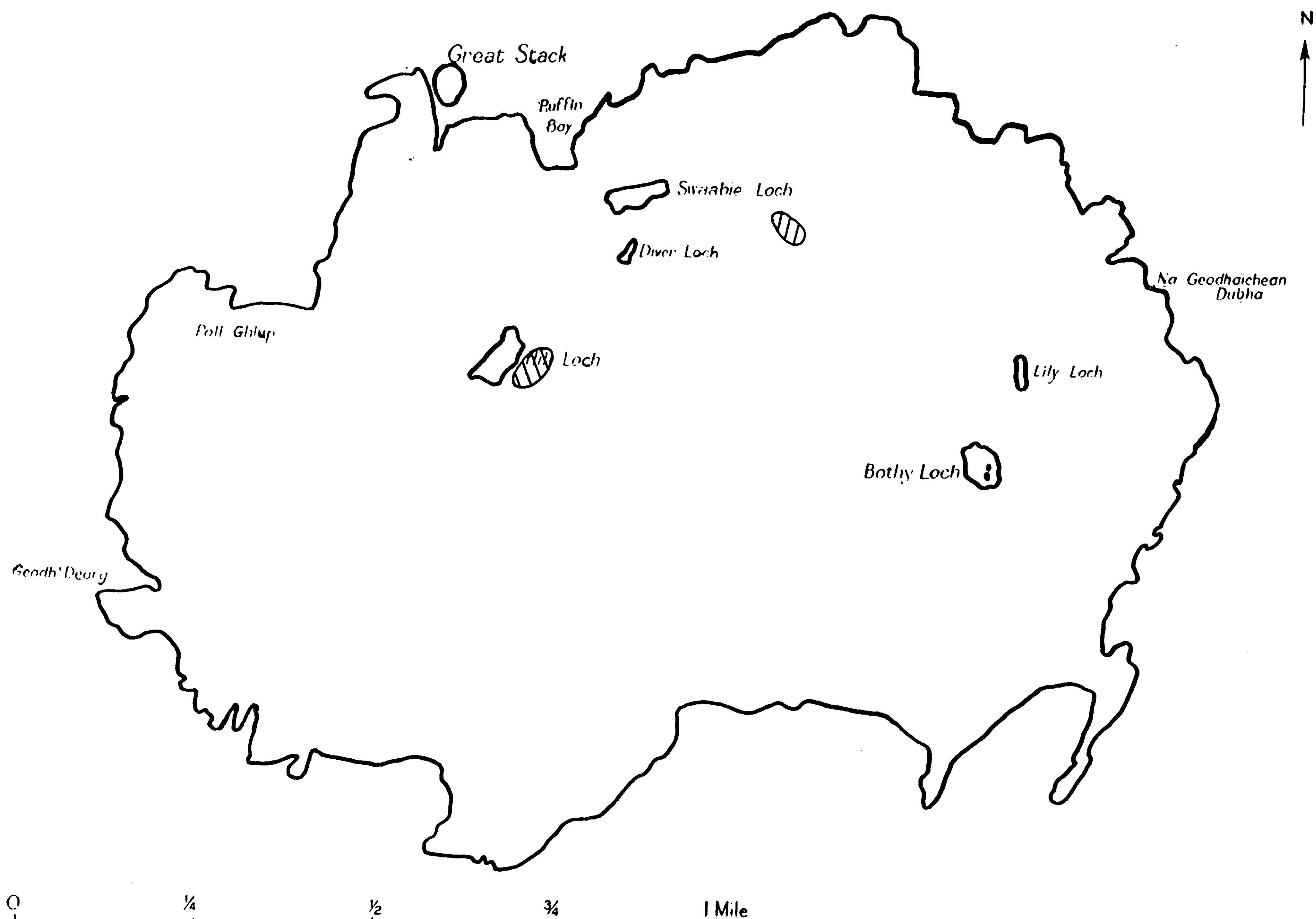
4.2 Methods

The diet of nonbreeders was determined by collecting all pellets found on the club sites every four to seven days. Nonbreeders gather in specific areas known as club sites, and as breeders avoid and other species are generally excluded from these sites pellets collected here represent the diet of nonbreeding great skuas (Furness and Hislop 1981). In 1989 pellets were collected from club sites A and B (see Figure 4.1), but collection from club A was stopped between 30 May and 12 July due to a pair of red-throated divers breeding on Hill Loch. In 1990 pellets of nonbreeders were collected only from club B, again due to a pair of breeding red-throated divers.

Pellets from territories of 17 breeding pairs were collected between 1 and 15 July in 1990. The territories were cleared of all pellets found at three to six day intervals.

In 1989 adult great skuas were captured using a clap net and any regurgitates were noted. Chicks were handled in both 1989 and 1990 and regurgitates were used to obtain information

Figure 4.1 Map of Handa showing the location of both club sites used by great skuas. The lined areas indicate the club sites.


N
Great Stack
Puffin Bay
Swaabie Loch
Diver Loch
Loch
Poll Ghlup
Na Geodhaichean Dubha
Lily Loch
Bothy Loch
Geodh' Deury
0
¼
½
¾
1 Mile

on their diet.

Many of the regurgitated whitefish pellets contained otoliths which were used to determine the size and species of the fish taken (Härkönen 1986).

4.3 Results

The diets of nonbreeders for both years are given in Table 4.1.

Table 4.1. Diets of nonbreeding great skuas on Handa between 5 May - 24 July, 1989 and 19 May - 18 July, 1990.

Year	n	Bird(%)	Whitefish(%)	Sandeel(%)	Other(%)
1989	714	68.5	18.3	11.3	1.8
1990	533	70.5	16.1	11.8	1.5

n is the number of regurgitated pellets analysed for each year

In 1989, 714 pellets were collected between 5 May and 24 July, of which 68.5% were bird pellets, 18.3% whitefish pellets, 11.3% sandeel pellets and 1.8% other pellets. The "other" food items consumed were lamb, goose barnacles, crabs, gastropods and a plastic bag. In 1990 a total of 533 pellets were collected from club B between 19 May and 18 July. 70.5% of these were bird pellets, 16.1% whitefish pellets, 11.8% sandeel pellets and 1.5% other pellets. Besides bird, whitefish and sandeel pellets, pellets containing guillemot eggs, crabs, squat lobsters, goose barnacles and a squid beak were found. There is no significant difference between the proportions of different food items consumed by nonbreeders in the two years (Chi-square with three degrees of freedom = 1.32, P>0.01).

Although it was usually not possible to determine the exact bird species from the bird pellets, I am sure that most of the bird pellets resulted from the consumption of auks or kittiwakes because skulls, beaks and undigested feathers were sometimes regurgitated which were identified as coming from these seabirds. Some probably also resulted from fulmars and gulls being eaten.

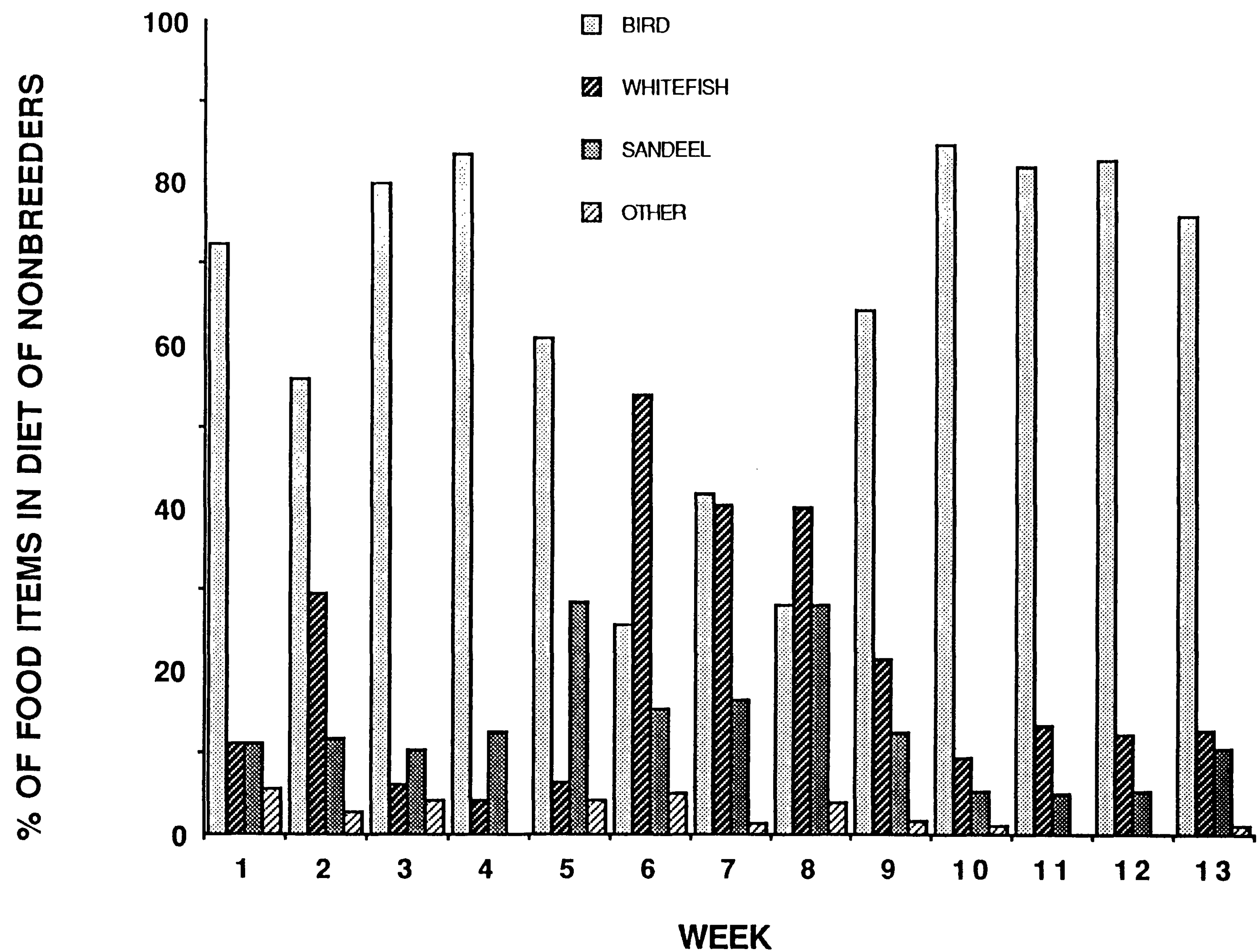
Figures 4.2 and 4.3 show the percentages of food items in the diets of nonbreeders for 1989 and 1990 over the season. Weeks were numbered starting with 1 May and week 13 ends with 30 July (see Table 4.2 which also gives the sample sizes for both years). The same numbering of weeks was used for both years.

