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THE BIOLOGY OF SEABIRDS UTILISING FISHERY WASTE IN SHETLAND

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ABSTRACT

The aim of this study was to examine the role of fishery waste in the ecology of scavenging seabirds in Shetland. Changes in the populations of these scavenging seabirds were discussed. Fulmars, Gannets and possibly Great Black-backed Gulls are still increasing but Herring and Lesser Black-backed Gulls and probably Great Skuas are decreasing.

The breeding performances of Herring Gulls, Great Skuas and Fulmars were studied on the Isle of Noss in 1983 and 1984. Great Skuas fledged fewer chicks than elsewhere but the breeding success of Herring Gulls and Fulmars was comparable to other areas. Chick condition of the three species did not differ significantly between years or from chicks of the same species measured elsewhere.

Seabird diet was examined on Noss from 1983 to 1985. Whitefish occurred most commonly in Herring Gull chick regurgitates while intertidal invertebrates were most important in adult food remains. Most Great Skua chick regurgitates contained whitefish. Whitefish and seabird were the commonest food types recorded in the diet of breeding and non-breeding Great Skuas and Sandeel was recorded more often early in the season. Whitefish (including offal) occurred more frequently than Sandeel in the regurgitates of Fulmar adults and chicks. Haddock, Whiting, Norway Pout and Sandeel were the commonest fish species to occur in pellets regurgitated by gulls and Great Skuas. Otolith lengths of Whiting and Haddock regurgitated by Great Skuas were smaller than the lengths regurgitated by Great Black-backed Gulls which, in turn, were smaller than those regurgitated by Herring Gulls.

Behind whitefish trawlers in Shetland, Fulmars occurred in highest numbers and Great Black-backed Gulls were next in importance. Fewer Great Skuas, Gannets, Herring and Lesser Black-backed Gulls were present. More birds attended trawlers far out to sea than close inshore.

About 27% of whitefish catches was discarded and about 90% of offal and 75% of discarded fish were consumed by seabirds. Trawler waste around Shetland could support approximately 200,000 seabirds. Haddock and Whiting were the two commonest discard species. Fulmars consumed most of the offal. Great Black-backed Gulls took most of the discards, but Gannets and Great Skuas also consumed many. Herring Gulls obtained little fishery waste at sea. Flatfish and gurnards were swallowed less often and gadoids more often than expected. Gannets and Great Black-backed Gulls swallowed most fish that they handled but the other bird species had a lower success rate. Fewer Haddock and Whiting than other fish species were dropped. Great Black-backed Gulls and Great Skuas stole more fish than other bird species. Great Black-backed Gulls and Gannets stole more fish than they lost to kleptoparasites but the other bird species had more fish stolen.

Haddock and Whiting swallowed by Great Skuas, Herring and Lesser Black-backed Gulls were smaller than the mean discard length. The proportion of fish dropped by seabirds increased with fish length. The lengths of dropped and stolen fish were longer than the mean lengths swallowed by each bird species. Larger birds swallowed larger fish. Handling times of fish increased with increasing fish length. Great Black-backed Gulls and Gannets swallowed fish more quickly than other birds.

Fulmars feeding on offal at a whitefish trawler in Shetland

Seabirds feeding on discards behind a whitefish trawler in Shetland

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.

Anne V. Hudson

CONTENTS

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SUMMARY

The aim of this study was to explore the role of waste from fishing boats in the ecology of scavenging seabirds in Shetland. In particular, I examined aspects of breeding ecology that might be sensitive to food availability and made direct observations of feeding behaviour and diets.

1. Changes in the populations of scavenging seabirds in Shetland are discussed. Numbers of Fulmars, Gannets and Great Skuas have increased enormously this century. Fulmars and Gannets are still increasing but numbers of Great Skuas are presently stable or perhaps declining. The breeding population of Great Black-backed Gulls has fluctuated but appears to be stable or slightly increasing, unlike the Herring Gull and Lesser Black-backed Gull, both currently declining .

2. The median laying dates of the first egg of Herring Gull clutches on Noss were 12 May 1983 and 11 May 1984. The mean egg volume index of Herring Gull eggs in 1983 was larger than the mean egg volume index in 1984.

3. The condition of chicks from different brood sizes did not differ statistically from each other. Herring Gull chick condition did not differ significantly between the three years 1983 to 1985. No clear-cut differences were evident between the weights of Herring Gull chicks in Shetland compared with chicks measured in Strathclyde.

4. Parental attendance at Herring Gull nest sites decreased during the season both in 1983 and in 1984, but adults spent marginally more time foraging in 1983 than in 1984.

5. The feed rates per brood, for 6 broods of Herring Gulls, varied during the seasons in 1983 and in 1984; overall they were marginally higher in 1984 than in 1983.

6. A minimum of 0.83 Herring Gull chicks per pair fledged in 1983 and a minimum of 0.66 chicks in 1984.

7. The median laying dates of Great Skua clutches on Noss were 19 May 1983 and 17 May 1984. No significant differences were evident between the mean egg volume indices of Great Skua eggs measured in 1983 and in 1984.

8. The condition of Great Skua chicks measured on Noss from 1983 to 1985 were similar, although the 1983 birds tended to be slightly heavier than the 1984 birds. The weights of Great Skua chicks measured on Foula from 1975 to 1984 were similar between years and did not differ significantly from the condition of the Noss birds.

9. The weights of Arctic Skua chicks measured on Foula from 1976 to 1983 did not differ greatly between years.

10. The conclusion to be drawn from the lack of differences in chick condition exhibited between years is that chick growth and condition are probably not sensitive measures of small-scale differences in food availability between years.

11. On Noss, 0.84 - 0.94 Great Skua chicks fledged per pair in 1983 and 0.73 - 0.99 in 1984.

12. The median laying dates of Fulmar eggs on Noss were 19 May 1983 and 18 May 1984. The mean egg volume indices of Fulmar eggs measured in 1983 and 1984 were similar.

13. The weights of inland and coastal Fulmar chicks in 1984 and 1985 on Noss were generally similar. Overall, Fulmar chicks in 1983 tended to weigh more than in 1984 or in 1985. Growth rates of Fulmar chicks measured on Foula and St. Kilda were similar to those of the Noss chicks.

14. Parental attendance of Fulmar adults at nest sites on Noss decreased during the season in 1983 and 1984.

15. The mean feed rate per Fulmar chick was lower in 1983 than in 1984.

16. In 1983, 85% of Fulmar chicks (that hatched) survived to fledge, but in 1984 the fledging rate was reduced to 66%. Losses were largely due to predation.

17. Fish, other than Sandeel, occurred in over 50% of all Herring Gull chick regurgitates from 1983 to 1985; Sandeel, terrestrial invertebrates and human waste food occurred less commonly. More Herring Gull chick regurgitates contained Sandeel in 1983 than in 1984 or 1985.

18. Intertidal invertebrates accounted for over 90% of the hard (non-pellet) food remains and the regurgitated pellets left by breeding Herring Gulls on Noss from 1983 to 1985. On mainland Shetland sites, whitefish was found more commonly in regurgitated pellets than on Noss. In 1984, more regurgitated pellets contained whitefish bones than in 1983 or 1985 on Noss.

19. Most Great Skua chick regurgitates contained whitefish with fewer composed of Sandeel and seabird remains.

20. On Noss, the recorded diet of breeding Great Skuas consisted mainly of whitefish and seabird from 1983 to 1985. In 1984, more whitefish and less seabird occurred in food remains than in 1983. In 1985, seabird was more common and whitefish less common than in 1983 or 1984.

21. Whitefish and seabirds accounted for the majority of food items recorded in pellets regurgitated by non-breeding Great Skuas on Noss from 1983 to 1985 and the proportions of each did not differ significantly between years. However, a higher proportion of Sandeel was recorded in

1985 than in 1983 and Sandeel was also much more common early in the season than later.

22. Whitefish (including offal) was more common than Sandeel in the food samples regurgitated by Fulmar chicks on Noss from 1983 to 1985.

23. Whitefish (including offal) occurred in most of the food samples regurgitated by adult Fulmars from 1983 to 1985 on Noss.

24. Rabbit, fish and bird were the three commonest food types in the diet of breeding Great Black-backed Gulls on Noss in 1985.

25. Haddock, Whiting, Norway Pout and Sandeel were the commonest species of fish (identified from otoliths) to occur in pellets regurgitated by gulls and Great Skuas on Noss from 1983 to 1985.

26. In Shetland, the otolith lengths of Whiting and Haddock regurgitated by Great Skuas were smaller than the lengths regurgitated by Great Black-backed Gulls; both species regurgitated smaller otoliths than did Herring Gulls.

27. Fulmars occurred in highest numbers behind whitefish trawlers in Shetland, with Great Black-backed Gulls next in importance. Fewer Great Skuas, Gannets, Herring and Lesser Black-backed Gulls were present.

28. More birds attended trawlers far out to sea than close inshore. The numbers of Herring Gulls present were higher very close to land (within two miles) than further out; the numbers of Fulmars decreased as the boats neared harbour.

29. Fewer birds attended sandeel boats than whitefish boats.

30. The weights of fish caught by whitefish boats on which I travelled are presented; on average, 27% of whitefish catches were discarded.

31. Approximately 90% of offal and 75% of discarded fish were estimated to be consumed by seabirds at sea.

32. The yearly landings of whitefish caught in Shetland waters by UK vessels were used to determine the amounts of offal and discarded fish available to scavenging seabirds. The total number of birds capable of being sustained by fishery waste in Shetland was calculated at about 200,000 birds per year.

33. Haddock and Whiting were the two commonest fish species to be discarded from whitefish trawlers in Shetland and measured, on average, 28-29cm in length.

34. Fulmars consumed most of the offal discarded. Most discarded fish were taken by Great Black-backed Gulls, but Gannets and Great Skuas also took many. Herring Gulls did not obtain much fishery waste at sea in Shetland.

35. Flatfish and gurnard were swallowed less often than expected by seabirds, whereas gadoids were taken more often. Large fish were not taken. Gannets took more gurnard than did any of the other bird species. Gannets and Great Black-backed Gulls swallowed over 70% of all fish they handled but the other bird species had a lower success rate. Fish dropped by one bird were often swallowed by another bird

36. More Cod, gurnard and flatfish than Whiting and Haddock were dropped. Different bird species dropped different fish species. Herring and Lesser Black-backed Gulls dropped relatively more fish than the other bird species.

37. Great Black-backed Gulls and Great Skuas stole relatively more fish than other bird species. Great Black-backed Gulls and Gannets stole more fish than they lost to other kleptoparasites but the other bird species had more fish stolen from them than they managed to steal.

38. The mean lengths of Haddock and Whiting swallowed by Gannets and of Haddock swallowed by Great Black-backed Gulls were longer than the mean lengths discarded. There was no difference between the mean length of Whiting swallowed by Great Black-backed Gulls and the mean length discarded. The other bird species swallowed Haddock and Whiting that were smaller than the mean lengths discarded.

39. The proportion of fish dropped by seabirds increased with increasing fish length and the mean fish lengths of fish dropped by seabirds were longer than the mean lengths swallowed by them.

40. The mean lengths of fish stolen from seabirds were generally longer than the mean lengths swallowed by them. The mean lengths of fish stolen by seabirds were generally similar to the mean lengths swallowed.

41. The maximum size of fish taken by seabirds was observed. Larger birds could take larger fish.

42. Handling times of fish increased with increasing fish length. Great Black-backed Gulls and Gannets swallowed fish more quickly than did Herring Gulls and Great Skuas.

43. Haddock took longer to swallow than did Whiting, owing to their wider girth.

44. Each bird species was more likely to steal fish from their own species rather than from other bird species.

45. Species best able to exploit discards and offal under present circumstances (Fulmars, Gannets and Great Black-backed Gulls) are increasing in numbers in Shetland. Species least successful in exploiting discards (Great Skuas, Herring Gulls, Lesser Black-backed Gulls and Kittiwakes) are decreasing in numbers. Nevertheless, I was unable to demonstrate convincing effects of discard availability on breeding success for any of these species and it is not clear that population trends reflect influences of discarding practice on seabird breeding biology, although exploitation of offal and discards is extensive and highly competitive.

CHAPTER 1

INTRODUCTION

During this century many seabird populations around the British Isles have increased very dramatically. This increase has been particularly marked in scavenging species such as the large gulls, the Fulmar *Fulmarus glacialis* (in northern areas in particular), the Gannet *Sula bassana* and the Great Skua *Catharacta skua* (in northernmost Britain) (Cramp *et al.*, 1974). Some people have attributed the expanding populations to decreased human persecution (e.g Coulson 1963, Potts 1969), whilst other workers suggest that the increase in waste foods disposed by man has been the primary cause, for example foods such as rubbish at dumps (Monaghan 1978, Sibly & McCleery 1983a) and fishery waste from whitefish trawlers (Fisher, 1952). Some workers argue that both the increased protection afforded to seabirds at their breeding sites and the provision of extra food in the form of fish offal and discarded fish at sea have allowed the expansion of certain seabird populations (e.g. Bourne, 1973). Other factors such as climatic or oceanographic changes, as suggested by Salomonsen (1965) and Brown (1970), may have helped to sustain the population increases, although it is unlikely that these alone could have produced such huge population expansions. It is probable that a combination of the above factors allowed the enormous increases in the numbers of some seabird species witnessed during this century. It has been suggested that we cannot correlate the increases of some gull species in Britain with an increased food supply but we may be seeing a time lapse during which they were adjusting their behaviour before exploiting man's waste (Harris, 1970). Certainly, gulls are now one of the most adept groups of seabirds at utilising waste foods today, whether on land or at sea. Sibly and McCleery (1983a) have even gone as far as to say that Herring Gulls *Larus argentatus* could not breed at Walney if they were deprived of refuse tips.

The decrease in human persecution of seabirds at the end of the last century coincided with an increase in waste discarded by humans, in places such as refuse tips, at sewage outlets and behind whitefish trawlers. Not only did human waste from trawlers increase, but the amount of whitefish caught by man increased, thus reducing the numbers of predatory fish available to feed on smaller fish such as Sandeel

Ammodytes marinus (Furness, 1984b). These smaller, non-commercial, fish species were then able to increase and they provided an alternative and increasing food supply for seabirds. The rates of increase of certain seabird species have been highest where the Sandeel is considered to be most abundant. For example, populations on Shetland that fed on Sandeels increased faster than the same species on St. Kilda where fishing pressures are lower and seabird diets more varied (Furness, 1984b). Only when industrial fisheries expanded in the 1960's, did competetion for this source of food between man and birds become a possibility. In many parts of the world, where pelagic fishing pressures have increased, seabirds have come under pressure (Furness & Ainley, 1984). Norway Pout *Trisopterus esmarkii* is another important food fish for larger whitefish (Muus & Dahlstrøm, 1974) and increased industrial fishing, particularly by Danes, may adversely affect the numbers of these predatory whitefish, thus reducing man's catches. In the last few years fisheries biologists have begun to consider ecosystem effects of fish stock exploitation rather than thinking in terms of each stock as an isolated entity. How seabirds, as natural predators of small fish, fit into this ecosystem model is rather uncertain. Clearly, overexploitation of food fish can cause breeding failure in seabirds and increases in fish stocks can allow seabirds to increase (Furness & Monaghan, 1987). However, the mechanisms by which seabird population sizes are regulated are unknown. Recent work suggests that food availability near breeding colonies during the breeding season can affect breeding success (Gaston *et al.*, 1983) and that breeding seabirds compete for food (Furness & Birkhead, 1984). However, no quantitative work has been done before this study to investigate food availability to scavenging seabirds or the extent to which these seabirds depend on trawler waste during the breeding season.

Whitefish are demersal, generally living on the bottom of the sea or just above it (Muus & Dahlstrøm, 1974). Although vertical migration is exhibited by some species of 0-group whitefish (Bailey, 1975), they nearly always remain in mid-water or near the bottom rather than in the upper layers. These small fish (0-group referring to fish in their first year) thus occur in water that is too deep for them to be available to scavenging seabirds. We know from studies of seabird diets that whitefish often form a major component of the diets of large species

(Harris 1965, Furness & Hislop 1981). As these fish in their natural environment are largely inaccessible to seabirds, being too deep in the water, they must be made available by some mechanism. The answer lies with commercial fishing vessels. Seabirds obtain whitefish either directly from the trawlers as they discard undersized fish at sea or else by stealing fish from market after they have been landed. Offal, consisting of the liver and guts of fish, is also commonly discarded at sea and provides an additional supply of food to seabirds which is much sought after, particularly by Fulmars in Shetland. Thus, in theory, we can estimate the quantity of food available to scavenging seabirds (in the form of discards and offal) from data on fish catches and discarding rates. This should allow scavenging seabird ecology to be set in the context of quantified food availability.

When whitefish are discarded from trawlers, they are usually dead or moribund. Survival rates of both round fish and flatfish are very low following landing on deck, mostly due to physiological and biochemical changes brought about by the stress and damage of capture. Damage is not only caused by the pressure exerted on fish as they are hauled from the depths to the sea surface but also from the physical damage from nets (Burton, 1984). Any fears that the predation of discarded whitefish by seabirds is having an adverse effect on whitefish populations, by depleting their stocks, are unfounded for the above reasons. Seabird predation did not have an impact upon the survival of any of the fish species discarded from trawlers off the Plymouth coast (Burton, 1984). These moribund and dead fish are thus providing a source of food that would otherwise be largely unavailable to seabirds.

Much work has been conducted on the feeding of gulls at rubbish tips (e.g. Kihlman & Larsson 1974, Monaghan 1978, 1980, Burger 1981), but little work has been done to quantify the amount of food consumed by seabirds behind trawlers. We know that large numbers of birds attend whitefish boats (e.g. Lockley & Marchant, 1951), which are said to have a "magnetic attraction" to seabirds such as Fulmars and gulls (Oliver, 1983). Over the continental shelf of Grays Harbour, Washington the higher abundance of many seabird species within 6km of fishing vessels was attributed to the attraction that the discards held for the birds (Wahl & Heinemann, 1979). Fishing south west of the Skelligs to south west of Scilly, Dare (1982) noticed that seabirds, other than auks and Manx Shearwaters *Puffinus puffinus* and Cory's Shearwaters *Calonectus diomedea* were attracted to fish and offal. In the North Sea, however, little evidence of association of seabirds with fishing vessels was observed during winter but in the pre-breeding season the distribution of birds became more northerly with large concentrations of seabirds in the vicinity of trawlers, especially around Shetland and Orkney (Blake *et al*, 1984). The fact that so many birds collect behind commercial fishing vessels suggests that large amounts of food must be available.

As outlined previously, the populations of scavenging seabirds have increased greatly around the British Isles, and around Shetland in particular, in recent years (Fisher 1952, Cramp *et al.* 1974, Berry & Johnston 1980). Sufficient food must be available to sustain these population increases and if populations begin to decline, one obvious question to be asked is whether the food supply has diminished. To answer this question, the diet of the birds involved must first be determined. Throughout this thesis, the breeding biology, diets and feeding ecology of seabirds that scavenge behind whitefish trawlers in Shetland and their relationships with the whitefish industry will be examined, although such seabird-fisheries relationships are complex and any one change can have a range of effects (Furness, 1982b). I then want to examine the role that discards and offal play in the breeding and feeding ecology of these scavenging seabirds and also to calculate the numbers of birds that could be sustained by fishery waste in Shetland.

In Chapter 2, I outline the status of the populations of breeding scavenging seabirds in Shetland to determine which species are increasing or decreasing in numbers. It may then prove possible to link changes in the breeding numbers with the availability of waste food.

In Chapter 3, the methods employed throughout the study are presented, beginning with fieldwork conducted on the Isle of Noss, where I examined the breeding biology of three scavenging seabird species, the Herring Gull, the Great Skua and the Fulmar, all of which bred in readily accessible sites on Noss. This work involved determining the breeding success of individual pairs, monitoring study sites to determine parental attendance at the nest and feed rates to chicks and also measuring the growth rate of chicks. The latter allows one to compare chick condition between years and to see whether this relates to food availability. Also described in this chapter are the methods used to collect data on the diet of the three species mentioned above on Noss; in addition, the diets of breeding Great Black-backed Gulls *Larus marinus* on Noss were examined. During 1985, diets of Herring Gulls, Lesser Black-backed Gulls *Larus fuscus* and Great Black-backed Gulls were looked at from sites in mainland Shetland. Diets of Great Black-backed Gulls and Great Skuas on Foula were also examined. Finally, I describe the work conducted from trawlers and the use of aerial surveys.

The next five chapters present the results obtained during the three summers 1983 to 1985 in Shetland. In Chapter 4, data on the breeding biology of the Herring Gull, Great Skua and Fulmar on Noss are presented. Following this are the results collected on the diets of these seabirds (Chapter 5). In Chapter 6, I present information on the species and sizes of fish consumed by Herring Gulls, Great Skuas and Great Black-backed Gulls on Noss, by gulls on mainland Shetland and by Great Skuas and Great Black-backed Gulls on Foula.

Chapters 7 amd 8 form the main core and most original part of the thesis and detail the results gathered from whitefish trawlers and from aerial observations. Data are presented on the amounts of food available at sea, in the form of discarded fish and offal (Chapter 7). Also included are data on the numbers and species of birds following whitefish trawlers, the type and amount of food consumed by each species and the patterns of exploitation of the food resources adopted by each species. The potential numbers of birds capable of being supported by fishery waste in Shetland are estimated. Chapter 8 illustrates the feeding interactions and success rates of birds at whitefish trawlers, both during the gutting and discarding process by the fishermen and during bouts of controlled discarding conducted by me.

Lastly, all the results are discussed in context with each other and with other published work. Conclusions are drawn about the effect of fisheries on seabird populations in Shetland and the possible effect that changes in fishery practices could have in the future. The mesh size of whitefish nets is to be increased throughout the North Sea in January 1987 from 80mm to 85mm and to 90mm three years later and effects of this change are considered.

All figures, tables and appendices have been placed at the back of the thesis and are separated by a coloured card.

Certain abbreviations of birds' names have been used throughout many of the tables:-

HGull = Herring Gull

GBbG = Great Black-backed Gull

LBbG = Lesser Black-backed Gull

BHG = Black-headed Gull

Also in tables, significance levels are sometimes quoted by an asterisk:-

* = $0.05 > p \geq 0.01$

** = $0.01 > p \geq 0.001$

*** = $p < 0.001$

NS = Not significant, $p \geq 0.05$

CHAPTER 2

CHANGES IN THE POPULATIONS OF SCAVENGING SEABIRDS IN SHETLAND

2.1 INTRODUCTION

During this century there have been large changes in the numbers of certain seabird species in Shetland. Before 1900 few Fulmars, Gannets or Great Skuas were to be found breeding anywhere in Shetland. Today, the Fulmar is one of the most numerous seabird species breeding there and birds may be seen along most stretches of Shetland coastline. The Gannet, on the other hand, is concentrated in a few large colonies. The Great Skua, nesting inland and away from the cliffs, has spread onto the majority of the islands. Gulls appear at cliff and inland sites throughout Shetland. In this chapter, I outline the status of breeding Fulmars, Gannets, Great Skuas and gulls in Shetland, drawing the information from various literature sources. All the figures supplied by the Seabird Colony Register for 1986 are provisional and where data from 1986 are not available, the most recent counts are used (Lloyd, *in litt.*).

2.2 FULMAR

Fulmars have been known to breed on St. Kilda, a group of islands situated over 30 miles west of the Outer Hebrides, for at least 800 to 900 years (Lockwood 1954, Fisher 1966). There are no positive, scientific records of them breeding there until the seventeenth century, when Martin Martin made a detailed account of the life-history and habits of Fulmars, following a visit to St. Kilda in 1697 (*in* Fisher, 1952). There is no indication that Fulmars were to be found elsewhere in Britain at this time (Fisher, 1952). St. Kilda supported large numbers of Fulmars, with the inhabitants of those islands relying heavily upon them as a source of food, harvesting the chicks shortly before they were due to fledge each year (Steel, 1965). This custom continued until the islands were evacuated in August 1929. The Fulmar population has increased since then, but at a fairly slow rate, rising from *ca.* 25,000 pairs in 1829-43 (Fisher, 1966) to 44,000 sites in 1977 (Harris & Murray, 1978). A different situation has been observed in Shetland.

In the mid-nineteenth century, Saxby said that the Fulmar never bred in Shetland and that to see it one must go offshore with the "haaf" (long line) fishermen (*in* Berry & Johnston, 1980). The situation remained like this until the late 1870's when Fulmars were first seen during the breeding season on Foula, the most westerly island of Shetland. It is possible that these birds were of Icelandic origin rather than originating from St. Kilda (Fisher, 1952). Fulmars were not proved to be breeding on Foula until 1878 when 12 pairs nested there (Raeburn, 1888). By 1897 Fulmars were breeding on Ramna Stacks and Hermaness and in 1898 they were first recorded breeding on the Noup of Noss (Godfrey, 1899). Since that time, Fulmars have increased rapidly, spreading not only all around Shetland but around most of the coastline of the British Isles. The increases in the Shetland populations have been well documented (Fisher, 1966) and are summarised below (Table 2.1); the difference between the 1959 and 1969/70 counts represents a 226% increase in population.

By 1978, the population of breeding Fulmars in Shetland was estimated to be greater than 150,000, representing 30-40% of the British total (Berry & Johnston, 1980), and the numbers have increased since then, with over 213,000 breeding pairs being recorded in 1986 (Seabird Colony Register, NCC). This figure is probably an underestimate as Fulmars on Foula have not been counted since 1978. The increase of the Fulmar has been universal in Shetland and has been monitored at some individual sites, where regular counts have been conducted over a number of years, for example on the Isle of Noss (Table 2.2).

Coastal sites on Noss may be nearing capacity occupance as in recent years there has been a movement to inland nesting sites, away from the more traditionally favoured coastal sites. In 1974, there were four inland nesting pairs of Fulmars on Noss and this figure increased to 14 pairs in 1976, 44 pairs in 1982 and 1983 (Willcox *et al.*, 1986) and 59 pairs in 1985 (McKay & Crossthwaite, 1985). On Foula, a spread to inland sites has occurred on a larger scale and now many hundreds of inland breeding Fulmars may be seen.

Other areas have seen similar, equally dramatic increases in their Fulmar populations. On Fair Isle the number of occupied sites increased from 5,000 in 1959 to 17,264 in 1969/70; on Hermaness from 5,880 in 1965 (Dott, 1967, which he acknowledges may include non-breeders as the counts took place in late June) to 9,463 in 1969/70; on Saxa Vord, Unst from 1,635 in 1965 to 3,211 in 1969/70 (Cramp *et al.*, 1974) and on Foula from 9,000 in 1959 (Jackson, 1959) to 10,500 in 1969 (Mawby, 1970) and to 38,555 in 1976 (Furness, 1981a).

2.3 GANNET

The Gannet has been present in Shetland waters for a very long time, with bones being found from the Bronze Age in middens at Jarlshof, an archaeological site near Sumburgh, to the south of mainland Shetland (Berry & Johnston, 1980). Proof of breeding was not established, but Gannets continued to provide a food source for a very long time. Only after widespread persecution of Gannets ceased at the beginning of this century did large breeding colonies become established in Shetland. Gannets first bred on the Isle of Noss in 1914 (MacPherson, 1933) and on Hermaness, Unst three years later (Cramp *et al.*, 1974). Both colonies increased in size rapidly (Table 2.3). In 1982, there were 4,863 nests on Noss (Dore & Willcox, 1982) and by 1984 there were 5,231 occupied nests (Dickson & Tyler, 1984) or 6,900 occupied sites (based on a land count, Wanless *et al.* 1986). The Hermaness breeding population had increased to 8,100 nests or 14,400 occupied sites by 1984/5 (Wanless *et al.*, 1986). By 1978 there were 30 breeding pairs in a more recently established colony on Fair Isle (Berry & Johnston, 1980) and this colony had increased in size to 138 nests by 1984/5 (Wanless *et al.*, 1986). A small breeding colony of Gannets has also become established recently on Foula, where the first breeding attempt occurred during 1980, although nests had been built in previous years (Furness, 1983a). In 1984/5 there were 210 occupied sites on Foula (Wanless *et al.*, 1986). The overall Shetland population has increased greatly since 1969, or the year of colonisation in recently established colonies, increasing at an average rate of 1.3% and 1.8% per annum on Noss and Hermaness respectively and at a rate of 41.6% and 61.7% on Fair Isle and Foula, the two new Shetland colonies (Wanless *et al.*, 1986). In 1986, there was a total of 15,603 Gannet nests in Shetland (Seabird Colony Register, NCC).

2.4 GREAT SKUA

Great Skuas were not recorded breeding in Shetland until the eighteenth century. In 1774, they bred at two sites, one at Saxavord in Unst where three pairs nested and the second site on Foula where six to seven pairs nested (Low, 1879). From then until the end of the nineteenth century, numbers of Great Skuas fluctuated, with alternating bouts of persecution and protection. The varying fortunes of these skuas during those early years have been well documented (e.g Furness, 1977) but suffice it to say here that since persecution of Great Skuas ceased at the end of the nineteenth century, the populations have increased enormously. During the 1880's, small numbers of Great Skuas nested only on Unst, Foula, Yell and the very north mainland of Shetland (Cramp *et al.*, 1974) but the Great Skua has expanded its range since then to occupy 22 islands in Shetland. The Foula colony expanded at an average rate of 7% per annum between 1900 and 1975, when approaching 3,000 pairs nested (Furness, 1977). The population on Foula has stabilised now and perhaps even declined slightly in recent years, as shown by population estimates for 1978 to 1980 of 2,950, 2,800 and 2,670 breeding pairs respectively (Furness, 1983a) and an estimate of 2,495 pairs in 1986 (Ewins *et al.*, 1986).

The Great Skua was first proven to breed on Noss in 1910 but, although one pair laid eggs in 1913 and 1914, the eggs were stolen (Perry, 1948). From the 1920's onwards, the population increased steadily at a rate of 3% per annum, reaching 113 breeding pairs in 1946 (Perry, 1948). More recently, the rate of increase has accelerated to 6% per annum (Willcox *et al.*, 1986) and by 1983, 388 pairs bred on Noss (Dore & Willcox, 1983). Some of these birds were immigrants from Foula, as shown by colour rings.

On Noss, the colony area occupied by Great Skuas has not expanded at the same rate at which the population has increased. Between 1946 and 1983, the breeding population increased from 113 to 388 pairs on Noss, whereas the colony area only expanded from 0.87km^2 to 1.6km^2 and the average nesting density rose from 130 to 242.5 nests per km^2. However, the nests are not evenly spaced, with many more nests being built, at a very high density, immediately around the club sites by young or inexperienced birds (Willcox *et al.*, 1983). It is doubtful whether there is sufficient room on Noss for the colony to continue expanding at that rate. During 1984 and 1985, no complete census was made of Great Skua numbers nesting on Noss, but the population appeared to have suffered a slight decline. By 1985, areas of the colony that had been densely populated during the previous year did not appear to have as many nests. One possible explanation is shooting, both on the Isle of Noss itself as part of a control programme (although only 10 pairs were shot), and also out at sea where an unknown number were reputedly shot by fishermen. Thus, the apparent stabilisation of the Noss population could be caused either by man or else be due to natural causes. Future counts may help to clarify the true situation.

The total count for all of Shetland in 1986 shows that, overall, numbers have stabilised since 1980 and, in fact, may now be on the decrease (Table 2.4).

2.5 GULLS

2.5.1 Introduction

From the above it can be seen that there have been substantial and fairly continuous increases in the breeding populations of Fulmars, Gannets and Great Skuas in Shetland since the end of the last century. The picture for the large gulls is not so straightforward.

There are few accurate counts of gulls in Shetland and the available information is fragmented and sometimes contradictory. Difficulties in censusing gulls may, in part, be to blame for the discrepancies noted between counts.

2.5.2 Lesser Black-backed Gull

The Lesser Black-backed Gull appears to have decreased in numbers throughout Shetland since the last century (Venables & Venables 1955, Berry & Johnston 1980), but the story is confused. Cramp *et al.* (1974) reported a small Shetland population of 520 to 570 pairs in 1969/70, whereas Berry and Johnston (1980), recorded 1000 breeding pairs in 1978, nearly twice the number thought to be breeding less than ten years previously. Counts conducted in 1973/74 (Harris, 1976) suggest a significantly larger breeding population than noted in the two works just mentioned, with 2,000 breeding pairs at Sumburgh alone. The latest figures available reveal a smaller breeding population, with only 567 pairs recorded in all of Shetland in 1986 (Seabird Colony Register, NCC).

Whatever the true total Shetland population, numbers have declined on the Isle of Noss. Whilst there were approximately 100 breeding pairs in 1946 (Perry, 1948), this figure decreased steadily until only one pair remained by 1983 (Willcox *et al.*, 1986). During 1984 and 1985, no Lesser Black-backed Gulls bred at all on Noss (pers. obs.). On Foula, very few breeding pairs have ever been recorded (Furness, 1983a). On Mousa, numbers have fluctuated between about 40 and 100 breeding pairs (Turner-Ettlinger 1964, Harris 1976) but are reasonably stable now, with about 100 pairs (Ewins, 1984).

2.5.3 Herring Gull

In 1978, Berry and Johnston (1980) called the Herring Gull the most numerous of the large gulls, numbering about 10,000 pairs in 1978, similar to the estimated population in 1969/70 of 10,150 breeding pairs (Cramp *et al.*, 1974). However, like the Lesser Black-backed Gulls, Herring Gulls appear to have suffered declines, especially in recent years and in some areas in particular. The 1986 total of 5336 breeding pairs (Seabird Colony Register, NCC) was nearly half that recorded in 1978, suggesting a pronounced recent decline in Herring Gull numbers.

The breeding populations of Herring Gulls on Noss have been fairly well documented. In 1774 they were first recorded nesting on Cradle Holm (Low, 1879). By 1887 there were more than 1,000 pairs, mostly on cliff ledges but some nested on the hill of Setter (Raeburn 1888, Evans & Buckley 1899). During this century numbers of breeding pairs have declined (Table 2.5). Although the 1983 figure of 175 clutches was higher than the 1982 value of 130 nests with eggs (and, indeed, the 1980 figure), this was probably due to a more complete census rather than an actual increase. A single count has been found to underestimate Herring and Lesser Black-backed Gull populations, unless made late in the season when all clutches are completed, but by which stage the earliest laid clutches have hatched (Wanless & Harris, 1984). During 1983, each nest containing eggs was recorded over a protracted period (from early May until late June) and the count included some replacement clutches (see Chap. 4). In 1984 and 1985, the numbers of nests recorded with eggs, over a similar period of time each year, had decreased considerably, with 128 in 1984 and only 89 in 1985 being recorded. By 1986, only 88 nests were found (Seabird Colony Register, NCC).

On Mousa too, Herring Gull numbers have declined during the last 20 years, from many hundreds in 1964 (Turner-Ettlinger, 1964) to about 50 to 60 pairs in 1983 and 1984 (Ewins, 1983 and 1984). On Foula, the Herring Gulls have followed a similar fate. Although no numbers are provided, it is known that they nested in 1890 and 1948; the highest number of nests was recorded in 1960 when 40 pairs bred. This figure decreased to 25 pairs by 1973, 21 by 1978 and only 3 by 1981 (Furness, 1983a), indicating a definite decline in numbers.

2.5.4 Great Black-backed Gull

On the Isle of Noss, Great Black-backed Gulls were first recorded on Cradle Holm in 1774 (Low, 1879) and numbers appear to have fluctuated between then and the end of the nineteenth century, with a minimum of 250 pairs being reported in 1887 (Raeburn, 1888), when Noss harboured the largest colony of breeding Great Black-backed Gulls in Shetland. This century has also seen a fluctuating population on Noss (Table 2.6). The majority of the Noss population is to be found on Cradle Holm, a stack to the east of Noss. This is a difficult area to census, which may account for some diferences in population estimates but the overall trend is downwards. The number of breeding pairs on the main island of Noss decreased from 14 to 11 to seven from 1983 to 1985 respectively.

On Mousa, the population has remained very low during the past 20 years, with no more than 10 breeding pairs, (Turner-Ettlinger 1964, Harris 1976, Ewins 1983 and 1984) and with no particular trend to increase or decrease. On Foula, the small breeding population continues to vary slightly between years, ranging from 15 pairs (1960) to 20 pairs (1978), but appears to be on the increase now as 48 breeding pairs were recorded in 1981 (Furness, 1983a). In 1974 many of the counts at Great Black-backed Gull colonies were significantly higher than the Seafarer counts in 1969/70, indicating a population increase, for example at Vaila and Papa Stour (Harris, 1976).

In 1978, the estimated Shetland breeding population of 2,500 pairs (Berry & Johnston, 1980) was considerably lower than the 1986 total, when 3361 breeding pairs were recorded (Seabird Colony Register, NCC). From the above examples of populations on Noss, Mousa and Foula, where both increases and decreases have been quoted, one may assume that the overall population is approximately stable or increasing slightly but with strong variations between sites. Counts are scant and erratic, partly because Great Black-backed Gulls tend to nest on stacks which are generally inaccessible to man.

2.6 DISCUSSION

The relaxation of human persecution (Cramp *et al.* 1974, Furness 1977) allowed the populations of Great Skuas and Gannets to expand at the turn of the century. Since then they have increased at an enormous rate, indicating that an abundant supply of food must have been available throughout the period. The even larger expansion of the Fulmar population must also have relied on a plentiful supply of food.

The apparent overall decrease in Lesser Black-backed Gull numbers has not been explained satisfactorily; some people attribute it to changes in fishing practices (Venables & Venables, 1955) whereas another theory is that the Lesser Black-backed Gulls were usurped by Great Skuas and Great Black-backed Gulls (Cramp *et al.*, 1974). A series of surveys, spanning several years, would be needed to ascertain the true status of Lesser Black-backed Gulls throughout Shetland and to determine whether numbers are still declining in Shetland as a whole. The Seabird Colony Register may fulfil this role.

No entirely satisfactory explanation has been found to explain the decrease in Herring Gull numbers either. Some theories suggest that the change in fishing practice is the cause, as for the Lesser Black-backed Gull (Venables & Venables, 1955). Others suggest that competition from other birds, in particular from Fulmars but also from Great Black-backed Gulls and Great Skuas, is to blame (Cramp *et al.*, 1974). Fulmars can take over the gulls' nesting sites as was observed to a certain extent on Noss from 1983 to 1985 and this point is discussed further in Chapter 4.

In summary, the populations of Fulmars, Gannets and Great Skuas in Shetland have increased greatly this century. Fulmars and Gannets continue to increase while Great Skua numbers are now levelling off (Table 2.4 & 2.7). The numbers of breeding gulls have fluctuated throughout the years but now the Lesser Black-backed Gulls and Herring Gulls are apparently on the decline, whereas Great Black-backed Gull numbers may be stable or slightly increasing.

Since there are very few data on the diets of scavenging seabirds in Shetland for the period before the mid-1970's, it is difficult to relate the population trends and changes in trends to diet and hence, by inference, to food availability. Later in this thesis I shall examine the diets and feeding ecology of these species and attempt to relate these to the population trends described above.

CHAPTER 3

METHODS

3.1 BREEDING BIOLOGY

3.1.1 General methods

During 1983 and 1984 aspects of the breeding biology of Herring Gulls, Great Skuas and Fulmars were studied on the Isle of Noss. Where possible, laying dates were determined by observation, or by subtracting the known incubation period from the observed hatching date. In some cases this was impossible, e.g. where eggs failed to hatch. The laying date of eggs of unknown age was determined from egg measurements (see 3.1.2.a); egg volume remains constant during the period of incubation but egg weight (and therefore egg density) decreases (e.g. Haycock & Threlfall 1975, Furness & Furness 1981, Wooler & Dunlop, 1980). Thus, one can calculate egg age from a curve of decreasing egg density. For each of the three species, Herring Gull, Great Skua and Fulmar, an index of egg density (D) was calculated using the equation;

$$D = W/V$$

where $V = L \times B^2$

and V = index of egg volume

L = egg length cm

B = egg breadth cm

W = egg weight g

An index of egg density was being calculated solely to allow comparison between years on Noss during this study. Therefore, the introduction of a constant was considered unecessary, unlike other workers who have calculated actual egg density (e.g. Coulson 1963, Furness 1977).

I attempted to obtain indices that might be useful as measures of the ease with which birds were able to obtain food. Egg size was compared between years for each of the three species mentioned above. Egg size, represented by the egg volume index, may give an indication of general food availability (Hogstedt, 1981) and of bird condition (Lloyd, 1979). Egg size also decreases with laying date (e.g Coulson *et al.* 1969, Maunder & Threlfall 1972, Lloyd 1979) and throughout the season in the Herring Gull (Parsons, 1971), but analysis of the Noss data to show these trends was considered outside the scope of this study. Laying date, in its turn, is influenced by food availability (Perrins 1970, Perrins & Birkhead 1983). Thus, the value of egg size in this study was that differences in egg size between years may show us that the females are finding it difficult to obtain sufficient food to produce good quality eggs. Alternatively, differences may be due to a shift in the age composition of the breeding birds. Young birds have been shown to produce smaller eggs, not only in *Larus* gulls (Coulson & Thomas, 1978), but also in many other seabird species (e.g. Kittiwake *Rissa tridactyla* (Coulson 1963, Thomas 1983), Shag *Phalacrorax aristotelis* (Coulson *et al.*, 1969), Razorbill *Alca torda* (Lloyd, 1979)). However, Davis (1975a), found that egg volume increased with the age of the breeding Herring Gulls up to seven or eight years and then decreased among older birds.

A measure of chick condition was obtained by weighing chicks on a regular basis and measuring their wing length. Since seabird chicks continue to grow in terms of wing length and other body dimensions, whether they are well or poorly fed, and only show reduced growth rates when extremely undernourished (LeCroy & Collins 1972, Furness 1978a, Mineau et al. 1982), the weight of a chick in relation to its wing length might be of use as a measure of how well nourished the chick is. Thus I wanted to test the idea that weight gives an indication of chick condition while the wing length gives an estimate of chick age. Growth was illustrated by plotting mean weight against size classes of wing length. For wing lengths of less than 80mm, 10mm size classes were used, whereas equal to and above this value 20mm size classes were used.

I recorded egg and chick losses (where possible), hatching success and fledging success in each of the three species so that values for overall breeding success could be obtained, since breeding success might also reflect food availability.

Finally, parental attendance at nest sites and the number of feeds per chick were recorded for Herring Gulls and Fulmars since these also should be influenced by food availability.

During 1985, Noss was visited once a week to collect chick measurements. No individual nest outcomes were recorded in that year.

3.1.2 Herring Gull

3.1.2.a 1983

In 1983, 154 nests were marked and the eggs individually numbered in May and June (replacement clutches were included). The eggs were weighed to the nearest 0.1g using a Pesola spring balance and their length and breadth were measured to the nearest 0.1mm using Vernier calipers. Another 21 nests were recorded elsewhere on the island but these were accessible only by boat and so they were not studied further.

Around the time of hatching, the nests were visited every two days and the hatching success was noted for each nest site. Newly hatched chicks were marked individually by stapling a numbered tag, using Dymo tape, on the tarsus. The Dymo tag was replaced by a BTO metal ring when the chicks were 7 -10 days old. Thus, small chicks that had wandered from their nests could always be individually identified.