Table 4.2. Numbering of weeks used for Figures 4.2 and 4.3 and sample sizes of pellets collected.

Week	Dates	n for 1989	n for 1990
1	1 May - 7 May	18	-
2	8 May - 14 May	34	-
3	15 May - 21 May	49	73
4	22 May - 28 May	24	40
5	29 May - 4 June	46	34
6	5 June - 11 June	39	48
7	12 June - 18 June	67	30
8	19 June - 25 June	25	52
9	26 June - 2 July	56	71
10	3 July - 9 July	96	77
11	10 July - 16 July	60	46
12	17 July - 23 July	114	62
13	24 July - 30 July	86	-

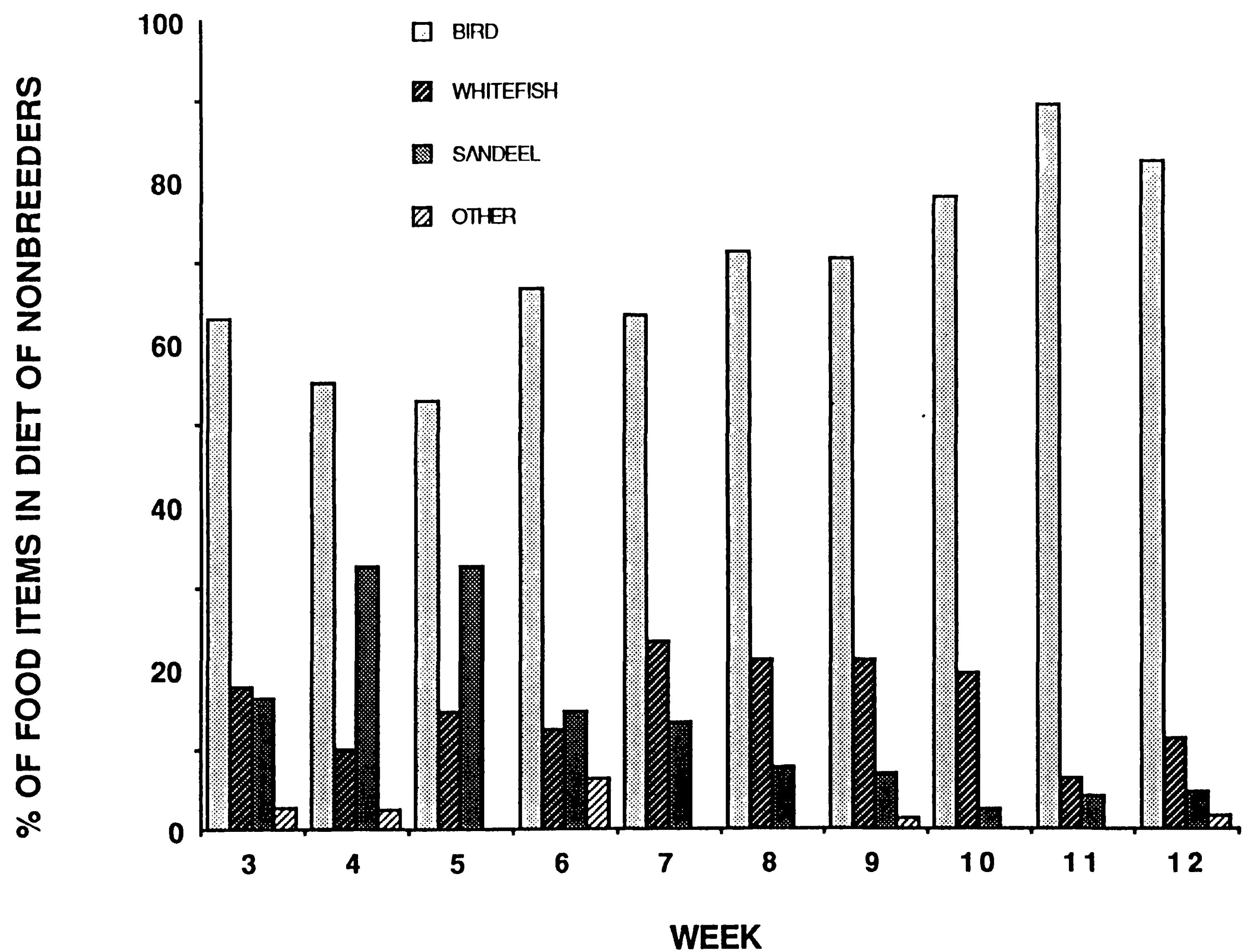
In 1989 bird meat was the major food source over most of the season except for weeks six and eight when whitefish was more important. In weeks nine to 13 the percentage of bird in

Figure 4.2 Bar chart showing the diet of nonbreeders over the season in 1989. See Table 4.2 for the dates of the numbered weeks and the sample sizes.



% OF FOOD ITEMS IN DIET OF NONBREEDERS
100
80
60
40
20
0
BIRD
WHITEFISH
SANDEEL
OTHER
1
2
3
4
5
6
7
8
9
10
11
12
13
WEEK

Figure 4.3 Bar chart showing the diet of nonbreeders over the season in 1990. See Table 4.2 for the dates of the numbered weeks and the sample sizes.


% OF FOOD ITEMS IN DIET OF NONBREEDERS
100
80
60
40
20
0
BIRD
WHITEFISH
SANDEEL
OTHER
3
4
5
6
7
8
9
10
11
12
WEEK

the diet rose to very high levels, the highest being 84.4% during week ten. The amounts of sandeel taken in 1989 decreased slightly towards the end of the season.

Throughout all of the 1990 season bird meat was the main food source for nonbreeders. The percentage of bird pellets rose steadily to a peak of 89.1% in week 11 and then dropped very slightly. The amount of sandeel in the diet was highest in weeks four and five after which there was a continuous decrease during the rest of the season. Whitefish levels were highest in week seven and then continually decreased.

In 1990, 173 pellets were collected from 17 breeding territories between 1 and 15 July, of which 75% were bird, 17% were whitefish, 7% were sandeel and 1% were guillemot eggs (see table 4.3). Breeders took less bird meat than nonbreeders in either year but the difference was not very large.

Equivalent data have been collected for the great skua colony on Foula, Shetland (Hamer et al. 1991) and are shown together with data from Handa Island in Table 4.3.

Table 4.3. Food items in pellets produced by great skuas on Foula and Handa between 1 and 15 July.

Year	n	Sandeel(%)	Whitefish(%)	Bird(%)	Other(%)
1973	100	71	27	2	0
1974	100	24	71	5	0
1975	100	21	69	6	4
1976	100	72	26	2	0
1977	100	59	35	4	2
1978	100	64	35	1	0
1979	100	41	54	3	2
1980	100	17	74	6	3
1981	100	18	77	4	1
1982	100	13	80	3	4
1983	305	9	70	17	4
1984	100	0	74	23	3
1986	200	0	82	14	5
1987	98	9	77	10	4
1988	200	0	73	24	4
1989	247	4	62	30	4
1989(B)	549	1	69	29	2
H1989	156	5	11	83	1
H1990	194	5	17	78	1
H1990(B)	173	7	17	75	1

For every year, n is the number of pellets analysed. (B) refers to breeding adults and H refers to data collected on Handa (all other data are from Foula, Hamer et al. 1991).

Both breeding and nonbreeding great skuas on Handa took a much larger percentage of bird meat than skuas on Foula. The highest percentage of bird found in the diets of great skuas on Foula was 30% in 1989, and the highest on Handa during the same time period was 83% in 1989. Levels of sandeel in the diets of nonbreeding birds on Foula have been fairly low since 1983 and are similar to levels of sandeel in the diets of birds on Handa in 1989 and 1990.

In 1989 six adults regurgitated sandeel while being handled and three regurgitated bird meat (see Table 4.4). This suggests that breeders may be taking more sandeels than is shown by the pellets collected, but the number of regurgitates is small. Three young regurgitated sandeel and one bird meat in 1989. In 1990 seven chicks regurgitated sandeel, one whitefish and one bird meat. Both chicks that regurgitated bird meat were near fledging. Although the sample size for chick regurgitates is small, they suggest that chicks are being fed a high proportion of sandeel in their diet.

Table 4.4. Regurgitates from adult and juvenile great skuas on Handa in 1989 and 1990.

Type of food	1989 Adults	1989 Young	1990 Young
Sandeel	6	3	7
Whitefish	0	0	1
Bird	3	1	1

The otoliths found in whitefish pellets can be used to identify the size and species of fish taken by the skuas. Table 4.5 gives the number of otoliths of each fish species found on club sites and territories. Norway pout *Trisopterus esmarkii* was the most commonly taken whitefish in both years, and the sizes of Norway pout eaten ranged between 11 and 23 cm. Whiting *Merlangius merlangus* was the next most common whitefish taken with fish lengths ranging between 15 and 31 cm. Haddock *Melanogrammus aeglefinus* was also taken fairly often in both years and ranged between 19 and 31 cm in length. These lengths are similar to those of fish taken by seabirds in Shetland (Hudson and Furness 1988). Norway pout was taken more frequently in 1990 than in 1989, but no fish catch data are available to see if this corresponds with varying stock sizes or recruitment.

Breeders seemed to take similar amounts of the same species of whitefish as nonbreeders. Hake Merluccius merluccius, torsk Brosme brosme, dab Limanda limanda, black sea bream Spondyliosoma cantharus and cod Gadus morrhua were also eaten but only in very small amounts. Black sea bream are not very common around the north coast of Scotland (Muus and Dahlstrom 1985) so it is slightly surprising that three otoliths from this species were found in 1989.

Table 4.5. Number of otoliths of each fish species found in whitefish pellets in 1989 and 1990.

Fish species	1989(NB)		1990(NB)		1990(B)	
	n	% of diet	n	% of diet	n	% of diet
Norway pout	46	36.5	109	51.4	16	45.7
Whiting	38	30.2	51	24.1	9	25.7
Haddock	33	26.2	45	21.2	8	22.9
Hake	0	0	5	2.4	0	0
Torsk	3	2.4	0	0	0	0
Dab	3	2.4	1	0.5	2	5.7
Black sea bream	3	2.4	0	0	0	0
Cod	0	0	1	0.5	0	0

(NB) refers to nonbreeders and (B) refers to breeders.
n is the number of otoliths.

4.4 Discussion

In 1989 there was a drop in the amount of bird meat taken around the middle of June. During this time the weather was generally very good which may have increased the level of fishing effort in the Minch. As no fishing data are available yet for 1989, this hypothesis can not be confirmed.

The diet of great skuas on Handa is quite different to that of skuas on Foula. Bird meat is a much more important food source to both breeders and nonbreeders on Handa and can provide as much as 89% of the total diet at certain times. There was a continual increase in the amount of bird meat taken after the middle of June in both 1989 and 1990. This coincides with the hatching of many young kittiwakes, guillemots and razorbills which are undoubtedly used as the major food source. Even before many young hatch bird meat is important in the diet of skuas. Adult and young kittiwakes and auks provide a stable and easily obtainable food source to great skuas on Handa. With the large numbers of seabirds present there is little competition between skuas and probably requires little foraging effort. I could not determine whether most of the birds taken were corpses or live birds, but I did see skuas feeding on corpses on the sea and picking young birds out of nests on cliffs. On Foula there is a much higher proportion of skuas to other seabirds (Furness 1981) than there is on Handa, so the competition for bird meat may be quite high.

Although the number of chick regurgitates is fairly small, they do suggest that chicks are being fed predominantly on sandeels. Sandeels have a higher calorific value than whitefish (Harris and Hislop 1978) and several studies have shown that chicks are fed on the most calorie-rich foods available (Barrett et al. 1987, Harris and Hislop 1978). Guillemots shot on Loch Broom near Ullapool were found to be feeding on sandeels (N. Harrison, pers. comm.) so there does not appear to be a shortage of sandeels or similar type fish in the Minch. Adult skuas may be feeding on bird meat only because it is a constant and easily obtainable food source and not because there is a shortage of sandeels. Skuas on Handa may never have had very high levels of sandeels concentrated in one area available to them, forcing them to make use of alternative food sources. Maybe the skuas in Shetland will "learn" to take more bird meat in their diet now that sandeel stocks have declined.

Chapter 5

Attendance levels of breeding great skuas and kittiwakes

5.1 Introduction

Territorial attendance of breeding birds may be a useful measure of local food availability. Data from Furness and Hislop (1981) suggest that great skuas never leave chicks unattended unless one adult can not obtain sufficient food for the young. The data also imply that all trips except perhaps the shortest ones are to forage. Attendance levels may therefore provide some information on food availability, although one must make sure that attendance is not being affected by other parameters such as weather.

The territorial attendance of breeding skuas was noted most days throughout the season and correlated with weather data in order to determine whether or not weather was affecting attendance levels. Kittiwake attendance of adults at nests was also noted at each visit.

5.2 Methods

In order to determine adult territorial attendance of breeding great skuas, between 25 and 30 nests were monitored most days. By noting whether zero, one or two adults were present on a territory a mean value of adult territorial attendance was then calculated. The same nests were always checked between 0900 and 1600 hours which is when skuas are likely to be foraging (Furness 1987b), and all 25 to 30 nests monitored produced live chicks. These data were collected on Handa Island in 1989 and 1990 by myself and on Foula in 1987 by Richard Caldow. In 1989 data were collected between 3 June and 24 July, in 1990 between 29 May and 13 July and in 1987 between

1 June and 20 July.

Attendance was monitored throughout the season and divided into three stages. The first stage was during incubation, the second was the first two weeks after the chicks hatched and the third was the rest of the pre-fledging period.

Weather data were obtained from the MET office. The nearest rainfall station to Handa is at Duartmore Bridge and 24 hour rain totals were used. Windspeed, visibility and temperature (dry bulb) readings from the station at Cape Wrath were used, and averages of the 0900, 1200 and 1500 readings for each day were calculated for each of these weather parameters. The weather station on Foula provided a 24 hour rainfall total and windspeed and temperature data. Again an average of the 0900, 1200 and 1500 readings was taken for windspeed, temperature and visibility. Visibilty readings from the station at Lerwick were used since the Foula station did not provide this.

The number of adult kittiwakes present at each nest was recorded during each visit to the nest on Handa in 1990, and the percentages of unattended nests of different brood sizes were calculated.

5.3 Results

Adult great skua attendance at nest sites started off high at the beginning of the season and decreased as it progressed. This pattern is similar for the three years examined, and Figures 5.1, 5.2 and 5.3 show the mean attendance levels over the season for Handa 1989, Handa 1990 and Foula 1987 respectively.

Figure 5.1 Graph showing the mean values of territorial attendances of adult great skuas on Handa from 3 June to 24 July, 1989. Each mean was calculated by noting how many adults were present each day on the same 30 territories.