Every second day the wing lengths and weights of a sample of at least 30 chicks were measured, so that a growth curve could be constructed for chicks from recently hatched to fledging individuals. The sample of chicks measured consisted of different individuals depending on my success in locating chicks, so that most chicks were measured on several occasions, but some chicks were found more often than others. The numbers of chicks fledging from each nest site were recorded, where known, so that an average fledging rate could be calculated.

Parental attendance of six pairs of Herring Gulls at their nest sites was recorded at Papil Geo (Fig. 3.1), where observations could be conducted above the geo without disturbance to the gulls. Eight watches, covering 51 hours, were conducted during the nestling and fledgling period. The number of parent birds at each nest site was recorded every 15 minutes and any parental change-overs were noted. If a bird was absent at one 15 minute interval (when nest attendance was scored) and present at the next one, it was recorded as being absent for 15 minutes. Any bird that departed and returned within one 15 minute interval was not included. The numbers and timings of all feeds were recorded so that the number of feeds per brood per hour could be calculated.

3.1.2.b 1984

The same methods that were used in 1983 were adopted in 1984, with a few minor alterations.

In all, 113 nests were studied through the season, out of a total of 128 Herring Gull nests containing eggs recorded on the island, and data on the breeding success of these gulls and on the chick growth rates were collected as in 1983.

Parental attendance and brood feed rates were examined in the same manner as during the previous year, but in addition one adult from each nest in Papil Geo was individually dyed with either rhodamine red or picric acid (yellow) or a combination of both. Thus, mates from each nest could be distinguished. Although females are generally smaller than males (Haycock & Threlfall 1975, Cramp & Simmons 1983), the difference in size between some of the birds was not easily distinguishable in the field, so dyeing the birds facilitated individual identification. Sponges that had been soaked in dye were placed on the nests of incubating birds and when one of the parents returned to the nest the dye was taken up on the breast feathers. This facilitated positive identification at each nest site. Nine observation periods, totalling 44 hours, were conducted during the nestling and fledgling period.

3.1.2.c 1985

In May and early June, nests were counted and clutch size noted. During June and July, chicks were weighed and their wing length measured to determine the growth rate for that year. Thus, the overall chick condition could be compared with chicks from the previous two years.

Chicks were also measured and weighed from other sites in Shetland for comparison - Seligeo (in Bressay), Dale's Voe (north of Lerwick), Sandwick and Clettnadal (both in West Burra) (Fig. 3.2). From here on, these sites shall be referred to collectively as mainland Shetland sites, even though Seligeo is on the island of Bressay.

3.1.3 Great Skua

3.1.3.a 1983

To study breeding success and chick growth rates for Great Skuas, a similar approach was adopted as used for the Herring Gulls.

Fifty nests were marked and the eggs numbered, weighed and measured. Hatching success was recorded. As the chicks hatched they were individually marked with a numbered Dymo tag on their tarsus, this being replaced by a BTO metal ring after about 8-10 days. Every second day, a sample of at least 30 chicks was weighed and the wing lengths measured. Fledging success for each nest site was noted where known.

3.1.3.b 1984

The study area was increased to include 70 nests. Apart from this, the same methods were followed as in 1983.

3.1.3.c 1985

No individual nesting outcomes were studied. Instead, as for the Herring Gulls, a sample of chicks was weighed and the wing lengths measured once a week.

3.1.4 Fulmar

3.1.4.a 1983

Along the south west coast of Noss (between y and y, Fig. 3.1), 81 sites were marked and the eggs were weighed and their length and breadth measured. Near hatching time, the nests were visited every second day to determine the date of hatching for each chick. The weight and wing length of 30 chicks were measured every four days. Fulmars have a relatively long nestling period of about 46 days (range 41-57, Fisher 1952) to about 53 days (range 49-58, Mougin 1967), so there was no need to weigh the chicks more frequently as the weight of the feeds would vary more than the average increase in weight over a shorter period of time. Also, Fulmars are susceptible to disturbance (e.g Carrick & Dunnet 1954, Ollason & Dunnet 1980) and, in addition, they are very inclined to regurgitate their food, so I wanted to avoid measuring any one chick too often. Taking measurements had to cease before the chicks were ready to fledge because the chicks regurgitated oil; large amounts of oil would foul the feathers of the chicks and result in the loss of the waterproofing quality of their plumage.

Fledging success was recorded for each study nest. Parental attendance at nest sites and the number of feeds per chick were studied at Papil Geo east (Fig. 3.1). Observations were conducted on seven occasions and covered a total of 108.5 hours. From 18.07.83 to 20.07.83 a continuous 48 hour observation was conducted, with the assistance of Miss Naomi Duxfield. For each observation period, the number of parent birds present at each nest site was recorded at 30 minute intervals and change-overs between parents were noted. The duration of foraging trips was determined by recording the departure and arrival times of the birds. When both birds were absent for much of the time this was possible only if a pair that had been dye-marked yellow was involved. Otherwise, it was not necessarily true that a bird that left earliest returned first, as demonstrated by pairs that had been dye-marked. As for the Herring Gulls, the presence or absence of a bird at each time interval gave its departure/arrival time. However, for Fulmars, half hour intervals were used, rather than 15 minutes, and any bird that departed and returned within one half hour interval was not recorded. Any bird that had been absent for a long time and then returned and departed again within one half hour interval was recorded as arriving and departing within the half hour. Many birds did not return within an observation period and so the trip duration (and potential foraging range) could not be determined.

Seven adults were dyed yellow with picric acid. The method employed was to go down the cliff on a climbing rope (and here I gratefully acknowledge the help of the two Noss wardens) and to spray the birds using a garden hand sprayer. Only one adult from a nest was dyed, so that each bird of the pair could be distinguished, one being white and one being yellow. However, two of these nests were subsequently deserted, possibly as a consequence of my disturbance, but perhaps due to natural causes. Nest losses are quite high near the time of hatching (Mougin 1967, Ollason & Dunnet 1980), at which stage these birds were marked. Of the five remaining nests with a yellow adult, only one pair reared a chick beyond a couple of weeks old, the chicks from the other sites being preyed upon, almost certainly by cats. Owing to this high chick mortality, a further area of cliff was observed which included unmarked birds. The disadvantage now incurred was that parental change-overs at the nest site during the hours of darkness were undetectable. Notwithstanding this problem, however, long observation watches were conducted to obtain as much information as possible with regard to parental attendance and chick feeding rates.

3.1.4.b 1984

In 1984, 83 nests were studied on Noss along the south west coast (between y and y) and along North Croo on the north coast (between z and z, Fig. 3.1). Data on nest outcomes and chick growth were collected as in 1983.

At Papil Geo three observation watches, covering a total of 48.5 hours, were conducted to determine parental attendance at nest sites and the number of feeds per chick. One adult from each of 10 nests was dyed yellow with picric acid to facilitate the recording of change-overs between adults at the nest sites. Owing to the prevailing windy conditions at the time, the Fulmars could not be sprayed with the dye. Accordingly, climbing ropes were used to go down the cliff, again with the help of the Noss wardens, and the adult Fulmars were then hooked off their nests and placed in a bag that had been lowered down on a string to the climber. The cliff-top worker hoisted up the bag and painted the bird with picric acid before releasing it.

3.1.4.c 1985

As for the Herring Gulls and Great Skuas, no data on individual nest outcomes were gathered. Chick condition was measured as in 1983 and 1984.

3.2 DIETS

3.2.1 General methods

For the three species, Herring Gull, Great Skua and Fulmar, food samples were collected from Noss to determine the diet of these scavenging seabirds during the breeding season. From 1983 to 1985 diet was observed directly, by identifying regurgitates from chicks and from Fulmar adults, and indirectly by examining regurgitated pellets and hard food remains found in the breeding territories or loafing areas of Great Skuas and gulls. Food samples from adult Great Black-backed Gulls on Noss were also examined during the three years 1983 to 1985 and from Herring Gulls and Great Black-backed Gulls on Bressay and mainland Shetland during 1985. The diets of Great Black-backed Gulls and Great Skuas on Foula were also examined. In addition, the composition of fish species consumed was determined by collecting otoliths (fish ear bones) in pellets regurgitated by gulls and Great Skuas, both on Noss and at other Shetland sites (see 3.3).

3.2.2 Herring Gull

Information on the diet of adult Herring Gulls on Noss was gathered by visiting two areas, Mansie's Berg west and Turr Ness (Fig. 3.1). During 1983 and 1984 visits were made every second day and all food remains and pellets were removed. Thus, any food remains collected on subsequent visits were known to be new. The pellets represent the hard, indigestible parts of food which are regurgitated by the adults and they contain individually recognisable food types. Any soft foods, such as fish offal and some human waste foods (for example bread), will not be recorded by this method. However, the method is directly comparable between years. Food identified in pellets regurgitated by the adults was analysed separately from hard food remains (prey remains not ingested) found around the nesting areas. Where crabs occurred, both on Noss and at Shetland mainland sites, the numbers consumed were estimated from the numbers of legs or carapaces.

Chick diet was studied by collecting food regurgitated by some of the chicks when they were handled. These samples contain soft parts of food and so are not directly comparable to the information obtained by analysis of the pellets produced by adults.

During 1985, dietary information on Herring Gulls was gathered from Noss once weekly and from mainland sites on Shetland (as in section 3.1.2.c) whenever they were visited.

3.2.3 Great Skua

Information on the diets of both breeding and non-breeding Great Skuas was collected and a small amount of data on chick diets was obtained from chick regurgitates. During 1983 and 1984 the two club sites on Noss (Setter and Maidens Paps, Fig. 3.1) were visited every four to six days and, in 1985, once a week, and all food remains and pellets were removed. Club sites represent collecting areas for non-breeding skuas (Perry 1948, Furness 1977) and they are clearly distinguishable, generally being composed of short, green grass which stands out amongst the surrounding taller vegetation of grasses, sedges and heather. Food remains and pellets found in nesting territories were collected, giving an indication of the diet of breeding adults.

Chicks rarely regurgitated when handled but when they did, the food type was noted.

3.2.4 Fulmar

Both adults and chicks regurgitate readily when handled; sometimes only oil is discharged but frequently the birds regurgitate food as well, allowing their diet to be studied (Furness & Todd, 1984). Regurgitates were identified on the spot where possible, but if the food types were not easily recognisable, the samples were collected, preserved in alcohol and identified later in the laboratory.

3.2.5 Great Black-backed Gull

On Noss, food samples and regurgitated pellets were collected from breeding territories of Great Black-backed Gulls and also from an area adjacent to Cradle Holm, a stack to the south east of Noss (Fig. 3.1) where Great Black-backed Gulls sometimes regurgitated pellets. Casual observations indicated that this area was not frequented by Herring Gulls or Great Skuas so that all remains and pellets were attributable to Great Black-backed Gulls.

3.3 OTOLITH IDENTIFICATION

When fish bones are regurgitated by seabirds, the individual fish species may be recognised from the saccular otoliths (earbones) which are species specific. Fish were collected from the "Leander", departing from Millport Marine Station on the Isle of Cumbrae, taken to the laboratory, measured and their otoliths were removed and measured. The otoliths were retained to build up an identification key for each species. In addition, several otoliths from each mm length class were embedded in plasticine, similar to the method of embedding *Gammarus pseudolimnaeus* in clear plasticine blocks (Waters & Hokenstrøm, 1980), to facilitate quick identification and measurement of otoliths collected in the field. Where otoliths were broken, their width was measured against whole otoliths in the reference key. Otolith length is proportional to fish length (e.g Furness & Hislop 1981, M. Jobling & A. Breiby unpubl.) and regressions of fish length against otolith length already exist for some species (Furness & Hislop, 1981 for Haddock *Melanogrammus aegelfinus*, Whiting *Merlangus merlangus*, Norway Pout and Sandeel, see App. IV), so that the lengths of fish consumed, in addition to the species, could be determined. Where no such correlations were available, regressions of fish length on otolith length were calculated.

This method of assessing fish species consumed is not being used in a quantitative manner to measure the birds' entire diet. The presence of otoliths does not provide information on the relative importance of fish in the bird' diets, nor does it necessarily measure the percentage of each species of fish actually consumed, as differential erosion of otoliths is known to occur in the stomachs of some fish predators (M. Jobling & A. Breiby, unpubl.). However, otoliths obtained in this study showed very little, if any, erosion and I consider that they do represent the fish component of the diet accurately.

Otoliths were collected from pellets regurgitated by breeding Herring Gulls on Noss from 1983 to 1985 and on mainland Shetland sites in 1985 (as specified in section 3.1.2.c). They were identified and measured to give an indication of the species and sizes of fish being consumed. The same procedure was followed for otoliths collected from breeding territories and non-breeding club sites of Great Skuas on Noss from 1983 to 1985. Otoliths were also collected from club sites and from breeding territories of Great Skuas on Foula, by myself during May 1983 and July 1985 and by other workers in June/July 1983 and 1984. Otoliths that had been gathered previously from Great Skua club sites and breeding territiories on Foula by R.W. Furness, in 1975 and from 1980 to 1983, were identified and measured. Otoliths that had been regurgitated by breeding Great Black-backed Gulls on Noss from 1983 - 1985 were also identified and measured. Fish pellets regurgitated by Great Black-backed Gulls were also collected from Strem Ness, a loafing site on Foula and the fish species and size were determined from the otoliths. In addition, otoliths were collected from five other areas throughout Shetland in 1985, namely Papa Stour (breeding area and non-breeding site), Virda Vatn roost site in West Burra, Sandwick Loch roost site also in West Burra, and West Beosetter roost site in Bressay. These sites shall be collectively called mainland Shetland, even though Papa Stour and Bressay are islands. In 1980, otoliths were also collected from a breeding colony of Lesser Black-backed Gulls and Herring Gulls and these were identified.

3.4 OBSERVATIONS AT SEA

3.4.1 Introduction

To assess the importance of fishery waste for seabirds it is possible to examine the numbers of scavenging seabirds attending whitefish trawlers and to determine the quantities of fish available to these birds. In addition, the ability of different birds to obtain food can be compared and species interactions examined. The methods used to determine the above will be outlined in turn.

3.4.2 Bird numbers at trawlers: trawler observations

3.4.2.a General methods

Birds were counted at regular intervals, from when the net first began to be hauled to the time when all gutting and discarding had ceased and the boat had been hosed down. Maximum counts of each bird species were recorded for every haul and the mean maximum number of birds of each species present for all the hauls per trip was calculated from these data. Counts of small numbers of birds (less than 100) were to the nearest five and were usually accurate; during bouts of no discarding, when fewer birds attended the boats, I estimated the size of small flocks of birds and then counted them individually to assess the accuracy of my estimates. I carried out this procedure throughout the duration of the project to keep a check on my counting. My estimates were correct to within five birds for flocks of less than 100 birds on nearly all occasions. The numbers of birds in larger flocks were estimated by counting in blocks of 10-50 birds, for flocks of up to approximately 500 birds and in blocks of 100 birds for flocks of about 500 birds and more. The counts were accurate to within 50 birds for flocks up to about 1000 birds and larger flocks were estimated to the nearest 100 birds.

Percentages of adults were recorded, where these could be distinguished, that is for gulls and Gannets. For Great Skuas and Fulmars, age could not be determined.

3.4.2.b 1984

During July and August in 1984, observations were conducted from whitefish trawlers around Shetland to count the numbers of seabirds feeding on discarded fish and offal. Information was collected from 23 hauls on four separate fishing trips on whitefish boats. Three trips were on the "Orion" from Hamnavoe on the west coast of Shetland, fishing approximately five to ten miles from the shore, and one on the "Athena" from Symbister, Whalsay on the east coast (Fig. 3.2), fishing about 20 miles east of Unst for two hauls and about 10 miles west of Muckle Flugga for the third haul. In addition, seven hauls from one trip on a sandeel boat, the "Franchise" from Lerwick, and one haul from a herring boat, the "Adenia", a Whalsay boat departing from Lerwick, provided contrasting data on bird numbers associated with sandeel and herring boats. The sandeel boat fished within a few miles of the east coast, between Noss and Sumburgh Head to the south, whereas the herring boat hauled between Fair Isle and Orkney. Thus, the different areas being fished must be taken into account. Additional information regarding bird numbers surrounding sandeel boats was collected on 13 occasions just south of Noss either from Noss or in a Zodiac inflatable in the water. From a distance, gull species and, on three occasions, Fulmars and gulls, could not be distinguished and thus numbers present were referred to either as gulls or as Fulmar/gulls.

3.4.2.c 1985

Observations on the numbers of seabirds behind whitefish trawlers were conducted from March to October 1985 in Shetland. Most trips were made on westside trawlers, the "Orion", "Dauntless", "Unison", "Venture", "Sunshine" and "Alis Wood", all departing from Hamnavoe or Scalloway (Fig. 3.2) and there was one trip on an eastside boat, the "Starina", leaving from Symbister in Whalsay. In all, 23 trips covering approximately 33 days were made, during which data from 151 hauls were collected.

Most of the fishing from the west coast was conducted approximately 10 miles (± 5 miles) from the southwest coast of Shetland in the Burra Haaf and west of Scousburgh and Fitful Head, to the south of Shetland. However, the Alis Wood tended to fish further north, off Papa Stour and the Ve Skerries (rocks just west of Papa Stour) and as far north as Eshaness and North Roe where trawling was generally within 10 miles of the coast. Some fishing trips were also conducted nearer Foula, thus up to 20 miles from mainland Shetland.

3.4.3 Bird numbers at trawlers: aerial observations

3.4.3.a General methods

The Shetland Islands Council (SIC) runs a pollution control service in connection with the Sullom Voe oil terminal and operates from Scatsta (Fig. 3.2). Each week-day, twice daily, an Islander aeroplane patrols Shetland waters, checking that oil tankers do not release oil on their way to or from Sullom Voe.

Trawlers are also to be found fishing in the areas patrolled by the pollution aeroplane, although fishing boats must keep away from the tanker lanes leading directly to and from the terminal. It was realised that aerial surveys of fishing boats would provide information about birds feeding behind a number of boats at any one time and on the general distribution of trawlers in Shetland waters. Whereas work from a trawler gives detailed information on feeding habits and interactions between bird species, it does not allow one to determine the number of birds feeding behind other fishing boats in the area, except when two boats pass very close to each other. Observations from the air permit one to count birds behind groups of trawlers and thus to estimate the average number of birds expected to be in attendance with each trawler fishing.

On some occasions, the boats were passed over very quickly so that accurate assessment of the species composition of the bird flocks was not possible. For this reason, birds were classed as unidentified. On other occasions, boats were passed at a great distance, so that it was not possible to see whether only a few birds were present; large flocks were visible from far away. Therefore, the numbers quoted are a minimum estimate of birds present in association with whitefish trawlers around Shetland at any one moment.

3.4.3.b 1984

During August and September 1984, three flights were made, with an overall duration of about four and a half hours, although no fishing boats were observed on one occasion. On each flight the numbers of whitefish boats and the birds behind them were counted. Small flocks of birds were counted accurately. Larger flock sizes were estimated, similar to the method employed from the stern of a trawler. The activity of each boat was noted, where visible, whether it was hauling, towing or steaming and whether gutting or discarding was occurring.

Many of the observations were conducted within 10 miles of the west coast of Shetland and all within 20 - 25 miles of land (Appendix V); the flights covered waters surrounding all Shetland.

3.4.3.c 1985

During 1985, aerial observations were conducted from March until October, so that any seasonal changes in bird numbers and species could be determined. In all, I participated in 18 flights, covering a period of approximately 22 hours. Most of the flights during 1985 were made to the northwest of Shetland, but some along the west and east coasts were also conducted (details in Appendix V). Many observations were 30 or more miles from the Shetland coast, passing over waters fished by large foreign vessels.

The trips conducted in March were during the pre-breeding season and the October trip was outside the breeding season. By March no nest building or clutch initiation had begun and birds such as the Great Skua had not even returned to Shetland from their winter in the south. By October all young had fledged, including Fulmars which have a protracted breeding season, and the migratory species such as the Great Skua were on their journey south again. The intervening months were divided into the breeding season (April until July) and the post-breeding season (August and September).

3.4.4. Quantities of fish caught and amounts discarded

The fishing methods employed by the trawlers were seine netting and light trawling and the boats were, on average, 60' - 80' in length. The seine netters tended to tow for about one to one and a half hours (allowing for up to seven hauls per day) and the trawlers for two to five hours, depending on size. Two hours was an average trawling time for a small trawler such as the "Alis Wood". The time to haul varied from about 10 minutes for seine nets to up to 20 minutes for light trawl nets. Gutting times varied, obviously, according to the catch size.

For each haul, the size of the overall catch landed on board was estimated according to the level of fish in each pond and the proportions discarded and the amounts kept for market were recorded. Decks are divided into ponds and by noting how many ponds were full and the capacity of the ponds when full, the total catch could be estimated reasonably accurately. In addition, a crew member gave his estimate; this was particularly helpful when on a new boat. For each trip, the haul estimates were summed to give a total amount of fish caught. For each haul, the proportion of the catch being discarded at sea (whether the fish were too small for market or of an unmarketable species) was estimated. The total haul estimates and total discard estimates were recorded and compared against the market landings at the end of each trip and were generally within one or two boxes of each other for small landings, indicating the accuracy of the method. For larger landings, the totals were generally in close agreement with each other, but where a larger difference existed (up to five boxes out), the discard rate was adjusted accordingly, as this is where the errors could most easily occur.

During daylight hours the proportions of discards consumed were estimated. This was not so easily done during the hours of darkness, when estimates depended on the flock size and species composition as well as noting the amount of waste being discarded. This method is thought to have given a fairly good indication of discard consumption rates, but would only be accurate to within about 10-15%. The amounts and type of food (offal or discard fish) consumed by each species was noted.

Samples of the discarded fish were kept aside and measured, to indicate the species composition and size of fish available for consumption by the seabirds. Fish being discarded by fishermen were collected and identified. On a couple of occasions, Haddock and Whiting were selected out by the fishermen but, apart from this, the selection of discards was random. Many of these fish were thrown over singly and their species and length, in cm, were noted (Appendix VI). Thus, fish sizes discarded could then be compared with the fish sizes consumed by seabirds. The consumer species and handling time was recorded. Handling time was the time, in seconds to the nearest 0.5 s, taken for the seabird to swallow or drop the fish from when the bird first picked it up, similar to the method employed by Riegner (1982) when studying prey-handling by Yellow-crowned Night Herons *Nyctanassa violacea*. Interactions between the seabirds themselves were also recorded. Such interactions included both fights and kleptoparasitism, the stealing of a fish by one seabird from another; also the birds often dropped fish. The maximum size of fish that each bird species could handle was determined for the two principal whitefish species, Haddock and Whiting, being discarded in Shetland waters and for other fish species where feasible. Thus, it was possible to build up a picture of food preferences for each species of bird and of the range in fish size that the different birds could actually handle.

CHAPTER 4

BREEDING BIOLOGY OF SCAVENGING SEABIRDS ON THE ISLE OF NOSS

4.1 INTRODUCTION

The breeding success of birds is often a reflection of prevailing environmental conditions; for example, food availability is an important ultimate factor determining timing and success of breeding (Perrins and Birkhead, 1983). Also, the breeding birds in decreasing populations often experience lower reproductive success than those in increasing populations (Harris, 1970) as a result of the environmental stresses to which they are subjected. In the present study, the breeding biology of scavenging seabirds on Noss was examined to determine whether success rates varied between years (when food availability might differ) and for species of known population status such as the Herring Gull, which declined in numbers on Noss during the three years of study. Thus, one might predict that both breeding success and chick growth rate would differ between years as a reflection of varying food availability and also that the Herring Gull might breed relatively less successfully than the Great Skua and Fulmar as its population is currently decreasing on Noss.

During 1983 and 1984, the breeding success (number of chicks hatching and fledging per nest) was measured for a sample of the Herring Gulls, Great Skuas and Fulmars breeding on Noss, following the methods outlined in Chapter 3.

From 1983 to 1985 the growth rates of chicks of each of the three species were measured in order to assess whether any differences in chick condition between years could be detected and to compare with data collected at Foula, primarily for Great Skuas, over a series of recent years. Again, methods are presented in Chapter 3.

In this chapter I shall outline the aspects of breeding biology that might be used to monitor the effects of food availability on seabird breeding biology and consider their value in this regard. Thus, this section is intended to assess the variations in breeding statistics and their sensitivity to food availability.

4.2 HERRING GULL

4.2.1 Timing of laying

Egg measurements (see 3.1.2.a) were used to determine the age of eggs of unknown laying date so that the timing of laying of the first egg in each clutch could be calculated. The index of egg density was plotted against days of incubation (Fig. 4.1) for eggs of known laying date from 1983 and 1984. For these, laying date was either observed directly or calculated from the known or estimated hatching date (see section 4.2.3). This assumes the incubation period for the first egg in a Herring Gull clutch is on average 29 days (Parsons 1972, Cramp & Simmons 1983).

For eggs that did not hatch the number of days for which the eggs had been incubated before being weighed and measured could be calculated from the equation

$$y = -196.32.x + 111.86$$

where y = days of incubation

x = index of egg density

The standard deviation about the regression was 3.05 days.

Median laying dates upon which Herring Gull clutches were started did not differ significantly between 1983 and 1984 (Fig. 4.2). The mean laying date for the first egg in all clutches laid in 1983 was 13 - 14 May. Bad weather in late May resulted in the loss of some clutches and, of clutches laid late in the season, seven were known to be replacements. When these replacements were excluded, the mean laying date was 12 May. The difference between the two laying dates is not statistically significant ($d = 1.1047$, $p > 0.1$), since these seven nests represented only 4% of all clutches for which laying dates were determined. The median laying date (both including and excluding known replacement clutches) was 12 May. In 1984 the mean laying date was also 12 May and the median laying date was 11 May (Table 4.1). In 1983 the distribution of laying date of the first egg in each clutch was determined from 39 clutches of known laying date, 43 of known hatching date, 37 calculated from the chick growth curve and 28 calculated from the index of egg density. In 1984, the distribution of laying dates was determined from 35 clutches of known laying date, 54 of known hatching date, 2 calculated from the chick growth curve and 19 calculated from the index of egg density.

4.2.2 Egg size

Egg volume indices were calculated from the equation

$$\text{Volume index} = \text{length} \times \text{breadth}^2$$

as used for calculating the index of egg density. No constant was used to determine actual egg volume. The published values differ (Table 4.2) and no constant was necessary to conduct comparisons between yearly egg volume indices on Noss.

Mean egg volume indices, excluding the known replacements in 1983, were calculated and compared. The index in 1983 (164.32 ±0.737 S.E., n = 357) was significantly larger than in 1984 (160.83 ±0.86 S.E., n = 283, d = 3.096, $p<0.05$). One 1984 egg in particular was tiny (volume index 98.922); however the mean excluding this egg (161.048) was still significantly lower than the mean egg volume index recorded in 1983 (d = 2.952, $p<0.05$).

4.2.3 Chick growth

The wing lengths of chicks hatched in 1983 and of known age were plotted and a conversion table (Appendix I) was used to estimate the age of chicks of unknown hatching date. This allowed the estimation of the laying dates of eggs of unknown laying or hatching date (section 4.2.1).

In 1983 the growth rates of Herring Gull chicks from broods of one, two and three were plotted separately (Fig. 4.3) to determine whether brood size influenced chick weights and hence condition (Appendix II). Small sample sizes for wings greater than 50mm long (by which stage the chicks were difficult to find) probably caused deviations from the curve. For example, for a wing length of 160 - 180mm, the weight for one chick from a brood of one (817g) was greater than the mean weights for broods of two or three. The same situation was found in the last two categories of wing length. Apart from these differences, there were no statistical differences between chicks from different brood sizes and so the data for all brood sizes were pooled.

The mean weights (± 2 standard errors) of chicks in each year were plotted against wing lengths (Fig. 4.4; details in Appendix II). The annual mean weights were also compared (Fig. 4.5) but chick condition did not differ significantly between years.

In order to compare the situation in Shetland with Herring Gull colonies elsewhere, in 1983 96 Herring Gull chicks with a wing range of 35mm to 227mm (Appendix II) were measured at Inchmarnock, Strathclyde. In 1985 114 chick measurements were also taken from Shetland sites other than on Noss, specified in section 3.1.2.c; these are collectively referred to as mainland sites (M/L), although a site on Bressay was included (Appendix II). The growth curves for the Inchmarnock and Shetland mainland chicks were plotted alongside those for chicks on Noss; the combined curve for all 1985 chicks measured (i.e. Noss and Shetland mainland), is also shown (Fig. 4.6). There are no clear-cut differences between the mean weights of each group of chicks. Sample sizes from Inchmarnock are small, especially for the smallest and largest chicks measured, but for the intermediate wing size classes, the mean weights vary between being lighter and then heavier than Shetland birds. In Shetland in 1985, the larger chicks from Noss tended to be slightly lighter than chicks from mainland sites, but sample sizes were small. In conclusion, it does not appear that one group of birds was faring either noticeably better or noticeably worse than the other groups.

4.2.4 Parental attendance and chick feed rate

Parental attendance and number of feeds per chick per hour were determined by observations at Papil Geo in 1983 and 1984 as outlined in 3.1.2.

Parental attendance decreased through the season, both in 1983 (Table 4.3) and in 1984 (Table 4.4). In 1983 two parents were present for 30% of the observation time in the second week of June and this decreased to less than 5% by mid-July. A similar pattern was observed in 1984 when two parents attended each nest site for 47% of the observation time in early June but only for 4% by early July. In 1983 both birds were absent more often than in 1984 from the third week of June onwards, but sample sizes of nests in the study areas were too small for any differences to be tested statistically. The fact that both birds had to spend more time away from the nest foraging in 1983 may be an indication that food was more difficult to obtain in 1983 than in 1984. If so, the length of time that parents spent away from the nests in each year and the number of feeds per brood could be expected to differ.

In 1983 the mean duration for 43 foraging trips of known length was 75 minutes (range 15 min. - 405 min.). The mean trip duration for each observation period varied between 15 minutes and 88 minutes (Table 4.5).

In 1984 the mean duration for 121 departures of known length was 57 minutes (range 15 min. - 255 min.). Many departures were of 15 minutes and were not necessarily to feed. However, on some occasions birds flew either to the tideline or inland, to feed on intertidal and terrestrial invertebrates in each case, and returned with food for the chicks. Therefore, all trips of 15 minutes duration were included in the calculation of mean trip duration. The mean trip duration for each observation period varied between 38 and 112 minutes (Table 4.6).

In 1983 the birds spent more time away from their nests, presumably looking for food. However, as mentioned above, differences between the two years must be treated with caution, in that many trips in 1984 were of very short duration and may not all have concerned gathering food.

In both years the feed rate (number of observed feeds per brood per hour) varied during the breeding season (Tables 4.3 and 4.4). The mean number of feeds per brood per hour was 0.2 in 1983 and 0.38 in 1984, which may indicate a more successful year in 1984. The highest feed rates of 0.48 and 0.40 per chick per hour occurred between 0600 and 2330 and a lower rate of 0.19 between 2300 and 0600, within a four-day period in mid-June 1983. Thus, due to the diurnal variation in gull feeding behaviour, the inclusion of night watches in 1983 may have reduced the overall measured feed rate. In addition, in 1983 observations were continued into mid-July by which time the observed feed rate had decreased. Many of the chicks had left their nest areas by this stage and all feeds may not have been observed. If the average feed rate is compared between the two years up to the date 23 June (as observations were conducted on this date in both years), there was still a higher feed rate in 1984 (0.45) than in 1983 (0.32), although numbers of feeds were only marginally different between seasons (χ^2_1 = 3.25, $p<0.1$). All of these observations suggest that food availability to

Herring Gulls for feeding their chicks differed rather little between 1983 and 1984, although marginally more food may have been available in 1984.

4.2.5 Hatching and fledging success

The mean number of eggs in 152 clutches examined in 1983 was 2.6 (0.032 S.E., n = 395). The mean clutch size in 113 nests examined in 1984 was 2.59 eggs (0.036 S.E., n = 293). In 1985, the mean clutch size in 60 clutches examined was 2.37 eggs (0.060 S.E., n = 142). However, some eggs may have been lost before the clutches were censused. Evidence for this comes from seven clutches of known size (found and marked during laying) in Papil Geo (Fig. 3.1) with a mean clutch size of 2.7 (0.112 S.E., n = 19).

In 1983, 70.1% of the recorded eggs hatched and the hatching rate in 1984 was similar at 71.7%. Failure to hatch and (presumed) predation were the most important causes of egg loss (Table 4.7). At least 13 eggs were incubated (and subsequently lost) by Fulmars that took over Herring Gull nests during the two years. In 1983, 20% and in 1984, 27% of the chicks hatched were known to have died before fledging.

In 1983, 187 chicks were definitely alive at 10 days (67.5% of those hatched), 160 (57.8%) of these at 20 days and 120 (43.3%) of these at 30 days. By 10 days, at least 41 chicks had definitely died or been taken by predators, leaving a further 49 chicks unaccounted for, that is of unknown fate. Of these, 38 were not seen after 10 days of age and so the majority probably did not survive. By examining the age at which chicks were known to die, one can determine at what stage mortality amongst birds of unknown fate is most likely to occur. Of 54 deaths of birds of known age, most occurred before 10 days (Table 4.8) and therefore it may be assumed that most birds reaching 30 days of age will fledge. This is also borne out by the fact that of 120 birds known to be alive at 30 days, only 6 were known to die before fledging. Thus, although six birds did die after 30 days, one can expect a minimum of 120 birds to have fledged if birds of unknown fate are taken into account. This would result in 0.79 chicks fledging per clutch (including clutches lost and replaced) or 0.83 per pair.

In 1984, 162 (77.1%) of chicks that hatched were known to be alive at 10 days old. At least 119 (56.7%) survived to 20 days and 75 (35.7%) to 30 days; the latter value is probably an underestimate as I had to spend much time away from Noss when chicks were at this age. As in 1983, highest mortality occurred amongst birds less than 10 days of age (Table 4.8). However, the level of mortality amongst older birds was very slightly higher in 1984 than in 1983. Of 210 chicks that hatched, 162 were definitely alive and 38 known to be dead at 10 days, leaving only 10 chicks of questionable fate. Four such chicks were not seen after 10 days so they had probably died. If only 75 chicks fledged, they would represent only 63% of those that had definitely survived until 20 days of age. The mortality rates for the different aged chicks probably reflects the little time available to search for chicks in 1984, rather than a greatly lowered fledging rate. However, assuming that a minimum of 75 chicks fledged in 1984, a minimum of 0.66 chicks fledged per pair.

The only information gathered on breeding success on Noss in 1985 came from Papil Geo (Fig. 3.1). This was collected both by myself and by the Noss warden. Seventeen out of 19 eggs in seven clutches (89.5%) hatched. Five (29.4%) chicks were known to have died, eight (47.1%) were known to fledge, leaving four (23.5%) of unknown fate. If all the latter fledged, the fledging rate would increase to 70.6%; the true fledging rate probably fell between the two values, i.e. 1.14 - 1.71 chicks fledging per pair. Papil Geo is a very sheltered bay and it is possible that the chicks are afforded more protection there than chicks reared in more exposed sites on Noss.

Some post-fledging mortality was evident on Noss. Eleven corpses of chicks ringed on Noss (6 in 1983, 5 in 1984) were found, following predation by Great Skuas. These represent 5% and 6.7% respectively of birds known to be alive at 30 days. Other Herring Gull corpses that had suffered a similar fate were found on Noss, but they could not be identified as Noss birds because no ring was found; often only one leg or no leg at all accompanied the corpses. Great Skuas killed the juvenile gulls either on land or, more commonly, at sea where they could be seen standing on the young gulls' heads and drowning them. Great Skuas were observed patrolling coastal areas where Herring Gull fledglings were gathered. Any juvenile that was slow to fly away was quickly spotted, chased and usually killed. The fact that many gulls were seen to be killed at sea implies that the number of post-fledging deaths of Herring Gulls ringed on Noss was probably an under-estimate. The true number of kills is unknown, but it could have a bearing on future recruitment to the breeding population of Herring Gulls on Noss. Post-fledging mortality could have been an influential factor in the decrease of this species recorded in recent years. Not only fledgling Herring Gulls are preyed upon by the skuas; adults are also taken. Again, the number of adults taken in this manner is not known but this cause of death must be considered when trying to account for the decline in the breeding population of Herring Gulls on Noss.

4.3 GREAT SKUA

4.3.1 Timing of laying

An index of egg density was calculated for each egg measurement in 1983 and 1984 and plotted against days of incubation where known (Fig. 4.7) in the same manner as for the Herring Gull. The period of incubation of Great Skuas is, on average, 29 days (Cramp & Simmons, 1983); thus the days of incubation could be estimated for clutches where the hatching dates were known, either from direct observations of chicks hatching or calculated from the chick wing length (using a conversion from chick wing length to chick age, see section 4.3.3). The laying dates of eggs that did not hatch were determined from the equation (calculated from eggs of known age)

$$y = -239.952.x + 134.141$$

The standard deviation about the regression line was 2.62 days.

In 1983 both the mean and median laying dates were 19 May while in 1984 they were two days earlier on 17 May. The difference between the two years is not significant ($d = 1.6507$, $p > 0.05$). The distribution of laying dates in 1983 was determined from 2 clutches of known laying date, 34 of known hatching date, 6 calculated from chick wing length and 8 calculated from the index of egg density and in 1984 from 65 clutches of known hatching date and 5 calculated from the index of egg density (Fig. 4.8, Table 4.9).

4.3.2 Egg size

In contrast to the result obtained for Herring Gulls, the mean egg volume indices for Great Skua eggs were not significantly different (d = 0.3664, $p > 0.1$) between 1983 (176.15 ± 1.384 S.E., n = 95) and 1984 (175.49 ± 1.152 S.E., n = 131), suggesting that the state of the breeders, the onset of breeding and food availability were not detectably different between years.

4.3.3 Chick growth

A conversion from chick wing length to age was constructed (Appendix I) so that the age of chicks of unknown hatching date could be calculated.

Following a similar procedure to that in section 4.2.3, mean weights (± 2 standard errors, approximately equal to 95% confidence intervals) were plotted against wing length for Great Skua chicks in 1983, 1984 and 1985 (Fig. 4.9). The mean weights for each year were then compared (Fig. 4.10) so that any differences in chick condition could be examined. No consistent, large differences were apparent although the 1983 birds did tend to be marginally heavier than the 1984 birds with the 1985 birds generally varying between the two (details in Appendix II). Chicks in 1983 with a wing length of 180-199mm weighed just significantly more than chicks with the same wing length in 1984 and 1985 ($p<0.05$) and larger chicks, with a wing length of 320-339mm were significantly heavier in 1983 than in 1984 ($p<0.05$).

On 18 July 1985 60 Great Skua chicks were measured at Hermaness, Unst. Although the sample sizes were very small, the mean weights obtained for each wing length size class did not differ markedly from the weights of Noss chicks (Appendix II). The data from Noss 1985 and Hermaness were combined to obtain one growth curve for 1985 (Fig. 4.11). This was considered justified because no significant differences existed between sites and because it also served to increase sample sizes and create a smoother curve for 1985. However, there is a tendency for the smaller chicks on Noss to be heavier and for the larger Noss chicks to be lighter than on Hermaness. Combining the data will mask this effect.

Data collected on Great Skua chick growth rates on Foula from 1975 - 1984 (R.W. Furness) were analysed in the same manner and plotted on one figure (Fig. 4.12). Owing to the general lack of clear-cut differences between years, the data were combined so that the overall growth rate of Foula chicks could be compared with the overall growth rate of Noss chicks (Fig. 4.13). Little difference was evident. Initially, the Noss chicks weighed slightly less than the Foula birds but then the situation was reversed and larger chicks tended to be heavier on Noss than on Foula.

It was thought that chick condition and hence weight might vary markedly between years. This has not been borne out by the data for Herring Gulls on Noss nor by the data for Great Skuas on Noss and Foula, and so data on the growth rates of Arctic Skua *Stercorarius parasiticus* chicks on on Foula were also examined for the eight years from 1976 - 1983. Weight and wing length, for wing length greater than or equal to 50mm and less than 160mm, were highly positively correlated for each year (Table 4.10) and these sections of the growth curve can be plotted as straight lines (Fig. 4.14). It can be seen that the lines are all very similar, with 1978 being the exception. Its slope is much lower than in other years. Thus Arctic Skua chicks appeared to gain weight more slowly than average in 1978. In contrast, in 1978, Great Skua chicks on Foula were in particularly good condition (Fig. 4.12). I conclude from these analyses that chick growth and condition is not a sensitive indication of year to year differences in food availability in skuas or gulls in Shetland over recent years.

4.3.4 Hatching and fledging success

The mean clutch size of 50 clutches in 1983 was 1.9 eggs (0.04 S.E.) and of 70 clutches in 1984 was 1.94 eggs (0.028 S.E.), giving a mean clutch size of 1.925 (0.024 S.E.) for the two years.

The hatching rate was similar between years at 82.1% in 1983 and 84.6% in 1984. The commonest cause of egg loss was failure to hatch (Table 4.11). The number of chicks alive at 10 days was similar between years, 64.1% of those hatched in 1983 and 65.2% in 1984. Of those chicks alive at 10 days in 1983, 2 (4%) were known to have died before fledging. In all, 39.7% of chicks that hatched in the study area in 1983 were known to have died or to have been preyed upon (Table 4.11), 53.8% fledged and 6.4% were of unknown fate; these were chicks that survived to at least 10 days but were not seen, dead or alive, nearer the time of fledging. This gave rise to a value of 0.84 to 0.94 chicks fledging per pair. The recorded fledging value of 53.8% is thought to reflect closely the actual fledging rate, as many large chicks were seen prior to fledging. Of the 42 chicks concerned, 37 were known to be alive at 30 days of which at least 27 were alive at 35 days and 17 at 40 days. Five chicks were last seen between 23 and 30 days old, but vicious attacks by parents in their territories indicated their presence near the time of fledging. It is likely, therefore, that most of these chicks survived to fledge. Although cannibalism increased as fledging approached, the corpses were fairly conspicuous and so it is unlikely that a large number of chicks recorded alive at 30 to 40 days and not seen subsequently (alive or dead) were taken by predators.

In 1984, 13.3% of the chicks alive at 10 days were known to have died before fledging. The known (minimum) fledging rate was low (44.4%), because I had tc spend much time away from Noss in mid-July. It was thought that another 7.8% of the chicks could have fledged, as they were alive between 20 and 30 days old, which would increase the fledging rate to 52.2%. Another 7.8% of the chicks were of unknown fate but they were not seen after 10 days and so many of them may not have survived. However, if these unknown birds are included with the fledged birds, the fledging rate is increased to 60%, i.e. 0.73 to 0.99 chicks fledging per pair. Thus breeding success of Great Skuas on Noss in 1983 and 1984 was much less than recorded on Foula in 1975 and 1976 (Furness, 1984a).

4.4 FULMAR

4.4.1 Timing of laying

Following the same procedure as for the Herring Gulls and Great Skuas, an index of egg density was plotted against egg age (as days of incubation) (Fig. 4.15), so that the laying date of eggs that did not hatch could be determined. The mean incubation period for Fulmars is about 51 days (taken between the mean values of 53 days (Fisher, 1952) and 49 days (Mougin, 1967), but the range is great, 41-57 days) and the laying date was calculated for birds of known hatching date using the value 51 days. Known laying dates were not obtained as this would have involved disturbing the sitting adults to see whether an egg was present. Such disturbance would have been necessary at regular intervals to determine laying dates and so was not carried out for this very reason, as disturbance has been shown to cause considerable egg loss in the Fulmar (Ollason & Dunnet, 1980).