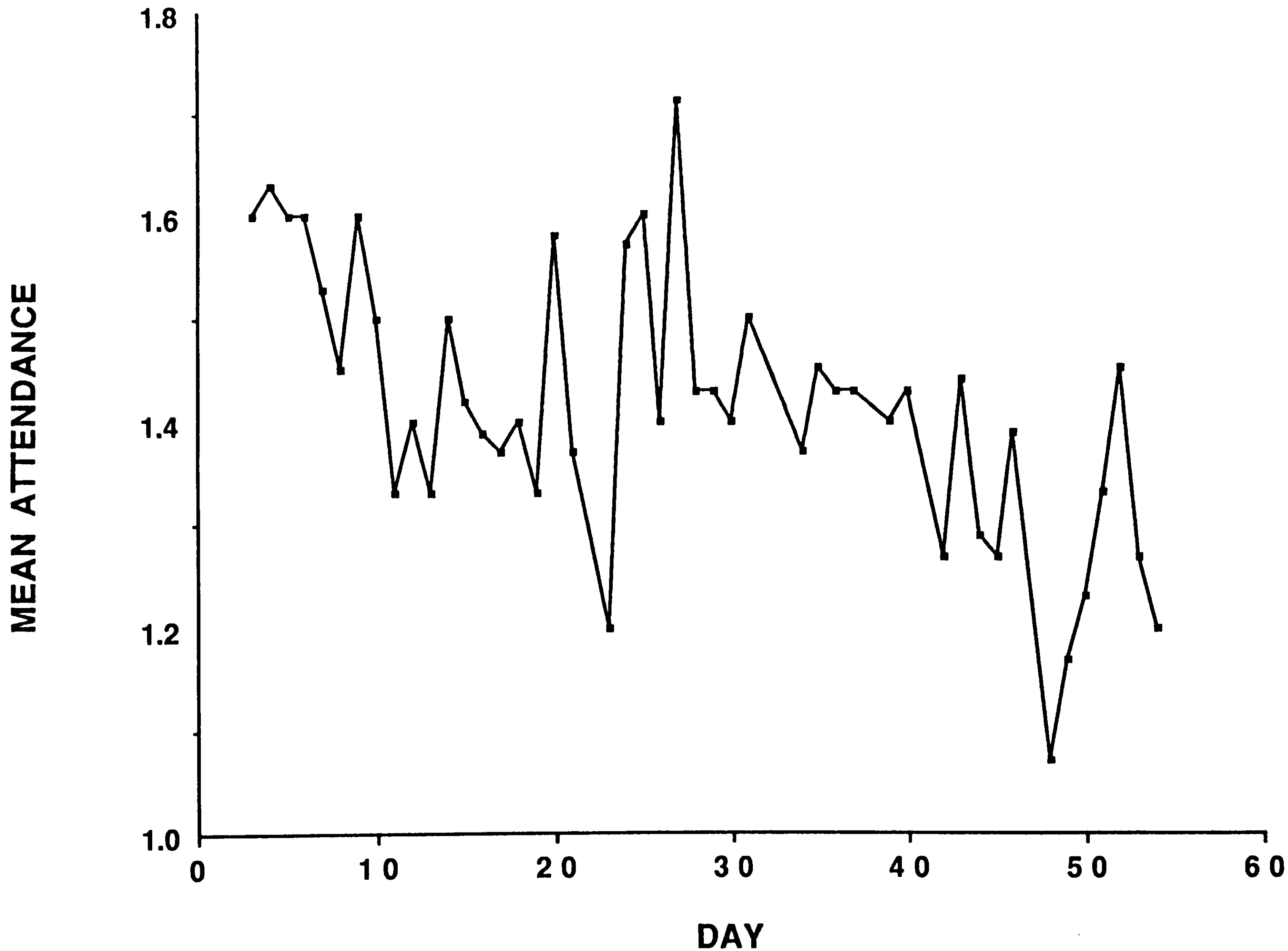

MEAN ATTENDANCE
1.8
1.6
1.4
1.2
1.0
0
10
20
30
40
50
60
DAY

Figure 5.2 Graph showing the mean values of territorial attendances of adult great skuas on Handa from 29 May to 13 July, 1990. Each mean was calculated by noting how many adults were present each day on the same 30 territories.

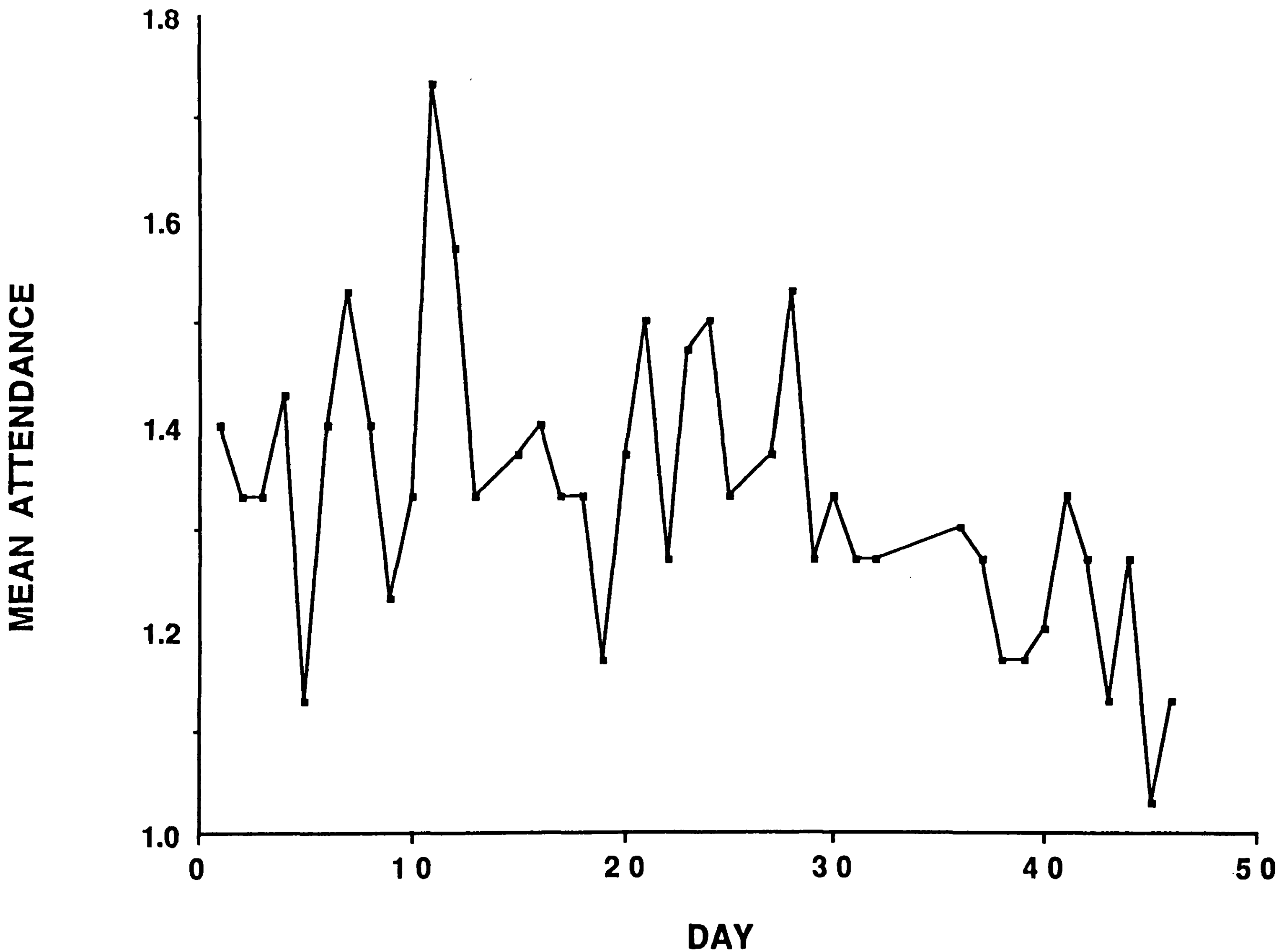
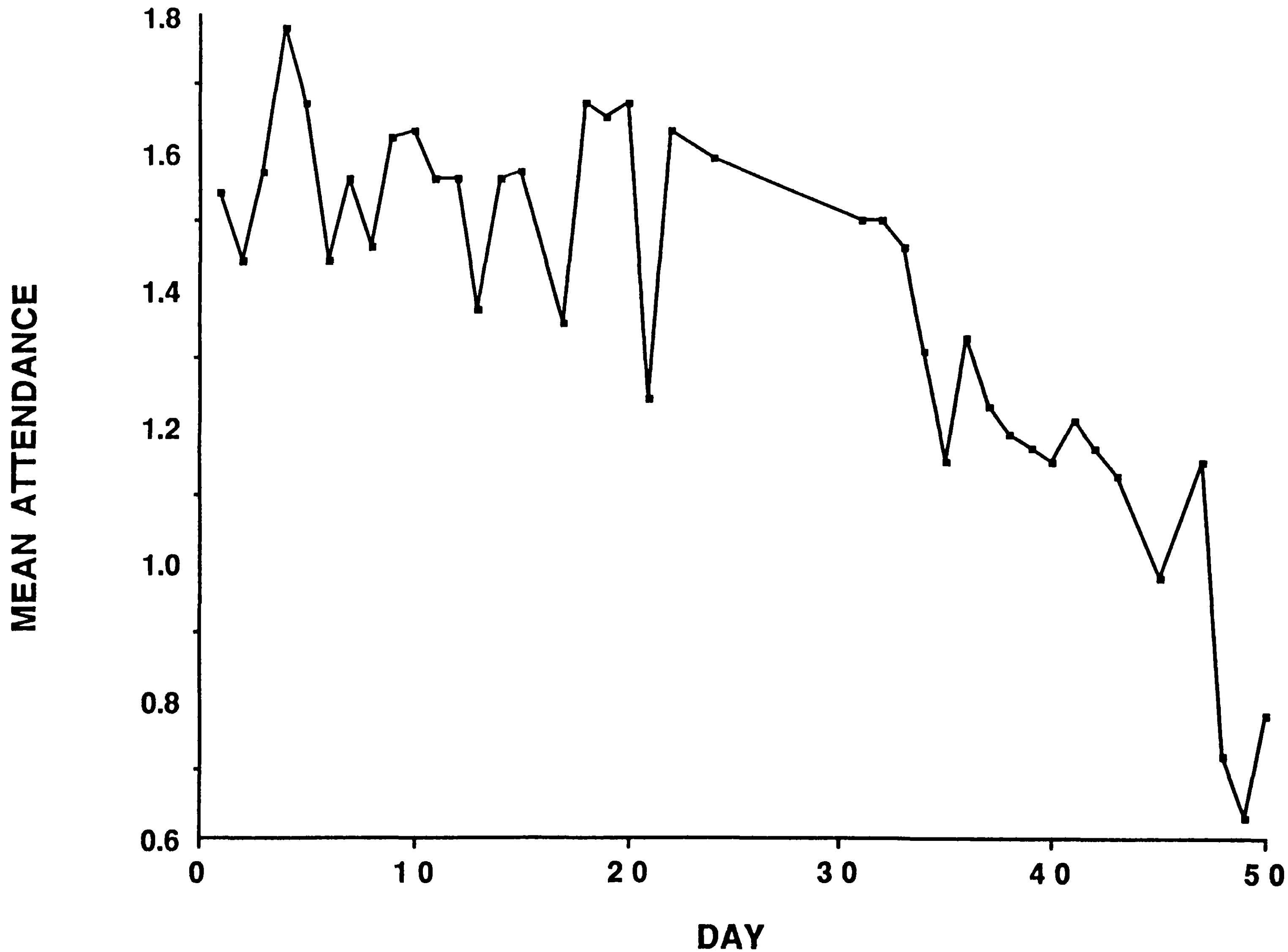

MEAN ATTENDANCE
1.8
1.6
1.4
1.2
1.0
0
10
20
30
40
50
DAY

Figure 5.3 Graph showing the mean values of territorial attendances of adult great skuas on Foula from 1 June to 20 July, 1987. Each mean was calculated by noting how many adults were present each day on the same 25 to 30 territories. These data were collected by Richard Caldow.


MEAN ATTENDANCE
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0
10
20
30
40
50
DAY

Although the general pattern of attendance is the same in all three years, there is a difference between the stages of the seasons. Table 5.1 gives the mean attendances at different stages of the season for Foula and Handa. All data for Foula are taken from Hamer et al. 1991.

Table 5.1. Territorial attendances of adult great skuas on Foula in 1976, 1987-1989, and on Handa in 1989 and 1990.

Year	n	stage of season	mean no. of birds present	% nests with both birds absent
1976	160	3	1.47	0.00
1987	60	1	1.54	0.10
1987	60	2	1.54	0.00
1987	58	3	1.07	10.34
1988	156	1	1.55	1.28
1988	150	2	1.52	1.28
1988	32	3	1.03	12.50
1989	194	1	1.51	1.55
1989	185	2	1.45	1.08
1989	90	3	1.17	11.11
1989(H)	300	1	1.53	0.00
1989(H)	373	2	1.43	0.00
1989(H)	625	3	1.35	1.92
1990(H)	563	1	1.38	0.00
1990(H)	349	2	1.36	0.57
1990(H)	318	3	1.20	1.89

For stages of season: 1=incubation, 2=the first two weeks after hatching, 3=the rest of the pre-fledging period.
n is the number of observations producing each mean and (H) refers to Handa data (otherwise data are from Foula, Hamer et al. 1991).

For all years the mean attendance during stages 1 and 2 is fairly high, betweeen 1.36 and 1.55, but during stage 3 there is a marked decrease for Foula between 1987 and 1989. The mean attendance for Handa at stage 3 in 1990 (1.20) is almost as low as for Foula in 1989 (1.17), but the percentage of nests with both birds absent is very much lower for Handa (1.89% compared to 11.11% for Foula). The percentage of nests with both birds absent rises from around 1% for stages 1 and 2 to over 10% in stage 3 for years 1987 to 1989 on Foula, but remains below 2% throughout the season on Handa in both 1989 and 1990.

In order to determine whether or not adult great skua attendance was affected by rainfall, windspeed, temperature or visibility, a stepwise multiple regression of average daily attendance against date and weather factors was performed. Data from Handa 1989 and 1990 and Foula 1987 were used, and in all three cases date accounted for most of the variance in average daily attendance. The variance in average daily attendance accounted for by date was 35.8%, 25.1% and 66.6% for Handa 1989, Handa 1990 and Foula 1987 respectively ($P < 0.01$). Only in 1989 did rain have a significant effect on attendance levels on Handa and accounted for a further 6.5% of the variance in average daily attendance ($P < 0.05$). From the equation one can tell that as rainfall increases average daily attendance at the nest site increases as well. Weather did not have a significant effect during the other two years.

Since the number of rainy days and the amount of rainfall were not the same in all three years, the data were examined to determine whether this was an important factor. A Chi-square test showed that there was no significant difference in the number of days with zero or a trace of rain and the number of days with more than a trace of rain between the three years

(Chi-square with two degrees of freedom = 2.01, n=124, $P > 0.1$). The average rainfall per day was 2.2 mm, 4.7 mm and 1.1 mm for Handa 1989, Handa 1990 and Foula 1987 respectively, and an ANOVA for unequal sample sizes showed that there was a significant variance between the amounts of rain in the three years, $F_s = 5.24$ (2,121), $P < 0.01$.

The percentages of unattended kittiwake nests of different brood sizes are shown in Table 5.2. Prior to 27 June all nests were being incubated and no nests were ever seen unattended. There was a significant decline in mean kittiwake attendance as the season progressed, as determined by Spearman's rank correlation ($r_s = -1$, n=5, $P < 0.05$). Although 100% of nests with broods of three were unattended on two visits, the sample size for broods of three is very small and therefore the result may not be very accurate. On 18 July 46% of all nests with broods of two were left unattended, but some chicks were already being left unattended within a week of hatching. The highest percentage of unattended nests with broods of one was 26% on 18 July. The mean percentage of unattended nests was 14.3% for broods of one and 28.5% for broods of two.

Table 5.2. Percentages of broods of one, two and three kittiwake chicks left unattended, Handa 1990.

	broods of one		broods of two		broods of three	
	number checked	% unattended	number checked	% unattended	number checked	% unattended
27 June	45	2	102	9	0	0
4 July	74	4	177	12	0	0
9 July	101	9	164	30	2	100
13 July	97	22	158	41	1	0
18 July	97	26	156	46	1	100
mean unattended		14.3		28.5		75.0

5.4 Discussion

The levels of great skua attendance decrease in all years during the third stage of the season (the pre-fledging period excluding the first two weeks after hatching) because this is when the chicks have the greatest food requirement (Furness 1977). It is during this time period that the greatest demands are placed on adults to obtain food for their young, so if food availability is low one would expect to see the effects at this stage. Between 1987 and 1989 breeding great skuas on Foula were probably working as hard as possible (Hamer et al. 1991) which was marked by a high percentage of unattended nests. Although the mean number of birds present on territories was nearly as low on Handa in 1990 as on Foula, the percentage of unattended nests was at most 2% on Handa compared to 12% on Foula. The percentage of nests with both parents absent might be a more accurate measure of how difficult birds are finding it to obtain food than the mean number of birds present on a territory.

It is possible that attendance may be affected by factors other than food availability such as weather. The multiple regression carried out on the data shows that great skuas were affected by rain on Handa in 1989 and were more likely to stay on their territory during rainfall. It is not the number of days of rain that are significant but the amounts of rain.

There are several explanations as to why great skuas on Handa in 1990 and on Foula in 1987 were not significantly affected by rain:

i) food availability may have been lower and birds were foraging as much as possible,

ii) there was too little rain to make any difference or,

iii) there was too much rain and birds could not avoid it.

In 1990 the breeding success rate and the percentage of nests with both birds absent were almost exactly the same as in 1989, so it seems unlikely that the birds were struggling to find enough food. The average daily rainfall in 1990 was more than twice that of 1989, so it seems possible that the birds could not avoid the rain and had to forage in poor weather conditions.

Although there was little rain on Foula in 1987, it seems more likely that great skuas were struggling to obtain enough food. This is supported by the low breeding success rate and the high percentage of unattended nest sites.

In all three years examined, average daily attendance on the previous day had a significant effect on attendance the following day. The results show that average daily attendance is likely to be similar on two consecutive days which suggests that it is the time of season which is important. In 1989 when rain did have an effect on attendance, the effect was only significant when considered with date and not significant in a correlation with only average daily attendance and rain.

It is possible for rain to affect attendance levels of great skuas, but food availability and requirements are probably a much more important influence. When birds have the chance they may avoid foraging in the rain, but they may not have this choice if there is a large amount of rain or if they are struggling to find enough food. It is unlikely that great skuas on Handa were affected by tides as they predominantly fed on other birds, but in other communities where fish are a major source of food they may be.