The laying dates of eggs that did not hatch were calculated from the equation

$$y = -434.809.x + 255.660$$

The standard deviation about the regression line was 3.91 days.

In both 1983 and 1984 the mean laying date was 19 May whilst the median laying dates occurred on 19 May 1983 and 18 May 1984 (Fig. 4.16, Table 4.12).

4.4.2 Egg size

The mean egg volume indices did not differ significantly between 1983 (186.63 ± 1.805 S.E., n = 78) and 1984 (184.8 ± 2.080 S.E., n = 72, d = 0.663, p > 0.1).

4.4.3 Chick growth

A conversion table of wing length to chick age in days (Appendix I) for Fulmars allowed the age of chicks of unknown hatching date to be determined. It also permitted the estimation of laying date.

Fulmar chick growth was plotted as for the Herring Gull and Great Skua chicks. In 1984 and 1985 the weights of inland chicks were measured in addition to coastal chicks on Noss to assess whether any large differences were evident between the chicks raised at each type of site (Fig. 4.17); except for two size classes of wing length, no significant differences were apparent (Appendix II). Coastal birds from each year weighed significantly more than the inland chicks in 1984 ($p<0.05$) for chicks with a wing length of 70-79mm and for chicks with a wing length of 160-179mm coastal chicks in 1985 weighed significantly more than the 1984 birds ($p<0.05$). Since only two comparisons out of 59 indicated significant differences at the 5% probability level, the mean weights (± 2 standard errors) of all Fulmar chicks (from inland and coastal sites) were combined for each year 1983 - 1985 (Fig. 4.18). These mean weights for each year were also compared (Fig. 4.19). With the exception of very small birds and those with a wing length of 260 - 280mm, the chicks in 1983 were generally heavier than in 1984 and 1985, but only significantly so for three different wing lengths. Chicks in 1983 weighed significantly more than chicks in 1984 for birds with wings measuring 140-159mm and 220-239mm ($p<0.05$) and were heavier than 1985 chicks with wing lengths of 200-219mm ($p<0.05$). The high weight plotted for a wing length of 280 - 300mm in 1983 refers to one chick only and may be atypical (details in Appendix II). Nevertheless, the data do suggest that Fulmar chick growth may have been slightly better on Noss in 1983 than in 1984 or 1985.

Partial growth curves were collected from Foula in 1979 and 1983 and from St. Kilda in 1981 and 1983 (R.W. Furness, *in litt.*). These data were treated by the same method as the Noss data. The mean Noss growth curve for the three years 1983 -1985 was plotted as a solid line so that the relative condition of chicks from the other islands could be examined and compared visually (Fig. 4.20).

The chicks on Foula in 1979 closely followed the mean growth curve drawn from all Noss chicks up to a wing length of 160mm. Chicks in the succeeding two wing categories were heavier than average. One chick with a wing length of 202mm weighed only 780g, hence the very low point on the figure; as only one chick is involved, it does not merit further discussion.

The chicks on Foula in 1983 weighed, on average, slightly less than those in 1979 and did not vary very much from the average Noss chick weights (Appendix II). The weights in the last two categories of wing length each represent one chick only and so may be ignored.

The numbers of chicks measured on St. Kilda in 1981 ($n = 58$) and 1984 ($n = 80$) were small (Appendix II) by comparison with Noss. With the exception of the smallest and largest chicks measured on St. Kilda (each category with $n = 2$), the chick weights were similar to those on Noss (Fig. 4.20).

The condition of chicks, measured by mean weight within categories of wing length, was generally similar between years and between sites. Largest deviations from the Noss curve exist where sample sizes of chicks from other areas were very small and thus the means were more variable and less reliable.

4.4.4 Parental attendance and chick feed rate

Observations in both 1983 and 1984 revealed that parental attendance at Fulmar nest sites decreased markedly through the season, (Tables 4.13a and 4.13b). The decrease was more pronounced than observed at Herring Gull nest sites owing to the fact that both Fulmar adults leave their nests for long periods of time once their chicks are a couple of weeks old and they may forage a long way from the breeding colony (e.g. Dunnet & Ollason 1982, Furness & Todd 1984).

In both years, each site was attended by at least one parent when the chicks were young (less than about two weeks old), but with time the proportion of nests with neither parent present increased. The proportion of nests with two adults present at any time was always low.

The mean duration time for 29 periods of absence, where time of return was recorded, in 1983 was 8 hours 28 minutes (range 30 min. to 29 hours). The median duration of Fulmar trips within one 48 hour observation period was 8 to 9 hours (Fig. 4.21). The minimum duration of absence was known for 121 bird trips in 1983 (Table 4.14), over 70% of which were longer than six hours, in agreement with the median duration of 8 to 9 hours recorded during the 48 hour observation. Most departures occurred in the morning and evening (Fig. 4.22a).

The mean duration time could not be recorded adequately in 1984 because the lengths of observation periods were too short. In 1983 a continuous 48 hour observation was conducted but this was not possible in 1984 and 17½ hours was the longest period of observation in that year. On 26 occasions when the total departure duration was unknown, over 70% were longer than 10 hours (Table 4.14). As in 1983, most departures occurred in the morning and evening (Fig. 4.22b).

In 1983 chick feed rates increased through the season, from 0.03 to 0.1 per chick per hour (Table 4.13a). In 1984 the feed rate (observed at five nests with dye-marked adults) during the second observation period was comparable with that at the same period in 1983 (Table 4.13b). However the recorded feed rate for the first observation period in 1984 was calculated, assuming one feed per parental changeover and was lower than during the succeeding observation period but higher than the same period in 1983. The observed feeding rates in 1984 including nests with no dye-marked adults (n = 20) were lower than those recorded at the five nests with dye-marked adults (0.068 on 29.07.84 and 0.009 on 19.08.84). The mean chick feed rate was lower overall in 1983 (0.014 including 12 hours of darkness; 0.016 excluding 12 hours of darkness; n = 15) than in 1984 (0.057, n = 5; 0.043, n = 20) (statistical values are presented in Table 4.15). (Note: the yearly mean feed rates are not means of the individual feed rates as recorded in Table 4.13 but are means of the total number of feeds throughout the season relative to the number of nest hours, that is the number of nests times the number of hours of observation.)

4.4.5 Hatching and fledging success

During 1983, 66% of the 81 marked Fulmar eggs hatched and in 1984 78.3% of the 83 eggs under study hatched. However, much of the early egg loss would have already occurred by the time the eggs were marked on Noss (beginning 1 June in 1983 and 27 June in 1984) and this is reflected in the relatively high hatching rates observed (Table 4.16). (Most egg loss occurs within the first three days after egg-laying; Dunnet *et al.* 1963, Mougin 1967.)

The fledging rate was known for each year on Noss. In 1983, 85% of those chicks that hatched survived to fledge. Of those that did not fledge, 50% died and 50% were taken by predators (Table 4.16). In 1984 there was a reduced rate of fledging, with only 66.2% of chicks that hatched surviving to fledge; 91% of the chick mortality was caused by predation. It is thought that feral cats were the principal predators as they were often seen along the banks of Voe of the Mels (Fig. 3.1). All chicks taken were either from near the top or from near the bottom of the banks, but not from sites half way up that would not have been so accessible to cats. In addition, a few headless half-eaten corpses of Fulmar chicks were found, both from inland and from coastal sites, in areas in which feral cats frequently were observed.

4.5 DISCUSSION

4.5.1 Herring Gull

The median laying dates of 12 May 1983 and 11 May 1984 fall between the mean and median dates recorded elsewhere (Table 4.17). The timing of laying may be affected by latitude (Perrins & Birkhead, 1983); therefore, the laying dates of Herring Gulls in different latitudes, such as those studied by Erwin (1971) on Rhode Island and by Haycock and Threlfall (1975) in Newfoundland, may differ accordingly.

At least 13 Herring Gull eggs were incubated by Fulmars, but later lost, on Noss in 1983 and 1984. This habit has been reported before. Morton Boyd (1959) found a Fulmar incubating Great Black-backed Gull eggs, and Brown (1960), Richards (1964) and MacDonald (1980) all reported Fulmars incubating Herring Gull eggs. However as MacDonald (1980) observed, gulls may take over nest sites in the temporary absence of Fulmars, some of whom displace the Herring Gulls upon their return. In mid-April Fulmars leave the colony in a pre-laying exodus so that, for a period of approximately two weeks, numbers attending the colony reach a much reduced level (MacDonald, 1977), leaving nest sites vacant and therefore available to take-over (albeit temporary) by Herring Gulls or by other seabird species such as Kittiwakes, as observed in Co. Durham (Coulson & Horobin, 1972). Observations earlier in the season would be necessary to confirm that this is actually occurring on Noss.

In 1983, adult Herring Gulls spent more time away from their nests, probably foraging for food, and also a lower mean number of feeds per brood was observed in 1983. No information regarding the quantity or quality of food is available. Unlike auks, which bring whole fish to their chicks in their beaks permitting an estimate of fish length, gulls feed their chicks by regurgitation and the food is often never seen by an observer. As the peak in Herring Gull sleeping occurs between 0000 and 0200 hours (Galusha & Amlaner, 1978), little or no feeding occurs between 0200 and 0400 hours

(Sibly & McCleery, 1983b) and less activity was recorded during the dark and twilight hours in 1983, no overnight watches were conducted in 1984. Thus, the differences observed between adult departure times and chick feed rates at Papil Geo in 1983 and 1984 may be exaggerated.

The breeding success of Herring Gulls on Noss can be compared with that of Herring Gulls nesting in other areas. Brown (1967) found a mean clutch size of 2.56 for Herring Gulls nesting on Walney Island, northwest Lancashire. Harris (1964), on the other hand, recorded a slightly higher mean clutch size of 2.8 from 220 nests studied on Skomer, Pembrokeshire and Haycock & Threlfall (1975) found mean clutch sizes of 2.70 and 2.73 in 1970 and 1971 on Gull Island, Newfoundland. On Sandy Point, Rhode Island Erwin (1971) found a mean clutch size of 2.9 eggs for Herring Gulls nesting away from Great Black-backed Gulls and of 2.69 for Herring Gulls nesting in close proximity to Great Black-backed Gulls, both values being higher than noted on Noss. Other workers quote a decrease in mean clutch size throughout the season, ranging from about 2.8 early in the season (Parsons, 1975) to 2.4 late in the season (Davis, 1975a). The mean clutch size of 2.6 each year on Noss refers to clutches laid throughout the season and so it compares favourably with the findings of the above authors.

The hatching success of Herring Gulls on Noss was similar between years in this study and similar to data recorded elsewhere (Table 4.18). Noss birds, although suffering a lower hatching rate than that recorded for the Rhode Island Herring Gulls nesting away from predatory Great Black-backed Gulls (82%), do not have a particularly low hatching rate compared to most other colonies.

The fledging rate is more difficult to determine accurately, owing to the fact that the gull chicks may run far from their nests and hide very effectively under rocks or any available vegetation cover. For this reason the percentages of chicks surviving to 10 and 20 days old were compared between years on Noss and with other studies. More chicks (77% compared to 67.5%) were definitely known to survive to 10 days in 1984 than in 1983, but in 1984 more time was spent searching for young chicks and less time for older chicks. On Walney Island, 67% of chicks definitely survived to 10 days old (Brown, 1967), which is similar to the value found on Noss in 1983.

Fledging rates for Herring Gulls vary between sites; this difference may be real or it may be caused by the difficulty in assessing numbers actually fledging. On Noss the minimum fledging values presented are intermediate between, but generally similar to, fledging rates reported from other sites (Table 4.18). A higher fledging rate was found in Bristol Channel colonies, with 1 to 1.5 chicks fledging per pair, when the colonies were expanding at a rate of 10% per annum (Harris, 1970). According to Harris (1970), colonies with slower rates of increase have lower chick production. Therefore the Herring Gulls on Noss, suffering a population decline at present, might not be expected to show especially high fledging rates.

4.5.2 Great Skua

The mean clutch size recorded on Noss each year was much the same as that reported for 781 Shetland clutches (mean 1.93, Cramp & Simmons, 1983) and the mean value of 1.9 eggs per pair in 881 nests studied on Foula in 1975 and 1976 (Furness, 1984a). Here the similarities in the breeding success of Great Skuas on Noss and Foula end.

Over 80% of the eggs studied on Noss in 1983 and 1984 hatched, contrasting with an average value of about 70% on Foula in 1975 and 1976 (Furness, 1977). Differences between the two islands include the number of birds breeding on each island (*ca.* 3000 pairs on Foula and less than 400 pairs on Noss) and the number of birds being studied (881 nests on Foula and 120 nests on Noss).

The hatching rate was higher on Noss than on Foula but the fledging rate was much lower. In 1983 on Noss, 54% to 60% of hatched chicks fledged (44% to 50% of all eggs laid) and in 1984 44% to 60% of hatched chicks fledged (38% to 51% of all eggs laid). The Foula fledging rate was very much higher, at 93% of all chicks that hatched (65% of all eggs laid) (Furness, 1984a). By comparison, in a similar type of study between 1963 and 1965 on the Brown Skua *Catharacta skua lonnbergii* at Signy Island, South Orkney Island, the fledging rate varied between 81% and 96% of chicks that hatched (Burton, 1968). The number of Brown Skua chicks that fledged per pair was, on average, 0.95 (range 0.65 to 1.30) per pair present or 1.19 (range 0.9 to 1.36) per pair that laid.

Thus, Noss chicks are suffering much higher mortality rates than skua chicks elsewhere. Initially it was thought that nesting density might be an influential factor. On Noss, the colony is dense, averaging 242.5 nests per km^2 (Willcox *et al.*, 1983), which is equal to an average nesting territory of 0.412 hectares. However, the nesting density is not evenly spread, with a disproportionate number of pairs breeding within a very small area around the Setter club site (Fig. 3.1) where the average territory area of some 40 pairs was only 0.0275 hectares in 1983 (Willcox *et al.*, 1986), which is equivalent to a nesting density of 3636 pairs per km^2. This is not very different to the situation observed on Foula where patchy nesting densities also occur. These vary from 50 km^{-2} to 600 km^{-2} in large areas of the colony but may increase to as high as 5000 nests km^{-2} at the edge of club sites (Furness, 1977). Nesting density thus does not appear to differ very greatly between the two islands and is unlikely, therefore, to be the cause of the low fledging success of the Noss chicks. However, the collection of more data from areas of known nesting density would help to determine the possible effects of overcrowding in specific areas of the colony.

Chicks dying of starvation when they were very young and also cannibalism or death caused by attack from another Great Skua were the commonest known causes of mortality on Noss. In 1983, only two chicks were killed by cannibalism in the study area but 11 were killed thus in 1984. In 1983 one chick of less than 10 days of age was known to have been preyed upon by a Great Black-backed Gull, as its ring was found in a pellet regurgitated by the gull in its territory. Other chicks that were missing, and therefore unaccounted for, could have suffered a similar (but unrecorded) fate. The main difference, it appears, between Noss and Foula is the level of predation and of chick starvation, both being very much higher on Noss.

4.5.3 Fulmar

Fisher (1952) notes that most birds lay their eggs between 20 and 29 May (range 5 May-7 June, or even later) but he gives no precise data. The mean hatching date for 24 birds on Eynhallow in Orkney in 1952 was 6 July (Carrick & Dunnet, 1954), indicating a mean laying date of 16 May, assuming 51 days of incubation. These workers also note that the hatching (and therefore the laying) dates were probably later in 1951 than in 1952 owing to a cold spring. Data collected from 1960 to 1962 at the same site arrived at a median laying date of 22 May (Ollason & Dunnet, 1978), 21-22 May in 1960 and 1961 and about 23 May in 1962 (Dunnet *et al.*, 1963).

The laying dates of six Fulmar eggs from Kongsfjord near Nye Alesund, Spitzbergen were determined indirectly by estimating the daily loss of egg mass (Rahn *et al.*, 1984). Eggs were laid between 16 and 31 May with a mean on 26 May, which is slightly later than was observed on Noss in this study. Both the Noss and the Spitzbergen laying dates were calculated rather than observed directly and the latter sample size was very small and referred to birds breeding in more northerly latitudes. As stated earlier, latitude may affect the onset of the breeding season, thus biasing comparisons of laying dates between sites of differing latitude. The study does indicate, nevertheless, that eggs are laid primarily during the second half of May.

The incubation period of Fulmars on Noss was unknown and was estimated by taking the mid-value of published estimates (Fisher 1952, Mougin 1967). If it is assumed that 51 days is a slight overestimate (see below), then the Noss laying dates would be put forward by a couple of days and would agree more closely with the peak laying periods observed at Eynhallow (e.g. Ollason & Dunnet, 1978). Working on the Semidi Islands in Alaska, Hatch (1979) determined the incubation period, to the nearest day, for 52 eggs. He found a mean incubation period of 48.4 days (range 46 to 57) similar to the mean value of 49 days (range 47 to 50) observed by Mougin (1967). This figure was not used initially because it refers to the situation in Alaska where it was considered that conditions probably differ from those on Noss, owing to differences in latitude and climatic factors. Fisher (1952) summarises the periods during which most eggs are laid for a variety of places. Most egg laying occurs during the last 10 days of May (Table 4.19) but in more northerly latitudes, for example Greenland and the Canadian

Arctic, most eggs were laid in early June. Thus, these laying dates cannot be adopted for the Noss birds.

During incubation and chick rearing, previous studies have indicated that Fulmars do travel long distances (e.g Dunnet & Ollason 1982, Furness & Todd 1984) and the data collected during the present study infer that this could also be happening on Noss. On Foula, over 70% of the foraging trips in mid-July were no more than 10 hours long and the median occurred at 6 hours (Furness & Todd, 1984), two hours less than on Noss. The observations were conducted at about the same stage in the season, although in different years (15-19.07.81 on Foula and 18-20.07.83 for the 48 hour watch on Noss), so seasonal differences may be discounted. A 10 hour departure could give a potential range of 200km (see Furness & Todd, 1984), so it is possible that many of the Noss birds are travelling far away to feed. Alternatively, if they are relying on fish offal from trawlers for much of their food they may be spending much time sitting on the sea waiting for gutting and discarding to occur, as Fulmars can be seen to do around trawlers in Shetland waters.

An absence of 48 hours would allow a bird to fly up to 960km away (assuming a direct flight at 40km per hour as in Furness & Todd, 1984). This distance is unlikely to be realised, as a bird would probably not fly at this speed all the time. A breeding Fulmar was found (and released) 466km from its breeding colony on Eynhallow (Dunnet & Ollason, 1982), although it is unknown whether this bird returned to its nest site to help to feed its chick, which subsequently fledged. Thus, birds absent for periods exceeding 48 hours could easily be travelling 200 - 400km or more, even allowing half of their departure time for feeding. It is not really surprising that, within an observation period of less than 18 hours, few departures and returns of one bird were recorded on Noss. The minimum durations of Fulmar departures from Noss agree with other observations (e.g. Dunnet & Ollason, 1982) that the birds could be travelling long distances to feed.

On Foula, Furness and Todd (1984) found a morning and evening peak in Fulmar activity and a similar situation occurred on Noss, both in 1983 and 1984 (Figs. 4.22a and 4.22b). In contrast, a morning peak only occurred on St. Kilda, suggesting that birds were feeding at night (Furness & Todd, 1984). On Noss the indications are that feeding occurs both by day and by night, as birds generally return and depart in mid-morning and late afternoon.

Towards the end of July, nights in Shetland become completely dark, making continuous overnight observations impossible. At this stage, both adults are normally absent from the nest site so the strategy of noting adult change-overs by the presence of a normal white or of a yellow dye-marked bird cannot be employed. Night feeds are therefore unrecorded, making the true estimation of feed rates impossible.

On 31 July 1983 the number of feeds per chick per hour was 0.07 and on 29 July 1984 it was 0.082. At a similar period in 1981 (30 -31 July) a 48 hour observation was conducted on St. Kilda. During this time 23 nests were visited 74 times by adults and the chicks were fed on each occasion. This allows 0.067 feeds per chick per hour. Taking into account no (observed) returns (and thus no feeds) at night, this feed rate compares well with the feed rate on Noss in each year at the same period. Thus it appears that the frequency of feeding does not differ greatly between St. Kilda and Noss. Data collected on Foula early in the chick-rearing period contrasted with the St. Kilda feed rates (Furness & Todd, 1984) and it was suggested that a difference might exist in the time spent foraging by parent Fulmars between each site. This study suggests that those differences are probably attributable to the difference in chick age, rather than to any major difference in feed rate. It is probably safer to compare trip duration and feed rate between colonies at the same stage in chick-rearing.

During 1983, fewer Fulmar eggs under study hatched than in 1984 on Noss. However, since most eggs were not marked until some time after laying, some eggs were almost certainly lost before the eggs were marked, so the true hatching rate is unknown. Most egg loss occurs within the first three days after egg-laying (Dunnet *et al.* 1963, Mougin 1967), although Mougin (1967) recorded a second peak in egg mortality around the time of hatching. Hatching rates can vary from year to year at one site. On the Semidi Islands, the hatching rate was very low in 1976 (22%) but much higher in 1977 (66%) (Hatch, 1979). On Noss in 1984, the eggs were marked very late in the season (on or after 27 June), by which stage all but the mortality occurring near the time of hatching had occurred. This resulted in the exceptionally high observed hatching rate of 78%.

The Noss Fulmar fledging rates are similar to those in the literature, where studies have recorded a range in fledging success, of chicks that hatched, from 66.5% (Nettleship, 1977) to 83.9% (Mougin, 1967) (Table 4.20). The Noss values are close to the two extremes quoted.

On Noss the true egg loss was unknown and therefore any percentage breeding success recorded is an overestimate. This can be demonstrated by contrasting Noss results with data from other areas. On Eynhallow, for example, breeding success ranged from 16% to 52% over a 28-year period (Dunnet *et al.*, 1979), although early egg losses are not included. Both Dunnet's work and that of Hatch (1979) indicate the great variability in egg survival. In 1976 less than 15% of eggs successfully hatched and fledged in the Semidi Islands and yet by 1977 this figure had more than trebled and the percentage breeding success recorded was 51% (Hatch, 1979); much of the difference was caused by very high egg mortality in 1976. The least variable stage normally occurs between the chick hatching and fledging (Table 4.20). It can be seen that Noss chicks suffered the largest difference in fledging rate, from chicks hatched and, as explained earlier, this was caused by an abnormally high predation rate in 1984.

It appears, both from the present study and from studies by other workers, that Fulmars have very variable breeding successes between years and that this variation between years within a site is as great as that between sites.

4.6 CONCLUSIONS

The breeding success of the three species was similar in 1983 and 1984, except for Fulmars where predation was the cause of a high mortality rate in 1984. Furthermore, the breeding successes of the Herring Gull and Fulmar on Noss were, broadly speaking, similar to those observed in other areas, thereby indicating that food shortage during the breeding season was not a severe problem for these species of birds. The number of Great Skuas fledging per pair was lower on Noss than on Foula in the late 1970's.

There was little variation between years in the condition (demonstrated by weight) of chicks for the three species Herring Gull, Great Skua and Fulmar. Furthermore, the condition of chicks measured from other sites in Shetland and elsewhere on the Scottish mainland did not differ significantly from the Noss birds. Chick condition does not appear to be affected by small scale differences in food availability as it is highly unlikely that food availability is the same between years and between sites. Therefore, chick weight may not be very valuable as an indicator of minor differences in prevailing environmental conditions from place to place and year to year. As a result, chick weight in relation to wing length appears to be an insensitive measure of the ability of adults to provision their young. There is some evidence from my limited measurements of breeding adult activity budgets that these are more sensitive to food availability and it may be suggested that birds increase foraging effort in order to maintain the optimal rate of chick provisioning. Unfortunately, measurement of activity budgets requires continuous observation of groups of nests over long periods of time and so is impractical for an individual fieldworker.

CHAPTER 5

DIETS OF SCAVENGING SEABIRDS ON NOSS AND MAINLAND SHETLAND: REGURGITATES AND PELLETS

5.1 INTRODUCTION

In Shetland, populations of scavenging seabirds increased hugely throughout the earlier part of this century, but at that stage no detailed studies of the seabirds' diets were carried out. Presently, the Fulmar and Gannet populations are increasing at a fast rate, the Great Black-backed Gull populations are increasing at a slower rate or are stable in numbers, the populations of Great Skuas appear to be levelling off (Furness 1983a, pers. obs.) while the Herring Gull, Lesser Black-backed Gull and Kittiwake numbers are now declining at many colonies (cf. Chapter 2). We are now in a position to examine the diet of scavenging seabirds in Shetland to determine whether the decrease in some populations reflects the amount of trawler waste food available to these species. In particular, by examining the diet of both adults and chicks, it is possible to establish whether a difference between them exists and whether one group relies more on a particular type of food than another. The determination of diet will assess the use of (and so possibly indicate the importance of) fishery waste to the breeding populations of seabird species.

To determine the entire diet of adults, one would need to identify their stomach contents (e.g. Hartley, 1948). As this would necessitate either killing the birds to allow dissections, or catching the adults to obtain stomach contents by use of a stomach pump or emetic, such a method was not used in this study. (All methods of diet determination are outlined in section 3.2.) A combination of methods of assessing diet is the most satisfactory, for example by using both enumeration of occurrences or frequency within the bird stomach and enumeration of the foods found (Hartley, 1948), or by combining analyses of pellets, faecal material and stomach contents (obtained by emetics and/or dissection) as carried out in a study of the Magpie *Pica pica* diet (Tatner, 1983). Tatner could identify the hard parts of food items (largely terrestrial invertebrates) in each method of analysis of diet and therefore they could be compared quantitatively.

Such is not possible for all species. The Grey Heron *Ardea cinerea*, for example, uses acidic gastric juices to digest all fish bones, which results in pellets showing no sign of fish remains even though fish form the bulk of the Heron's diet (Hibbert-Ware, 1940). Thus pellet analysis must be observed with caution, a sentiment echoed strongly by M. Jobling and A. Breiby (unpubl.d).

The determination of diet from observed food remains alone is not quantitatively correct as the enumeration of foods found tends to exaggerate the importance of small food items which may be less important in terms of weight, volume and calorific value (Hartley 1948, Furness & Hislop 1981).

Accepting these limitations, many studies (this one included) rely on pellets and food remains as an indicator of the diets of adult gulls and skuas, as the analysis of stomach contents is not always feasible. The results presented below for adult gulls and Great Skuas do not pretend to encompass the entire diets, as soft food remains are not represented in regurgitated pellets. The results are, however, directly comparable between years within this study and, further, they may be compared with some studies undertaken elsewhere.

In this chapter, the results for Herring Gull diets will be presented first, followed by details of the Great Skua and Fulmar diets respectively. For each species, data on the diets of chicks will be given first. A small amount of data on diets of adult Great Black-backed Gulls is also provided.

5.2 HERRING GULL

5.2.1 Chick diet

Of 192 regurgitates (each of which could contain more than one food type) collected during the three years from 1983 to 1985, nine were from mainland sites (see 3.1.2.c) and the remainder were from Noss, 51 in 1983, 106 in 1984 and 26 in 1985. Overall, fish other than Sandeel (referred to from here onwards as whitefish, although fish such as Herring *Clupea harengus* and Mackerel *Scomber scombrus* are included in this category) formed the most important constituent of the chicks' diet, occurring in over 50% of all regurgitates, and Sandeel was next in importance (23%), followed by terrestrial invertebrates (13%) and human waste foods (12.5%); all other food types occurred in less than 5% of the regurgitates (Table 5. 1). Details of the diet in each year are presented in Appendix III.

The percentage occurrence of food items in chick regurgitates was very similar between 1984 and 1985 on Noss, but somewhat different in 1983 when Sandeel was more important than whitefish. The occurrence of whitefish and Sandeel in the diet of Herring Gull chicks was compared between years. All the Chi^2 tests with one degree of freedom have been corrected using Yates' Correction for Continuity. The diet in 1983 was significantly different from that in 1984 (χ^2_1=12.17, $p<0.001$) and from that in 1985 (χ^2_1=4.85, $p<0.05$), with more Sandeel and less whitefish occurring in 1983; the diets were similar in 1984 and 1985.

To test for the effect of season the food types regurgitated up to and including 25 June were compared with the food types regurgitated after this date, for the three years 1983 to 1985. To test whether older chicks regurgitated the same food as younger chicks, the food types regurgitated by chicks up to and including 15 days of age were compared with those regurgitated by chicks greater than this age, for the years 1983 and 1984.

In 1983 there was no significant difference in the amount of Sandeel and whitefish regurgitated by chicks early compared to late in the season (Table 5.2a). Similarly, there was no significant difference between the amount of Sandeel and whitefish regurgitated by young or by old chicks (Table 5.2b).

In 1984, significantly more Sandeel and less whitefish were consumed early in the season and significantly less Sandeel and more whitefish late in the season (χ^2_1= 16.38, $p<0.001$; Table 5.3a). This trend was also reflected in the diets of chicks of different ages, with young chicks regurgitating significantly more Sandeel and less whitefish than older chicks (χ^2_1=8.24, $p<0.01$; Table 5.3b). The occurrence of terrestrial invertebrates and human waste foods did not differ significantly, either with season or with chick age, suggesting that the high percentage of Sandeel occurring in the regurgitates of young chicks could be caused, in part anyway, by the availability of Sandeel. In 1985 there was no significant difference in the amounts of whitefish and Sandeel regurgitated early and late in the season (Table 5.4).

5.2.2 Breeding adult diet

The occurrence of food items in regurgitated pellets has been tabled separately from the occurrence of hard food non-pellet remains

(Tables 5.5a and 5.5b, details in Appendix III). On Noss, intertidal invertebrates accounted for over 90% of food items recorded in each year, both in pellets and as hard food remains. From mainland sites whitefish was more important than on Noss, occurring in nearly 14% of the regurgitated pellets. Of the hard food remains, nearly 100% were of intertidal invertebrates.

The two methods of diet analysis produce significantly different results (χ^2_2=576, $p<0.001$). Whitefish, for example, were represented in pellets but not as hard food remains; birds, on the other hand, were represented by hard food remains by the presence of feet and/or wings but did not occur in pellets. For this reason, the two sets of data were analysed separately. However, intertidal invertebrates occurred in over 90% of the food samples using either technique.

The diets were compared statistically between years and between sites. Whitefish occurred more often in pellets regurgitated by breeding Herring Gulls on Noss in 1984 than in 1983 (χ^2_2=33.5, $p<0.001$) or in 1985 (χ^2_2=61.99, $p<0.001$) and a greater proportion of pellets contained whitefish in 1983 than in 1985 (χ^2_2=13.32, $p<0.01$). Birds from mainland sites regurgitated a greater proportion of whitefish pellets than did Herring Gulls from Noss in 1983 (χ^2_2=448, $p<0.001$), 1984 (χ^2_2=121, $p<0.001$) and 1985 (χ^2_2=345, $p<0.001$).

Within mainland sites, more whitefish and less intertidal invertebrates and other foods occurred in pellets regurgitated by gulls on the east coast than in pellets regurgitated by the gulls on the west coast (χ^2_2=28.59, $p<0.001$). The west coast sites were all in West Burra, just south of Hamnavoe and Scalloway and adjacent to the Burra Haaf, an area of sea much fished by the Scalloway boats. If this fishing area gave the Herring Gulls nesting on West Burra an immediate advantage over east coast gulls (in that the gulls might have easy access to the fishery waste) then one would expect the west coast sites to have more fish pellets than the east coast sites (Dale's Voe and Bressay). In fact, the converse was true. This poses another question: if east coast birds feed on more fish than west coast birds, why do the Noss birds, also on the east coast, feed on so little fish? The answer remains unresolved. If intertidal invertebrates were, in fact, the preferred food, then one could say that the Herring Gulls' diets reflects the availability of these rather than fish, and that east coast birds feed on fish because there are few invertebrates. However, as stated above, Noss is also on the east coast and very close to Bressay, so this seems an unlikely solution.

The data from the east coast and Noss pellets in 1985 were combined and then compared with the west coast pellets. The west coast birds regurgitated significantly more pellets containing fish and other foods and less containing intertidal invertebrates (χ^2_2=91.9, $p<0.001$) than the east coast plus Noss birds.

Apart from intertidal invertebrate remains, the sample sizes of hard parts of other foods were very small, and so no statistical tests were applicable. There was little difference between years on Noss, with intertidal invertebrates constituting the major component. The food occurring at mainland sites appeared fairly similar to that on Noss but relatively fewer bird remains were found.

In essence, adult Herring Gulls appeared to feed more on intertidal invertebrates than on fish since both prey items give rise to pellets and most pellets consisted of intertidal invertebrate remains.

5.3 GREAT SKUA

5.3.1 Chick diet

Very few chicks regurgitated their food upon handling. Consequently, the sample sizes obtained were very small, with a total of 20 regurgitates being collected during the three year period (Table 5.6). Sample sizes were too small to allow meaningful statistical comparisons between years. Overall, whitefish was regurgitated most commonly and Sandeel and seabirds were less important. Only one type of food occurred in each regurgitate. Data for the three years were combined to allow comparisons between food types regurgitated early (in June) and late (in July) in the season (Table 5.7a) and by young (up to and including 15 days old) and old chicks (over 15 days old) (Table 5.7b). No significant differences were detected in each case.

5.3.2 Adult diet

5.3.2.a Breeding adult

The recorded diet of breeding Great Skuas appeared fairly similar between 1983 and 1984, with whitefish and seabirds accounting for over 90% of all food items (Table 5.8), although significantly more whitefish and less seabird occurred in 1984 than in 1983 (χ^2_1=7.30, p<0.01). In 1985 seabird was very much more common and whitefish very much less so than in 1983 (χ^2_1=75.35, p<0.001) and in 1984 (χ^2_1=113.60, p<0.001; full dietary details are given in Appendix III). During 1985, the Kittiwakes on Noss had a disastrous breeding season and adults, eggs and chicks all fell easy prey to Great Skuas as a consequence: eggs and young were left unattended on nest sites and were easily accessible to the skuas. Certain pairs of Great Skua were highly prey-selective. In one territory alone 54 Kittiwake eggs were found, indicating that once these birds had preyed upon a few eggs they then concentrated on eggs, now a freely available food source. Kittiwake eggs had not been taken in large numbers in 1983 or in 1984.

Of 41 food pellets collected on one visit to Hermaness, Unst in mid-July, over 75% were of seabird. On Hermaness, Puffin *Fratercula arctica* adults were common prey, although not all seabird pellets were identifiable to species.

Overall, for the three year period, seabirds and whitefish were the most important food types in the diet of breeding Great Skuas.

5.3.2.b Non-breeding adult

The diet of non-breeding adults was examined in a similar manner to the breeding adults, but food pellet contents were identified from club sites, the areas in which non-breeders congregated.

As for the breeding Great Skuas, whitefish and seabirds accounted for the majority of food items recorded in pellets (Table 5.9; details in Appendix III). There was no significant difference between the amount of whitefish and seabird recorded in each year (p>0.05). Sandeel was significantly more common in 1985 than in 1983 (χ^2_2=9.57, p<0.01), but no significant differences (p>0.05) were recorded in the amounts of Sandeel occurring between 1984 and 1983 or between 1984 and 1985. However, these results may be biased by the seasonality of Sandeel as a food item (see below).

The occurrence of Sandeel was very seasonal with most being recorded in May and June (Table 5.10). In 1983, 98% of all Sandeel pellets occurred before 1 July. In 1984, 97% of all Sandeel pellets and in 1985 all Sandeel pellets were collected before 1 July. Thus, during May and June the percentage occurrence of Sandeel in the diet of non-breeders was very much higher than later in the season or recorded for the whole season (Fig. 5.1). Of food samples collected during May and June, 20.0% contained Sandeel in 1983, 14.4% in 1984 and 18.1% in 1985. The sudden drop in Sandeel occurrence was not caused by a decrease in my search effort, as in 1983 54%, in 1984 37% and in 1985 31% of all food samples were collected after 1 July.

Forty-one food samples were collected from a club site at Hermaness on 18 July, of which approximately two thirds were of whitefish and one third of seabird (Table 5.9).

The combined diet of breeding Great Skuas on Noss for the three years 1983 to 1985 was significantly different from the diet of non-breeding Great Skuas on Noss over the same period (χ^2_4=508.76, p<0.001), with non-breeders feeding on more whitefish, Sandeel and Rabbit *Oryctolagus cuniculus* and fewer seabirds than the breeders. On Unst, too, the breeding birds fed on more seabirds than did the non-breeders. On Noss the food samples were collected throughout the breeding seasons each year, so seasonal differences should not have affected the comparison. However, a bias does exist for breeders in that in May, when many pellets regurgitated by non-breeders were collected, food samples in breeding territories were not found regularly and this may suggest incorrectly that Sandeel is more important in the diet of non-breeders than of breeders.

5.4 FULMAR

5.4.1 Chick diet

The diet of Fulmar chicks was similar between years on Noss, with whitefish (including offal) being more important than Sandeel (Table 5.11). Included in the category of Sandeel are tiny fish whose small backbones could not be distinguished readily from those of Sandeel. There were no significant differences (p>0.05 in all cases) in the proportions of whitefish, Sandeel and other food items present in the chicks' diets in each year. For the three years combined, whitefish occurred in over 60% of the chick regurgitates, whereas Sandeel occurred in just over 30% of all regurgitates.

5.4.2 Breeding adult diet

The number of regurgitates obtained from breeding Fulmars was smaller than from chicks because adults were handled only when they were incubating eggs or brooding very young chicks. Thereafter, the adults flew away upon my arrival and, later in the season, were generally absent from the nest site altogether.

In 1983, three out of the four regurgitates collected contained Sandeel and one contained whitefish. In 1984 and 1985, whitefish occurred in all Fulmar adult regurgitates (Table 5.12), but Sandeel was not so important, occurring in less than 20% of the food samples. The overall composition of the diet, for the three years, was similar to that in 1984 and 1985, with whitefish and/or offal occurring in nearly all regurgitates. Offal was included in the category of whitefish as it often occurred with whitefish tissues and, in its semi-digested state, could not always be separated from other fish remains.

The diets of chicks and adults (summed for the three years) were found to differ significantly from each other (χ^2_2=13.6, $p<0.01$), with foods other than whitefish and Sandeel occurring more frequently in the diet of chicks than of adults. Chicks also consumed proportionately more Sandeel than did the adults, while the adults fed to a greater extent upon whitefish. As the diet of adults was only determined early in the season, seasonal differences, rather than real dietary differences between adults and chicks, cannot be ruled out. Sample sizes are too small to determine whether a statistical difference exists between the diet of incubating and brooding adults.

5.5 GREAT BLACK-BACKED GULL

During 1985, Rabbit and fish, followed next by bird, occurred most commonly in the pellets regurgitated by breeding Great Black-backed Gulls on Noss (Table 5.13; details in Appendix III). No information regarding the consumption of soft foods was gathered. The importance of Rabbit may be an overestimate, in that more than one pellet would have been regurgitated for each Rabbit consumed, whereas one fish generally gave rise to one regurgitated pellet (seen by the occurrence of a pair of otoliths in each pellet, as a rule). Kittiwake and auk chicks were the birds most commonly preyed upon.

Shellfish, excluding Mussel *Mytilus edulis*, occurred as food remains; these data have been treated separately from the pellets regurgitated by the Great Black-backed Gulls. Mussel occurred in pellets.

5.6 DISCUSSION

5.6.1 Herring Gull

Whitefish was the most common constituent in the regurgitates of Herring Gull chicks on Noss in each year 1983 to 1985, similar to the situation in Holland (Spaans, 1971) where marine fish occurred in over three quarters of the regurgitates.

The data collected on the diet of adult Herring Gulls in Shetland during this study contrast with analyses of food remains from Skomer, Pembrokeshire (Harris, 1965); there, marine invertebrates accounted for only 23% of food samples examined while the bulk of them (69%) contained human waste foods, of which fish from Milford Haven was very important. This utilisation of fish waste from Milford Haven was documented a decade later (Davis, 1975b), reflecting the continued use of a locally available and abundant source of human waste food. In other areas, the diets of Herring Gulls differ again. Analysis of pellets in Antrim revealed a strong reliance on terrestrial invertebrates (Melville, 1974). On Walney Island earthworms and other terrestrial invertebrates were also important sources of food, along with domestic waste from refuse tips, but Mussel and crabs were also commonly consumed (Sibly & McCleery, 1983b). In an inland-breeding population of Herring Gulls in southern Sweden, waste grain, earthworms and insects were frequently eaten, but were not as important as fish which were taken directly from the lake (Andersson, 1970). The Mediterranean Herring Gull *Larus argentatus michaelis*, although consuming predominantly terrestrial foods, took fish when they were available, both by active fishing but also by scavenging in the wake of human activities (Witt *et al.*, 1981). This again illustrates the opportunistic nature of Herring Gulls, which has also been emphasised by Haycock & Threlfall (1975) who found that gulls in Newfoundland concentrated on petrels, Mussel, human refuse and offal up to the time when most chicks were hatching. After this, the Herring Gulls switched their diet to Capelin *Mallotus villosus* which became locally abundant at this time. Herring Gulls utilise available food sources to the maximum by altering their feeding patterns within the day, for example by moving from the littoral zone at high tide to other sites such as refuse tips (Kihlman & Larsson 1974, Sibly & McCleery 1983b). The adaptive nature of the gulls in their dietary behaviour allows them to maximise intake of these intermittently abundant food supplies.

The almost total reliance of adult Herring Gulls in Shetland on intertidal invertebrates seems peculiar, in light of the above examples of gulls' diets in other areas. Domestic refuse is, perhaps, not so abundant in Shetland as elsewhere but it is not clear whether terrestrial invertebrates are scarce in Shetland. Although earthworms and other soft-bodied organisms would not be readily recorded in pellets regurgitated by adults, earthworm setae and hard-bodied invertebrates would provide obvious remains and yet they occurred only spasmodically; terrestrial invertebrates were also uncommon in the diet of chicks. Much lower numbers of Herring Gull adults were observed feeding on pasture than in the intertidal zone in Shetland. Fish were very much more important in the diet of chicks than of adults (similar to the situation in the north of Holland, Spaans 1971), indicating that the parents chose to feed this relatively high quality food to their young.

Although Herring Gulls are opportunistic feeders (e.g. Harris 1965, Haycock & Threlfall 1975), feeding on any locally abundant food supply, individuals or groups of individuals do often have preferences (e.g. Harris 1965, Davis 1975b). It has been shown that individuals tend to specialise on one or more of the foods available to them and that just because a food is available, it does not mean that it must be utilised (McCleery & Sibly, 1986). On Noss, where intertidal invertebrates occurred almost to the exclusion of other food types, perhaps the gulls were all specialists in feeding on intertidal invertebrates, or maybe they concentrated on this food as there were abundant supplies nearby both on Noss and Bressay. Herring Gulls were frequently observed feeding at the tideline on both islands. An alternative explanation. that Herring Gulls were unable to exploit available discards at fishing boats as a result of interspecific competition and size of discard fish, will be discussed later.

5.6.2 Great Skuas

In the diet of Great Skuas on Noss between 1983 and 1985, Sandeel was found to be largely unimportant, in sharp contrast to the situation on Foula between 1973 and 1976. Whereas less than 25% of the 17 chick regurgitates on Noss were of Sandeel, over 65% of 145 regurgitates on Foula contained Sandeel (Furness & Hislop, 1981). In the same study on Foula, approximately 42% of pellets regurgitated by breeding adults and 26% by non-breeders were of Sandeel; on Noss Sandeel was represented in about 1% and 10%, respectively, of pellets and food samples collected from May to August in the three years 1983-1985. In 1983 and 1984 it is believed that Sandeel stocks around Shetland were less than in preceding years (Heubeck, 1986) and this may explain why Great Skuas relied less on Sandeel in this study than found by Furness and Hislop (1981).