Although no data on kittiwake attendance were collected in 1989, I do not recall seeing many unattended nests at any stage of the breeding season. On Handa in 1990 some chicks were already being left unattended within a week of hatching. Although up to 50% of broods of young kittiwakes have been left unattended on the Isle of May, the chicks were not usually left until they had reached three to four weeks of age (Wanless and Harris 1989). On the Isle of May the breeding success of kittiwakes was fairly low (0.8 mean young fledged per completed nest) the year that many broods were left unattended, but on Handa the breeding success remained high. Predation of young kittiwakes did not seem to be a problem, possibly because there are few skuas in comparison with the large numbers of kittiwakes. The low attendance of adult kittiwakes at their nests suggests that they may be having difficulties obtaining enough food for their chicks and themselves.

Chapter 6

Weights of great skua chicks

6.1 Introduction

Chick growth may give some insight into food supply at certain times. Cairns (1987) suggested that chick growth varies with food supply when supplies are poor or moderate, but that growth is limited by intrinsic factors when food is abundant. If there is a shortage of food, this is most likely to become apparent when the chicks are older as they will require more food during this time. Chick growth rate would reflect the state of the food supply only during the chick rearing period.

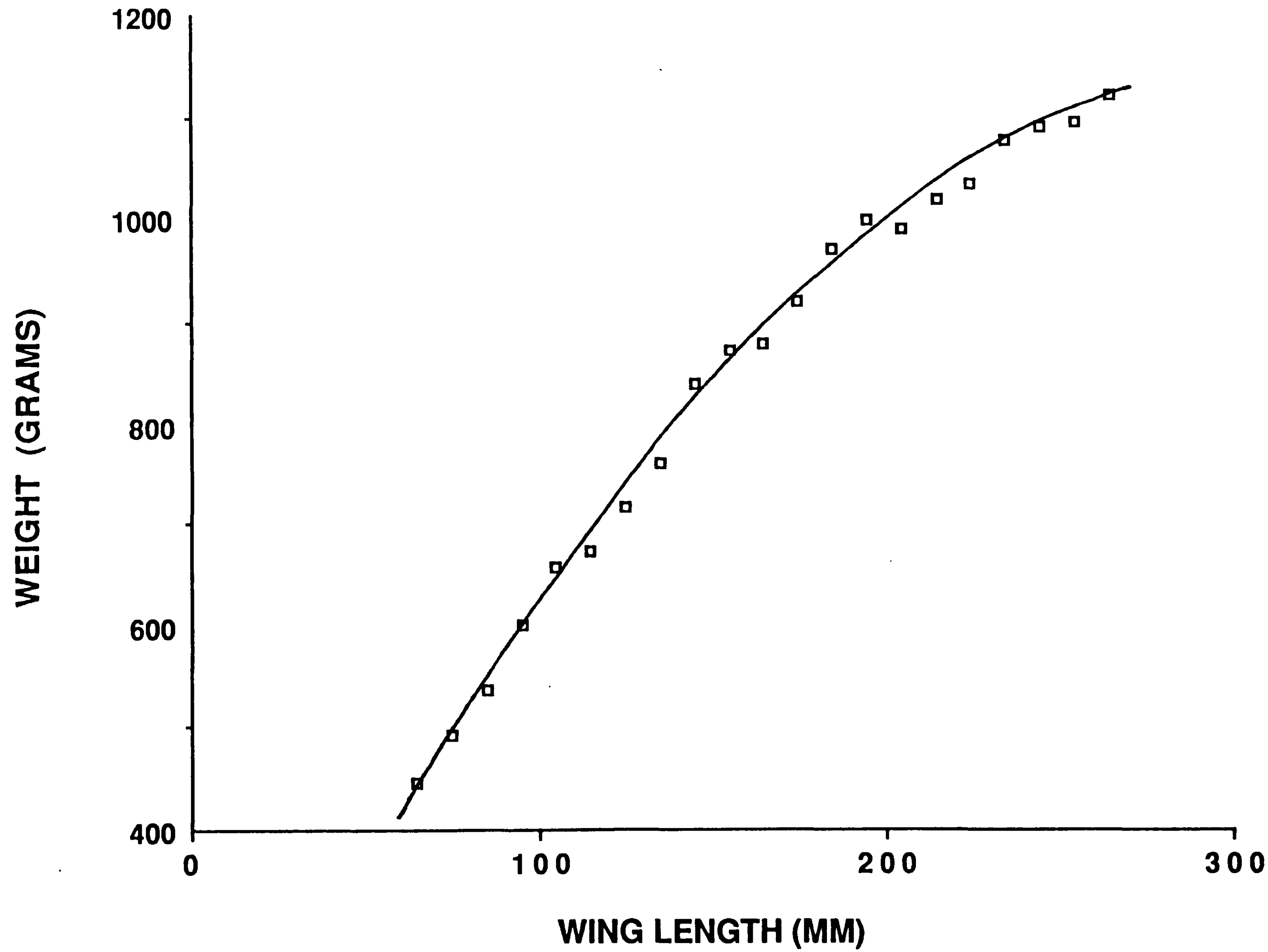
6.2 Methods

Great skua chicks were weighed using a cloth sack and a spring balance. Only chicks that were between 13 and 34 days of age were used in the analysis as this is the period of most rapid daily mass gain (Furness 1983). The ages of chicks were calculated from the wing length (Furness 1977) and chick weights were compared to chicks weighed on Foula in 1975.

6.3 Results

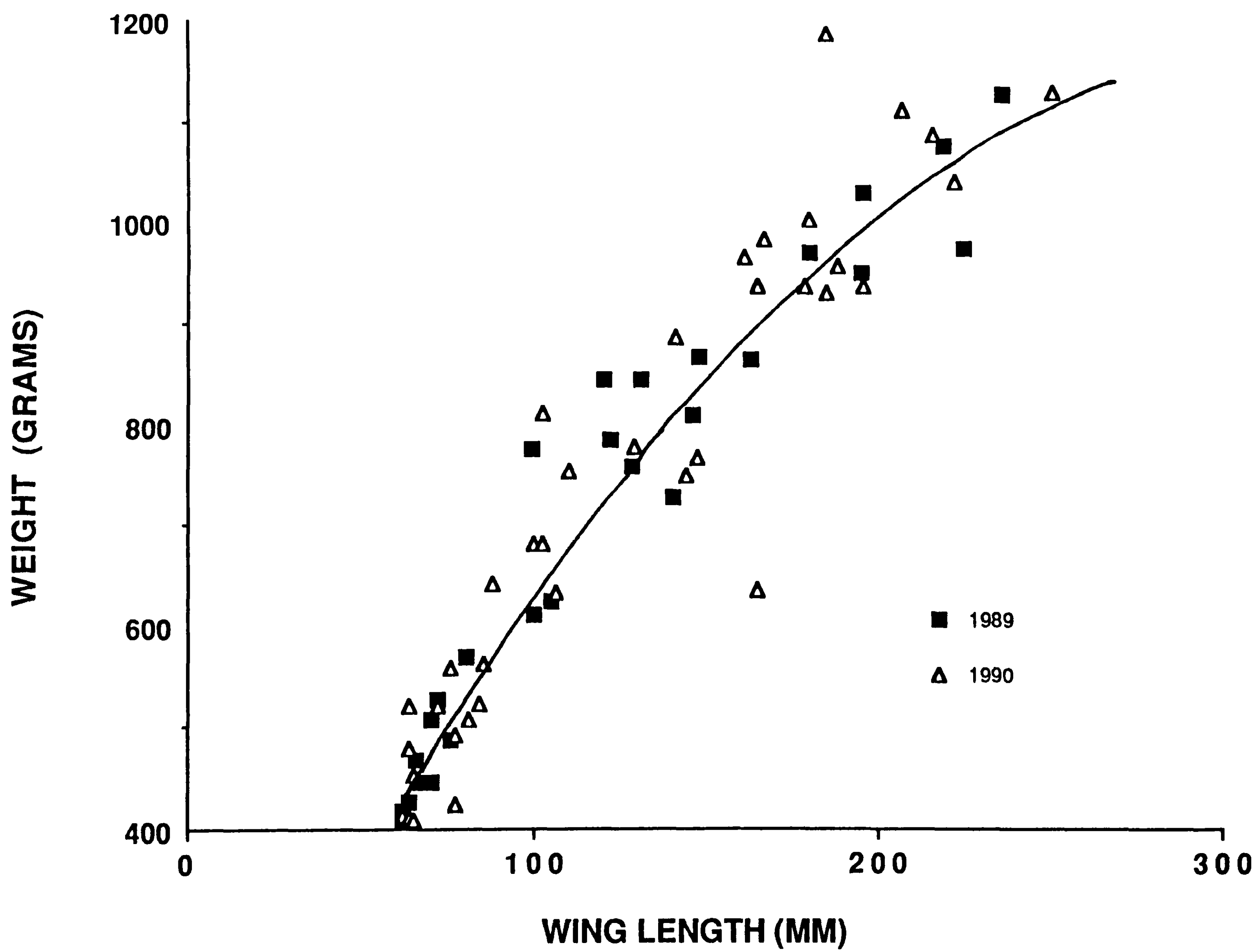
Data on Foula chicks were taken from Furness (1977) and are shown in Figure 6.1. A curve was drawn through the data by eye as this provided the best fit. The curve represents "typical" great skua chick growth of chicks that are doing well. This curve was superimposed on data from Handa. Figure 6.2 shows the weight against wing length of individual chicks measured on Handa in 1989 and 1990. If the Handa chicks were doing as well as those on Foula, one would expect equal numbers of Handa

Figure 6.1 Graph of chick weight against wing length of great skua chicks hatched in 1975 at Foula before 21 June. Data taken from Furness 1977.



WEIGHT (GRAMS)
1200
1000
800
600
400
0
100
200
300
WING LENGTH (MM)

Figure 6.2 Graph of chick weight against wing length of great skua chicks hatched on Handa in 1989 and 1990. The curve is taken from Figure 6.1 in order to compare chick growth between Handa and Foula chicks. For 1989 n=28 and for 1990 n=37.


WEIGHT (GRAMS)
1200
1000
800
600
400
0
100
200
300
WING LENGTH (MM)
1989
1990

chicks above and below the curve representing Foula data. In 1989 14 individuals were above the curve, 11 below and three on the curve. In 1990 19 were above, 14 below and four on the curve. There was no significant difference between the number of chick weights above and below the Foula growth curve (Chi-square with one degree of freedom = 0.01, n=58, P > 0.05). In 1990 there was one chick which was very heavy for its wing length and one which was very light. These are possibly mistakes made during weighing but do not affect the overall results. The data show that the chicks on Handa between 13 and 34 days of age were doing as well as those on Foula in 1975, possibly even slightly better.

6.4 Discussion

Several studies have shown that a lack of appropriate food results in poor chick growth (Barrett et al. 1987, Barrett and Runde 1980, Hamer et al. 1991, Monaghan et al. 1989). The results from this study show that great skua chicks were doing very well on Handa in 1989 and 1990, which indicates that there was no shortage of food. It seems that young great skuas were being fed predominantly on sandeels or similar type fish, although the sample size was rather small (see Chapter 4 on diet). There is no indication from the chick weight data that there was a shortage of food.

Chapter 7

Discussion

Discussion

This study provides important background information for any further seabird studies on Handa Island and also gives some indication of food availability in the surrounding environment. The parameters examined were breeding success of various seabird species, diet of great skuas, attendance levels of great skuas and kittiwakes and great skua chick weights. Each of these may provide information on food levels, although some may be more useful than others.

Breeding success

The breeding success rates of kittiwakes, guillemots, razorbills, fulmars, great skuas and arctic skuas were monitored during the 1989 and 1990 breeding seasons. All species had fairly successful breeding seasons compared to other seabird colonies around Britain with skuas doing very well (see Chapter 3). Although other factors such as poor parental care and predation can affect breeding success (Barrett and Runde 1980, Coulson 1968), they would only reduce breeding success and not increase it. Therefore the breeding success rates indicate that there is enough food available in the area. One would expect the breeding success rates to decrease if the food levels were to fall beyond a certain level.

Diet

The diet of great skuas was analysed and although it was not really an indicator of food levels in this study, diet may provide useful information about availability of certain food types (Vermeer and Westrheim 1984). Both breeding and nonbreeding adult great skuas were found to be feeding predominantly on other birds whereas chicks were being fed mostly on sandeels or similar type fish (see Chapter 4). This would suggest that although sandeels are available, bird meat may be easier to obtain or require less foraging activity. Bird meat may be the preferred food, but great skuas on Foula fed predominantly on sandeels when these were readily available (Hamer et al. 1991). If the availability of certain food items were to change in future years, the diet might change as well. This has occurred in Shetland (Hamer et al. 1991) where skuas have changed their diet from mostly sandeel to whitefish.

Attendance levels

The attendance levels of breeding great skuas and kittiwakes were probably the best indicators of food availability in this study. For great skuas both the mean number of birds present on a territory and the percentage of nests with both birds absent were calculated (see Table 5.1). Although great skuas on Handa had similar mean levels of nest attendance as those on Foula during poor breeding years, the percentage of nests with both birds absent was much lower. This suggests that the percentage of nests with both birds absent may be a finer indicator of food availability. The differences in diet may play a role in determining territorial attendance as different food types may require different foraging methods. The attendance levels of great skuas imply that there is enough food available to them, but it is probably not highly abundant.

Many kittiwake nests were being left unattended in 1990 (see Table 5.2). One would not expect adults to leave their young unattended which suggests that kittiwakes were struggling to find enough food to feed their young. The breeding success rate was still reasonable, so it seems that they were able to compensate for the lower food availability by increasing their foraging effort. If food levels were to drop even more, one would expect to see a decrease in breeding success. Kittiwakes do not seem to have an alternative food source which great skuas have and would therefore be expected to suffer from reduced levels of sandeels or similar type fish before great skuas.

Chick weights

Great skua chick weights showed that chicks were growing well, implying that enough food was being provided. Very young chicks do not require much food so if there is a food shortage, one would expect to see older chicks suffer before younger ones.

This study supports Cairns' hypothesis that attendance levels are sensitive when food availability is moderate to good (Cairns 1987). The fish catch data from the Minch area (see Chapter 2) suggest that there is no food shortage which is supported by the breeding success rates of several seabird species on Handa. There is a coastal convergence at the Butt of Lewis between the two northbound branches of the Coastal current which generates a complex circulation (Webb <u>et</u> <u>al.</u> 1990). This enriches the waters and corresponds very closely with the distribution of high densities of birds.

Various parameters can be useful in determining food availability, but different species may respond in different ways. Factors such as range of food eaten, diving depths, body size, foraging behaviour and weather conditions may all affect the seabird parameters (Ainley and Boekelheide 1983, Dunn 1973, Pearson 1968, Walsberg 1983), complicating the relationship between them and food availability. By knowing as much as possible about a species, the use of it as an indicator of food levels improves.

References

Ainley, D.G. & Boekelheide, R.J. (1983). An ecological comparison of oceanic seabird communities of the South Pacific Ocean. Studies in Avian Biology **8**: 2-23.

Anderson, D.W. & Gress, F. (1984). Brown Pelicans and the anchovy fishery off southern California. In Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships: 128-135. Nettleship, D.N., Sanger, G.A. & Springer, P.F. (eds.). Canadian Wildlife Service, Ottawa.

Anderson, D.W., Gress, F. & Mais, K.F. (1982). Brown pelicans: influence of food supply on reproduction. Oikos **39**: 23-31.

Anderson, D.W., Gress, F., Mais, K.F. & Kelly, P.R. (1980). Brown pelicans as anchovy stock indicators and their relationships to commercial fishing. Calif. Coop. Oceanic Fish. Invest. Rep. **21**: 54-61.

Anon. (1989). Report of the Industrial Fisheries Working Group. ICES, Doc. C.M. 1989/Assess:13.

Bailey, R.S., Furness, R.W., Gauld, J.A. & Kunzlik, P.A. (1991). Recent changes in the population of the sandeel (Ammodytes marinus Raitt) at Shetland in relation to estimates of seabird predation. ICES mar. Sci. Symp. **193**: 209-216.

Barrett, R.T., Anker-Nilssen, T., Rikardsen, F., Valde, K., Rov, N. & Vader, W. (1987). The food, growth and fledging success of Norwegian puffin chicks Fratercula arctica. Ornis Scand. **18**: 73-83.

Barrett, R.T. & Runde, O.J. (1980). Growth and survival of nestling kittiwakes Rissa tridactyla in Norway. Ornis Scand. **11**: 228-235.

Batty, L. (1989). Birds as monitors of marine environments. Biologist **36**: 151-154.

Birkhead, T.R. & Nettleship, D.N. (1982). The adaptive significance of egg size and laying date in thick-billed murres Uria lomvia. Ecology **63**: 300-306.

Boersma, P.D. (1978). Breeding patterns of Galapagos penguins as an indicator of oceanographic conditions. Science **200**: 1481-1483.

Bourne, W.R.P. (1976). Seabirds and pollution. In Marine Pollution: 403-502. Johnston, R. (ed.). Academic Press, London.

Cairns, D.K. (1987). Seabirds as Indicators of Marine Food Supplies. Biological Oceanography **5**: 261-271.

Coulson, J.C. (1968). Differences in the quality of birds nesting in the centre and on the edges of a colony. Nature **217**: 478-479.

Coulson, J.C., Monaghan, P., Butterfield, J., Duncan, N., Thomas, C. & Shedden, C. (1983). Seasonal changes in the herring gull in Britain: weight , moult, and mortality. Ardea **71**: 235-244.

Crawford, R.J.M. & Shelton, P.A. (1978). Pelagic fish and seabird interrelationships off the coasts of south west and South Africa. Biological Conservation **14**: 85-109.