On Noss, up to 50% of the food samples collected on any one occasion in May and June represented Sandeel, but by late June and July this figure had decreased to zero on most occasions. The seasonal change in diet, with Sandeel occurring mainly in May and June, was also noted on Foula (Furness & Hislop, 1981) and in areas of the North Sea (Tasker *et al.*, 1985). On Hermaness, no remains whatsoever of Sandeel were found throughout the Great Skua colony, not unexpectedly as the visit was made in July at a time when Sandeel was not commonly recorded on Noss or Foula.

Seabirds constituted an important component of the adult Great Skua diet on Noss, occurring in nearly 50% of breeding adult food remains and in about 24% of non-breeding adult pellets. By contrast, seabirds were very much less common in the diet of all categories of Great Skua on Foula in the mid-1970's (Furness & Hislop, 1981). Seabirds were unimportant in the diet of chicks on Noss.

Kittiwakes were the commonest seabird prey of Great Skuas on Noss. This is compatible with other studies (e.g. Lockie 1952, Bayes *et al.* 1964, Andersson 1976, Furness 1979). In the Faeroes, fish and Kittiwake were the commonest food although other birds, such as Guillemot *Uria aalge* and Great Skua chicks, were preyed upon (Bayes *et al.*, 1964); specialisation was also common. Of 30 broods, over 80% concentrated solely on either Kittiwake or fish and only five broods fed on a combination of the two. In another site, Kittiwake eggs were the favourite food, with 200 being consumed within 19 days (Bayes *et* *al.*, 1964). This is very similar to the situation on Noss in 1985, where all the Kittiwake egg remains recorded were found within one territory. Kittiwake eggs were also recorded in the diet of birds in Hermaness (Lockie, 1952), although Kittiwake chicks assumed more importance in that study. At Signy Island, South Orkney the eggs and chicks of penguins (abundant seabirds, like Kittiwakes in Shetland) formed the most important food source in the diet of the Brown Skua, with fish assuming a minor role (Burton, 1968). Thieving was unimportant there, unlike most northern colonies, where kleptoparasitism is a common feature (e.g. Pitt 1922, Perry 1948, Ingram 1949, Andersson 1976, Furness 1978b, Tasker *et al.* 1985).

Cannibalism occurred on Noss in all years and is not rare in this species (e.g. Lockie 1952, Furness 1979). In one colony in Faeroe, only small Great Skua chicks (i.e. less than 3 days old) were taken by other Great Skuas (Bayes *et al.*, 1964) whereas on Noss many young were siezed shortly before they were due to fledge. Furness (1982a) comments that a shortage in Sandeel availability to seabirds in 1980 caused an increase in cannibalism amongst Great Skuas. Whether the level of cannibalism observed on Noss in an indication that the birds were having difficulty in obtaining food is uncertain. Great Skuas are opportunists (e.g. Burton, 1968) and it may be that unattended, wandering chicks on Noss provided an easy source of food for the Great Skuas. Certainly, the situation on Noss appears quite different to that on Foula in the 1970's, where Sandeel was generally an important component of the Great Skuas' diet. A sudden decline in Sandeel availability might indeed force the adults to kill chicks for food.

5.6.3 Fulmar

In studying the diet of the Fulmar on Noss, my categories of offal, fish and Sandeel preclude any direct comparisons with dietary information collected from Fulmars on Foula and St. Kilda (Furness & Todd, 1984), where small fish (including Sandeel) were placed in one category and fish offal was kept separate from whitefish flesh. If all fish and offal are combined in each study, the results are directly comparable. In that case, fish (including whitefish, offal and small fish and Sandeel) occurred in 86.4% of all Noss chick regurgitates, 96.7% of Noss adult regurgitates, 85.9% of Foula regurgitates (adult and chick combined) and only 8.4% of St. Kilda regurgitates. This reiterates the findings of Furness and Todd (1984) that very different modes of feeding were occurring between Shetland and St. Kilda, where pelagic zooplankton were the most important component of the Fulmar diet.

Man's waste also featured in the regurgitates of Fulmars studied by Furness and Todd (1984). Polystyrene, paper, plastic and metal occurred occasionally in the regurgitates of Foula birds but more commonly in samples collected on St. Kilda. Only one Fulmar regurgitate contained polystyrene during the three year study on Noss.

It is possible that the incidence of planktonic crustaceans consumed by Fulmars on Noss was actually higher than recorded. Crustaceans are digested extremely rapidly, so that there may be no sign of crustaceans in a regurgitate, although a red colour may persist (Fisher, 1952). On Noss, many of the regurgitates were coloured, generally red or green, and it is quite possible that the red hue represented the remnants of a crustacean meal. The comparison of diet between years will not be invalidated, assuming that random choice will ensure an even spread of recently-arrived adults, or recently-fed chicks, being handled; these birds will regurgitate food that is less digested and so more readily recognisable.

5.6.4 Great Black-backed Gull

The diet of breeding Great Black-backed Gulls on Noss, consisting chiefly of shellfish, Rabbit, whitefish and bird, showed some similarities to Great Black-backed Gull diets elsewhere, although shellfish assumed more importance on Noss than in other studies (e.g. on Skomer, Harris 1965). In other areas, fish was the most important food type recorded, for example, Am Balg, W. Sutherland (Parslow & Bourne, 1973) and Iceland (Ingolfsson, 1976).

Only seven pairs of Great Black-backed Gulls nested on mainland Noss in 1985, the remainder breeding on Cradle Holm, an adjacent stack. The stack was inaccessible, so food samples were mostly collected from only the seven sites mentioned, but some were also taken from opposite the stack. Owing to the small number of pairs involved, individual preferences and specialisation will have a strong effect on the total composition of diet recorded. Specialisation is common amongst Great Black-backed Gulls (e.g. Saunders 1962, Parslow 1973) and on Noss most of the Kittiwake corpses in 1985, for example, occurred at one site. Similarly, on Skokholm some birds were found to concentrate on Manx

Shearwaters whilst others fed mainly on Rabbit or on fish (Conder, 1952).

On Noss, the seven, solitary sites studied were scattered along the north and east of the island, whereas on Cradle Holm a minimum of 90 pairs nested in 1985. It is quite possible that the birds breeding on Cradle Holm could have had a different diet from those on Noss itself, as work carried out on Great Saltee Island, Ireland showed that colonial breeding Great Black-backed Gulls concentrated on marine food (especially fish), whereas the solitary nesters concentrated on auk and gull chicks (Hudson, 1982). As the sample size of nests under study on Noss was small, no firm conclusions may be drawn, especially as the birds appear to have a varied diet, relying on shellfish, Rabbit, whitefish and birds each to some considerable extent.

5.7 CONCLUSIONS

This study has shown that whitefish discards form a major part of the diet of breeding and non-breeding Great Skuas and of Great Skua chicks, particularly when Sandeel availability is thought to be low. Offal and discards are also important in the Fulmar diet and form a major part of the Great Black-backed Gull diet. Although possibly important in the diet of Herring Gull chicks, discards are not an important component of the adults' diet.

CHAPTER 6

DIETS OF SCAVENGING SEABIRDS ON NOSS AND MAINLAND SHETLAND: OTOLITH IDENTIFICATION

6.1 INTRODUCTION

In Chapter 5, the general diet of scavenging seabirds was examined, but individual fish species may also be identified from otoliths, which are regurgitated by gulls and Great Skuas. This information can then be compared with the actual species of fish being discarded from whitefish trawlers fishing around Shetland (see Chapter 8). The percentage occurrence of each fish species is not necessarily a reflection of the importance of each species in the diet of the birds because sizes of fish vary and the fish vary in calorific content, both between species and between sizes (Furness & Hislop 1981, this study). However, the percentages may be compared between species of bird consumer to examine differences in feeding habits between them.

The results of data collected on Noss will be presented first followed by results from Foula and then mainland Shetland sites. Comparisons of fish lengths consumed will be made between areas and species.

6.2 OTOLITHS COLLECTED ON NOSS

6.2.1 Fish species

Between 1983 and 1985, 2070 otoliths were collected on Noss, 611 in 1983, 548 in 1984 and 911 in 1985 (Table 6.1). Most of these (66%) occurred in pellets regurgitated by Great Skuas on club sites, partly owing to the fact that food remains were concentrated into a small area of low vegetation cover and were thus easy to find.

Otoliths from Haddock and Whiting were generally the most numerous, although in non-breeding Great Skua pellets Norway Pout otoliths were second in importance (numerically) to Haddock and slightly more common than Whiting (Table 6.1). In fact, the number of Norway Pout recorded could be a slight overestimate as the otoliths are very similar to those of Poor Cod *Trisopterus minutus* and Bib *Trisopterus luscus* and some may have been wrongly identified. However, as the latter two species did not occur very frequently, this possible source of error will be minimal. Norway Pout otoliths did not occur very commonly in the pellets regurgitated by breeding Great Skuas.

Breeding Great Skuas consumed more Whiting than Haddock, whereas the non-breeders consumed more Haddock than Whiting; the difference between the fish species taken by breeders and non-breeders was significant (χ^2_1=12.91, p<0.001). Breeding Herring Gulls consumed approximately one and a half times more Whiting than Haddock, as determined from otolith identification, although sample sizes were small (Table 6.1). Conversely, breeding Great Black-backed Gulls consumed approximately two and a half times more Haddock than Whiting, the difference in diet from breeding Herring Gulls being significant (χ^2_1=30.25, p<0.001). The possible reasons for this may become clear when the sizes of fish consumed are examined.

Species of fish other than Haddock, Whiting and Norway Pout were unimportant constituents of pellets on Noss except for Sandeel, which represented 20% of otoliths identified from the pellets of non-breeding Great Skuas (Table 6.1).

6.2.2 Fish length

Median otolith lengths and equivalent fish lengths are presented for the five fish species Haddock, Whiting, Cod *Gadus morrhua*, Norway Pout and Sandeel (Table 6.2; details in Appendix IV). Comparisons of fish lengths consumed were made (when n > 20) using the two-tailed Kolmogorov-Smirnov test (Siegel, 1965). Where a D value is quoted below the associated probability is less than 5% unless otherwise stated.

Breeding Great Skuas consumed significantly larger Whiting than did non-breeders, although this difference was small (D=0.1769, n_1=141, n_2=309). Similarly, breeders took larger Haddock than did the non-breeders but, again, this difference was very small (D=0.1789, n_1=92, n_2=355). Breeding skuas appeared to consume much smaller Cod than the non-breeders, but the sample sizes in each case were small (six and seven respectively), making statistical testing inappropriate. Breeding and non-breeding Great Skuas took Norway Pout of a similar length. The length of Haddock consumed by both breeding and non-breeding Great Skuas was very obviously less than that of Whiting (Table 6.2).

The median length of Haddock consumed by breeding Great Black-backed Gulls was greater than the median length consumed by breeding Great Skuas (D=0.2038, n_1=188, n_2=92) and by non-breeding Great Skuas

($D=0.3159$, $n_1=188$, $n_2=356$). Similarly, breeding Great Black-backed Gulls took longer Whiting than did non-breeding Great Skuas ($D=0.3047$, $n_1=78$, $n_2=309$) but in the same length range as eaten by the breeding Great Skuas.

Herring Gulls, surprisingly, fed on large fish (Table 6.2). This was unexpected as Herring Gulls are smaller than Great Black-backed Gulls and one might have predicted that they would feed on smaller fish as a result. The median length of Whiting regurgitated by breeding Herring Gulls on Noss was significantly greater than the median length regurgitated by breeding Great Black-backed Gulls ($D=0.3404$, $n_1=58$, $n_2=78$), but there was no significant difference in the lengths of Haddock taken by each group of birds. The median length of Cod taken by breeding Herring Gulls was, at 36.9 - 40.8cm, about 5cm longer than the median length consumed by Great Black-backed Gulls (although the sample size was only four).

6.3 OTOLITHS COLLECTED ON FOULA

6.3.1 Fish species

The fish species from 3791 otoliths that had been collected on Foula in 1975 and between 1980 and 1985 were identified (Table 6.3). Otoliths from Whiting and Haddock accounted for over 85% of all otoliths examined. Significantly more Whiting otoliths occurred in pellets regurgitated by non-breeding Great Skuas and by non-breeding Great Black-backed Gulls than by breeding Great Skuas ($\chi^2_2=35.37$, $p<0.001$), although more Whiting than Haddock otoliths were regurgitated by breeding Great Skuas. Breeding Great Black-backed Gulls regurgitated more Haddock otoliths, but the sample sizes were small for both Haddock and Whiting. Norway Pout was not very common amongst any group. Sandeel occurred infrequently. Sandeel represented 12%, by number, of otoliths regurgitated by non-breeding Great Skuas. Sandeel otoliths are small enough to pass through the intestine of Great Black-backed Gulls and so tend not to be regurgitated by that species, but no Sandeel otoliths were found in the droppings of Herring Gulls or of Great Skuas.

6.3.2 Fish length

Non-breeding Great Skuas consumed larger Whiting than did breeders (D=0.2542, n_1=879, n_2=187), contrasting with the situation on Noss (Table 6.4). No significant difference was apparent between the lengths of Haddock taken by the two groups of Great Skua. Non-breeding Great Black-backed Gulls fed on larger Whiting than did non-breeding Great Skuas (D=0.2344, n_1=893, n_2=879) and so it also follows that they took longer Whiting than did breeding Great Skuas. Non-breeding Great Black-backed Gulls also took longer Haddock than did non-breeding Great Skuas (D=0.3879, n_1=699, n_2=436) or breeding Great Skuas (D=0.4373, n_1=699, n_2=130). The lengths of Sandeel taken by non-breeding Great Skuas were very much longer than those taken by breeding Great Black-backed Gulls (D=0.4646, n_1=185, n_2=193). However the otoliths for the breeding Great Black-backed Gulls were collected from faecal pellets and thus more erosion of the otoliths probably had occurred.

6.4 OTOLITHS COLLECTED ON MAINLAND SHETLAND

6.4.1 Fish species

Of 1275 otoliths collected from pellets regurgitated by gulls on mainland Shetland, over half came from loafing sites frequented by non-breeding Great Black-backed Gulls (Table 6.5). Whiting and Haddock jointly accounted for over 95% of all the otoliths examined, with other fish species assuming minor importance (Table 6.5).

6.4.2 Fish length

The median otolith and fish lengths were determined for each group of gulls (Table 6.6). Breeding Herring Gulls consumed larger Whiting than did breeding Lesser Black-backed Gulls in 1985 (D=0.5276, n_1=149, n_2=42), a mixed colony of breeding Lesser Black-backed Gulls and Herring Gulls in 1980 (D=0.5528, n_1=149, n_2=41) or non-breeding Great Black-backed Gulls in 1985 (D=0.2753, n_1=149, n_2=318). There was no significant difference in the length of Whiting taken by breeding Herring Gulls or by gulls feeding on fish from the fish factory at Scalloway (determined from otoliths collected from the north point of Trondra and from Scalloway Harbour).

The Haddock taken by breeding Herring Gulls were longer than those taken by breeding Lesser Black-backed Gulls (D=0.4908, n_1=129, n_2=35) or by non-breeding Great Black-backed Gulls (D=0.2820, n_1=129, n_2=337), but the same length as those taken by gulls loafing at Trondra and Scalloway.

Breeding Lesser Black-backed Gulls fed on smaller Whiting (D=0.3221, n_1=42, n_2=318) and Haddock (D=0.2862, n_1=35, n_2=337) than did non-breeding Great Black-backed Gulls in 1985. A mixed colony of breeding Lesser Black-backed Gulls and Herring Gulls in 1980 fed on Whiting of a similar length to those eaten by breeding Lesser Black-backed Gulls in 1985 and smaller than those taken by non-breeding Great Black-backed Gulls in 1985 (D=0.3055, n_1=41, n_2=318). This suggests that perhaps the mixed colony was composed mainly of Lesser Black-backed Gulls or that the otoliths were collected from pellets that had been regurgitated by Lesser Black-backed rather than Herring Gulls.

6.5 COMPARISONS BETWEEN SITES

There were no significant differences between the lengths of Whiting and Haddock consumed by breeding Herring Gulls on Noss or on mainland Shetland.

Breeding Great Skuas on Noss consumed larger Whiting than did breeding Great Skuas on Foula (D=0.2694, n_1=141, n_2=187), but this difference was not significant when otoliths collected in 1975 on Foula were omitted; those otoliths from Foula in 1975 were significantly smaller than those collected from 1980 to 1985 on Foula (D=0.5328, n_1=95, n_2=92). No significant difference was apparent in the length of Haddock consumed by Great Skuas on Noss and on Foula. However, the Whiting taken by non-breeding Great Skuas on Noss were significantly smaller than those taken by Foula birds (D=0.1617, n_1=309, n_2=879), as was Haddock (D=0.1713, n_1=356, n_2=436). Similarly, non-breeding Great Black-backed Gulls on Foula took larger Whiting (D=0.1207, n_1=893, n_2=318) and Haddock (D=0.1231, n_1=699, n_2=337) than did non-breeding Great Black-backed Gulls on mainland Shetland.

6.6 COMPARISONS BETWEEN BIRD SPECIES

Although certain slight differences were apparent in the lengths of fish taken by birds from different areas, the data for each group of birds (breeding or non-breeding of each species) were combined so that overall comparisons could be made between the lengths of fish consumed by breeders amd non-breeders, regardless of their breeding or loafing areas. All otoliths were included; thus the few otolith measurements from Great Skua pellets collected from Hermaness were included in the grand total.

Overall, the otolith lengths of Whiting regurgitated by breeding Great Skuas was significantly smaller than the lengths regurgitated by non-breeding Great Skuas ($D=0.0981$, $n_1=329$, $n_2=1189$), although this difference was small (details in Appendix IV). Breeding Great Black-backed Gulls consumed Whiting of a similar length to those taken by non-breeding Great Black-backed Gulls; non-breeding Great Black-backed Gulls took larger Whiting than did non-breeding Great Skuas ($D=0.2404$, $n_1=1211$, $n_2=1184$). The frequency of occurrence of otoliths of differing lengths is illustrated (Fig. 6.1).

The data for non-breeding and breeding Great Skuas and for non-breeding and breeding Great Black-backed Gulls were combined to allow comparisons with the fish sizes taken behind trawlers, where no distinction could be made between breeders and non-breeders (cf. Chapter 8). Overall, Great Black-backed Gulls consumed larger Whiting than did Great Skuas ($D=0.2517$, $n_1=1299$, $n_2=1518$). Breeding Herring Gulls took larger Whiting than did Great Skuas ($D=0.4708$, $n_1=208$, $n_2=1518$) or Great Black-backed Gulls ($D=0.3095$, $n_1=208$, $n_2=1299$) (Figs. 6.1, 6.3).

A similar situation was observed with the lengths of Haddock taken by the different birds, although breeding and non-breeding Great Skuas took Haddock of a similar length. Likewise, the length of Haddock taken by breeding and non-breeding Great Black-backed Gulls did not differ significantly from each other. The frequency of occurrence of otolith lengths is illustrated (Fig. 6.2).

The length of Haddock taken by all Great Skuas, regardless of their breeding status, was significantly smaller than the length taken by all Great Black-backed Gulls (including breeders and non-breeders) ($D=0.2965$, $n_1=1016$, $n_2=1247$). As for Whiting, Herring Gulls took Haddock that were significantly longer than those taken by Great Skuas

($D=0.4315$, $n_1=164$, $n_2=1016$) or by Great Black-backed Gulls ($D=0.2027$, $n_1=164$, $n_2=1247$) (Figs. 6.2, 6.3).

6.7 COMPARISONS BETWEEN FISH SPECIES

The lengths of Haddock and Whiting consumed by the seabirds were compared. Mean fish lengths consumed were determined by taking the mid-point of each size class, calculated from the otolith lengths; for example, Whiting in the size range 24.7-26.1cm (=13.5-14.5 otolith length) were all classed as being 25.4 cm long. The mean length of Whiting taken by seabirds was significantly longer than the mean length of Haddock, calculated from otoliths regurgitated by Great Skuas ($d=23.95$, $p<0.05$), Great Black-backed Gulls ($d=22.30$, $p<0.05$) and Herring Gulls ($d=7.77$, $p<0.05$).

6.8 DISCUSSION

The problems of making quantitative assessments of diet by otolith analysis have been discussed elsewhere (M. Jobling & A. Breiby, unpubl.). In this study, the occurrence and lengths of otoliths that had been regurgitated by gulls and skuas have been compared between sites and between species of bird. Gadoid otoliths are more resistant to erosion than are clupeid otoliths (M. Jobling & A. Breiby, unpubl.) and Whiting and Haddock occurred most commonly, with other gadoid species being largely unimportant. Thus, it is safe to conclude that these two fish species were indeed important in gull and skua diets in Shetland during the present study. Similarly, on Foula in 1975 (Furness & Hislop, 1981) and on Hermaness between 1974 and 1984 (T. Martin, pers. comm.) Haddock, Whiting and also Norway Pout were the most numerous whitefish species to be identified from otoliths regurgitated by Great Skuas. If errors in the fish length estimates from otolith measurements were occurring, one would expect Whiting lengths to be most greatly affected, as these have a long, thin, brittle point which is easily broken. However, a large proportion of all Whiting otoliths examined had an entire point, indicating that little abrasion had occurred. Otoliths in pellets regurgitated by gulls and skuas showed little or no signs of erosion and it is most unlikely that their lengths were reduced or that otoliths of other species were destroyed while in the bird stomachs. If the otoliths had been collected from faeces, more erosion, following the effects of gastric juices during digestion, and also abrasion would probably have occurred, resulting in less comparable results.

Many otoliths were entire but some were not and, as stated in the methods section, their breadth was used to estimate their length. If this introduced an error, it would have affected all groups of bird pellets (assuming an even and random distribution of broken otoliths), so comparisons are still valid. The error involved is thought to be minimal in that estimated lengths did not measure much less nor much more than entire otoliths. If otolith length was over- or under-estimated by even 1mm, it would have made a difference of 1.5-2cm in the calculated fish length of Whiting and Haddock. Actual fish length consumed at sea is needed as an independent method of assessing median fish lengths taken by each group of birds. This will be discussed in Chapter 8.

The length of Whiting otoliths occurring on Foula in the mid-1970's was smaller than recorded in this study, for which there are two possible explanations. Whiting otoliths collected in 1975 on Foula (Furness & Hislop, 1981) were remeasured in this study and my measurements showed that these otoliths were significantly smaller than those collected in the early 1980's, but they were longer than quoted by Furness & Hislop (1981). The length of otoliths with abraided ends may easily be slightly underestimated and the assessment of otolith length may partly account for the differences observed. As mentioned earlier, 1mm difference in otolith measurement accounts for 1.5cm fish length in Whiting. The differences observed between this study and that of Furness and Hislop (1981) appear to be a combination of real and observer differences. Many entire otoliths collected during this study have exceeded the maximum otolith lengths collected by Furness and Hislop (1981); thus, it is possible that some fish of longer length are now being discarded. As gadoid fish are demersal, they are not generally available to seabirds (being too deep in the water) and so it is assumed that all Cod, Haddock and Whiting were obtained from trawlers, either at sea or from fish markets.

No differences were apparent between breeding and non-breeding Great Black-backed Gulls in the average lengths of Haddock or of Whiting that they took. However, breeding Great Skuas generally took smaller Whiting than the non-breeders took, although no significant differences were evident between the lengths of Haddock taken by breeders and non-breeders. Curiously, the situation on Noss was the reverse, with breeding Great Skuas taking larger Whiting and Haddock than the non-breeders.

Overall, Herring Gulls consumed larger Whiting and Haddock than did Lesser Black-backed Gulls, Great Black-backed Gulls or Great Skuas. Great Black-backed Gulls took longer fish than did Lesser Black-backed Gulls and Great Skuas.

The fact that Herring Gulls took the largest fish may be explained by their habit of foraging at harbours and fish markets. They may often be seen standing on top of fish lorries, pecking through the canvas covering to try and steal fish. For example, one Cod consumed by a breeding Herring Gull on Noss in 1983 measured approximately 55cm, as determined from an otolith measuring 17mm (Appendix IV). It is unlikely that such a large Cod would be discarded at sea and also unlikely that a Herring Gull could consume a fish of this length at sea, as discussed later (Chapter 8). More probable is the explanation that it ate either just the head or the whole fish in Lerwick Harbour.

The length of Whiting taken by Herring Gulls, Great Black-backed Gulls and Great Skuas was significantly greater than the length of Haddock; Haddock has a wider girth than Whiting and this may contribute to the smaller length of Haddock taken by seabirds.

It would appear that an important part of all the whitefish eaten by Herring Gulls is obtained on land or at harbours, by stealing from the marketable catch, while Great Black-backed Gulls and Great Skuas obtain almost all of their whitefish as discards at fishing boats. The evidence for selection of particular size classes of whitefish will be considered in Chapter 8.

CHAPTER 7

BIRD NUMBERS AT TRAWLERS AND QUANTITIES OF FISH CAUGHT AND DISCARDED

7.1 INTRODUCTION

The numbers of seabirds attending whitefish trawlers and the quantities of food discarded by the boats need to be determined in order to assess the amounts of food available to seabirds and the use seabirds may make of this. The potential importance of fishery waste in supporting populations of seabirds in Shetland may then be assessed.

In this chapter I present data on the numbers of birds of different species observed behind whitefish trawlers in Shetland waters during 1984 and 1985. Birds were also counted behind sandeel boats and a herring boat in 1984, as described in section 3.4.2. The distance from the shore may be important in determining bird numbers and species composition and this aspect is also discussed. Aerial observations provided additional information on the numbers of birds attending trawlers over a wider area of sea to give an average value for birds per boat at any one moment.

Since individual seabirds may attend a trawler for a long or short, but unknown, period of time, counts of birds present at any one moment provide no data on the turnover rate of seabirds at trawlers. For example, on one occasion a Gannet was observed approaching the trawler during discarding; it then consumed three fish within a few minutes, before flying away again. If all Gannets only remain at trawlers for a short period of time, then the total number obtaining food will be greater than that indicated by "instantaneous" counts. Nevertheless, counts of birds present provide a useful comparison with studies carried out elsewhere (e.g. Watson, 1981) and allow comparisons between different areas being fished and between seasons. They also provide a gross indication of the relative numbers of different species exploiting fishery waste, although this aspect is most sensitive to species-differences in the time spent at boats by individual birds.

Quantities of fish landed on deck and quantities then discarded or kept for market were determined, as outlined in section 3.4.4.. The ratios so established were used to estimate quantities of fish discarded over a long period of time by examining market landings (DAFS data). In a similar manner, quantities of offal were also determined. The proportions of discards and offal consumed by seabirds were recorded from trips on trawlers and the average value obtained has been used to calculate total amounts consumed, by combining these data with DAFS records of market landings. By estimating the food requirements of scavenging seabirds from bioenergetics studies and combining this with calculated quantities of offal and discards consumed by seabirds, an estimate of the **maximum** number of birds which could be supported by this food supply has been calculated.

7.2 NUMBERS OF BIRDS ATTENDING TRAWLERS

7.2.1 Observations from whitefish trawlers

The average of the maximum number of each bird species present around a trawler for each haul was taken for each fishing trip made in 1984 (Table 7.1) and 1985 (Appendix V; seasonal summary presented in Table 7.2).

The Fulmar was generally the most numerous species to occur and the Great Black-backed Gull was the next most abundant species. Maxima of 2,500 Fulmars and 1,100 Great Black-backed Gulls were recorded at any one haul. Herring Gulls normally occurred in smaller numbers during the summer, usually ranging from 0 to 50 but sometimes up to 400 birds. On four occasions (17.07.84, 29.07.85, 09.08.85 and 02.09.85) the numbers of Herring Gulls recorded increased substantially during the final haul, with up to 800 birds present as the trawlers approached Scalloway Harbour. These birds flew out from the Scalloway Islands and had not attended the trawlers further out to sea and they only obtained food from the last haul. Thus, close inshore, Herring Gull numbers were high and Fulmar numbers were low. (See below for further analysis of this point.)

Great Skuas were present at most hauls, the main exceptions being when fishing was conducted near Papa Stour and Ve Skerries (Fig. 3.2). Only two pairs of Great Skuas nested on Papa Stour in 1985 (pers. obs.) and this may explain the scarcity of skuas attending fishing vessels in the vicinity. In all cases, no more than 75 Great Skuas were recorded at any one time at any one haul.

Gannets were present on all trips but not at every haul. Numbers were generally low but up to 200 were recorded on 18.06.85 as we steamed fast for Papa Stour; 100 were present when fishing to the east of Unst on 19.08.85.

Lesser Black-backed Gulls were often present in low numbers, but they were absent altogether for many hauls. Very low numbers of Black-headed Gulls *Larus ridibundus*, Storm Petrels *Hydrobates pelagicus*, Arctic Skuas, Arctic Terns *Sterna paradisaea*, Sooty Shearwaters *Puffinus griseus*, Shags and Puffins were recorded following close to fishing boats. There is no evidence that they were all involved in feeding on fishery waste. The Sooty Shearwaters were seen to surface-dive, which would suggest feeding, but whether on fishery waste or independent feeding could not be ascertained. As numbers of these species were always low their role in discard consumption is thought to be minimal.

The proportions of adult and non-adult birds were recorded for gulls and Gannets for as many hauls as was practicable (Table 7.3). Exceptions were in poor visibility and when the feeding flocks were far behind the trawlers. For all species that could be aged by plumage, most birds at the trawlers appeared to be in adult plumage.

The mean numbers of birds behind whitefish trawlers in 1985 was compared between seasons, that is between March (the pre-breeding season), April until July (the breeding season) and August to September (the post-breeding season). No significant differences were observed between bird numbers at trawlers during and after the breeding season. Mean Fulmar numbers were higher in March than during the breeding season but this difference was not significant. However, the March numbers were significantly higher than those recorded in August and September ($d_{5,5}$ = 2.59, $p<0.05$). Fewer Great Black-backed Gulls occurred behind whitefish trawlers in March than during the breeding season ($d_{8,6}$ = 2.50, $p<0.05$) and than during the post-breeding season, although the latter difference was not statistically significant. More Herring Gulls were observed behind whitefish trawlers in March than during the breeding season (d_5 = 4.95, $p<0.01$) or the post-breeding season (d_5 = 4.95, $p<0.01$). Gannet numbers were similar between all seasons. Great Skuas were not observed in March, as they had not returned to the breeding grounds by this stage. Kittiwake numbers, always low, did not differ significantly between seasons. Very few Lesser Black-backed Gulls were recorded in any season.

The effect that distance from the shore might have on bird numbers and species composition was not easy to test for; as boats neared the shore, the numbers of birds were continually changing and there was no sudden cut-off point at any specific distance from the shore. However, on the occasions when gutting continued until the boats were close to land, it was obvious from observations from the boats that the roles of Fulmars and Herring Gulls interchanged, with Herring Gulls becoming increasingly more plentiful. The peak numbers of Herring Gulls and Fulmars observed behind the trawlers during the early stages of gutting and discarding out at sea were compared with the numbers observed during the later stages of gutting and discarding as the boats neared Scalloway Harbour. On the four occasions noted above, significantly fewer Fulmars and more Herring Gulls occurred close inshore (less than two miles from land) compared to further out to sea (statistics in Table 7.4).

7.2.2 Observations from sandeel and herring boats.

The numbers of birds attending sandeel boats were recorded directly from a sandeel boat (Table 7.5) and also by observations from Noss and on a Zodiac inflatable (Table 7.6). Herring Gulls occurred in highest numbers, to a maximum of 150 birds and smaller numbers of Great Black-backed Gulls, Fulmars, Great Skuas and Gannets were observed. Lesser Black-backed Gulls and Kittiwakes were always scarce. Arctic Terns and Black Guillemots *Cepphus grylle* occurred in very low numbers on 18 July; the terns were observed dipping to the water surface as the net was hauled in and they may have obtained some Sandeels. From a distance the presence of these birds in low numbers would be difficult to detect, so they could have occurred more often than they were recorded from Noss. Very little waste food was discarded, although the gulls did manage to obtain a few Sandeels.

Although Herring Gulls predominated behind sandeel trawlers, the actual numbers present were fewer than behind whitefish boats during the breeding season in 1984 and 1985 ($d = 2.81$, $p<0.05$, Wilcoxon's rank sum test for two samples) and my observations indicated that seabirds obtained little food from the activities of sandeel boats.

One trip on a herring boat (7-9 August 1984) provided data on the numbers of birds present at one haul. The catch was hauled aboard between 2400 and 0125 hours (8-9 August) when it was pitch dark. Unusually, the fish were loaded immediately into the hold rather than being floated to allow evacuation of the fish stomachs. Approximately

1200 Fulmars, 20 Great Black-backed Gulls and 20 Herring Gulls were present. Owing to the darkness, it was not possible to see whether these birds had flown directly from one of the other six herring boats fishing in the vicinity or whether they had come from further afield. Some fish were lost overboard but this loss was minimal and very little food was available to the birds. Discussions with fishermen indicate that these observations were typical. However, the large number of Fulmars attracted on this one occasion suggests that they normally obtain some food, perhaps the spilt stomach contents of fish that have been left to float outside the boat.

7.2.3 Aerial observations.

The mean number of birds observed behind whitefish trawlers during aerial observations are presented for each season (Table 7.7a; details are in Appendix V). Although mean numbers appeared to differ between seasons, they were statistically similar (χ^2_3 = 1.08, p>0.05, Kruskall Wallis one-way analysis of variance by ranks test); the October count was omitted from the comparison as it included only one boat.

Significantly more birds (χ^2_1 = 5.17, p<0.05, Kruskall Wallis test) were observed far from land (greater than 15 miles) compared with numbers occurring behind whitefish trawlers within 15 miles of the shore (Table 7.7b).

The numbers of birds of different species attending trawlers were also examined and the Fulmar was found to be the most numerous species to occur. On those occasions when counts of each species present could not be made with any degree of accuracy, it was, nevertheless, obvious that Fulmars made up the bulk of the flock. Excluding the October count (n = 1), the numbers of Fulmars behind trawlers were compared between seasons (Table 7.8a), but no significant differences were evident (χ^2_3 = 1.19, p>0.05, Kruskal-Wallis test). However, significantly more Fulmars occurred behind trawlers far from land (i.e. greater than or equal to 15 miles from the shore, Table 7.8b) than close to shore (χ^2_1 = 5.28, p<0.05, Kruskal-Wallis test).

7.3 DISCARD RATES

7.3.1 Proportion of catch discarded

The total amounts of fish caught during each fishing trip are presented (Table 7.9). The discard rates, by total volume, varied from 7% to 82% but, on average, about 27% by volume of a catch was discarded.

The quantities of fish landed on board the trawlers and the quantities then discarded were quantified in terms of boxes. To equate this with data supplied by DAFS and to assess the weight of food available to seabirds, the boxes must be converted to weight.

The weight of one "box" of fish varies between regions and, prior to 1985, was considered to be 6.2 stones (39.37kg) in Lerwick (Jermyn, 1985). However, boxes are now supposed to weigh a standard amount for particular fish species, 45kg per box for Cod and 48kg per box for Haddock and Whiting (R. Johnson, pers. comm.). About a hundredweight of flatfish sell per box (or *ca.* 50 kg). To cater for these different values, an average of 7 stone (44.45kg) was used in my calculation; this is a compromise between the extremes estimated by others.

During the fishing trips on which I made observations in Shetland in 1985, approximately 1891 boxes were hauled, of which 1385 were landed and 506 discarded. The weight of fish was determined by multiplication, assuming that each box weighed 44.45 kg. Thus, 84055 kg were hauled, of which 61563 kg were landed for market and 22492 kg were discarded. The inaccuracies incurred by assuming that a box of small discards weighs the same as a box of large, marketable fish will be offset by the fact that each box for market is assumed to weigh 44.45kg (or 7 stone), whereas some will weigh less than this. In fact, a box of small discards will weigh slightly more than a box of large fish, since small fish fill the box more easily than large fish.

In Shetland, landings refer to gutted weight which represents 85-90% of round (ungutted) fish weight (Boswall 1960, Bailey & Hislop 1978). In this study, round weight was calculated using the formula

Round weight = Gutted weight X 1.125 (Jermyn, *in litt.*)

and the weight of offal was therefore equivalent to 11.1% of the round weight, or 12.5% of the landed weight. Thus, from the Shetland trips I made in 1985, approximately 7695 kg of offal would have been discarded.

7.3.2 Proportion of discards consumed by seabirds

For each haul, the proportion of discards consumed by seabirds was estimated. Details of feeding behaviour by each seabird species are presented in Chapter 8; here, solely the quantities consumed will be discussed.

Generally, where discard rates were low, the proportion of discards consumed was high, that is, if very little food was available to the birds very little of it was wasted. If very few birds, apart from Fulmars, were present, few of the discards were consumed. However, if huge amounts of waste fish were discarded en masse, more fish were liable to sink. In general, however, the fishing practices of the light trawlers and seine netters are such that there is a more or less continual flow of fish going overboard during the gutting and discarding process. This is especially true for boats with no shelter deck, where the fishermen gut, sort and discard fish simultaneously which results in a steady supply of waste fish for the birds. In boats with shelter decks, the fish collect in an inner gutter and are washed out by a hose so that there is a slight lull between bouts of discarding.

The offal was consumed beside the boat and virtually all of it was taken by Fulmars. The gulls and skuas were excluded from this area by the sheer volume of numbers and the aggression of Fulmars present. The Fulmars closest to the boat took the liver in preference and peripheral birds ate the entrails. At this stage, Great Black-backed Gulls, sometimes, and Great Skuas, rarely, obtained bits of stomachs. I estimated that 90-100% of discarded offal was consumed.

The discarded fish were consumed further behind the boat, as a result of the exclusion of other bird species from near to the trawler by Fulmars. Overall, about 75% of all discards were estimated to be consumed (Table 7.9). Discard consumption rates were recorded as less than 60% in only four out of 23 trips and exceeded 90% in seven out of 23 trips. To some extent, these estimates assume that the birds attempting to take discards far behind the boat are as likely to be successful as those that could be watched close to the boat. I was usually able to observe about half of the discards actually being consumed and inferred that about half of those that were left behind by the boat will also have been taken. By watching birds feeding behind other boats passing the one I was on I was able to see that birds were successfully taking discards out of the water long after the boat had passed by. Fish can float for some time (experiments from Millport on the Isle of Cumbrae showed that whitefish may float for over 5 minutes) and also they are often lifted to the surface by turbulence in the trawler's wake. They were observed being consumed as far behind the boat as the eye could see. Dense flocks of gulls, with Gannets and Great Skuas also generally present, were to be seen taking fish from the surface, diving for them (especially in the case of Gannets) and fighting over fish, long after the boat had left the area in which it discharged the fish.

My observations indicated that the numbers of fish that seabirds found difficult to swallow largely determined the discard consumption rates. Consumption was low when many flatfish, Dogfish or large gurnards were discarded (rare during this study) but high when many small whitefish were discarded. The Dogfish survived better than whitefish and swam to deeper water when discarded; the flatfish sank more quickly than whitefish in addition to being more difficult for seabirds to eat. As small whitefish made up the bulk of the discards, they provided a greater supply of food that the seabirds could successfully exploit. Also, when many gulls, Great Skuas and Gannets were present as the fish were being discarded, most of the waste was consumed. The efficiency with which birds can swallow fish is discussed in the following chapter.

In the hours of darkness, no observations of fish being consumed far behind the boat were possible, but birds were observed to feed on discards close to the boat. The estimates of discard consumption were based on the types of discards going overboard and the number and species of birds present, as discussed above. On only one trip (18-21.08.85) were the discard consumption rates during darkness estimated to be very low (approximately 50% and less than 10% during the two night hauls), whereas during other hauls conducted during darkness the consumption rates appeared to be as high as during daylight hours (e.g. 05-07.08.85; 07-09.08.85). Most of the small seine trawlers fished during daylight hours, while the other trawlers fished both during the night and day. However, in summer in Shetland, very few hours of darkness are experienced and so few hauls will be conducted during darkness.

7.4 YEARLY FISH LANDINGS IN SHETLAND

7.4.1 Calculations of amount of food discarded

Landings of total demersal fish, in 100kg units, by UK vessels fishing within statistical rectangles surrounding Shetland are provided by DAFS for each month of the year for each statistical rectangle and for each major method of fishing, i.e. motor trawl, light trawl and seine net. No data on pair trawling are presented. The landings for 1983, 1984 and 1985 have been analysed in detail.

The nine statistical rectangles immediately surrounding Shetland (50E7, 50E8, 50E9, 49E7, 49E8, 49E9, 48E7, 48E8, 48E9, Fig. 7.1) form an area which I will refer to as the inner Shetland zone. I will refer to the nineteen statistical rectangles outside this inner zone as the outer Shetland zone. The two zones are being separated because I conducted observations from whitefish trawlers within the inner zone only. Also, I only went out on Shetland boats and so gained no information on discarding practices of boats from elsewhere. Aerial observations covered areas of sea further from land than those fishing boats on which I travelled, especially to the north of Shetland, and again indicated that Fulmars were much the most abundant seabird species present. One cannot assume that a similar situation pertains within both the inner and outer zones. However, the total amount of food made available to seabirds, in the form of discards and offal, can be calculated and thus the maximum number of birds capable of being sustained by fishery waste may be assessed.

The fish landings for the inner and outer Shetland areas were summed to estimate the total amount of food made available to seabirds. Here it is worth diverging for a moment. DAFS data on fish landings caught within the Shetland area refer to the Shetland area as defined by DAFS (Jermyn, 1985). This is an arbitrary division of the seas, especially from the birds' point of view. Statistical rectangle 47E7 is close to Fair Isle but it is included in the Buchan fishery region as it is also very close to Orkney; Fair Isle birds and Orkney birds could mix within this area to feed. The statistical rectangles 52E6 and 52F0 are much further from Shetland than 47E7 and yet are included in the Shetland fishery region. So, when fish landings are examined to determine the total amount of food made available to seabirds, in the form of offal and discarded fish, the arbitrary nature of determining the area inside which food is discarded must be remembered. The calculation will, however, provide an index of food availability, although it cannot be stated that all Shetland scavenging seabirds feed within this area or that no birds from other breeding localities do so.

A second point to consider is the fact that DAFS provide data on fish landings by UK vessels but none regarding foreign trawler catches. From aerial surveys and from DAFS information on the number of foreign vessels reported inside the Shetland fishery region (approximately 850 sightings in winter and 1640 in summer in both 1983 and 1984, some vessels being recorded many times), it is obvious that a large number of foreign trawlers do fish within this area, although their total whitefish landings are much less than those of the Shetland fleet (ICES Bulletins Statistiques). DAFS data provide a minimum number of foreign vessels but give no information regarding the length of time for which each boat fished within the Shetland fishery region. Thus, the information cannot be used quantitatively but it does indicate that additional food will be made available to seabirds from these trawlers. It is probable that much of this food will be consumed by Fulmars as these large foreign trawlers fish further from land. As noted earlier, the numbers of Fulmars in a flock surrounding a trawler increase with distance from the shore.

Combining the three fishing methods, motor trawl, light trawl and seine net, the highest catches within the inner zone in each of the three years from 1983 to 1985 came from 48E8, to the south west of Shetland (Table 7.10). This area was heavily fished by small trawlers from the west of Shetland (Scalloway and Hamnavoe in particular). Next in importance was 50E9 to the north west of Shetland where many of the Whalsay boats fished, 49E9 to the east of Shetland and 48E9 to the south east of Shetland. The least important area in the three years was 50E7, west of the north of Shetland.

March was the most productive month in 1983 and 1984 for the nine inner statistical rectangles, for all fishing methods (Table 7.11). In 1985, more fish were caught in February than in any other month. December was the least productive month in all three years in the inner zone, but fishing halts for two weeks for Christmas and New Year and also gales sometimes prevent the boats from fishing at this time of year.

Included in the Shetland fishing area (Jermyn, 1985) are the 19 statistical rectangles comprising the outer Shetland zone. The statistical rectangles 52E6, 52E7, 52E8, 52E9, 52F0, 51E6, 51E7 and 50E6 yielded very little fish to UK vessels compared to inner statistical rectangles and compared to the other areas in the outer Shetland zone (not only from 1983 to 1985, but from 1973 to 1982 as well, DAFS data), were fished for very short periods of time in each year (DAFS data) and they are very far from Shetland, each statistical rectangle representing approximately 840km^2. I have no data for the amount of fishing conducted by foreign vessels in these statistical rectangles. Of the other statistical rectangles in the outer zone, 47F0 was the most productive area, followed by 49F0. Statistical rectangles 48F0, 47E8 and 50F0 and then 47E9 were the next most important areas.

In 1983 and 1984, more fish were caught in March, in the outer Shetland zone, than in any other month of the year while in 1985 February was the most productive month, similar to the situation observed nearer Shetland (Table 7.11).

The total amounts of food discarded by UK vessels within the entire Shetland area were examined for each year from 1973 to 1985 (Table 7.12). This allows calculation of the approximate amounts of fishery waste food available to Shetland seabirds during the past decade. Although fish landings do vary from year to year they tend to be within the same range (from 40957 to 53352 tonnes, apart from 1973 when many more fish were caught); thus, using the 1983 to 1985 landings to calculate food availability is likely to be representative of the general pattern of recent years. The 1984 landings represented the maximum catch and the 1985 landings the minimum catch since 1974.

The monthly landings were combined for summer and winter months for the inner and outer zones for each of the three years 1983 to 1985 (Table 7.13). In 1983, more fish were caught during the summer months than during the winter months in the inner zone but more during the winter months in the outer zone. In 1984 and 1985 more fish were caught in the winter months than in the summer months.

Except during the winter months of 1985, more fish were caught in the inner Shetland zone than in the outer statistical rectangles. The weights of discards and offal available to seabirds were calculated, as outlined in section 7.3.1. (Table 7.13).

7.4.2 Calculations of numbers of birds that could be sustained by fishery waste around Shetland

Clearly it is of interest to obtain an estimate of the number of scavenging seabirds that could be supported by the provision of fishery waste as a supply of food. A first estimate can be made by assuming that offal is consumed only by Fulmars and discarded fish only by Great Black-backed Gulls and expressing numbers in terms of these two bird species.

Fulmars weigh, on average, 810g and Great Black-backed Gulls 1600g (Cramp & Simmons 1977, 1983, Furness 1983a). From studies of field metabolic rates and of the metabolic rates of birds in controlled conditions in captivity, it appears that seabirds require approximately 3 times BMR (basal metabolic rate) to support their daily energy budgets (Drent & Daan 1980, Ellis 1984, Guillet and Furness 1985, Birt, Cairns, Macko & Montevecchi *in litt.*). Details may differ with different foraging techniques and between winter and the breeding season, but until more detailed studies are conducted this value is as representative as possible. Ellis (1984) also warns that DEB's (daily energy budgets) are not simple multiples of BMR and are not always adequately predicted by existing equations. However, he lists the DEB's for seven seabird species, all determined by the isotopically labelled water method, and these are considered to be the most accurate data available. They range between 2.6 and 5.2 times BMR, so the value of 3 times BMR being used in this study will probably be reasonable. Walsberg (1983), in his equation 8, relates DEB to the weight of birds by

$$\ln (E_{Tot}) = \ln 13.05 + 0.6052 \ln (M_B)$$

where E_{Tot} is the total daily energy expenditure and M_B the bird mass in g. When this equation is used the resultant energy requirements for birds weighing over 1000g are less than three times BMR, but Walsberg did not base his calculation on seabirds. He included a variety of studies of passerines and one of starving penguins and his results do not seem to be either appropriate or reliable for seabirds in this study.

Using equation 5.5 from Kendeigh *et al.* (1977)

$$BMR\ (kcal) = 0.5224W^{0.7347} \pm 1.237$$

and converting to kJ, the BMR for the Fulmar is 300 kJ day^{-1} and for the Great Black-backed Gull is 494 kJ day^{-1}, Discards have a calorific value of approximately 5 kJ g^{-1}, determined by bomb calorimetry of Whiting and Haddock and data from the literature (Table 7.14). The calorific content of offal was also determined, by bomb calorimetry (Table 7.14) and is equivalent to approximately 11 kJ g^{-1}.

Not all food consumed is available for metabolism (Wiens, 1984) and so a value for the assimilation efficiency needs to be introduced. However, no single value exists for seabirds. Values of 80% (Furness 1978b, Furness & Cooper 1982, Furness & Monaghan 1987), 75% (Croxall & Prince, 1982) and 70% (Schneider & Hunt, 1982) have all been variously derived from Kendeigh *et al.* (1977). In these calculations, the value of 75% (as in Furness *et al.*, in press) will be used.

Following the above assumptions, a Fulmar will need to consume 109g of offal per day and a Great Black-backed Gull will need 395g of discards per day, to satisfy their energy demands. These figures can then be used to calculate the number of Fulmars and Great Black-backed Gulls per day that could gain sufficient food from trawlers, assuming that 90% of all offal and 75% of all discards are consumed (by Fulmars and Great Black-backed Gulls respectively).

Using DAFS data for 1983 to 1985 as a general pattern of fishery catches from Shetland waters, it appears that usually more birds will be provided for during the winter months and more in the inner Shetland zone than in the outer zone. Taking 1984 amd 1985 as the two extremes of the last decade, the range in the numbers of birds capable of being sustained by fishery waste were determined (Table 7.15).

During the summer months of 1984, a total of 126,000 Fulmars and 85,000 Great Black-backed Gulls could have obtained sufficient food from trawler waste to satisfy their energy demands (basing calculations on the aforementioned assumptions). Nearly twice as many birds would be provided for in the inner zone compared to the outer zone. During the winter months of 1984, potentially 175,000 Fulmars and 118,000 Great Black-backed Gulls could have survived on offal and discards with, again, more birds gaining food in the inner Shetland zone. In 1985, the total numbers of birds that could be sustained on fishery waste alone was lower, at 92,000 Fulmars and 62,000 Great Black-backed Gulls in summer and 140,000 Fulmars and 94,000 Great Black-backed Gulls in winter. Overall, therefore, approximately 200,000 birds are provided for by fishery waste in Shetland waters, although fewer birds can rely entirely on this source of food in the summer than in winter months. Obviously these figures are gross estimates as, for example, no account has been taken of other bird species feeding behind trawlers, or of the fact that many more birds might partially fulfil their dietary requirements behind trawlers, rather than some obtaining all their food there. However, it does serve to give an index of bird numbers expected to be able to rely entirely on fishery waste around Shetland, approximately 200,000 birds per day, throughout an entire year.

7.5 DISCUSSION

Following direct observations from trawlers of bird numbers attending whitefish boats around Shetland, Fulmars were found to be the most abundant species and Great Black-backed Gulls were next in importance. Herring Gulls were commonest close inshore but were generally scarce further from the shore, where the proportion of Fulmars present increased. This observation has been noted elsewhere (e.g. Lockley & Marchant 1951, Hillis 1971).

Aerial observations allowed the determination of a mean count of bird numbers per fishing vessel. The mean values did not only refer to boats that were hauling but included boats of all activity. The mean numbers of birds recorded behind trawlers in Shetland were generally higher than the value of 517 noted in the Irish Sea between 1972 and 1975 from 62 spot counts around small trawlers during all fishing activities (Watson, 1981). In the Irish Sea, rather low numbers of Fulmars were observed (maximum 100) and the Herring Gull was the most numerous species (maximum 1000), while in Shetland the Fulmar was present in much greater numbers; the difference in the mean number of birds attending trawlers between the two areas probably stems from the relative abundance of the Fulmar. Near Rockall, the Fulmar was again the most abundant bird species in association with trawlers. Frequently 2,000-3,000 were present when large amounts of offal were discarded and on one occasion approximately 5,000 were observed (Lockley & Marchant, 1951). These figures compare with the aerial surveys of trawlers fishing further from Shetland than the boats from which observations were actually conducted, with up to 8,000 Fulmars present around two large stern trawlers fishing close to each other north west of Unst.

Rather smaller numbers of Fulmars have been reported from more southerly locations (Boswall 1960, Hillis 1971).

Herring Gulls and Kittiwakes appear to be most abundant near to shore and around small vessels, especially those employed in mixed shellfish/demersal trawling (*Nephrops*, or Norway Lobster trawlers). These boats catch many undersized fish, much too small for market and therefore many are discarded and available to the smaller bird species (winter work in the Clyde during this study, to be published elsewhere, Hillis 1971, Watson 1981). Off the west coast of Scotland, a higher proportion of Great Black-backed Gulls occurred, rather than Herring Gulls although here, too, Fulmar numbers were low, at 100 to 150 (Boswall, 1960). Further north, the same observer noted similar numbers of Fulmars, up to 15 Great Skuas but very few gulls (Boswall, 1977). Thus, the range in numbers of diferent seabird species behind trawlers is great (Table 7.16).

The patterns of attendance of seabirds behind whitefish trawlers and sandeel boats in Shetland were quite different from each other. Fewer birds were observed behind sandeel boats, where the Herring Gull was the commonest species to occur. Observations from Mousa agree with this: up to 150 Herring Gulls were regularly seen to fly out to the sandeel trawlers when they hauled during the summers of 1983 and 1984 (P. Ewins, pers. comm.). In contrast, the proportions, but not necessarily the numbers, of Herring Gulls were much lower behind whitefish boats where the Fulmar occurred in highest numbers.

Close to the west coast of Shetland are fishing grounds suitable for, and widely used by, the smaller trawlers. The small size of these boats limits their catch size and therefore the amount of waste discarded, which in turn probably affects the numbers of birds present. The larger boats fish further from the coast and are not confined to Shetland or even Scottish and English boats; many trawlers are from other European countries and some are vast stern trawlers. Whilst no direct information was gathered from these types of boats during this project, it is very likely that each trawl would be of several hours duration and that more fish would be caught per haul than by the small seine trawlers. Certainly, the enormous numbers of birds following in their wake would suggest that this is the case.

Small-scale experiments have previously been conducted from trawlers to determine the proportion of discarded food consumed.

Fishing near North Rona and Sula Sgeir, Boswall (1960) followed the fate of 100 pieces of gut thrown overboard by the fishermen, piece by piece. Of these, 95 bits were consumed, mostly by Fulmars and Great Black-backed Gulls, although Boswall also notes that when the boat was nearly stationary the Fulmars obtained virtually all the offal. Both the amount consumed and the latter observation are similar to the situation seen in Shetland during the present study.

The quantities of fish discarded vary enormously between fishing grounds, seasons and even from haul to haul (Boswall 1960, Bailey & Hislop 1978, Lake 1984, this study). Few detailed data on discard rates are available, but some information is provided by DAFS on the proportion of Haddock, Whiting and Cod discarded (Jermyn & Robb, 1981). For Shetland, combining the discard rates (by weight) of Haddock, Whiting and Cod for trawl and seine gears, collected on individual discard cruises from 1975 to 1980, a mean of 18.4% by weight was discarded. However, the discard rates of each species were not similar. 22.7% (range 14-27.1%) of Haddock, 21.6% (range 5.7-25.8%) of Whiting and 1.2% (range 0.4-3.4%) of Cod were discarded. The discard rates between the methods of fishing (seine and trawl gear) were not similar either, with 27.2% caught by seine and 16% caught by trawl being discarded. Again, Cod was discarded in smallest amounts (11% by seine, 0.35% by trawl), with more Haddock (39.7% by seine, 18.9% by trawl) and Whiting (18.7% by seine, 22.7% by trawl) being discarded. Working from the port of Plymouth, Lake (1984) estimated that 48% of the total weight of finfish landed from the south west fisheries was discarded, somewhat higher than recorded in Scottish waters.

In this study, total discard rates by volume (of all species of fish) were assessed, rather than species by species estimation by weight or numbers, so no direct comparisons between my results and those obtained by DAFS are possible. However, the results do appear broadly similar. Cod is rarely discarded, as found by DAFS (Jermyn & Robb, 1981) and during this study, but for some other species, such as Red Gurnard *Aspitrigla cuculus* and Grey Gurnard *Eutrigla gurnardus*, all fish caught were discarded. If the discard rates of Whiting and Haddock are combined (22.1% overall, 28.3% for seine and 20.1% for trawl), they closely resemble the results from this study (27%). The elimination of the low discard rate of Cod should counteract the high discard rates of other, non-commercial species, so that the discard rates for Haddock and Whiting, the species caught in greatest quantity, should approximate the total discard rate.

Other data provided by Jermyn and Robb (1981) indicate that a total of 37.1% by weight of all Haddock, Whiting and Cod caught in the North Sea by UK vessels is discarded, so large differences in discard rates between areas must be occurring. At this total fleet level, 43.8% of all Haddock, 35.8% of all Whiting and 19.9% of all Cod were discarded between 1975 and 1980 and again very much higher discard rates were obtained by the seine gear.

The calculations of the numbers of birds capable of being sustained by fishery waste in Shetland are based solely on landings by UK vessels, supplied by DAFS. Additional food will presumably be made available to seabirds from foreign vessels fishing in Shetland and also from fishery waste in harbours. Herring Gulls, for example, gained little food from behind trawlers during this study and most of the fish consumed by these gulls, determined from otolith length, were larger than those being discarded at sea, indicating that they were scavenged from harbours or fish factories (see Chapter 6). Assuming discard rates to remain similar between summer and winter months, more birds could derive sufficient food in winter to satisfy their energy demands as this is the time when most fish are caught. Many birds, particularly Herring Gulls, overwinter around Shetland, migrating from their breeding grounds in N. Norway (Coulson *et al.*, 1984). These extra birds may benefit from the provision of additional fishery waste during these months, when other, natural food sources may be more scarce.

7.6 CONCLUSIONS

Following the determination of seabird numbers behind whitefish trawlers in Shetland, the amounts of offal and discarded fish that they consumed were assessed. Using information from DAFS regarding total landings of demersal fish by UK vessels fishing in Shetland waters, the total numbers of seabirds that could be supported by fishery waste were calculated at approximately 200,000 birds.

CHAPTER 8

FEEDING INTERACTIONS OF SEABIRDS BEHIND WHITEFISH TRAWLERS

8.1 INTRODUCTION

The efficiency with which birds could handle fish discarded from trawlers was examined. Firstly, the species composition (8.2) and then the sizes of fish being discarded were determined (8.3). The behaviour of the various bird species in consuming offal and discarded fish is discussed (8.4) and then data on the selection of fish by seabirds are presented (8.5), followed by information on handling times (speed with which birds swallow fish, 8.6). Lastly, kleptoparasitism is discussed.

8.2 SPECIES OF FISH DISCARDED

Whiting and Haddock were the commonest species to be discarded experimentally by me, accounting for over 70% of all fish thrown overboard (Table 8.1). Bearing in mind that I attempted to obtain random samples of discards to measure, this figure probably closely reflects the true discard composition.

Cod was discarded rarely compared to Haddock and Whiting as most Cod caught were large and therefore were kept for market. Red and Grey Gurnard occurred quite commonly in catches and all were discarded. Many of the Grey Gurnard were caught on one trip (18-20.08.85), when we were fishing off the north east coast. Flatfish were discarded less commonly than round fish, since flatfish represented a small part of the catch. Long Rough Dab *Hippoglossoides platessoides* and Lemon Sole *Microstomus kitt* were the two commonest species of flatfish and smaller numbers of Witch *Glyptocephalus cynoglossus*, Megrim *Lepidorhombus whiffiagonis* and Plaice *Pleuronectes platessa* were discarded.

Norway Pout was not often found amongst discards and DAFS have found the same (S. Jermyn, pers. comm.). This observation must be remembered with respect to Chapter 6, where I showed that Norway Pout otoliths occurred commonly in pellets regurgitated by Great Skuas. Further discussion of this point will follow in Chapter 9.

The other fish species recorded did not occur in large numbers (Table 8.1), but not recorded in the list of discarded fish, however, are Dogfish *Scyliorhinus caniculus*. The fishermen discarded these overboard immediately upon their removal from the nets or when they were first found in the ponds. Dogfish were only kept for market if a large number was caught, when the fishermen were offered a minimum price for them, as there is not much demand for Dogfish in Shetland (A. Jamieson, pers. comm.). The dogfish were generally large and were usually seen to swim away and so were not available to the seabirds.

8.3 SIZES OF FISH DISCARDED

The median length of discarded Whiting was 29cm, of Haddock was 28cm and of Cod was 32cm (Table 8.1). The minimum legal landing sizes are 27cm for Whiting and Haddock and 30cm for Cod (Jermyn, 1985); thus, the median discard lengths are 1-2cm greater than the minimum legal landing size.

Whiting and Haddock were the commonest discard species and so details of their discard lengths (and subsequent fates following discarding, 8.5) will be discussed in detail. Some reference to Cod will be made as a contrast, because the median discard length of Cod was 3cm and 4cm longer than for Whiting and Haddock respectively.

Few Saithe *Pollachius virens* were caught and so discard numbers were low. However, of those that were discarded, the median discard length recorded was 39cm, longer than the maximum fish length that many seabirds can handle (8.5). There is not much market for Saithe in Shetland and most that are caught are discarded, hence the large discard lengths recorded (Appendix VI). As for Dogfish, if a large quantity was caught in one haul, the Saithe were kept and sold at a minimum price; otherwise, when few were caught, it was not worth bringing them to market. The same applied for Mackerel.

The median discard length for Red Gurnard was 25cm and for Grey Gurnard was 32cm. These species were not generally marketable in Shetland either, regardless of their length; the maximum length recorded for a Grey Gurnard was 44cm. The median lengths of discarded flatfish ranged from 21cm to 28cm.

8.4. BEHAVIOUR OF SEABIRDS CONSUMING OFFAL AND DISCARDS

Having determined the sizes of fish available to scavenging seabirds the exploitation of this food source by the seabirds was examined. In this section only the general behaviour of the birds consuming offal and discards will be discussed. Quantitative relationships follow in later sections.

8.4.1 Fulmar

On all trips virtually all of the offal discarded was seen to be consumed by seabirds. Furthermore, most offal in Shetland was taken by Fulmars. Sometimes during the early stages of gutting and discarding, the gulls and Great Skuas obtained offal before the numbers of Fulmars had reached their maxima. Thus, when few Fulmars were in attendance at trawlers at the beginning of gutting they obtained rather little of the offal, but as their numbers increased during the gutting procedure, so the percentage of offal taken by Fulmars increased. This is demonstrated by counts of the number of whole pieces of offal seen to be swallowed by seabirds in five minute periods. For example, on three occasions, the percentage of offal consumed by Fulmars rather than by other birds increased from 51.5% to 94.4% in the first 15 minutes of offal discharge, from 54.2% to 80.6% in the first 20 minutes and from 48.8% to 83.6% in the first 15 minutes, as Fulmar numbers increased in the immediate vicinity of the trawler where the offal was being discharged. On most occasions, nearly all of the offal was consumed by the Fulmars (Table 8.2) as they were usually present in large numbers from when offal was first discarded.

Attempts to quantify the consumers of offal, piece by piece, were difficult. The large gulls and Great Skuas generally took whole pieces of offal if they were available, or else pieces of stomach less favoured by Fulmars, whereas groups of Fulmars tended to fight over offal with many individuals obtaining tiny scraps. Thus, an accurate assessment of the amount of offal consumed by each bird per species present was not possible. However, Fulmars generally obtained over 90% of the offal going overboard, the exceptions being either when very few Fulmars were present or when a very large number of Herring Gulls was present in relation to the numbers of Fulmars (Table 8.2). Both situations were rare in Shetland during the summer months when I was on trawlers, except when land was approached and Fulmars became more scarce and Herring Gulls more numerous.

By and large, the Fulmars appeared superior in every way over the other scavenging species in their ability to obtain offal. When the boat was stationary, the Fulmars gathered in such dense flocks around the trawler that other bird species were precluded from landing in the area. When the boat moved, the Fulmars flew alongside, quickly dropping down to snatch the offal as it was discharged. Where large volumes of offal were discharged at once, as for example when the scuppers were washed out at the end of gutting, very tightly packed groups of 30-100 or more Fulmars collected almost immediately and the offal was consumed within seconds. The Fulmars were able to reach the offal exceedingly quickly by "paddling" across the water and at the same time flapping their wings, rather than taking off and flying as the gulls and skuas did. The Fulmars chose the liver in preference, with those birds furthest from the boat taking the guts.

Fulmars did swallow some fish, although these tended to be very small and were only consumed during periods when no offal was being discarded. Often, Fulmars ripped open the bellies of fish to feed on the liver and guts, again when there was a lull in the discharge of offal. However, frequently while they were tackling fish, the larger gulls and the skuas stole the fish or else Gannets dived for them.

8.4.2 Gannet

Gannets were very successful in obtaining fish discarded from whitefish trawlers in Shetland. They were observed diving deep for fish that had sunk and also shallow-diving for fish submerged only a small depth below the sea surface. Gannets were rarely observed to take offal.

On one occasion, a Gannet was observed to approach the trawler from a distance and, almost immediately, it dived and obtained a fish. It repeated this procedure twice and then flew away. This points to two factors. Firstly, each Gannet can consume more than one fish in a very short period of time: the fish had not been measured but were judged to be over 30cm in length. A 30cm Whiting would weigh approximately 235g (DAFS data), which would provide about 1175kJ of food value, thus three such fish constitute more than sufficient food for one Gannet for one day (2399kJ/g, assuming a daily energy requirement of approximately 3BMR). Secondly, the turn-over rate of Gannets at trawlers must be rapid (if this bird is typical of most Gannets), as it flew in and departed within a few minutes. Thus, the average number of Gannets recorded at an instant per trawler per haul gives little indication of the total number of Gannets that may feed behind trawlers.

8.4.3 Great Black-backed Gull

Great Black-backed Gulls were the most numerous seabird to feed on discards during the trawler trips I made in Shetland in 1985. They gathered on the water during hauling above the point where the net would hit the surface and by the time the net was visible, hundreds of Great Black-backed Gulls were generally waiting. At this stage, the net was some distance from the boat so the feeding behaviour and success of individuals were not distinguishable. As the net was drawn in towards the boat, the Great Black-backed Gulls tended to linger behind, while the Fulmars crowded close to the trawler. Once gutting and discarding began, the Great Black-backed Gulls obtained offal only if few Fulmars were present. Usually, they waited for fish to be discarded, when they quickly snatched them from the sea surface. Great Black-backed Gulls often stole fish from other birds, particularly from Fulmars near to the boat. (Kleptoparasitism will be discussed further in section 8.7.). Fights frequently broke out amongst a group of gulls, with many birds fighting over one fish and one of two outcomes was possible. Sometimes, one bird alone was the victor, either the original possessor of the fish or else an aggressor. At other times, the fish was torn apart by the birds so that more than one gull obtained food.

8.4.4 Great Skua

Great Skuas obtained little offal, owing to the presence and aggression of large numbers of Fulmars. They often tried to plummet down amidst a group of Fulmars fighting over offal, but they were rarely successful in stealing any pieces.

The Great Skuas concentrated, instead, upon taking whole fish. They obtained some as the net was hauled towards the boat, either by stealing fish through the codend, or by taking small fish that had already been forced out through the codend. Most fish taken by Great Skuas were those that had been discarded by the fishermen. Sometimes, they took fish close to the trawler but, as a rule, the Fulmars were waiting for offal there so the skuas stayed behind the trawler with the Gannets and gulls. They either took fish directly from the sea surface or else stole them from other Great Skuas or from gulls and, in turn, their own fish were often stolen by gulls. Often the skuas were chased and forced to drop the fish; this aspect will be discussed further in section 8.7.

8.4.5. Herring Gull

Herring Gulls were generally not very successful in obtaining fish and offal behind whitefish boats in Shetland during the summer. Much of their time was spent sitting on the trawler rather than in searching for food.

When offal was discarded, the Herring Gulls were successful when the gulls were present in large numbers. However, once Fulmar numbers built up and they settled on the water, the Herring Gulls hovered overhead; when offal was then discharged, the Fulmars scuttled across the water and had consumed most of the offal by the time the Herring Gulls had dipped down to try and obtain some. Small numbers of Herring Gulls were successful, however, even when many Fulmars were present. They managed to snatch pieces of offal from the sides of the boats whereas the Fulmars waited for the offal to go overboard and land on the sea. On three occasions when this was tested quantitatively, Herring Gulls obtained more offal than did the Great Black-backed Gulls, relative to the numbers of each species present (Table 8.3), for example $t = 31.73$, 4df; $t = 5.26$, 26df; $t = 5.84$, 8df; $p < 0.001$ in each case.

Herring Gulls did manage to swallow some discarded fish, but as a rule these gulls were dominated by the larger Great Black-backed Gulls and by Great Skuas and thus they found it hard to obtain fish. Also, many of the fish that they did take were subsequently stolen or else the gulls were forced to drop the fish. In addition, many of the fish discarded were too large for the Herring Gulls to handle. These two points will be discussed in the following section.

8.4.6 Lesser Black-backed Gull

Lesser Black-backed Gulls occurred in low numbers around trawlers in Shetland in the summer and thus they obtained only small quantities of fish and offal. Their behaviour more closely resembled that of the Herring Gulls rather than the Great Black-backed Gulls, in that they tended to sit on the gunwhale and shelter-deck and watch other birds take the food for much of the time. The Lesser Black-backed Gulls took little offal.

8.4.7 Kittiwake

In contrast to the situation in some other areas (e.g. the Clyde, the Irish Sea), Kittiwakes rarely attempted to take fish or offal and were only observed in small numbers behind the whitefish trawlers in Shetland.

8.5 SELECTION OF DISCARD FISH BY SEABIRDS

8.5.1 Fish species

Nearly half of the fish that were experimentally discarded were seen to be swallowed. Many of the other fish will have been swallowed too, but it often proved impossible to record the ultimate fate of individual discards. Sometimes the boat was moving so that the fish disappeared out of sight before its fate could be determined, other times the sea was choppy and I lost sight of the fish more quickly. On other occasions, birds flew away into the distance carrying the fish and I could not see whether the fish was swallowed or dropped. Many fish were simply picked up and swallowed, but in some cases birds either dropped the fish or another bird forced it to drop it or physically snatched the fish from it. In other instances, fish were ignored by seabirds. It was my impression that somewhere between 60% and 90% of discards were usually consumed by seabirds, while the remainder were either too large, of unpopular fish species (and so were ignored by seabirds). or were desirable as food but sank before being consumed. In this section I consider the selection of fish by each bird species.

8.5.1.a Percentage of each fish species seen to be swallowed by seabirds

Fish of different species were discarded in unequal numbers but, in fact, the proportions of each species seen to be swallowed by seabirds also differed (Table 8.1). Species for which discards numbered less than 20 were ignored in terms of statistical comparison, except for flatfish as all flatfish species were combined into one group. The resulting total number (3776) of discarded fish seen to be swallowed, as a percentage (50%) of all those discarded, was used to derive expected values for all fish species (Table 8.4). Whiting, Haddock, Cod and Norway Pout were swallowed very much more often than expected, whereas gurnard (Grey and Red), Saithe and, in particular, flatfish were swallowed more seldom than expected (X^2_5 = 674.4, $p<0.001$).

Within these selections, the consumption of these fish species, from which the expected values were derived, was not divided equally between the different bird species (Table 8.4). Adult Great Black-backed Gulls and non-adult Great Black-backed Gulls (intermediates and immatures combined) consumed fish species in different proportions (X^2_5 = 11.75, $p<0.05$). They consumed Whiting, Haddock, gurnard and Norway Pout in approximately equal proportions but non-adults swallowed fewer flatfish than did adults and no Cod at all.

The species of fish swallowed by adult Gannets was very different from those swallowed by adult Great Black-backed Gulls (X^2_5 = 487.23, $p<0.001$), with Great Black-backed Gulls taking fewer gurnard. Great Skuas swallowed more Whiting and less Haddock and gurnard than expected compared to adult Great Black-backed Gulls (X^2_3 = 56.84, $p<0.001$).

There was no significant difference between the numbers each of Whiting, Haddock, Cod, gurnard and flatfish swallowed by Herring Gulls and adult Great Black-backed Gulls (X^2_4 = 2.06, NS). Adult Great Black-backed Gulls and Lesser Black-backed Gulls swallowed Whiting, Haddock and Cod in similar proportions (X^2_2 = 0.84, NS) and Fulmars and adult Great Black-backed Gulls swallowed Whiting, Haddock and gurnard in similar proportions (X^2_2 = 1.74, NS).

Adult Gannets swallowed fewer Whiting, a similar proportion of Haddock and Cod and more gurnard than did Herring Gulls (X^2_3 = 42.61, $p<0.001$). The Gannets also took different fish from Great Skuas (X^2_3 = 193.23, $p<0.001$), swallowing many more gurnard and Cod, similar proportions of Haddock but less Whiting than the skuas. Herring Gulls swallowed more Haddock and Norway Pout but less Whiting than did Great Skuas (X^2_2 = 24.82, $p<0.001$).

Great Black-backed Gulls and Gannets swallowed over 75% of all fish that they handled, whereas Herring Gulls, Lesser Black-backed Gulls, Great Skuas and Fulmars swallowed a much smaller percentage (Table 8.8a).

8.5.1.b Percentage of each fish species seen to be dropped by seabirds

Different species of fish were not dropped in equal proportions by the seabirds, the proportions ranging from 0-22% of each fish species handled; in all, 6.1% of all fish handled were seen to be dropped. The number of fish dropped, as a percentage of the total numbers of fish swallowed (8.42%), was used to compute expected numbers dropped, given the null hypothesis that all species of fish were equally likely to be dropped. The different fish species were not dropped at random (χ^2_6 =231.6, $p<0.001$, Table 8.5). Very few Whiting were dropped and fewer Haddock than expected were dropped. No Saithe or Norway Pout were dropped but many more Cod, Gurnard and flatfish than expected were dropped.

Different fish species were more likely to be dropped by different bird species (Table 8.6). Adult and non-adult Great Black-backed Gulls dropped similar proportions of Whiting, Haddock, Cod, gurnard and flatfish. Adult Great Black-backed Gulls dropped more Cod and flatfish, marginally more Haddock and less gurnard than expected and approximately equal proportions of Whiting compared to adult Gannets. Adult Great Black-backed Gulls dropped fewer Whiting and Haddock but more Cod, gurnard and flatfish than expected compared to adult Herring Gulls, but approximately equal proportions of Whiting and Haddock as Great Skuas. Adult Gannets dropped less Whiting, very much less Haddock and much more gurnard than expected in comparison with adult Herring Gulls but the numbers of Whiting and Haddock dropped by adult Gannets did not differ significantly from the expected number when compared with the number dropped by Great Skuas. Adult Herring Gulls and Great Skuas dropped similar proportions of Whiting and Haddock.

Herring Gulls and Lesser Black-backed Gulls dropped a relatively high proportion of all fish they handled (Table 8.8a) compared to the other bird species.

8.5.1.c Percentage of each fish species stolen from one bird by another bird

Birds were seen to fight over fish and to steal fish that other birds were trying to consume. Less than 10% of the fish discarded of any one species were kleptoparasitised (Table 8.7a), but one fish could be stolen more than once and every bird that stole a fish did not necessarily swallow it. Expected values were derived from the proportion of all fish kleptoparasitised in relation to the total number swallowed. When these expected values were compared with the observed numbers, it was found that the incidence of kleptoparasitism of each fish species did not differ significantly, that is, no one fish species was selectively stolen in preference to other species (X^2_7 = 6.96, p>0.05).

Some birds stole more fish than they had stolen from them (cf. Tables 8.7a and 8.7b). When the total number of fish (of all sizes and all species) stolen by a bird species was compared to the total number of fish swallowed, dropped or stolen from each species, it was also clear that some bird species stole many more fish than others (Table 8.8a). Overall, adult Great Black-backed Gulls and Great Skuas stole more fish than expected (assuming all birds should stand an equal chance of stealing fish) and non-adult Great Black-backed Gulls and Gannets, Herring Gulls, Lesser Black-backed Gulls and Fulmars of all ages stole fewer fish than expected (X^2_6 = 57.26, p<0.001).

Great Skuas stole the highest proportion of fish, relative to the total number of all fish that they handled, followed by adult Great Black-backed Gulls and then adult Gannets. Non-adult Great Black-backed Gulls stole fewer fish than the adults. Herring Gulls and Fulmars stole very few fish and Lesser Black-backed Gulls stole none at all.

These results were compared against a null hypothesis that each species and age class of bird should steal as many fish as they had stolen from them (Table 8.8b). Adult Great Black-backed Gulls stole more fish from other birds than they had stolen from them whereas Herring Gulls, Lesser Black-backed Gulls, Great Skuas (only just significantly so) and Fulmars lost more by kleptoparasitism than they gained. Gannets and intermediate and immature Great Black-backed Gulls lost statistically similar numbers of fish to kleptoparasites as those they gained by kleptoparasitism. Over 40% of all fish handled by Fulmars were stolen from them.

8.5.2 Fish lengths

Having examined the selection of species of fish, it was also possible to determine whether selection of fish by length was occurring. The mean lengths of all Haddock and Whiting discarded were compared with the mean lengths of fish that were seen to be swallowed, dropped or stolen by each age class and species of bird (where sample sizes permitted statistical comparison). The maximum lengths of fish taken by the different bird species were examined.

8.5.2.a Sizes of fish seen to be swallowed

The mean fish lengths of Haddock and Whiting swallowed by seabirds were determined (Tables 8.9a and 8.9b). The mean length of Haddock consumed by adult Great Black-backed Gulls was significantly longer than the mean length of all Haddock discarded, even though the actual difference in fish length was only 0.35cm. (All statistical values are presented in Tables 8.9a and 8.9b). There was no significant difference between the mean length of Whiting swallowed by Great Black-backed Gull adults and those discarded experimentally. The mean lengths of Haddock and Whiting swallowed by intermediate Great Black-backed Gulls and of Whiting by immatures did not differ significantly from the mean lengths of those discarded; immature Great Black-backed Gulls swallowed smaller Haddock than the mean length discarded. Gannet adults took larger Haddock and Whiting than those discarded. Herring Gull adults, Great Skuas and Fulmars swallowed Haddock and Whiting with mean lengths significantly smaller than the mean lengths of discarded fish. Lesser Black-backed Gulls swallowed Haddock that were significantly smaller than the mean length discarded, but Whiting were of a statistically similar length. Sample sizes of fish swallowed by Lesser Black-backed Gulls were very small.

8.5.2.b Sizes of fish seen to be dropped

The mean lengths of Haddock and Whiting that were dropped by seabirds were determined and were compared with the mean lengths of fish discarded and swallowed, for sample sizes greater than 10 (Tables 8.10a and 8.10b). Except for Whiting dropped by adult Herring Gulls, the lengths of dropped Haddock and Whiting were greater than the mean discard lengths (all significance levels are given in Tables 8.10a and 8.10b), that is, for adult Great Black-backed Gulls, Great Skuas and adult Lesser Black-backed Gulls. In all cases, mean fish lengths of dropped fish were significantly greater than mean lengths of fish swallowed each by Great Black-backed Gulls, Herring Gulls, Lesser Black-backed Gulls and Great Skuas.

The percentage of Haddock and Whiting that were dropped by, or stolen from, Great Skuas and Herring Gulls increased with increasing fish length (Table 8.11a). There was, perhaps, a slight trend for a higher proportion of large fish to be dropped by adult Great Black-backed Gulls (Table 8.11b), but it was not so pronounced as for the two smaller species.

8.5.2.c Size of fish that were kleptoparasitised

The mean fish lengths that were stolen from seabirds by other seabirds were determined and compared with the mean lengths of fish discarded and swallowed (Tables 8.12a and 8.12b). The mean lengths of Haddock and Whiting stolen from adult Great Black-backed Gulls and from Great Skuas, of Haddock from adult Herring Gulls and of Whiting from Gannets and Lesser Black-backed Gulls were significantly longer than the mean lengths of all discards (all significance levels are presented in Tables 8.12a and 8.12b). Haddock and Whiting stolen from Fulmars were smaller than those discarded. Whiting stolen from Herring Gulls and Haddock stolen from Lesser Black-backed Gulls and adult Gannets were not significantly different in length from the length of those discarded. The mean lengths of Haddock stolen from adult and immature Great Black-backed Gulls, adult Herring Gulls, adult Lesser Black-backed Gulls, Great Skuas and Fulmars were all significantly longer than the mean lengths of Haddock swallowed by each species of bird. Adult Gannets lost fish by kleptoparasitism that were not significantly different in length to the mean length of Haddock that they swallowed. The mean length of Whiting stolen from adult Great Black-backed Gulls, adult Gannets, Great Skuas, adult Herring Gulls, Fulmars and adult Lesser Black-backed Gulls were all significantly longer than the mean length of Whiting swallowed by each species of bird.

The mean lengths of Haddock and Whiting stolen by adult Great Black-backed Gulls and of Whiting stolen by adult Gannets were significantly longer than the mean discard lengths (Tables 8.13a and 8.13b). Haddock stolen by Great Skuas were smaller than those discarded whereas Whiting stolen by Great Skuas and Haddock and Whiting kleptoparasitised by immature Great Black-backed Gulls were not significantly different from the mean discard lengths. The mean length of Haddock stolen by adult and immature Great Black-backed Gulls, adult Gannets and Great Skuas did not differ significantly from the mean lengths swallowed by each species. The mean length of Whiting stolen by immature Great Black-backed Gulls and adult Gannets were of a similar length to the mean length swallowed by each species. However, adult Great Black-backed Gulls stole Whiting that were just significantly longer than the mean length of Whiting that they swallowed. Great Skuas stole Whiting that were significantly longer than the mean length they swallowed; this length was very similar to the mean length discarded and may be a factor of food availability rather than choice.

The mean discard lengths of Haddock and Whiting stolen from Great Black-backed Gulls did not differ significantly from those stolen by adult Great Black-backed Gulls. The same was true for adult Gannets and for Haddock kleptoparasitised by and from immature Great Black-backed Gulls. However, the mean fish lengths of Haddock and Whiting stolen from Great Skuas were longer than the mean lengths stolen by Great Skuas ($d=2.967$, $p<0.01$ and $d=3.201$, $p<0.002$).

8.5.2.d Maximum sizes of discards consumed by seabirds

Some indication of the maximum length of fish that birds could handle was gathered by watching birds go towards fish and then leave them, or else try to pick up fish that were too large for them to manage to swallow and also by examining the maximum lengths of fish seen to be swallowed (Table 8.14).

Lesser Black-backed Gulls were observed on three occasions to "ignore" a 28cm Haddock and on three occasions a 30cm Haddock. (I define "ignore" as the following behaviour: the bird flew down towards the discard but then, instead of attempting to pick it out of the water, it flew on.) A 31cm Haddock and one 33cm Whiting (but none of 31cm or 32cm) were swallowed by Lesser Black-backed Gulls. Herring Gulls ignored Haddock between 28cm and 33cm in length on 23 separate occasions and swallowed none greater than 31cm long. They ignored Whiting of between 29cm and 35cm in length five times and were never observed to swallow Whiting longer than 30cm. Three and four year old Herring Gulls were not seen to swallow Haddock or Whiting longer than 27cm and Herring Gulls of two years old and less took them only up to a length of 25cm. Great Skuas once ignored each a 25cm and a 30cm Haddock and for Haddock over 29cm they were frequently observed to chew the fish's head in order to make it easier to swallow. On one occasion a Great Skua followed the same procedure for a 32cm Whiting.

Great Skuas were seen to ignore a 38cm Whiting, a Grey Gurnard of 31cm, a 42cm Mackerel and a 43cm Hake. The maximum length of Haddock seen to be taken by a Great Skua was 31cm and of Whiting was 35cm (although none were taken measuring 34cm). Great Black-backed Gulls, particularly immatures and intermediates, experienced difficulty in picking up a Cod of 38cm; this fish was dropped many times by gulls of all ages, but was finally swallowed by an adult. The maximum length of Haddock seen to be swallowed by an adult Great Black-backed Gull was 38cm (but none measuring 36 and 37 were taken) and of Whiting was 39cm (although again the next size taken was 3cm smaller). Intermediate Great Black-backed Gulls took Whiting of 34cm and Haddock of 33cm and immatures swallowed Whiting of 35cm and Haddock of 32cm. A Great Black-backed Gull once was observed to ignore a 27cm Red Gurnard and immatures ignored Red Gurnard measuring 29cm. All age classes ignored Grey Gurnard 31cm and longer on several occasions. As stated earlier, the fate of some fish was often unknown because the birds flew out of sight before dropping or swallowing the fish. Thus, the maximum length of Gurnard that they could handle was unknown, although they were observed to take Gurnard up to a length of 32cm. Great Black-backed Gulls could not swallow a 43cm Saithe, or a Hake *Merluccius merluccius* of the same length. Flatfish of a smaller length tended to be difficult to swallow, owing to their broad outline, and Great Black-backed Gulls were observed to drop repeatedly a Witch of 29cm, a Lemon Sole of 27cm and usually to ignore any flatfish greater than about 28cm. A Gannet could not handle a Megrim of 36cm at all, nor could two Gannets swallow a gutted Cod of 50cm, nor Ling *Molva molva* of 61cm and 62cm (although Ling are very long, thin fish). Gannets found Grey Gurnard of 42cm, 43cm and 44cm too big to deal with. The maximum length of Haddock seen to be swallowed by a Gannet was 39cm and of Whiting was 38cm. One Fulmar was observed to eat a Haddock measuring 30cm long, but this particular fish was extremely thin. The next largest Haddock seen to be swallowed by Fulmars was 26cm, whereas they could take Whiting up to 28cm and, on one occasion, 29cm.

8.6 HANDLING TIMES OF DISCARDS

8.6.1 Handling times of discards seen to be swallowed

Regressions of log handling time on log fish length illustrate the similarities and differences between the ability of birds to swallow each fish species (Table 8.15). Gurnard were difficult to swallow but the handling time for adult Great Black-backed Gulls, high for all fish lengths, was not significantly affected by fish length (Fig. 8.1; figures for the other ages and species of bird have not been reproduced here, as they all follow the same type of pattern). Gurnard have hard, bony heads with spines, and fish of any length are disliked by seabirds. Many of the discarded gurnard were carried by the birds for several minutes, before the bird vanished out of sight, so that the fates of these fish, whether they were dropped or swallowed, were unknown.

Between 23% and 48% of the variation in handling time was explained by fish length for Cod, Haddock and Whiting consumed by adult birds, with the exception of Whiting consumed by adult Gannets. In the case of immature (up to 2-year old) and intermediate (3- and 4-year old) Great Black-backed Gulls, little of the variation in handling time was explained by increase in fish length; the inexperience of these birds in handling fish may also have been of importance.