Crawford, R.J.M., Shelton, P.A. & Berruti, A. (1983). Cape cormorants as potential indicators of pelagic fish stocks off southern Africa. South African Journal of Science **79**: 466-468.

Duffy, D.C. (1983). Environmental uncertainty and commercial fishing: effects on Peruvian guano birds. Biological Conservation **26**: 227-238.

Dunn, E.K. (1973). Changes in fishing ability of terns associated with windspeed and sea surface conditions. Nature **244**: 520-521.

Ewins, P.J. (1985). Growth, diet, and mortality of arctic tern Sterna paradisaea chicks in Shetland. Seabird **8**: 59-68.

Furness, R.W. (1977). Studies on the breeding biology and population dynamics of the great skua Catharacta skua Brunnich. Unpubl. PhD thesis, Univ. of Durham.

Furness, R.W. (1981). The impact of predation by Great Skuas Catharacta skua on other seabird populations at a Shetland colony. Ibis **123**: 534-539.

Furness, R.W. (1983). Variations in size and growth of Great Skua Catharacta skua chicks in relation to adult age, hatching date, egg volume, brood size and hatching sequence. J. Zool., Lond. **199**: 101-116.

Furness, R.W. (1987a). Seabirds as monitors of the marine environment. ICBP Technical Publication **6**: 217-230.

Furness, R.W. (1987b). The Skuas. Calton: T. & A.D. Poyser.

Furness, R.W. (1989). Changes in diet and breeding ecology of seabirds on Foula, 1971-88. In Seabirds and sandeels; Proceedings of a Seminar held in Lerwick, Shetland, 15th-16th October 1988: 22-26. Heubeck, M. (ed.). Shetland Bird Club, Lerwick.

Furness, R.W. & Hislop, J.R.G. (1981). Diets and feeding ecology of Great skuas Catharacta skua during the breeding season in Shetland. J. Zool., Lond. **195**: 1-23.

Furness, R.W. & Monaghan, P. (1987). Seabird ecology. Blackie & Son Ltd., Glasgow.

Gaston, A.J. & Nettleship, D.N. (1982). Factors determining seasonal changes in attendance at colonies of the thick-billed murre Uria lomvia. Auk **99**: 468-473.

Goodlad, J. (1989). Industrial fishing in Shetland waters. In Seabirds and sandeels; Proceedings of a Seminar held in Lerwick, Shetland, 15th-16th October 1988: 50-59. Heubeck, M. (ed.). Shetland Bird Club, Lerwick.

Härkönen, T. (1986). Guide to the Otoliths of the Bony Fishes of the Northeast Atlantic. Danbiu ApS., Hellerup.

Hamer, K.C., Furness, R.W. & Caldow, R.W.G. (1991). The effects of changes in food availability on the breeding ecology of great skuas Catharacta skua in Shetland. J. Zool., Lond. **223**: 175-188.

Harris, M. (1989). Recent breeding success of seabirds around the British Isles. In Seabirds and sandeels; Proceedings of a Seminar held in Lerwick, Shetland, 15th-16th October 1988: 19-21. Heubeck, M. (ed.). Shetland Bird Club, Lerwick.

Harris, M.P. & Hislop, J.R.G. (1978). The food of young Puffins, Fratercula arctica. J. Zool., Lond. **185**: 213-236.

Harris, M.P. & Wanless, S. (1988). The breeding biology of Guillemots Uria lomvia on the Isle of May over a six year period. Ibis **130**: 172-192.

Harris, M.P. & Wanless, S. (1990). Breeding success of British kittiwakes Rissa tridactyla in 1986-88: Evidence for changing conditions in the Northern North Sea. J. of Applied Ecology **27**: 172-187.

Heubeck, M. (1989). Seabirds and sandeels; Proceedings of a seminar held in Lerwick, Shetland, 15th-16th October 1988. Shetland Bird Club, Lerwick.

Heubeck, M., Harvey, P.V. & Robertson, I.S. (1987). Chick production at Kittiwake Rissa tridactyla colonies in Shetland, 1986. Seabird **10**: 34-42.

Hislop, J.R.G. & Harris, M.P. (1985). Recent changes in the food of young Puffins Fratercula arctica on the Isle of May in relation to fish stocks. Ibis **127**: 234-239.

Hudson, A.V. & Furness, R.W. (1988). Utilization of discarded fish by scavenging seabirds behind whitefish trawlers in Shetland. J. Zool., Lond. **215**: 151-166.

Hunt, G.L. & Butler, J.L. (1980). Reproductive ecology of Western Gulls and Xantus' Murrelets with respect to food resources in the Southern California Bight. Calif. Coop. Oceanic Fish. Invest. Rep. **21**: 62-67.

Hunt, G.L. & Hunt, M.W. (1976a). Gull chick survival: The significance of growth rates, timing of breeding and territory size. Ecology **57**: 62-75.

Hunt, G.L. & Hunt, M.W. (1976b). Exploitation of fluctuating food resources by Western Gulls. Auk **93**: 301-307.

Kunzlik, P.A. (1989). Small fish around Shetland. In Seabirds and sandeels; Proceedings of a Seminar held in Lerwick, Shetland, 15th-16th October 1988: 38-49. Heubeck, M. (ed.). Shetland Bird Club, Lerwick.

Lloyd, C., Tasker, M.L. & Partridge, K. (1991). The Status of Seabirds in Britain and Ireland. T. & A.D. Poyser, London.

Monaghan, P., Uttley, J. & Burns, D. (1988). The relationship between reproductive effort and breeding success in Arctic Terns. In Seabird food and feeding ecology; Proceedings of the third international conference of the Seabird Group: 35-36. Tasker, M.L. (ed.).

Monaghan, P., Uttley, J.D., Burns, M.D., Thaine, C. & Blackwood, J. (1989). The relationship between food supply, reproductive effort and breeding success in Arctic Terns Sterna paradisaea. J. of Anim. Ecol. **58**: 261-274.

Montevecchi, W.A., Birt, V.L. & Cairns, D.K. (1988). Dietary Changes of Seabirds Associated with Local Fisheries Failures. Biological Oceanography **5**: 153-161.

Muus, B.J. & Dahlstrom, P. (1985). Collins Guide to the Sea Fishes of Britain and North-Western Europe. Collins, London.

Pearson, T.H. (1968). The feeding biology of seabird species on the Farne Islands, Northumberland. J. of Anim. Ecol. **37**: 521-552.

Ricklefs, R.E., Duffy, D.C. & Coulter, M. (1984). Weight gain of blue-footed booby chicks: an indicator of marine resources. Ornis Scand. **15**: 162-166.

Schreiber, R.W. & Schreiber, E.A. (1984). Central Pacific seabirds and the El Nino Southern Oscillation: 1982 to 1983 perspectives. Science **225**: 713-716.

Springer, A.M., Roseneau, D.G., Lloyd, D.S., McRoy, C.P. & Murphy, E.C. (1986). Seabird responses to fluctuating prey availability in the eastern Bering Sea. Marine Ecology Progress Series **32**: 1-12.

Springer, A.M., Roseneau, D.G., Murphy, E.C. & Springer, M.I. (1984). Environmental controls of marine food webs: Food habits of seabirds in the eastern Chukchi Sea. Canadian Journal of Fisheries and Aquatic Sciences **41**: 1202-1215.

Thompson, D.R., Hamer, K.C. & Furness, R.W. (1991). Mercury accumulation in Great Skuas Catharacta skua of known age and sex, and its effects upon breeding and survival. J. of Applied Ecology **28**: 672-684.

Vader, W., Barrett, R.T., Erikstad, K.E. & Strann, K.-B. (1990). Differential responses of common and thick-billed murres Uria spp. to a crash in the capelin stock in the southern Barents Sea. Studies in Avian Biology **14**: 175-180.

Vermeer, K. & Westrheim, S.J. (1984). Fish changes in diets of nestling rhinoceros auklets and their implications. In Marine Birds: Their Feeding Ecology and Commercial Fisheries Relationships: 96-105. Nettleship, D.N., Sanger, G.A. & Springer, P.F. (eds.). Canadian Wildlife Service, Ottawa.

Walsberg, G.E. (1983). Avian ecological energetics. In Avian Biology 7: 161-220. Farner, D.S., King, J.R. & Parkes, K.C. (eds.). Academic, New York.

Walsh, P.M. (1990). The use of seabirds as monitors of metal levels in oceans. In Heavy Metals in the Marine Environment: 183-204. Furness, R.W. & Rainbow, P.S. (eds.). CRC Press, Boca Raton, Florida.

Wanless, S. & Harris, M.P. (1989). Kittiwake attendance patterns during chick rearing on the Isle of May. Scottish Birds **15**: 156-161.

Webb, A., Harrison, N.M., Leaper, G.M., Steele, R.D., Tasker, M.L. & Pienkowski, M.W. (1990). Seabird distribution west of Britain. (Nature Conservancy Council). Final report of Phase 3 of the NCC Seabirds at Sea Project November 1986 - March 1990.