The slopes of the regression lines were compared to determine (a) whether a difference exists in the rate of change of handling time for different bird species swallowing a particular fish species and (b) whether a difference exists in the rate of change of handling time for each bird species swallowing different fish species.

No significant differences existed in the rate of change in time taken by birds of different age and species to swallow Haddock, except for Great Skuas which took proportionately longer to swallow Haddock of increasing length than did adult Great Black-backed Gulls and adult Gannets (statistical comparisons in Table 8.16a). The same was true for Whiting but, in addition, Great Black-backed Gull adults took longer to swallow Whiting of increasing length than did adult Gannets (Table 8.16b). No significant differences were apparent between the rate of change of handling time of Haddock and of Whiting by each bird species (Table 8.16c).

Although the rate of change of handling time may not differ between species of fish and between the consumer bird species, the actual handling times themselves may differ. The log handling times for fish of 28cm length (this represents the median length discarded of Haddock and Whiting combined) were compared between species (Statistical tests are presented in Table 8.17). As the slopes of the regression lines of each fish species were generally not significantly different from each other, it is only necessary to compare the handling times for one fish length.

Great Black-backed Gull adults swallowed 28cm Haddock and Whiting significantly more quickly than did intermediate and immature Great Black-backed Gulls, Great Skuas, Herring Gulls and Fulmars, but in a similar time to that taken by adult Gannets. Adult Gannets swallowed both fish species more quickly than did intermediate Great Black-backed Gulls, Great Skuas, Herring Gulls and Fulmars, they swallowed Whiting more quickly than did immature Great Black-backed Gulls but Haddock in about the same time. Great Skuas swallowed both Haddock and Whiting more quickly than did Fulmars, in a similar time to that taken by Herring Gulls and more slowly than did intermediate and immature Great Black-backed Gulls. Herring Gulls swallowed 28cm Haddock and Whiting more quickly than did Fulmars, but Haddock more slowly than intermediate and immature Great Black-backed Gulls and Whiting in about the same time. Intermediate age classes of Great Black-backed Gulls swallowed both species of fish in a similar time to that taken by immature Great Black-backed Gulls.

Adult Great Black-backed Gulls swallowed 28cm Whiting significantly more quickly than Haddock of the same length but the handling time of Cod was not significantly different from that of Haddock or Whiting, although the sample size for Cod was very much smaller. Intermediate and immature Great Black-backed Gulls, adult Gannets and Fulmars exhibited no significant differences in their ability to swallow Haddock and Whiting, but Great Skuas and Herring Gull adults swallowed Whiting significantly more quickly than Haddock. Haddock have a wider girth than Whiting, by about 1cm for fish in the length range 13cm - 35cm (DAFS data, Fig. 8.2). Thus, fish girth affects the rate at which fish can be swallowed. Great Skuas, in particular, were observed to have difficulty in consuming Haddock and often nibbled at the fish's head before being able to swallow it. This difficulty to handle Haddock as efficiently as Whiting is reflected in the large difference observed between the handling times of the two fish species by Great Skuas.

The overall difference between the bird species in their ability to handle fish may be illustrated graphically by plotting median handling times for each fish length consumed, for Haddock (Fig. 8.3), Whiting (Fig.8.4) and Cod (Tables 8.18a, 8.18b and 8.18c). Overall, Gannets were seen to swallow the largest fish and in the shortest time, with Great Black-backed Gulls not far behind. Great Skuas, Herring Gulls and Fulmars took a longer time to swallow smaller fish.

8.6.2 Handling times of fish seen to be dropped or stolen

Fish length was unimportant in determining the length of time before Haddock and Whiting were dropped or stolen and the slopes of all regressions between handling time and fish length were not significantly different from zero (Table 8.19). For Great Black-backed Gulls, Herring Gulls and Fulmars, fish length accounted for less than 0.2% of the variation in handling time before the fish was lost. For Great Skuas, a plot of handling time against fish length suggests that longer fish were held for a shorter period of time, but again length was actually unimportant, as it was also for Gannets and Lesser Black-backed Gulls.

8.7 INTERACTIONS BETWEEN SEABIRDS

The numbers of interactions with Fulmars were probably underestimated because it was not always easy to discern whether the Fulmars were actually in ownership of fish before they were taken by another bird. Also, not all birds that took a fish from another bird then managed to swallow it. However, all fish that were seen to be dropped and then picked up by other birds or stolen directly from one bird by another were recorded. Here, I concentrate solely on Haddock, Whiting and Cod.

Great Black-backed Gulls obtained 412 fish that they had kleptoparasitised from other birds or that other birds had dropped and most of these were taken from other Great Black-backed Gulls (Table 8.20). Great Skuas took 124 fish that had been dropped by, or stolen from, other birds and Gannets took 53 fish. Non-adult Great Black-backed Gulls took 51 fish in this manner. Herring Gulls were rarely observed to take fish that had previously been dropped by other birds, nor were they often seen to steal fish. Lesser Black-backed Gulls were never seen to steal fish nor to pick up fish that other birds had dropped. Only two Fulmars were seen to take fish from a different bird species. Often, many Fulmars milled around fish and the fish changed "owners" many times, but it was not possible to assign ownership to one particular bird.

The interactions between bird species were not random (Table 8.21, χ^2_{18}=315.78, p<0.01), with each species most likely to steal from their own species or to pick up fish that birds of their own species had dropped.

These interactions may, in turn, have been affected by the species of fish being dropped or stolen; Great Black-backed Gulls stole or picked up more Haddock but less Whiting than expected, whereas Gannets and Great Skuas took more Whiting and fewer Haddock than predicted (χ^2_3=16.40, p<0.001). It is very probable that Great Skuas deliberately attempted to steal from other species that were carrying Whiting rather than Haddock, bearing in mind the strong selection for Whiting that were swallowed by Great Skuas (see 8.5.1.a).

8.8 DISCUSSION

Seabirds feeding on fishery waste behind Shetland whitefish trawlers fell into two quite separate categories. Firstly, Fulmars fed to a great extent on offal, a point similarly noticed off the north west coast of Scotland (Boswall, 1960). Competition for the offal was great, with the owners being challenged by other Fulmars. Such competition for food amongst Fulmars has been discussed by Enquist *et al.* (1985), who developed a simple model to determine the behaviour pattern and aggressive interactions of Fulmars feeding on food resources that represent different food values. The aggressive behaviour of Fulmars was also recorded during observations from the research platform Nordsee, where Fulmars were seen to be dominant to all species of *Larus* gulls in competition for food and they were also observed to be very aggressive towards Pomarine Skuas *Stercorarius pomarinus* (Rosler, 1980). Secondly, gulls, Great Skuas and Gannets fed more on discarded fish and here a distinct hierarchy was noted. Great Black-backed Gulls swallowed most fish, followed by Great Skuas and Gannets, but Herring Gulls took fewer fish and Lesser Black-backed Gulls took less than 50 fish during the experimental discarding that I conducted from trawlers in 1985. In fact, Lesser Black-backed Gulls dropped more fish than they managed to swallow.

In Chapter 7, I calculated that approximately 200,000 seabirds could be sustained on fishery waste discarded in Shetland waters. More strictly, these seabirds referred to Fulmars (assuming that they were the only consumers of offal) and Great Black-backed Gulls (assuming that they were the only consumers of discards). As demonstrated in this chapter, however, other seabird species also consumed discards and, to a lesser extent, offal. The effect of making such assumptions will be unimportant though as the smaller size of birds such as Herring Gulls and Great Skuas will be offset by the larger size of Gannets. In this chapter I have also discussed the fate of fish that I discarded experimentally. By calculating the weight of Haddock and Whiting (that I discarded experimentally) consumed by each species, using equations supplied by DAFS (Jermyn, *in litt.*), I was able to determine the calorific intake of each fish species by the different birds. The number and sizes of Haddock consumed by Great Black-backed Gulls accounted for 80% of their total estimated calorific value (Table 8.22). Similarly, Great Black-backed Gulls consumed most (73%) of the calorific value of discarded whitefish. Therefore, the assumption that Great Black-backed Gulls were the sole discard consumers in the estimation of bird numbers capable of being sustained by fishery waste is not far removed from the actual situation at sea.

Herring Gulls were not generally present in very large numbers and they did not often obtain large amounts of food, although they did appear to be more successful than the Great Black-backed Gulls in obtaining offal. In winter, according to the fishermen, the situation is quite different with many more Herring Gulls attending trawlers and obtaining food, both offal and discards. Many of these gulls may be migrants from further north (Coulson *et al.*, 1984); these birds are larger than their British counterparts and this may account for their higher (reputed) success rate. The fishermen also report that the gulls are bolder after the Christmas break, taking more food from the deck and also taking food directly from their hands. They attribute this to starvation, as all Shetland boats stop fishing for the holiday period and thus a large food source is denied the birds. The true extent of this effect could be tested by weighing a large sample of birds before and after Christmas.

Haddock and Whiting were the two species of fish most commonly discarded and these two fish species were most frequently swallowed by seabirds too. Many Gurnard were discarded and, although many of the smaller ones were eaten (virtually all by Great Black-backed Gulls and Gannets), they were more difficult to swallow owing to their hard, spiny heads. Flatfish were generally ignored when more favoured species, such as Haddock and Whiting, were available. Only small flatfish could be consumed by the seabirds, as otherwise they were too broad to be swallowed by the birds.

Gannets and Great Black-backed Gulls consumed larger fish than did Great Skuas and the smaller gull species and this factor may have an important bearing on the number of fish actually, and capable of being, taken by the seabirds. The mean length of Haddock and Whiting discarded was longer than the mean length consumed by Great Skuas, Herring Gulls and Fulmars, indicating that the sizes of fish being discarded are often too large for the smaller seabirds to swallow. Further evidence for this comes from examining the handling times of fish of differing lengths by the different seabird species. Handling time increased with increasing fish length, but increased more quickly for the smaller bird species, that is Herring Gulls, Great Skuas and Fulmars took longer to handle small fish than did the larger birds. Great Black-backed Gulls and Gannets experienced no difficulty in swallowing fish of 28cm and 29cm (the median discard lengths of Haddock and Whiting), whereas the smaller birds did, suggesting that the larger birds have a distinct advantage over the other species in their ability to take fish. Should fishing practices change (for example when the cod end mesh size increases in January 1987) and only larger fish be available to the seabirds, then it is the larger birds only that will be able to make use of this food source.

The proportions of fish dropped by or stolen from adult Herring Gulls and from Great Skuas increased as fish length increased, demonstrating, once again, that the larger fish being discarded from Shetland trawlers were unlikely to be consumed by these smaller species. Adult Great Black-backed Gulls, on the other hand, did not drop many fish. The length of fish stolen from birds was generally longer than the mean length swallowed; long fish had a longer handling time and were more likely to be stolen by other birds. Many studies of kleptoparasitism have shown that kleptoparasites tend to attack victims carrying particularly large food items and it has been stated that kleptoparasites select victims according to their food rewards (Brockmann & Barnard, 1979), but since handling time increases with fish length, it may simply be that victims with larger fish are available to be attacked for longer. Kleptoparasites may not be selecting according to fish size and data for Great Skuas suggest that this species actually selects victims with smaller fish and with Whiting rather than Haddock.

Handling times for Haddock were generally slightly higher than for Whiting because Haddock have a wider girth, per unit length. The disadvantages incurred in taking longer to swallow a Haddock may be outweighed by the advantage of the extra weight of fish per unit length. A 30cm Haddock will weigh approximately 265g compared to 235g for a Whiting of the same length (DAFS data). However, this may not hold true for Great Skuas which consumed about half the number of Haddock compared to Whiting; these birds were observed to have considerable difficulty in swallowing Haddock, especially those measuring 29cm in length or more.

The handling time of prey taken by herons increases with increasing prey length (Quinney *et al.* 1981, Riegner 1982, Smith 1984) and is generally longer for flatfish than for roundfish (Cook, 1978), as was found for fish taken by seabirds during this study. Kushlan (1981) discusses the capture and handling of prey by ciconiiform waders and reiterates the above. Handling time is constant below a certain prey size but for larger prey it becomes an exponential function of prey size (Schoener, 1971); the same was determined in the present study. By taking very large prey items, the probability of a kleptoparasitic attack increases for the White Ibis *Platalea alba* (Kushlan, 1979). This robbing could restrict the diet of the victim in that certain types of prey that are difficult to handle (large fish, flatfish or fish with spines, in this study) are likely to be lost to kleptoparasites.

Adult Great Black-backed Gulls were more successful than non-adults, obtaining more fish than expected, whereas non-adults obtained fewer. Although all age classes stole more fish than they had stolen from them, adults stole proportionately very many more, or put another way, they had fewer fish taken from them. Adults took longer fish than non-adults and they also handled the fish more quickly. Increased adult efficiency and success has also been recorded for the Herring Gull around prawn trawlers in the Clyde, where adults dropped fewer fish, were more selective in the size of fish they chose and overall they obtained more fish than did immatures (Furness *et al.*, in press). Similarly, north west of Orkney, adult Gannets took many more fish than expected, on the basis of flock composition (A. Webb, in litt.). A. Webb also noticed that, relative to their numbers, Fulmars were observed to take fewer discards than expected, while Great Skuas took more, similar to the results collected in this study. Juvenile Grey Herons are also less efficient foragers than adults (Cook, 1978). Efficiency at feeding is learnt quickly but initially adults are generally more successful than younger birds, as also shown in the number of plunge dives by Sandwich Terns *Sterna sandvicensis* resulting in capture of prey (Dunn, 1972).

The foraging activity of Herring Gulls feeding at refuse tips increased progressively from immatures to adult birds (Grieg *et al.*, 1983). In Mexico, adult Laughing Gulls *Larus atricilla* chose juvenile Brown Pelicans *Pelecanus occidentalis* in preference to adults as their victims for kleptoparasitic attacks, even though adult Brown Pelicans were more successful in their foraging attempts than juveniles. Juveniles were less efficient at evading kleptoparasitic attacks by the gulls, thereby increasing the food available for the Laughing Gulls (Carroll & Cramer, 1985). Larger sample sizes of parasitism amongst gulls would be necessary to determine whether a similar strategy is adopted by gulls behind whitefish trawlers in Shetland. In the Mexico study, juvenile Laughing Gulls did not select the juvenile Brown Pelicans as victims. At rubbish dumps in New Jersey and Mexico, adult Herring and Ring-billed Gulls *Larus delawarensis* engaged in kleptoparasitism more often than young gulls and also they were chased less often than were young gulls, although there were no differences in kleptoparasitic success rates (Burger & Gochfeld, 1981). In that study, Great Black-backed Gulls were seldom victims of kleptoparasitic attacks. When Laughing Gulls in Mexico were supplied with lumps of chopped liver, adults were more successful than non-adults; the younger gulls were unable to obtain and keep larger pieces. Improvement occurred with age and experience.

In Shetland, more large fish were dropped than small ones, especially by Herrring Gulls and Great Skuas which had difficulty in handling the length of fish discarded there. This has been reported for other species as well, such as the Yellow-crowned Night Heron (Riegner, 1982).

Kleptoparasitism, the stealing of one food item from one bird by another (which may be either interspecific or intraspecific), has been well documented (e.g. Burger & Gochfeld 1981, Thompson 1986) and is particularly common amongst certain families of seabirds (e.g. Brockmann & Barnard 1979, Furness in press). During the present study, Great Skuas kleptoparasitised the highest proportion of all fish handled by each species but they were less successful than Great Black-backed Gulls because they lost more fish to other kleptoparasites than they actually gained. This may have been due to the fact that the fish were rather long for Great Skuas to handle efficiently rather than the fact that they have less well-developed kleptoparasitic skills than the larger gulls. Many of the fish being discarded were too large for the skuas to swallow quickly and therefore they carried the fish for longer than did the Great Black-backed Gulls. The mean length of discards stolen from Great Skuas was greater than the mean length stolen by them, which indicates that those fish that were stolen from them were too large for them to handle efficiently. Conspicuous prey increases the likelihood of kleptoparasitism (Brockmann & Barnard, 1979); either the fish size or the length of time taken to handle the fish could be the key in determining conspicuousness of prey. In the Minas Basin in Nova Scotia, fish that were large and took a long time to handle were the only ones to be stolen from Great Blue Herons *Ardea herodias* by gulls. Small fish could be swallowed quickly, thus minimising the time in which another bird could steal the fish (Quinney *et al.*, 1981).

Brockmann & Barnard (1979) report that kleptoparasitism is especially common amongst mixed flocks of birds and such a situation was observed behind the whitefish trawlers during this study. In contrast to this, Thompson (1986) found that Black-headed Gulls foraged most efficiently in single-species host flocks, the hosts being plovers; apparently attacks involving Lapwings *Vanellus vanellus* incurred smaller costs and also gulls were more numerous and competitive in mixed species host flocks.

Great Skuas do not restrict their kleptoparasitic activites to fish being discarded at sea but steal prey from many seabird species at their breeding colonies (e.g. Andersson 1976, Furness 1978b). Thus kleptoparasitism by Great Skuas at sea is not purely an adaptation to prevailing circumstances but is part of the feeding behaviour of the Great Skua during the breeding season.

Kleptoparasitism has been recorded for Herring and Lesser Black-backed Gulls elsewhere (Verbeek 1977, Hudson 1985) but was not common behind whitefish trawlers in Shetland. It is probable that the relatively large size of the discards was the determinant factor.

DISCUSSION

Scavenging seabirds feed extensively on discards and offal behind whitefish trawlers, but few people have tried to quantify the availability of this food source to birds nor estimate the numbers of birds capable of being supported by it. The extent to which trawler waste has contributed to the increase in seabird populations this century has attracted wider discussion. Fisher (1952) was one of the first to attribute population increases, particularly of the Fulmar, to waste from the whaling and whitefish industries. Whether the availability of fish offal caused the large increase in the Shetland population of Fulmars, or simply facilitated it, remains uncertain. Brown (1970) noted that there was no correlation between the highest numbers of Fulmars and the best fishing grounds off the east coast of Canada. Fulmars were common on the fishing banks off Newfoundland but not off Nova Scotia, but were also common off Greenland where less fishing occurs. The water off Nova Scotia is warmer than that off Newfoundland and Greenland and perhaps water temperature and other oceanographic factors control the distribution of Fulmars in the W. Atlantic, rather than the fishing industry (Brown, 1970). However, it is worth noting that Canadian fishermen process their catch differently from European fishermen. Off Canada, fish guts are discarded still attached to the head and so they sink fast. As a result, the fishery fleet may make little food available to Fulmars.

By contrast, in the Southern Benguela Current region there has either been an increase in numbers of seabirds, especially of cephalopod-eating Procellariiformes, during the past 30 years coinciding with an increase in the amount of fishing in the area, or else a significant change in the local distribution of seabirds (Abrams, 1983). In the North Sea highest numbers of breeding Fulmars are found in areas where the whitefish industry is most important (Furness *et al.*, in press). This might suggest that the availability of offal has influenced the spread of the Fulmar, particularly around Shetland. This suggestion is given further credence by the fact that further south in the British Isles, where Fulmar numbers are lower, smaller quantities of offal are discarded (Furness *et al.*, in press). To confuse the issue, however, it has also been shown that breeding

Fulmars on Foula fed largely on Sandeel at a time when these were readily available (Furness & Todd, 1984), rather than on offal. From 1983 to 1985 on Noss, Sandeel was not recorded in Fulmar regurgitates so often, probably due to a decrease in Sandeel availability during those years (Heubeck, 1986) and Fulmars fed mostly on offal and whitefish.

The increase in the Fulmar population in Shetland shows little sign of reaching an end. Thus, although the largest increases in Fulmars have coincided with areas of highest whitefish fishing activity, the evidence is not yet conclusive that offal availability caused the expansion of the populations in the first instance, or we might expect all birds to continue to rely largely on offal rather than on Sandeel. However, the situation may be more complex. Perhaps where whitefish fishing is most common, the Sandeel stocks were allowed to expand, owing to a reduced predation rate by the larger fish (Furness, 1984b). Maybe it was this increased stock of Sandeel that allowed the continued expansion of the Shetland population of Fulmars, so that it is not just the offal that is important in sustaining population increases. Perhaps Fulmar numbers in Shetland increased initially in response to the increased offal availability and then they switched their diet to Sandeels when these built up in numbers. Now that Sandeel stocks are declining, the role that offal plays in the population dynamics of Fulmars may become greater than in the recent past. The ease with which Fulmars can obtain offal behind whitefish trawlers means that the reduction in the availabiity of Sandeels poses little threat to these birds, as long as offal remains a plentiful food supply.

Gannets, still increasing in numbers in Shetland, feed to a certain extent on whitefish discards but, apparently, higher numbers are associated with whitefish trawlers during the pre-breeding season than during the breeding season (Blake *et al.*, 1984). In the summer, sufficient numbers of live fish may be available to the Gannets so that they do not have to rely on whitefish discards to such a degree. Therefore, to assess the effect of whitefish discards on Gannet populations in Shetland, we would need to study the diets of Gannets throughout the entire year. This was not possible in the present study and it would, in fact, be a difficult task to achieve in any study. Detailed observations of the feeding behaviour of Gannets attending whitefish trawlers all year round might throw some light on the extent to which Gannets rely on discards and would indicate the months during which this food source is most important. It would be dangerous to suggest that fishery waste is not affecting the breeding and feeding ecology of Gannets if discards only form an important proportion of their diets for short periods of each year, for example during the pre-breeding season, when the easy availability of food might have a big effect on the subsequent breeding success of the adult birds. The increase observed in the numbers of breeding Gannets in Shetland this century may indeed have been supported, in part, by fishery waste. The increase in the stocks of small fish, following the decrease in numbers of larger, predatory fish due to man's exploitation, may also have contributed to the expansion of the Gannet population (Furness & Monaghan, 1987).

Competition between birds may reduce the amount of any one food source that a particular species may be able to exploit. Burger (1981) suggests that direct competition from Herring Gulls has prevented Laughing Gulls in New Jersey from feeding to a large extent at refuse dumps. Behind whitefish trawlers, a similar situation occurred where Fulmars were securing most of the offal discarded at sea, by out-competing all other bird species for this highly desirable food source.

Competition also manifested itself in the conflict for discarded fish behind the trawlers. Great Black-backed Gulls and Gannets were the two most successful species, taking larger fish than Herring Gulls and Great Skuas and also swallowing the fish more quickly. The fact that so many Great Black-backed Gulls were recorded feeding on discards suggests that these birds were getting a good return for their investment of energy, i.e. that this form of feeding was very profitable for the species. The greater efficiency exhibited by Great Black-backed Gulls and Gannets over Great Skuas and Herring Gulls is reflected in the current status of their breeding populations, in that the former two (and Fulmars) are increasing whereas Great Skua numbers have reached a plateau and Herring Gull numbers are in pronounced decline. It was evident during this study that Herring Gulls were obtaining very little waste food from trawlers, but whether this has affected their present decline in numbers is not known. The availability of an abundant food supply is a necessary prerequisite for expanding populations, as has been shown in Hornøy and Reinøy in N. Norway where seabird numbers are increasing and sufficient food is available to maintain these increasing populations (Furness & Barrett, 1985). Clearly food shortage, or some other factor (to be discussed below) has brought about the declining populations of certain seabird species in Shetland.

Increased adult efficiency at feeding has been recorded in a variety of situations (e.g. Dunn 1972, Monaghan 1980, Burger & Gochfeld 1981, Grieg *et al.* 1983) and intraspecific competition between birds of different ages was common behind trawlers. Adult Great Black-backed Gulls stole relatively more fish than did younger birds and they also swallowed fish more quickly. In addition, they were present in far greater numbers than the immatures, suggesting that it was uneconomical for large numbers of immatures to attend trawlers.

I collected no information on the breeding status of adult Great Black-backed Gulls feeding on discards at sea but by examining the diets of birds on land it was clear that both breeding and non-breeding Great Black-backed Gulls in Shetland fed on whitefish discards to quite a large extent, as indicated by the numbers of Whiting and Haddock otoliths. The increases in this species may have been caused by a decrease in human persecution or by other factors, but it is very likely that the amount of fishery waste consumed by these birds contributes to their continued well-being.

The availability of different food sources may be reflected in the diets of seabirds and may also affect their productivity in the long term. For example, on the Isle of May, the diet of young Puffins was seen to change from largely Sprats *Sprattus sprattus* to young Herring, following decreases in the populations of Sprats in the North Sea (Hislop & Harris, 1985). By examining yearly fluctuations in the market landings of whitefish in Shetland and relating them to variations in the diets of Great Skuas between years, it is possible to suggest the extent to which Great Skuas relied on fish discards during this study. This may help in assessing the possible impact of future changes in fishery practices. In 1984, more whitefish was recorded in the pellets regurgitated by breeding Great Skuas on Noss than in 1983 or 1985, and less whitefish in 1985 than in 1983. More whitefish were landed in 1984 than in 1983 or in 1985 in Shetland (DAFS data) and I predicted that more offal and discards were available to seabirds in 1984 than in 1985 (Chapter 7). Thus, it seems that the diets of Great

Skuas are indeed reflecting the availability of discarded whitefish from trawlers.

One anomaly was recorded in the diets of Great Skuas. Norway Pout otoliths occurred commonly in regurgitated pellets and yet Norway Pout was rarely seen on my trips at sea on trawlers. A similar situation has also been observed by DAFS staff (A.S. Jermyn, pers. comm.). Perhaps Norway Pout are small enough to be forced out of the net when the net is first hauled so that they become available to seabirds far behind the boats. By floating to the surface far behind the trawlers, they would not be recorded amongst our discards. If all Norway Pout follow a similar pattern of behaviour to 0-group fish (migrating to mid-water at dusk and returning to the bottom by day, Bailey 1975), they would remain unobtainable to Great Skuas except behind trawlers. Industrial fishing for Norway Pout is conducted in Shetland waters, principally by Danes, but I had no opportunity to travel on these boats to see whether any fish become available to seabirds when they are hauled aboard. Nevertheless, it seems odd that Norway Pout very rarley occur in pellets regurgitated by gulls, yet are frequently taken by Great Skuas.

In the present study, adult Herring Gulls relied almost entirely on intertidal invertebrates, but they fed their chicks on whitefish to a large extent. In 1984, more whitefish bones were found in regurgitated pellets than in 1983 or in 1985, suggesting, as in the diets of Great Skuas, an increased availability of whitefish in this year and, indeed, the market landings of whitefish in Shetland in 1984 were the highest for a decade (DAFS data). It is tempting to infer that the diets of Herring Gulls on Noss were reflecting this, but as demonstrated in Chapters 6, 7 and 8, however, Herring Gulls do not rely much on discard fish taken behind whitefish trawlers. The lengths of otoliths collected in regurgitated pellets suggest that adult Herring Gulls are scavenging fish (either entire or just the fish heads) from harbours and around fish factories, rather than from behind trawlers. It may be that in 1984, more landed fish were available to Herring Gulls at harbours. At sea, competition from Fulmars for offal was fierce and the average length of fish being discarded was too long for Herring Gulls to swallow quickly, with the result that Herring Gulls obtained little fishery waste behind whitefish trawlers in Shetland.

The factors controlling seabird populations are poorly understood, although widely discussed in the literature. The idea that seabird numbers are controlled by density-dependent factors, chiefly brought about by winter starvation (Lack, 1966) is not generally accepted by seabird biologists today, but perhaps should not be ruled out of hand totally as, for example, large wrecks of starved auks have been washed up on British shores on several occasions in recent years. Ashmole (1963) first put forward the idea that density-dependent factors, although relating to food availability, might operate during the breeding season when food sources might become depleted in the vicinity of (tropical) seabird colonies. Thus, he predicted that when colonies became over-populated, resulting in a scarcity of food, the breeding success of the birds would decrease. More recently, this theory was tested for temperate seabird colonies (Furness & Birkhead, 1984) with the conclusion that their distribution was compatible with the idea that colony sizes were determined by competition for food supplies during the summer; seabird colony sizes appear to be strongly influenced by the numbers of conspecifics competing for food near the colony. Colony size also depends on the location of the colony as those on islands have a greater area of sea in which to feed than those on coastlines (Birkhead & Furness, 1985). Thus, food supplies during the summer do appear to have an effect on the numbers of breeding birds. They also affect the breeding performance of birds, as predicted by Ashmole's hypothesis for regulation of tropical seabird populations. For example, the weights of fledging Brunnich's Guillemots were lower from larger colonies, as the adult birds had to travel further to feed and they fed less food to the chicks (Gaston *et al.*, 1983). Rowan (1965) does not entirely agree with Ashmole's idea that food shortage in summer will regulate seabird populations, for seabirds of south temperate seas anyway. Most of the birds there belong to the petrel family and many of these species have been shown to travel very long distances to feed. In addition, their chicks can survive without food for several days, and sometimes longer. Therefore, Rowan concludes that food shortage is unlikely to be a controlling factor in the population regulation of South Atlantic seabirds as food would hardly become scarce over the vast areas of sea that must be covered by these birds in their search for food. Other factors, such as nest site limitations, may regulate seabird colony sizes in certain situations (Potts *et al.*

1980, Duffy 1983) but are unlikely to be major regulatory factors for most seabird populations.

Certain seabird populations may not be regulated entirely by density-dependent factors. At the turn of this century the initial increases of many seabird populations was caused by the decrease in human persecution (Chapter 2). Once the populations began to expand, sufficient food had to be available in order to maintain these increases (Furness & Monaghan, 1987). Since then, density-dependent regulation may have come into effect, operating on these increased populations as, for example, food shortage is thought to have caused the decline of the Kittiwake in recent years (Coulson, 1983). Gannets, like other seabirds such as Kittiwakes and Great Skuas, increased due to a relaxation of human persecution but, unlike Kittiwakes and Great Skuas (in Shetland anyway) are still increasing, presumably because of an adequate food supply (Furness & Monaghan, 1987). Changes in fishing practices that have allowed increases in the stocks of small fish may now be the principal factor maintaining the continued expansion of the Gannet. Thus, for small populations or in situations where there is an artificially high availability of food (rubbish dumps, at sea due to changes in fishing practices), density-dependent regulation may not occur.

If we examine the current status of breeding scavenging seabirds in Shetland, we see that the availability - and utilisation - of trawler waste in summer is mirrored by the population trend of each species. Fulmars consumed nearly all of the offal behind trawlers, whereas Gannets and Great Black-backed Gulls were most successful in obtaining discards. These three species are increasing in Shetland at present. Great Skuas did obtain some discards, but were seen to have difficulty in consuming the larger fish. Herring and Lesser Black-backed Gulls and Kittiwakes obtained very little in the way of waste food behind whitefish trawlers in Shetland and all three species are currently declining in Shetland (Richardson 1985, Seabird Colony Register NCC). We could infer, using Ashmole's hypothesis for the regulation of population size, that the latter three populations are declining due to a food shortage in summer and that the exploitation of fishery waste at sea is a reflection of food availability.

However, the breeding performance of birds was also predicted to decrease once food became short (Ashmole, 1963). On Noss, the numbers of Herring Gulls decreased during the three year study and yet the birds' breeding performance was not seriously impaired. Their breeding success on Noss in 1983 and 1984 (Chapter 4) was similar to that recorded elsewhere, although lower than in an increasing gull colony (Harris, 1970), indicating that the decrease in numbers of breeding birds on Noss has not been reflected in their capacity to produce young. So, it appears that, following Ashmole's theory, Herring Gulls are not decreasing due to a food shortage in summer as their breeding performance has not been greatly lowered. Alternatively, a different form of population regulation may be operating. Drent and Daan (1980) suggest that, where populations are suffering hardships, the adults may decide whether or not to breed. This decision to breed is related to the body condition of the female, implying low survival prospects for any female which decides to breed when in poor condition. Those that do elect to breed may work harder in order to obtain sufficient food to provide for the needs of their chicks adequately. The present decline in the Herring Gull population may be caused by birds deciding not to breed, to enhance their survival prospects as they would then be in a position to choose whether or not to breed in the future. It is also possible that winter mortality is high for Herring Gulls. If that was the case, then population regulation might be operating by winter starvation, as proposed initially by Lack (1966). However, ring recovery data suggest that most mortality of adult Herring Gulls occurs late in the breeding season (Coulson *et al.*, 1983).

In contrast to the situation for Herring Gulls, the breeding success (measured by number of chicks fledging per pair) of Great Skuas was lower on Noss during this study than on Foula in the late 1970's (Furness, 1984a). If the halt in the population increase of Great Skuas, experienced all through this century until very recently, has been caused by a decrease in food availability during the breeding season, Ashmole's hypothesis would predict that the breeding success of Great Skuas should be lowered and this indeed appears to be happening. Therefore it seems as if the population trend of the Great Skua is being mirrored by a decrease in productivity, perhaps due to a reduction in food availability (both Sandeel and discards from trawlers) during the breeding season. Whether the lower fledging rate observed on Noss was a reflection of a lower food availability, or whether the high rate of cannibalism was caused by other factors (such as density of nests, for example, see below) is not certain. The death of young chicks due to starvation might be a reflection of the parents' inability to provide sufficient food for two chicks. The adults might well be able to provide sufficient food to sustain the appetite of the surviving chick so that overall chick condition (see below) would remain high and would not differ significantly between years. Owing to the broad nature of this study it did not prove possible to follow the fate of individual broods in sufficient detail in order to analyse the condition of chicks from broods of one and two and at different stages of the season. It is worth pointing out, however, that Great Skua numbers stopped increasing at the same time as breeding success seems to have fallen, and definitely not several years after a decrease in breeding success. The stabilisation of the population size cannot be directly due to a decrease in breeding success therefore, although both may be due to a reduction in food availability.

Population regulation may be controlled by the availability of nest sites of suitable quality. Reduced breeding success was recorded for Shags on the Farne Islands when the population increased beyond the number of good quality nest sites (Potts *et al.*, 1980). The decrease in numbers of breeding Great Skuas on Noss follows this theory as the nesting density was very high in 1983 (Willcox *et al.*, 1983) and the breeding performance of Noss Great Skuas was low. Nesting density might give an indication of nest quality, in that small territories may increase the chances of predation of chicks by other Great Skuas. However, nest density on Noss was no higher than on some parts of Foula in the 1970's.

Fulmars, continuing to increase in numbers in Shetland and feeding to a large extent on fish offal, bred less successfully in 1984 than in 1983 on Noss but, as explained in Chapter 4, this was largely due to an increased predation rate of the chicks. Thus, no conclusions can be drawn as to the type of population regulation mechanism operating on Fulmars, as judged by their breeding performance. The fact that their numbers are still increasing, however, suggests that density-dependent regulation is not yet operating to any great extent and that neither food nor nest sites are in short supply at present.

The problem of monitoring the state of breeding populations now arises. We have shown that if regulation operates in a density-dependent manner, caused by a food shortage during the breeding season (Ashmole 1963, Furness & Birkhead 1984) it may be reflected in the breeding performance of some seabirds, for example the Great Skua in Shetland. However, this is not always the case as Herring Gulls, although declining in numbers in Shetland, had a good breeding performance. Perhaps the condition of the breeding population and of the growing chicks may give us a further clue.

In 1983, the mean egg volume index of Herring Gull eggs was larger than in 1984, which might suggest that the adults were in better condition in 1983, an idea put forward by Lloyd (1979), and that food availability was greater in 1983, following the thinking of Hogstedt (1981). If this were so, one might expect the laying date to be earlier in 1983, as increased food availability influences date of laying (Perrins, 1970), but this was not the case. Once the chicks had hatched, parents spent marginally more time away from the nest sites foraging for food in 1983 than in 1984 and also feed rates per chick were slightly higher in 1984 (when whitefish availability was higher). This would suggest the opposite to that suggested by the mean egg volume index, namely that food was in shorter supply in 1983. Thus, a dichotomy exists, whereby features of birds' breeding success that may sometimes reflect food availability and adult body condition contradicted themselves during this study. We may infer from this that food was not extremely short in either year and that differences in breeding parameters were due, perhaps, to chance variation between years or that changes in food availability occurred within each season. Herring Gull chick condition from 1983 to 1985 was always good and did not differ significantly between years, showing that the birds that did breed were able to find sufficient food to provide adequately for their chicks. This is in line with the thinking of Drent and Daan (1980).

Breeding Great Skuas and Fulmars were probably in similar condition in 1983 and 1984 on Noss in that date of laying and mean egg volume indices did not differ significantly between years. Likewise, the condition of their chicks did not differ significantly between years, or from chicks measured at other sites, although chicks of both species tended to weigh slightly more in 1983 than in the succeeding two years. In contrast to this, the mean feed rate per Fulmar chick was slightly lower in 1983 than in 1984, suggesting a lower availability, or a lower intake, of food in 1983.

Food availability here is rather a general term in that food preferences have not been taken into account. For example, in a study on the Isle of May and St. Kilda, Puffins selected Sandeel and Sprat in preference to rockling and Whiting, the former providing a better food supply in terms of calorific intake (Harris & Hislop, 1978). Thus, although gadoid species of fish may always be abundant, it was the availability of clupeids and Sandeel that was important, as shown by the lowered fledging weights of Puffin chicks that were fed on Whiting on St. Kilda (Harris & Hislop, 1978). On Foula in the late 1970's, Great Skua chicks were fed mostly on Sandeel (Furness & Hislop, 1981), whereas on Noss in the present study Sandeel was less important than whitefish, although the number of chick regurgitates collected on Noss was small. Also, adult Great Skuas, both breeders and non-breeders, fed less on Sandeel on Noss than on Foula nearly a decade earlier. Following Harris and Hislop's (1978) findings, one might have expected Great Skua chick condition to be lower on Noss than on Foula, due to a lower consumption of Sandeel, but this was not the case, indicating that the adults that chose to breed were finding sufficient food to satisfy the energy demands of their growing chicks, reinforcing Drent and Daan's (1980) theory. In future, it may prove more useful to measure adult activity budgets and chick feed rates as measures of food availability and general state of health of the breeding populations rather than to measure the growth rates and condition of chicks.

The net mesh size in the North Sea is to increase from 80mm to 85mm in January 1987 and it is possible to assess the impact that this measure may have on breeding seabird populations in Shetland as a consequence of the provision of fewer discards. The effect of a decrease in Sandeel availability may exaggerate the impact of fewer small discards being available. Sandeel catches around Shetland have decreased markedly since 1982, due either to overexploitation by the fishing industry or to unknown natural factors causing poor spawning seasons and low levels of recruitment since 1983 (Gauld *et al.* 1986, Heubeck 1986). Until the level of recruitment increases, the numbers of Sandeel available to seabirds (and to man) will be lower than in recent years. Sandeels form an important part of the diet of chicks in that they are very rich in protein and lipid (Furness & Hislop, 1981). Therefore, a decrease in Sandeel availability could possibly result in a protein or calorific deficit in the chicks' diet and so the parents may have to forage for longer to maintain the growth rates of their chicks. If sufficient fish or offal could be scavenged from whitefish trawlers, then the possible predicament of scavenging seabirds would be less.

Fulmars, relying heavily on offal, are unlikely to be affected by changes in the net mesh size. In the long term, they may gain if the change has the intended effect of increasing total marketable catch. Great Black-backed Gulls and Gannets will probably not be adversely affected by a small increase in the net mesh size, as the size of discards will probably not increase too much. By showing that they can swallow large fish and also that they can swallow fish of all lengths more efficiently (quickly) than the smaller bird species, it is clear that they will retain this dominant position should the number of small discards decrease. On Noss, breeding Great Black-backed Gulls fed mostly on Rabbit, whitefish and other seabirds. Were whitefish to become unavailable to Great Black-backed Gulls, the level of predation on both Rabbit and other seabirds would probably increase or else the gulls would have to revert to feeding more on intertidal invertebrates as they do elsewhere (Hudson, 1982) and as Herring Gulls do in Shetland at present.

The effect that an increase in net mesh size may have on Great Skuas will depend on the numbers of small fish that will continue to be discarded. During the present study, Sandeel formed only a small proportion of Great Skua chick regurgitates on Noss, in contrast to chicks on Foula in the late 1970's (Furness & Hislop, 1981). They suggested that a high breeding success of Great Skuas may be maintained by the provision of discard whitefish, easily accessible to the birds when Sandeel availability is low. In the late 1970's, Sandeel availability was high and this was reflected in the diets of Great Skuas on Foula. Now that Sandeel is more difficult to obtain, demonstrated by its low occurrence in the diets of Great Skuas (this study) and the reduced catches by fishermen owing to the lowered stocks (Gauld *et al.* 1986, Heubeck 1986), Great Skuas may be relying on discarded whitefish from trawlers for a greater proportion of their energy demands. If the availability of this food source decreases, through the enlargement of the net mesh size, Great Skuas may have to turn to alternative food supplies, such as increased predation on other seabird species (Furness, 1981b). The possible implications of this have been discussed in detail (Furness, 1986) but, briefly, we may expect to see other seabird species suffer, also perhaps an increased predation rate on lambs, to the detriment of the local crofters and, eventually, a decline in the numbers of breeding Great Skuas themselves as the present populations could not be sustained by feeding on seabirds alone. It is possible that Great Skuas might turn their predatory attentions to other waste foods such as refuse tips, as a small number of Great Skuas were reported feeding at a dump in Shetland (Furness *et al.*, 1981). However, as human waste food did not appear in any of the adult food remains or in chick regurgitates in this study, it appears that this source of food is not widely used by Great Skuas. Also, refuse dumps are not very plentiful in Shetland (by comparison with areas in mainland Britain) and so the extent to which Great Skuas could rely on these to fulfil their dietary requirements would be limited.

Whether Herring Gulls relied on fishery waste to a greater extent in the past than now is unclear, but at present they scavenge most of their fishery waste from land rather than from further out to sea. Although an increase in fishing net mesh size will further reduce the number of small discards available to Herring Gulls, they may still be able to feed their chicks on whitefish by continuing to steal fish from markets.

The possibility of a decrease in food availability to all seabirds behind whitefish trawlers in Shetland is a very real threat. As mentioned above, the local Sandeel fishery has suffered a very serious decline since 1982. Sandeel are a food source for larger fish, such as Cod, Whiting and Haddock, the commonest whitefish species harvested in Shetland waters. Sprats, another commercially exploited fish species, declined in numbers off the north east coast of Britain in the late 1970's, but whether due to over-exploitation or to natural population fluctuations is uncertain (Blake, 1983). Sandeels seem to be following a similar fate, particularly around Shetland. Should the stocks of Sandeel become reduced still further and should other industrial fisheries increase, such as fishing for Norway Pout, the amounts of prey food available to whitefish may drop so low that the whitefish stocks fall into decline. This may already be happening in that the market landings were very much lower in 1985 than in 1984; alternatively, the low catches experienced in 1985 may simply be due to natural fluctuations.

We will have to wait for some years to decide whether whitefish stocks are on the decline. If they are decreasing, due to reduced Sandeel availability, then the effect that this decrease could have on scavenging seabirds in Shetland could be great. As calculated in Chapter 7, approximately 200,000 seabirds (out of a total estimated population of approximately 242,365 pairs of scavenging seabirds in Shetland) could derive sufficient food from trawler waste supplied by UK vessels fishing in Shetland waters. In 1985, rather fewer than 200,000 birds were catered for. This means that more birds would have had to rely on other food sources to satisfy their energy demands. Should both Sandeel and whitefish discards become scarce, the seabirds may find it difficult to provide for their chicks during the breeding season and more populations may decline.

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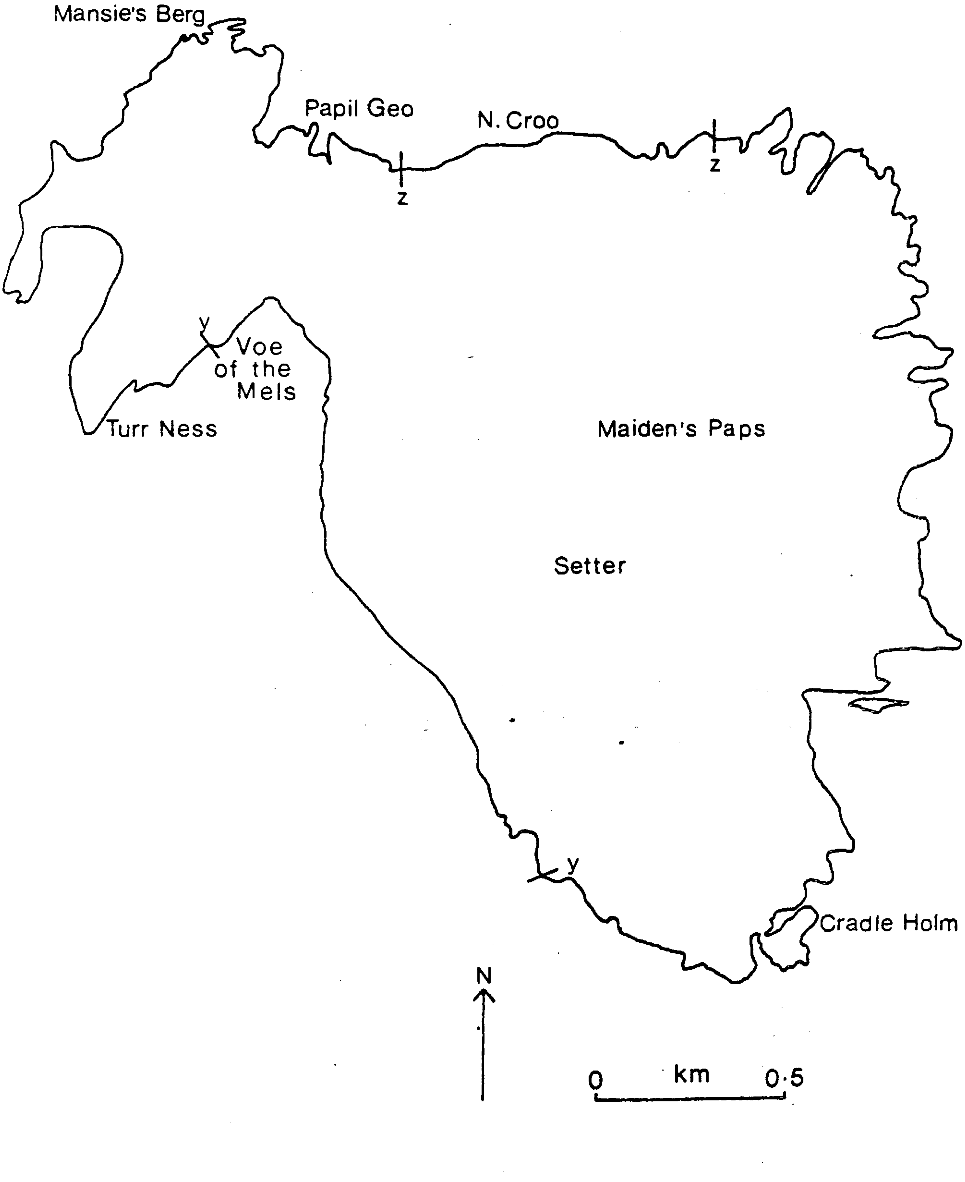

Fig. 3.1- Isle of Noss, Shetland.

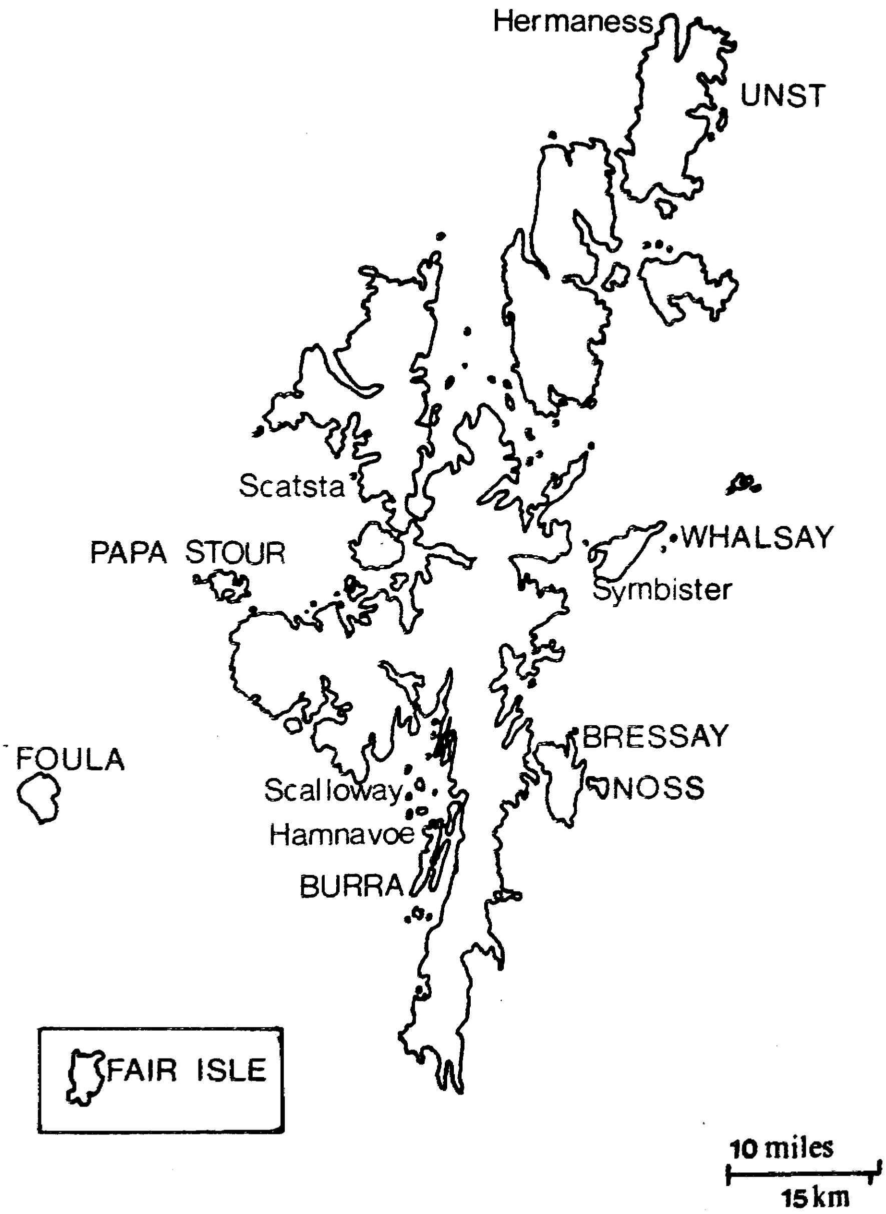

Fig. 3.2 Map of Shetland.

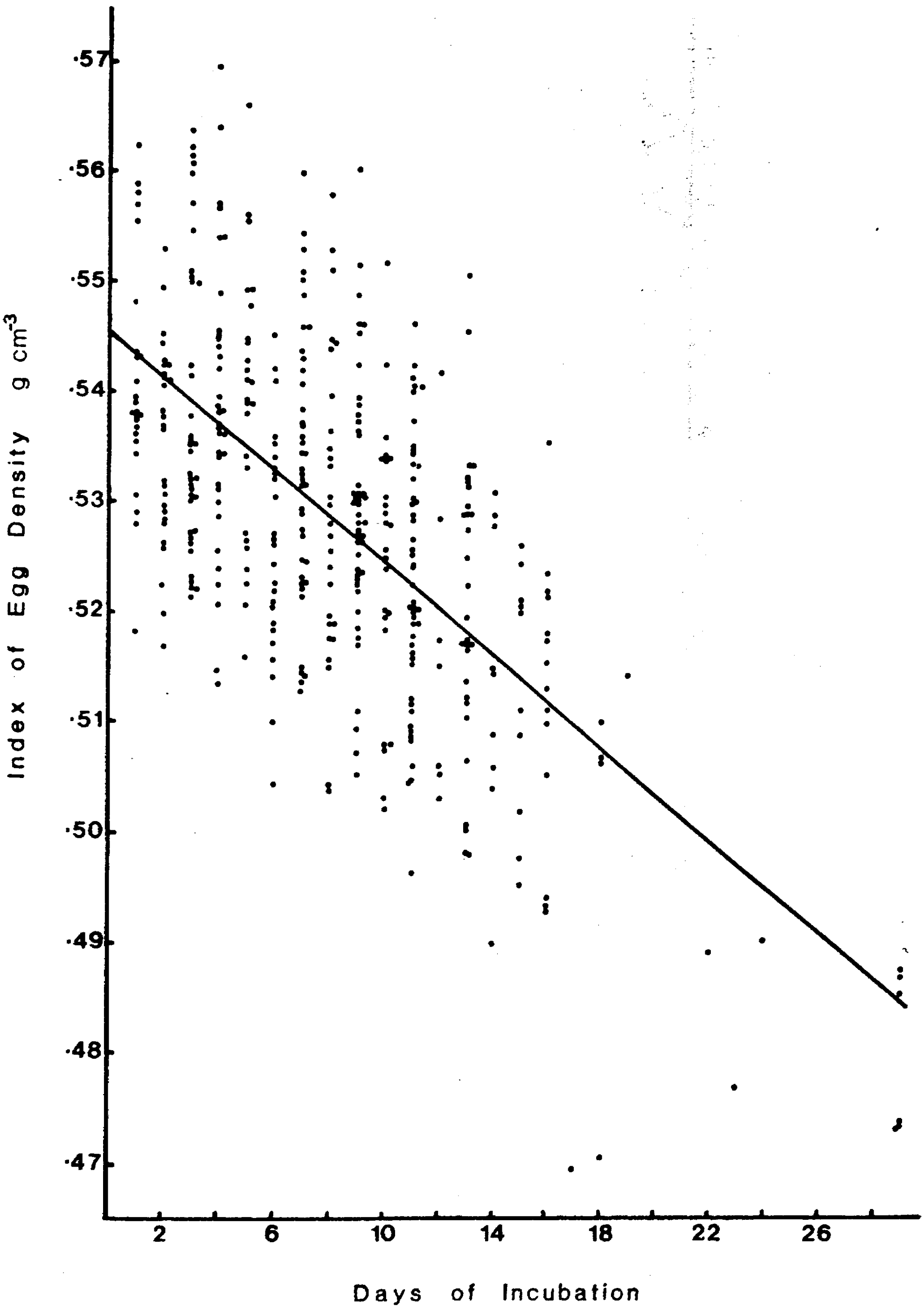

Fig. 4.1 Change in index of egg density during incubation for Herring Gulls, Noss 1983 and 1984.
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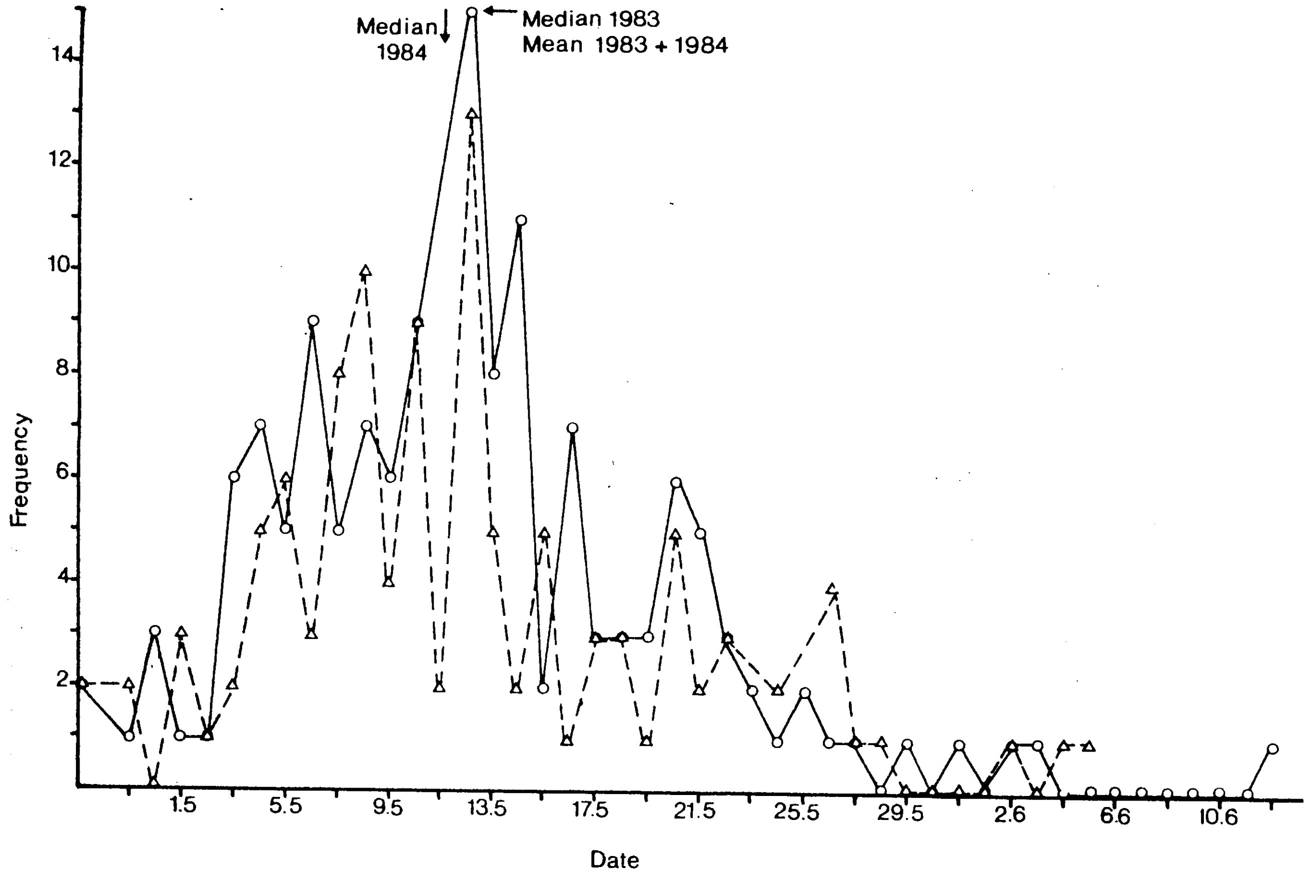

Fig. 4.2 Distribution of dates of clutch initiation for Herring Gulls, Noss 1983 (o) and 1984 (Δ).

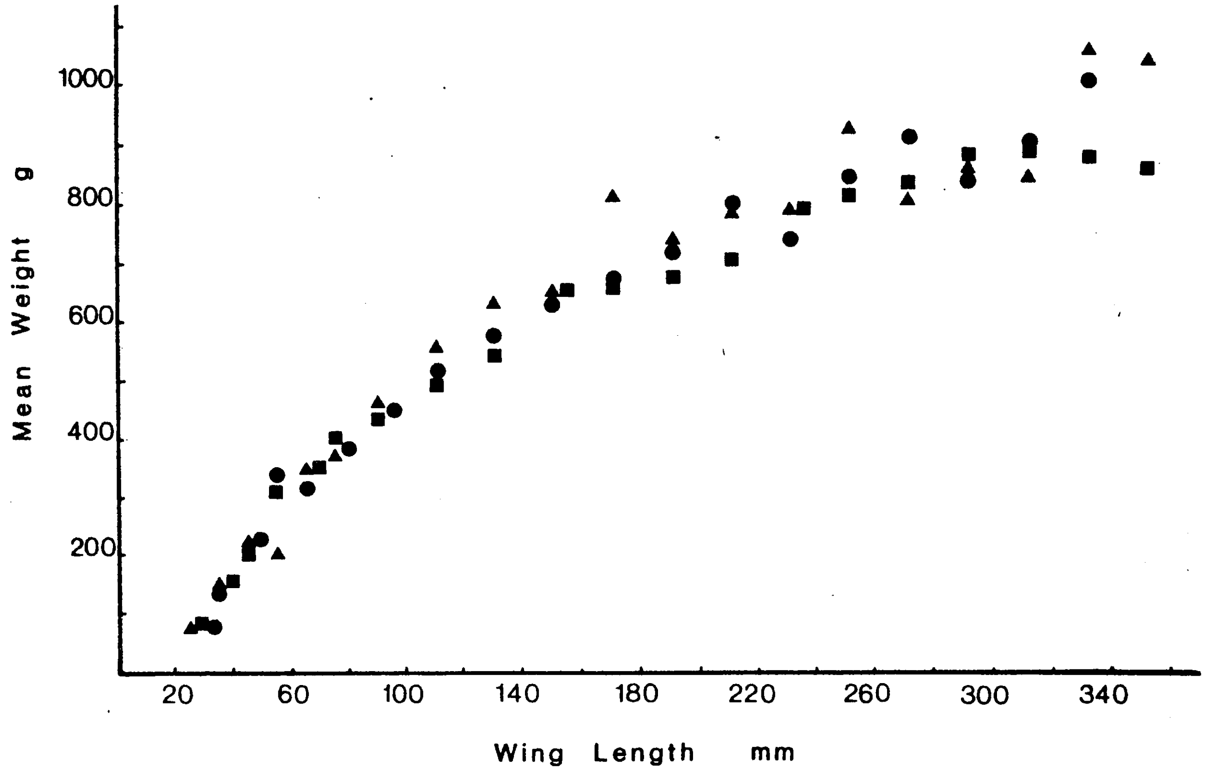

Fig. 4.3 Mean weight for each size class of wing length for Herring Gull chicks, Noss 1983, from broods of 1 (▲), 2 (■) and 3 (●).

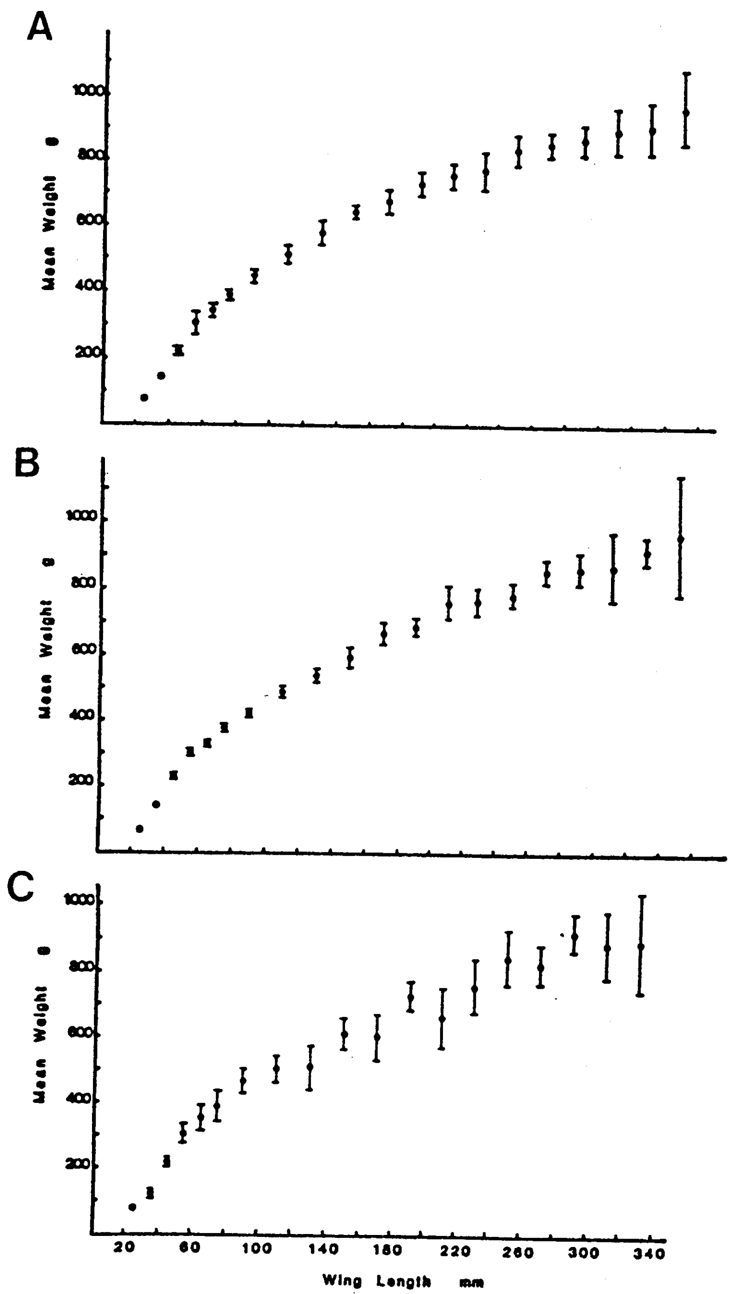

Fig. 4.4 Mean weight (± 2 S.E.) for each size class of wing length for Herring Gull chicks, Noss in (A) 1983, (B) 1984 and (C) 1985.

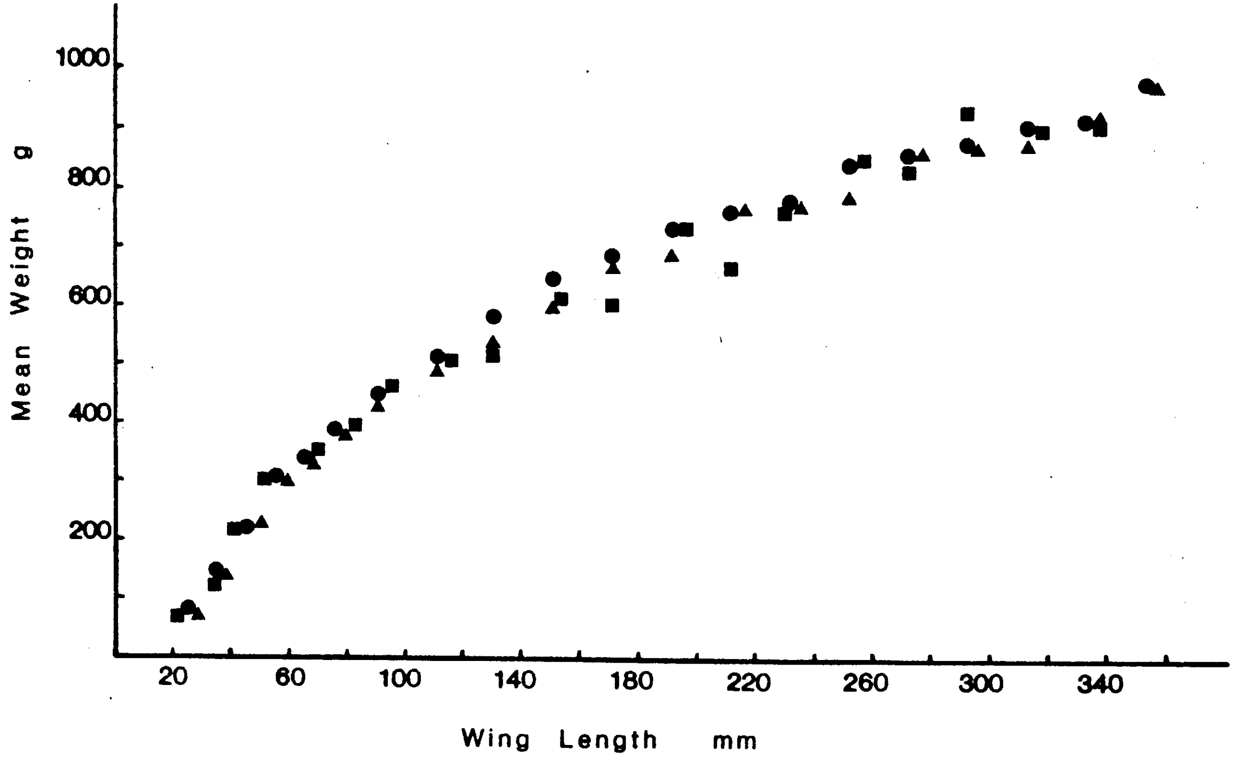

Fig. 4.5 Mean weight for each size class of wing length for Herring Gull chicks, Noss 1983 ● (n = 706), 1984 ▲ (n = 964) and 1985 ■ (n = 202).

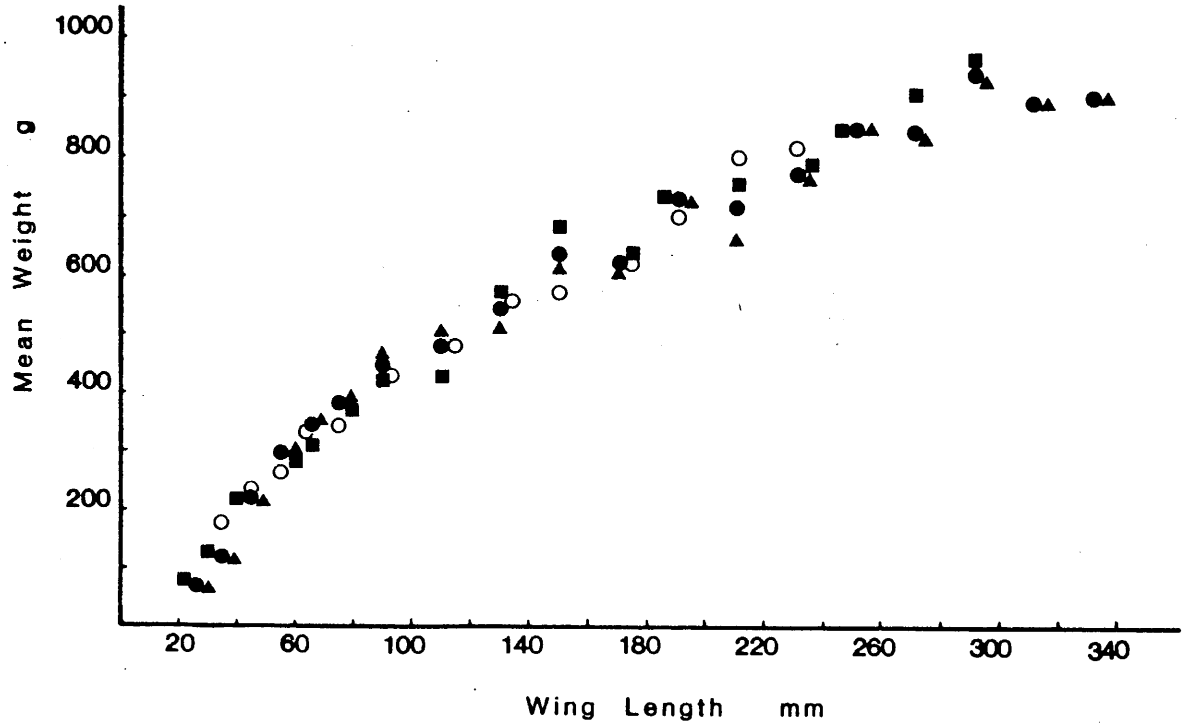

Fig. 4.6 Mean weight for each size class of wing length for Herring Gull chicks, Noss 1985 ▲, Shetland mainland ■ (n = 114), Noss and mainland ●, and Inchmarnock 1983 ○ (n = 96).

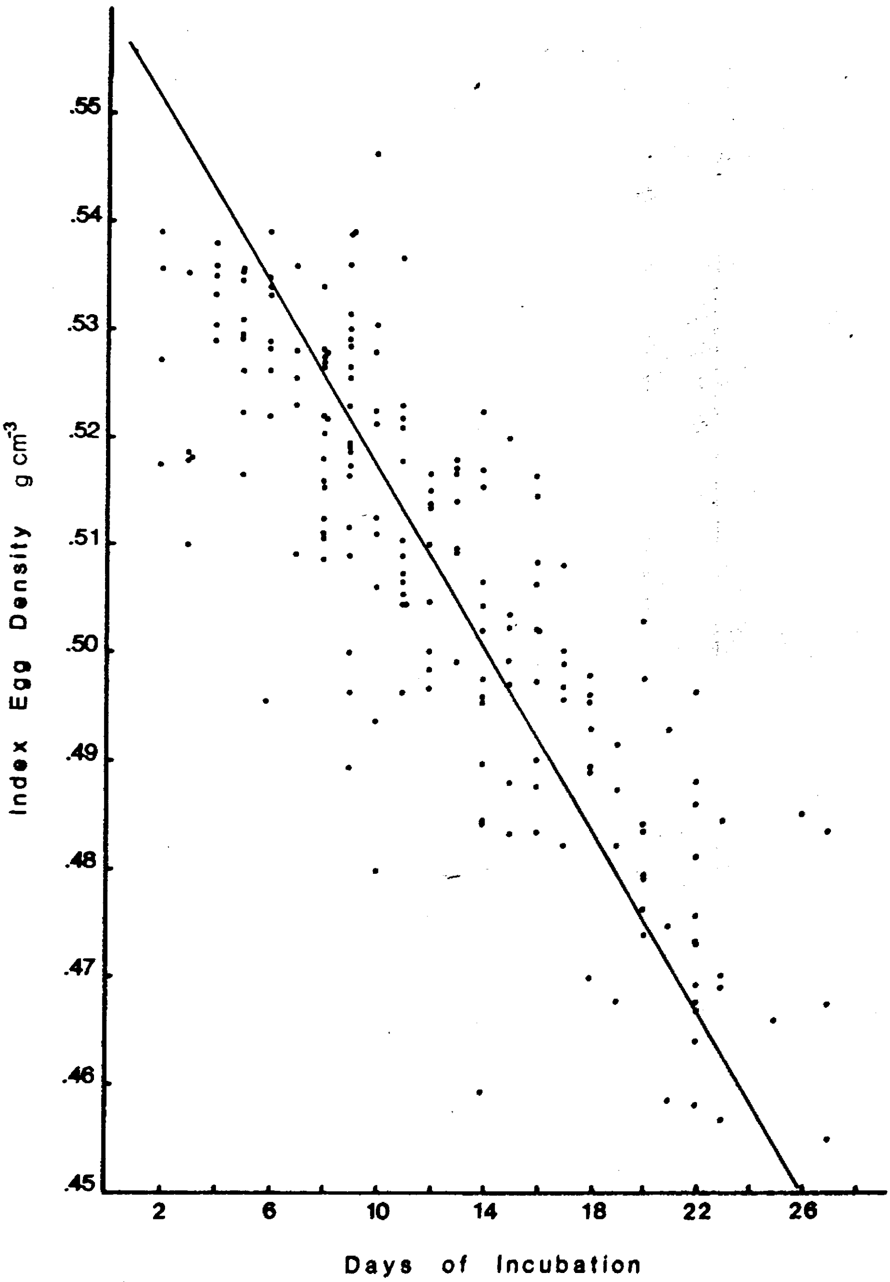

Fig. 4.7 Change in index of egg density during incubation for Great Skuas, Noss 1983 and 1984.
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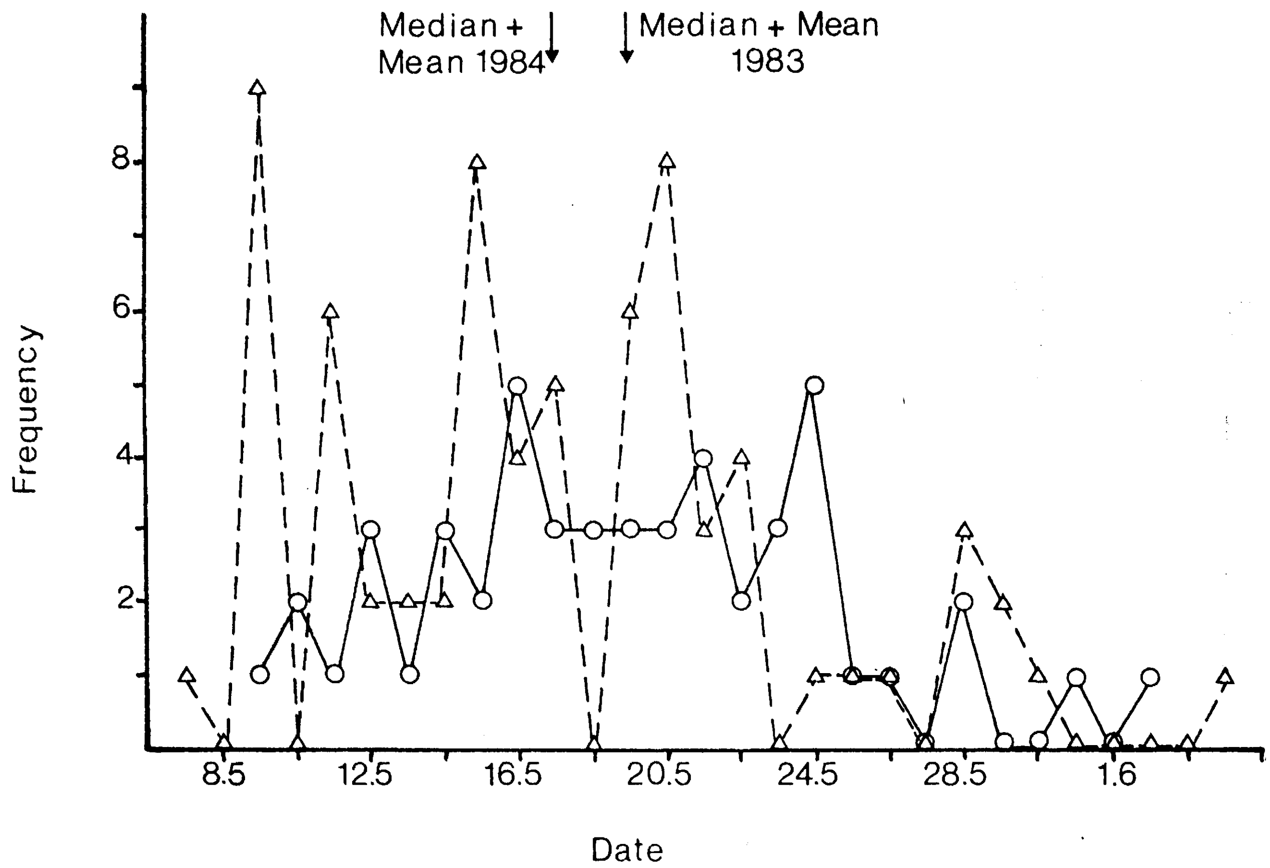

Fig. 4.8 Distribution of dates of clutch initiation for Great Skuas, Noss 1983 (○) and 1984 (△).

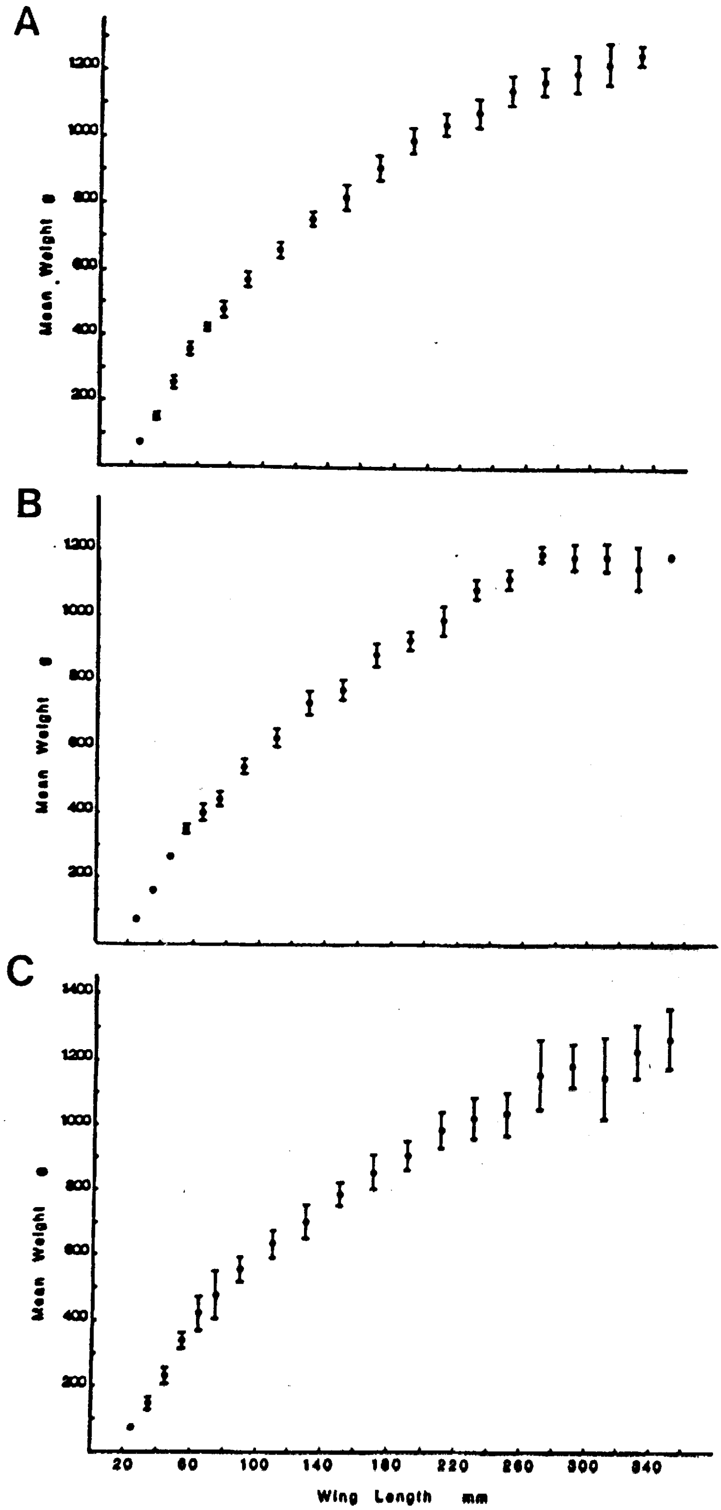

Fig. 4.9 Mean weight (± 2 S.E.) for each size class of wing length for Great Skua chicks, Noss in (A) 1983, (B) 1984 and (C) 1985.

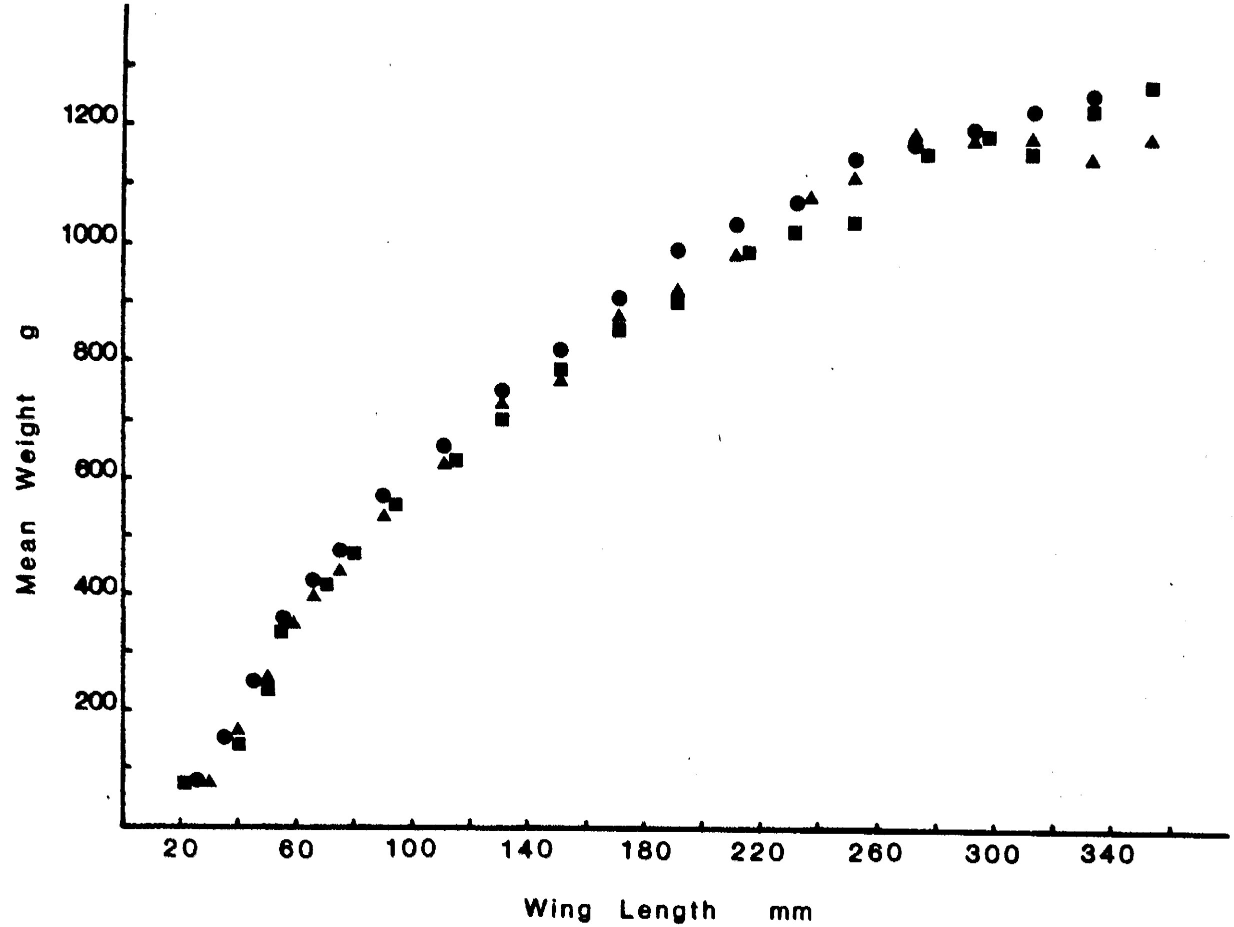

Fig. 4.10 Mean weight for each size class of wing length for Great Skua chicks, Noss 1983 ● (n = 536), 1984 ▲ (n = 698) and 1985 ■ (n = 231).

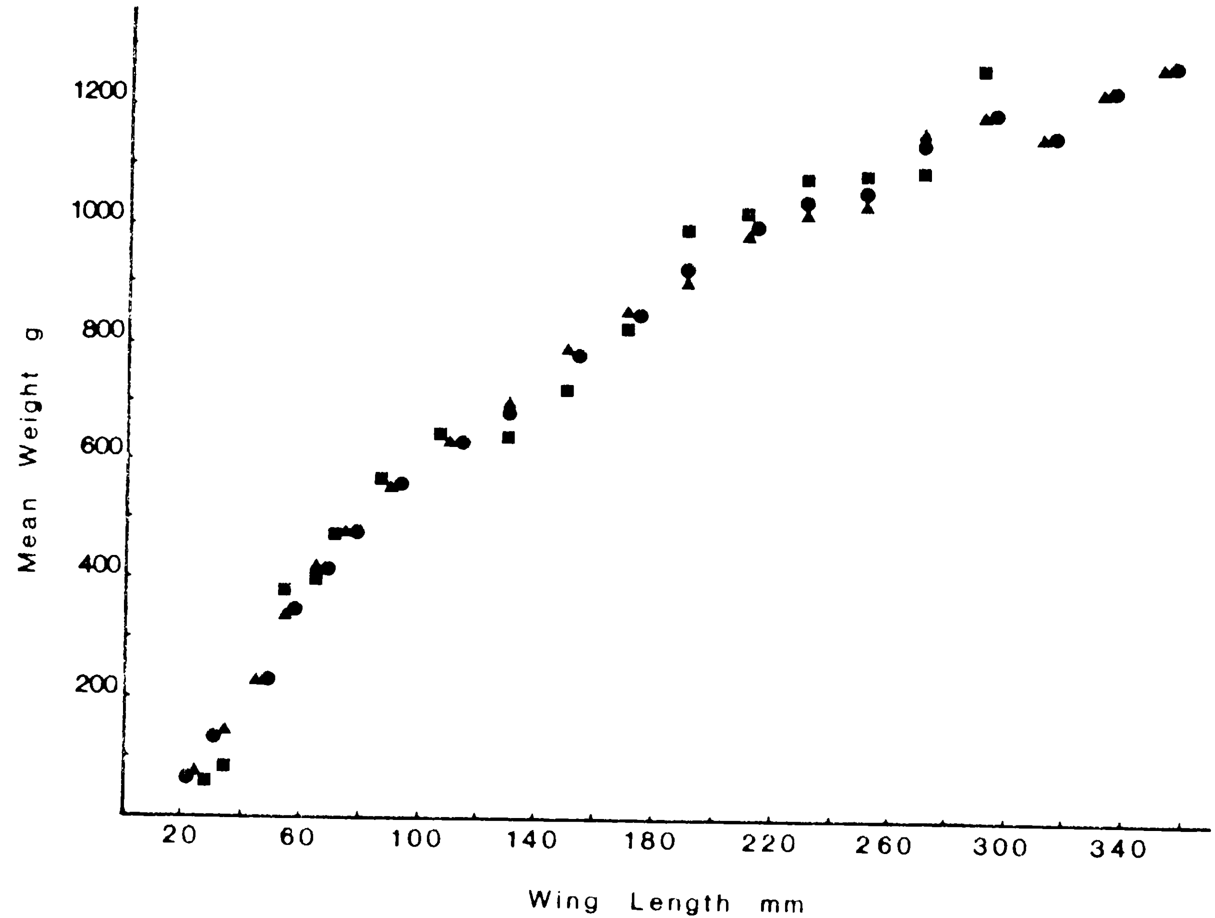

Fig. 4.11 Mean weight for each size class of wing length for Great Skua chicks, 1985. Noss ▲, Hermaness ■ (n = 60), and Noss & Hermaness ●.

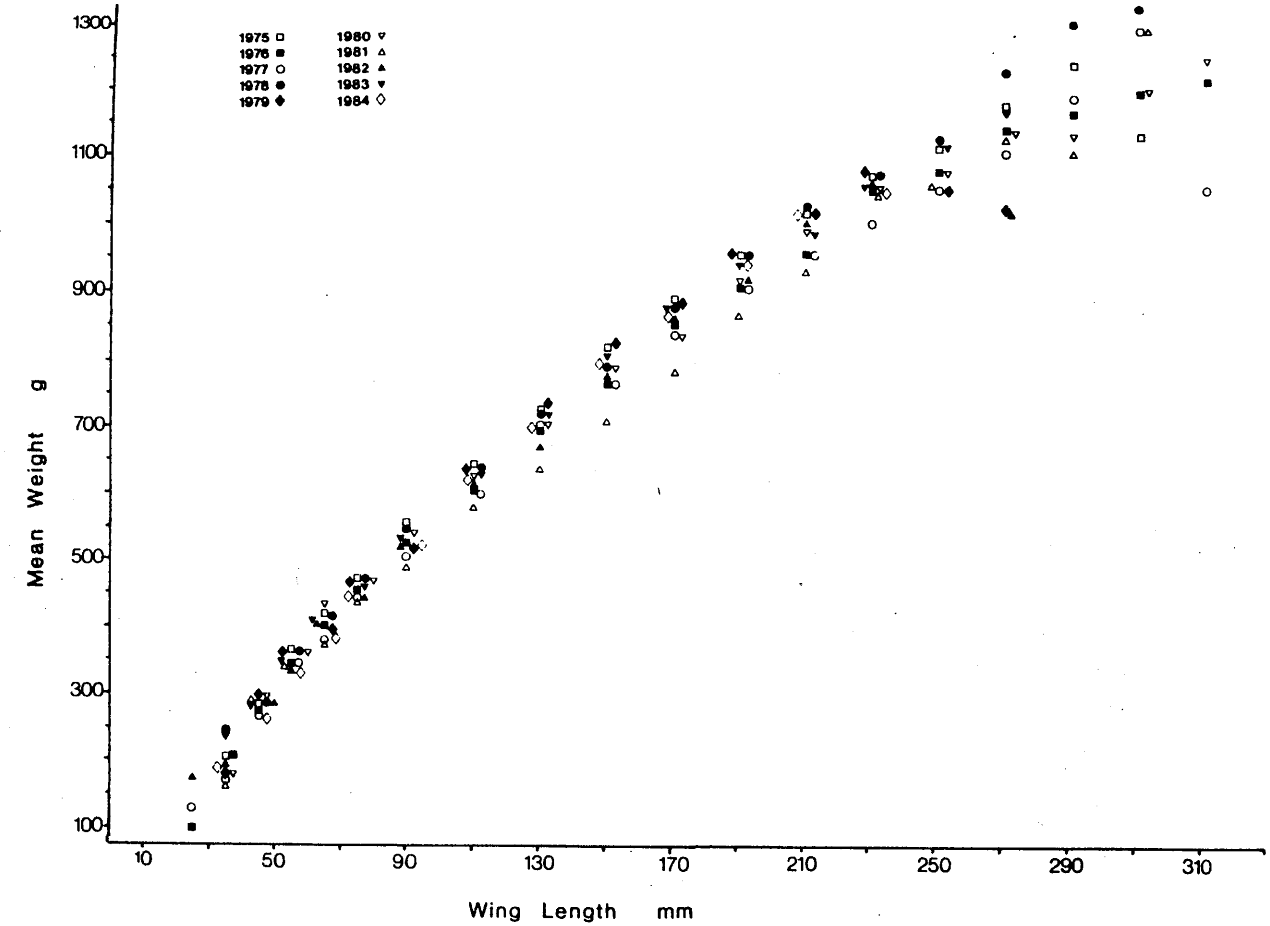

Fig. 4.12 Mean weight for each size class of wing length for Great Skua chicks, Foula 1975 - 1984.

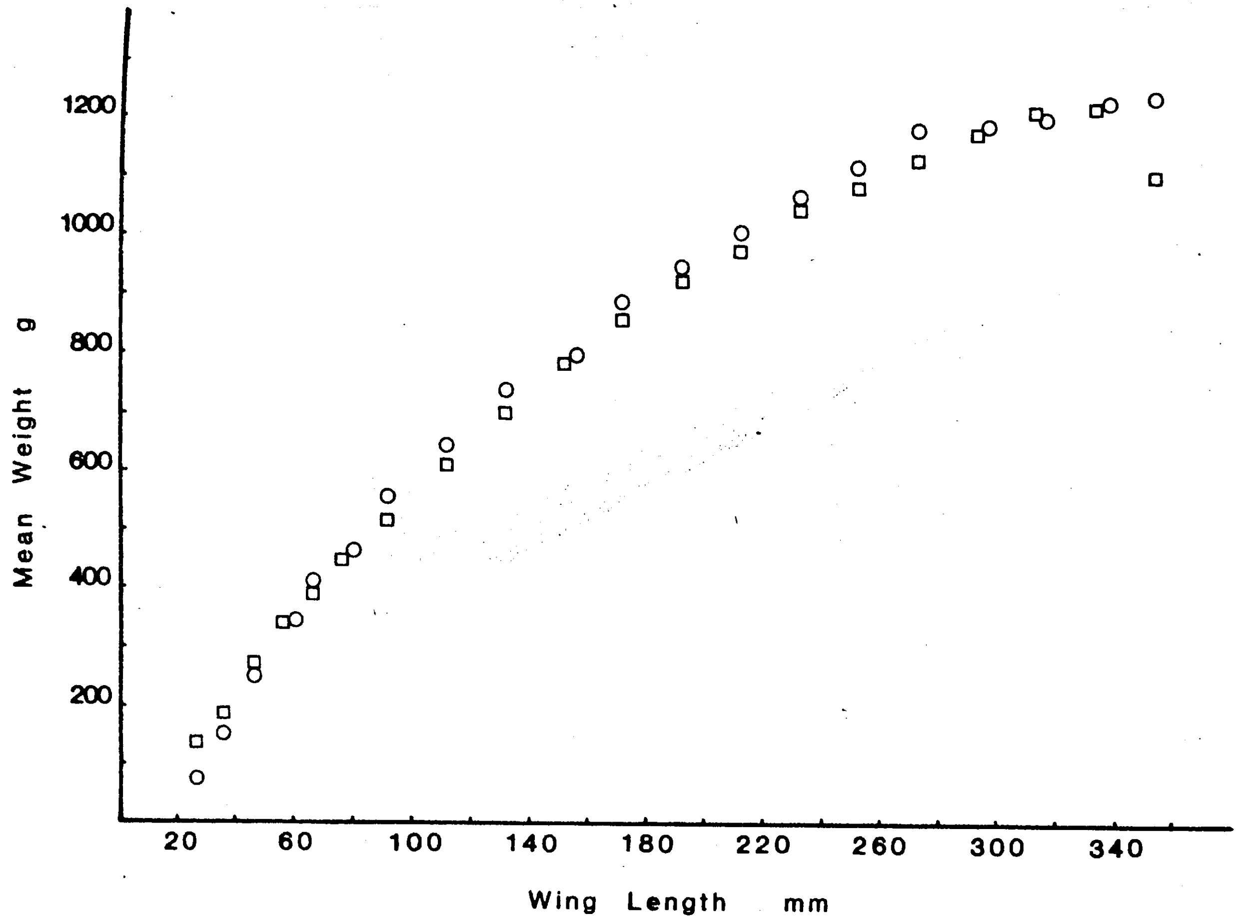

Fig. 4.13 Mean weight for each size class of wing length for Great Skua chicks, Noss 1983 - 1985 (○) and Foula 1975 - 1984 (□).

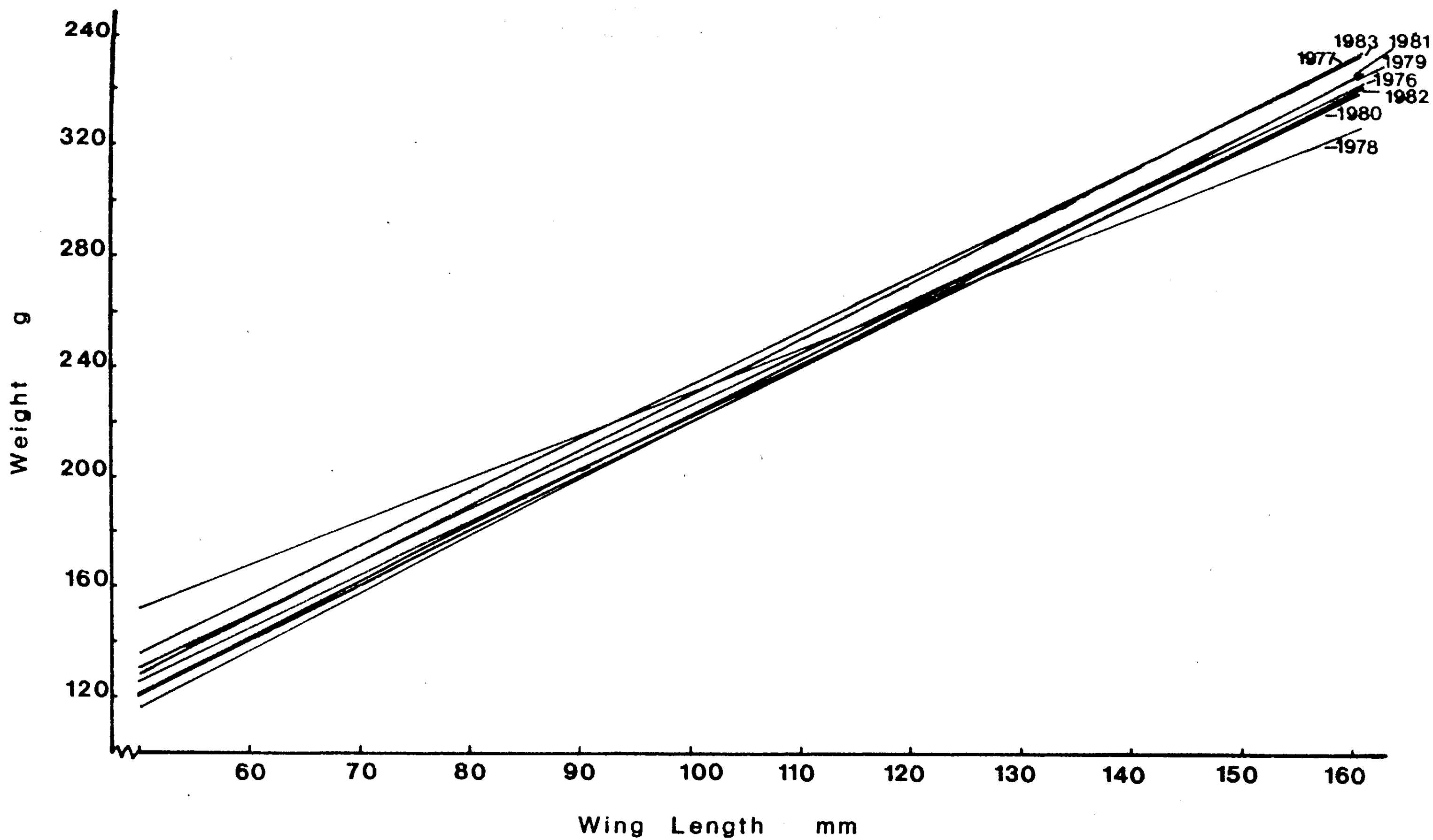

Fig. 4.14 Regression lines for weight against wing length (≥50mm and <160mm) for Arctic Skua chicks, Foula 1976 - 1983.

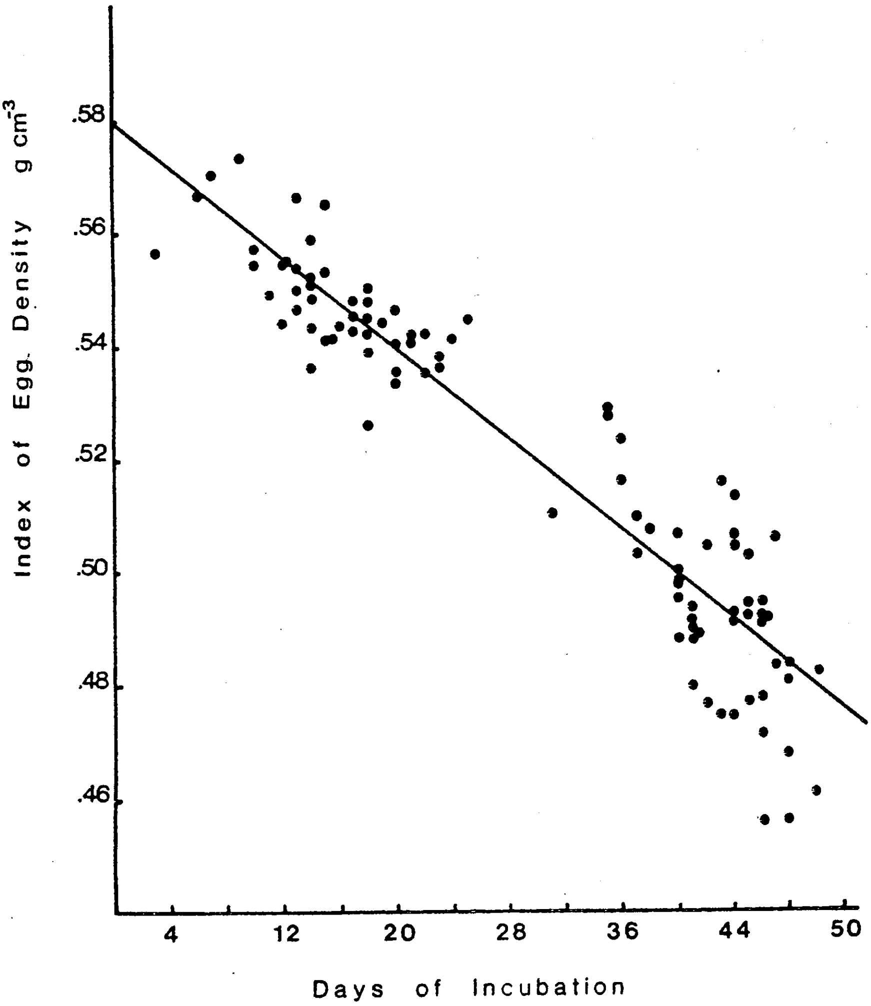

Fig. 4.15 Change in index of egg density during incubation for Fulmars, Noss 1983 and 1984.
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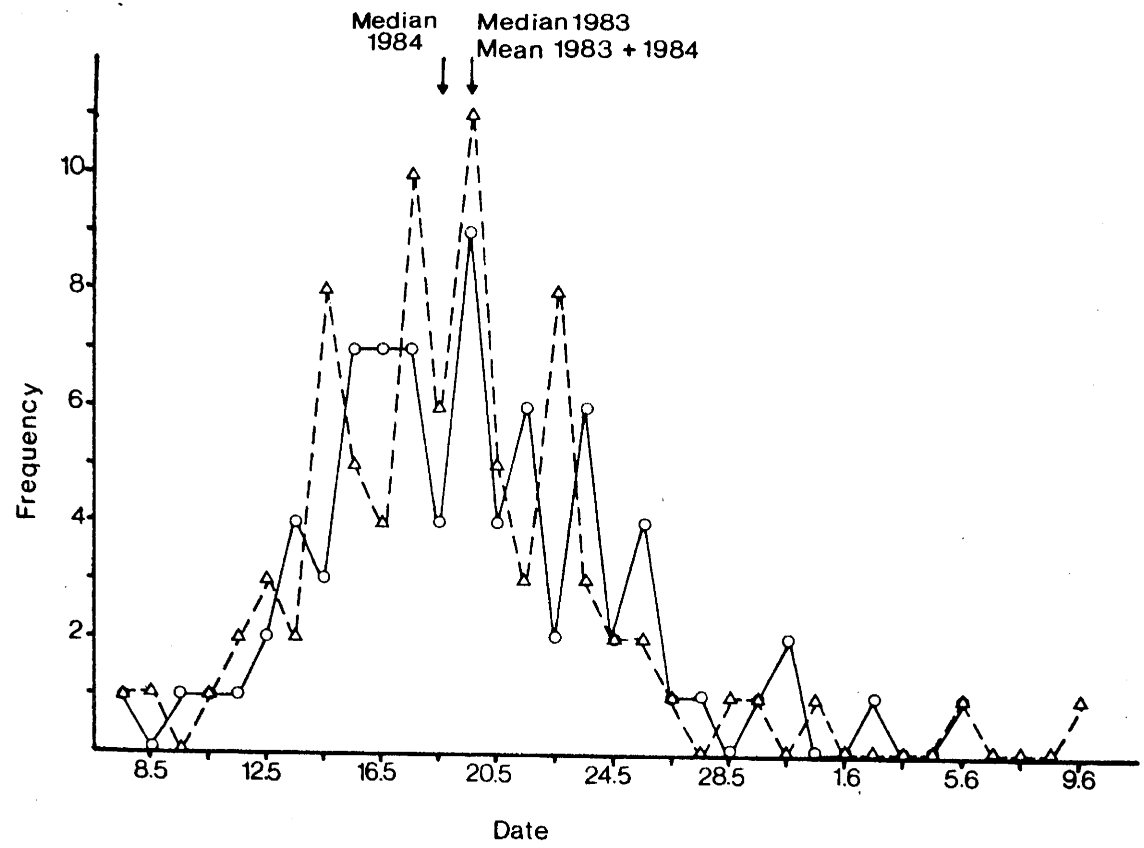

Fig. 4.16 Distribution of laying dates for Fulmar, Noss in 1983 (o) and 1984 (△).

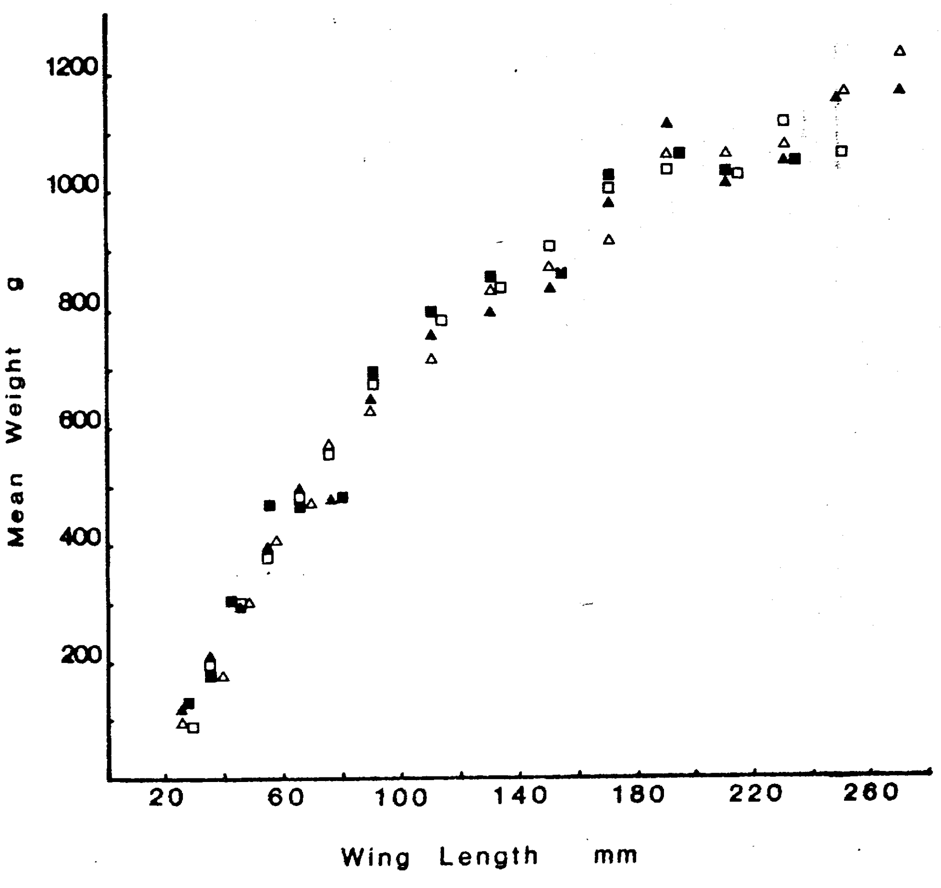

Fig. 4.17 Mean weight for each size class of wing length for Fulmar chicks in inland and coastal sites, Noss.
Inland 1984 ▲ (n = 51), 1985 ■ (n = 69);
Coastal 1984 △ (n = 284), 1985 □ (n = 276).

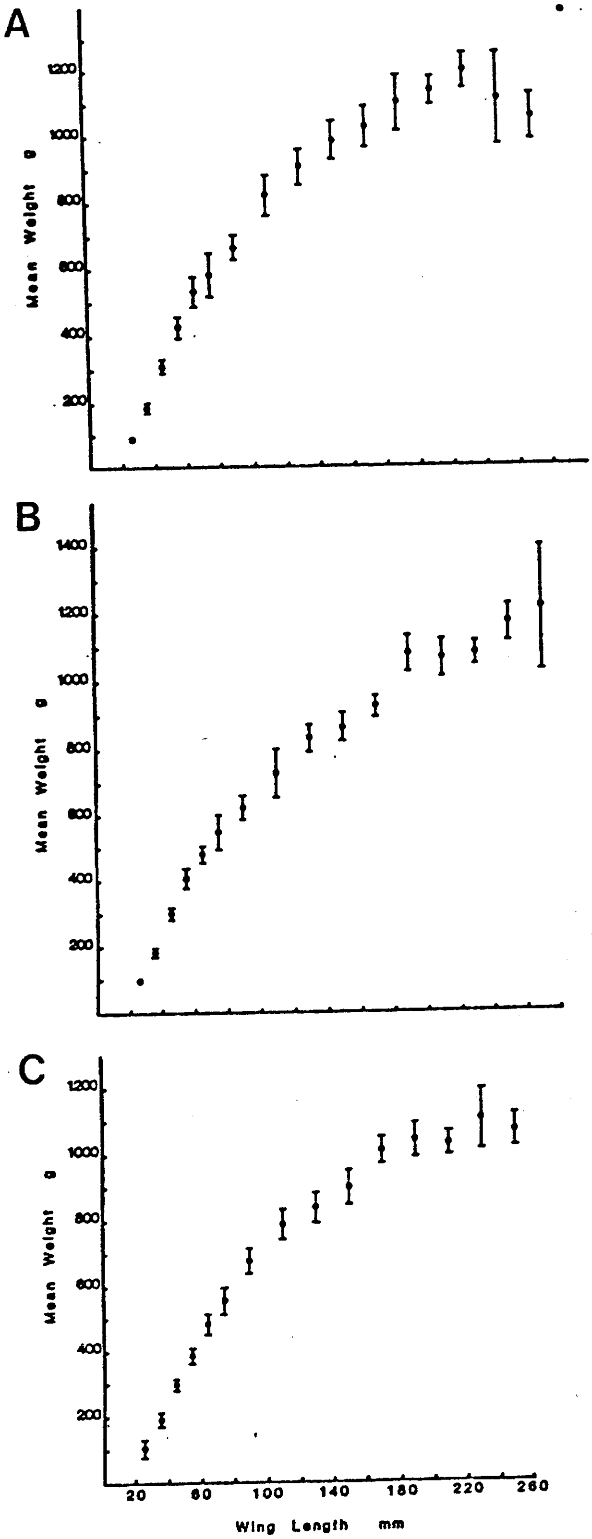

Fig. 4.18 Mean weight (± 2 S.E.) for each size class of wing length for Fulmar chicks, Noss in (A) 1983, (B) 1984 and (C) 1985.

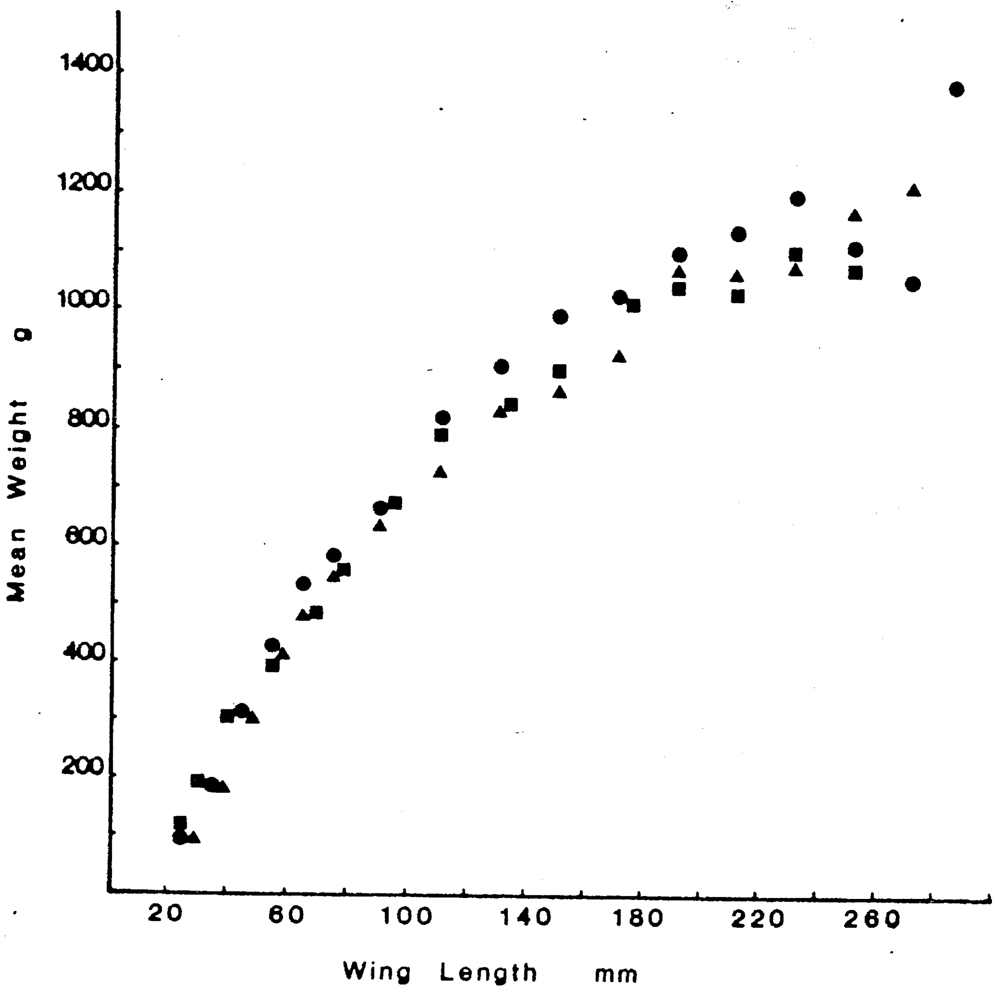

Fig. 4.19 Mean weight for each size class of wing length for Fulmar chicks, Noss 1983 ● (n = 320), 1984 ▲ (n = 335) and 1985 ■ (n = 345).

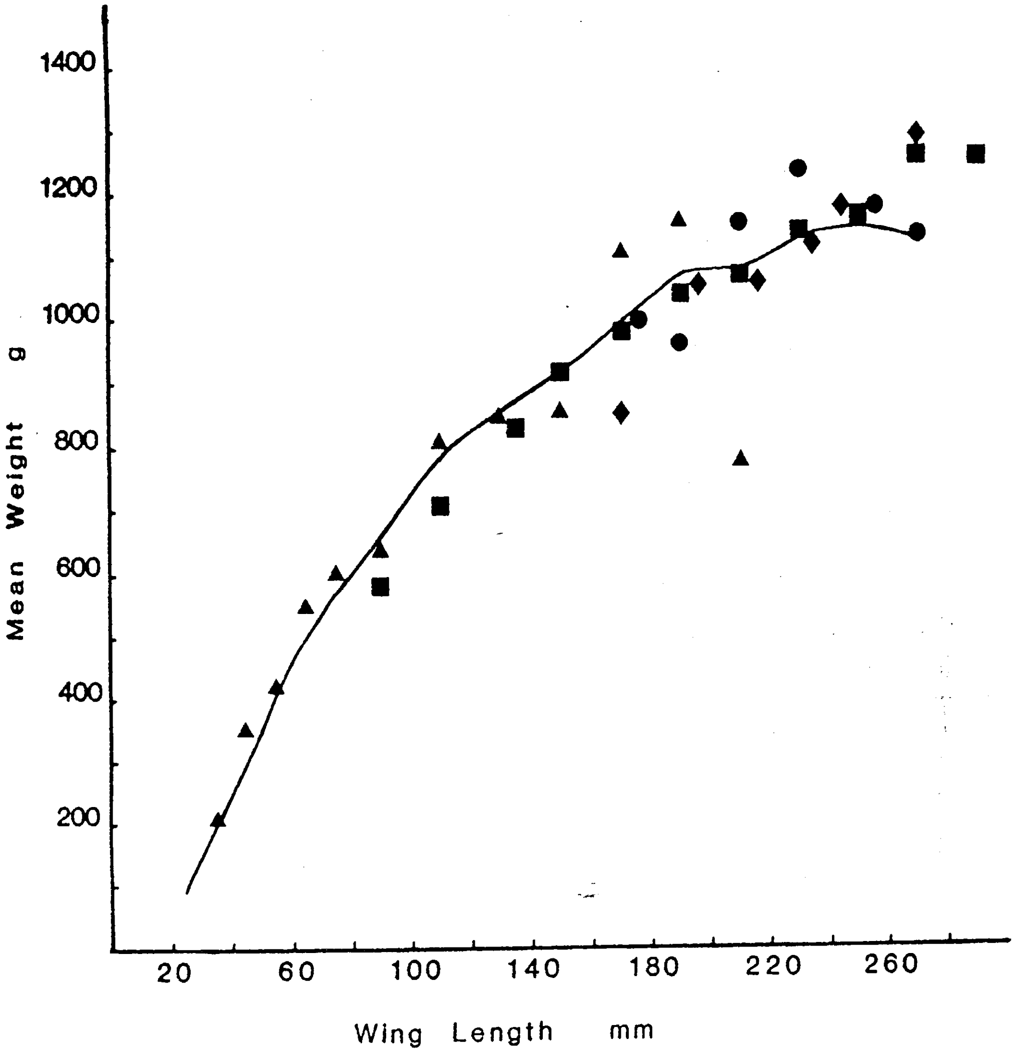

Fig. 4.20 Mean weight for each size class of wing length for Fulmar chicks on St. Kilda and Foula, compared to the mean Noss weight for 1983 - 1985 (solid line).
St. Kilda 1981 ● (n = 58), 1983 ◆ (n = 80):
Foula 1979 ▲ (n = 103), 1983 ■ (n = 600).

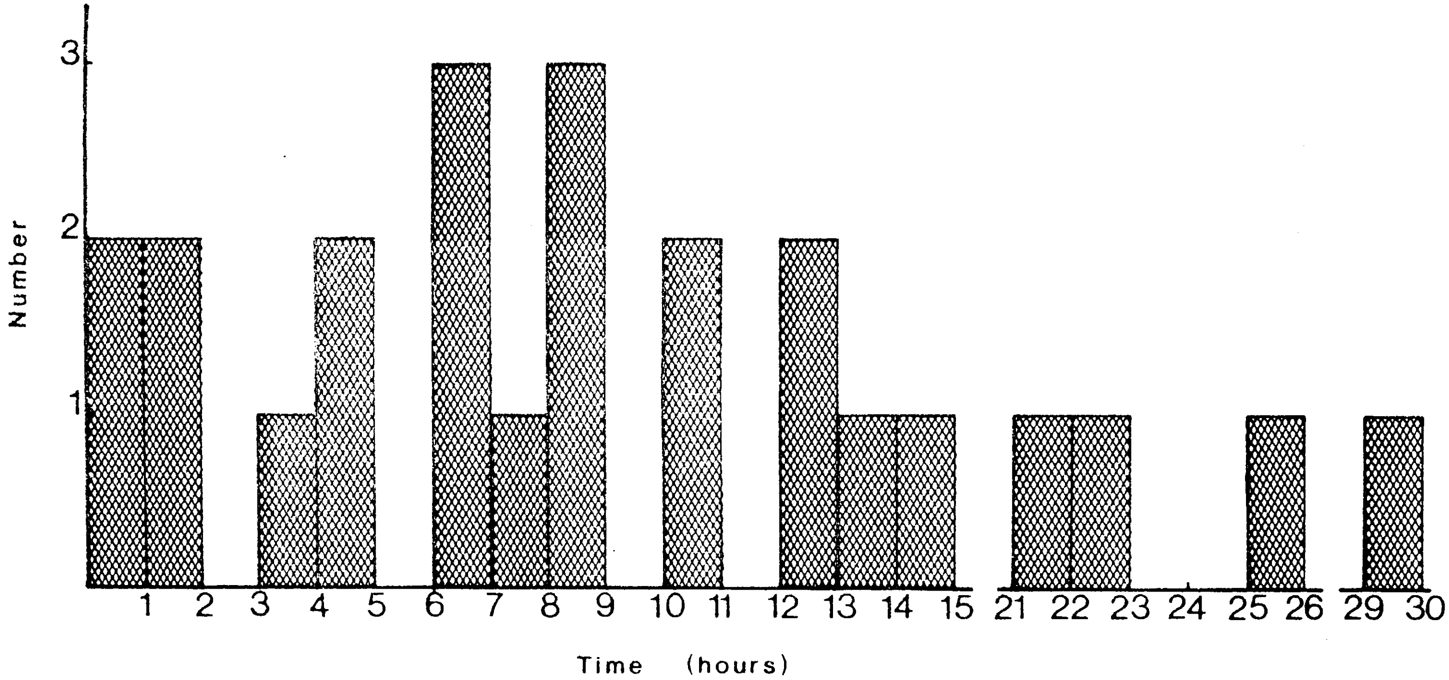

Fig. 4.21 Duration of foraging trips of breeding Fulmars from their nests on 18 - 20 July 1983, Papil Geo, Noss.

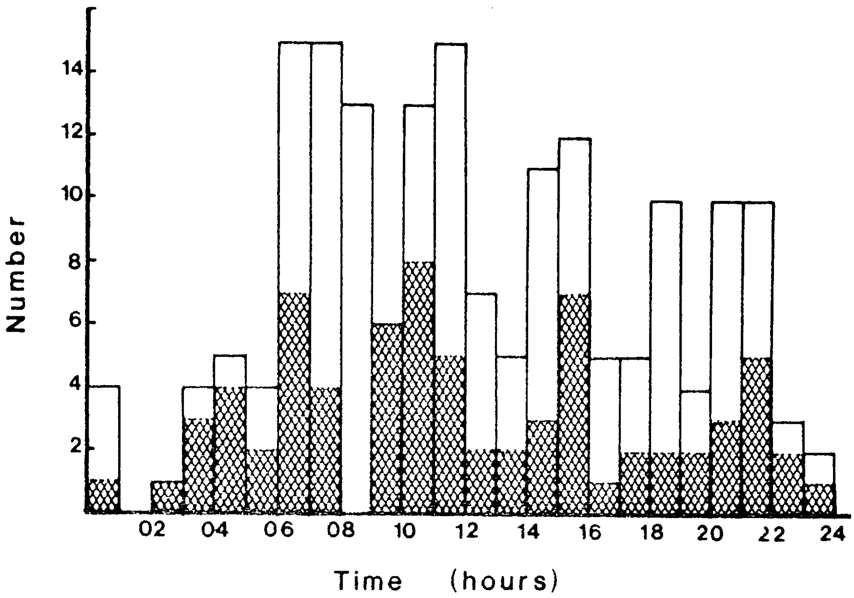

Fig. 4.22a Timing of departures of breeding Fulmars from their nest sites, Papil Geo, Noss 1983.
Shading represents departues during a continuous observation from 18 - 20 July. Unshaded areas represent all other observation periods.

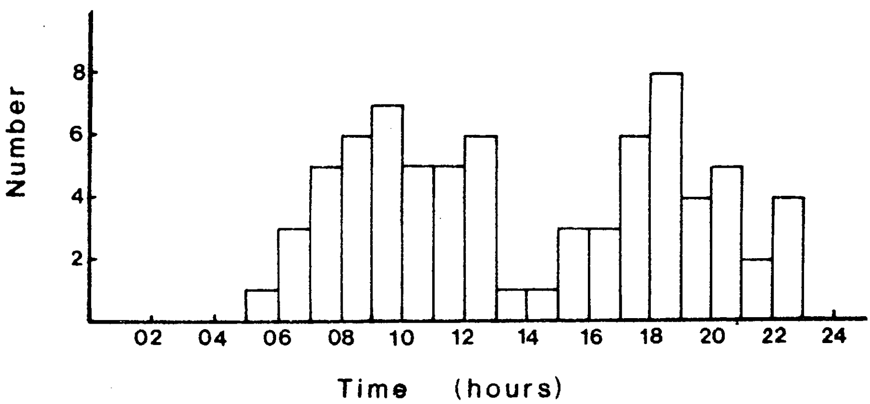

Fig. 4.22b Timing of departures of breeding Fulmars from their nest sites, Papil Geo, Noss 1984.

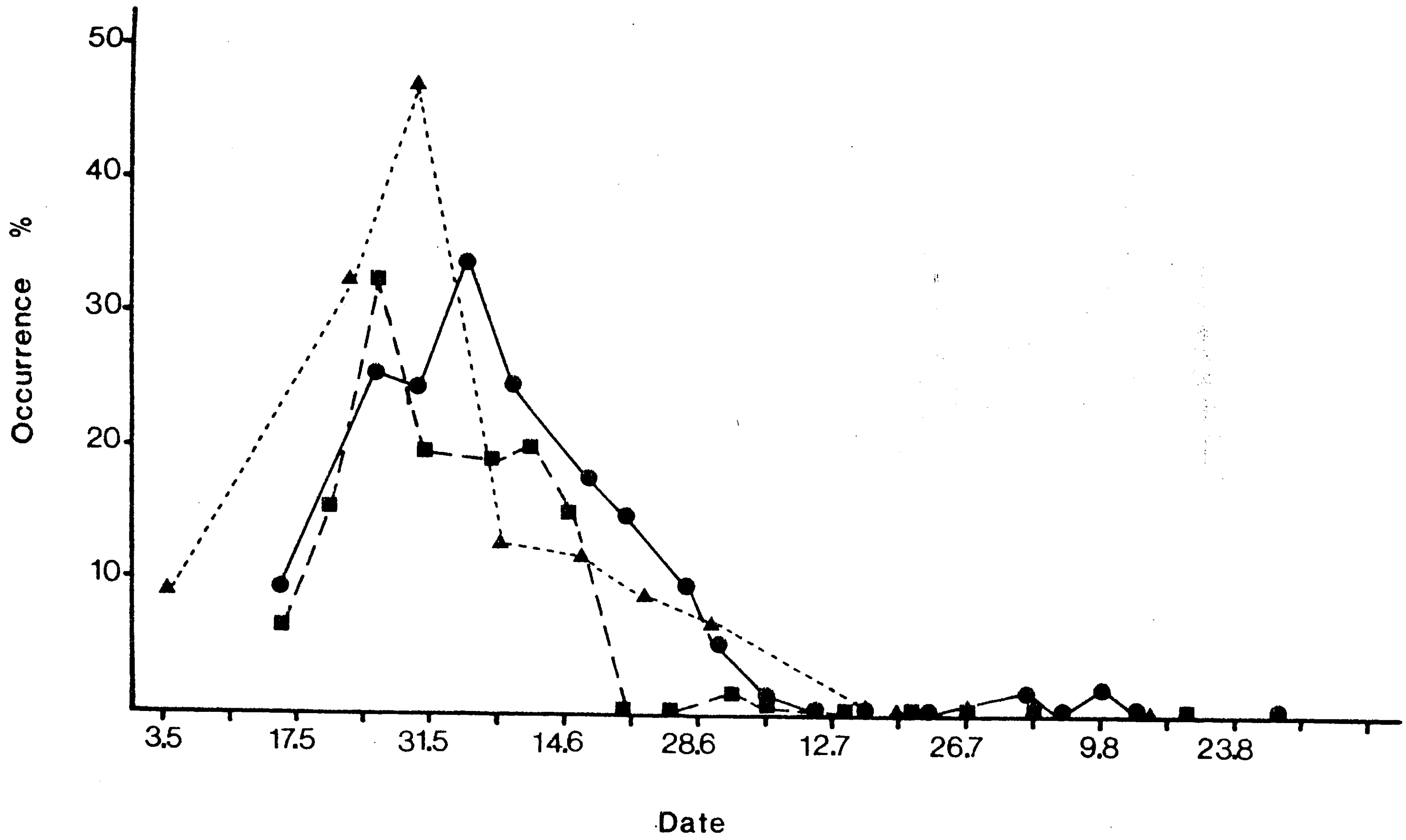

Fig. 5.1 Change in the percentage occurrence of Sandeel in food remains of non-breeding Great Skuas, Noss in 1983 (●), 1984 (■) and 1985 (▲).

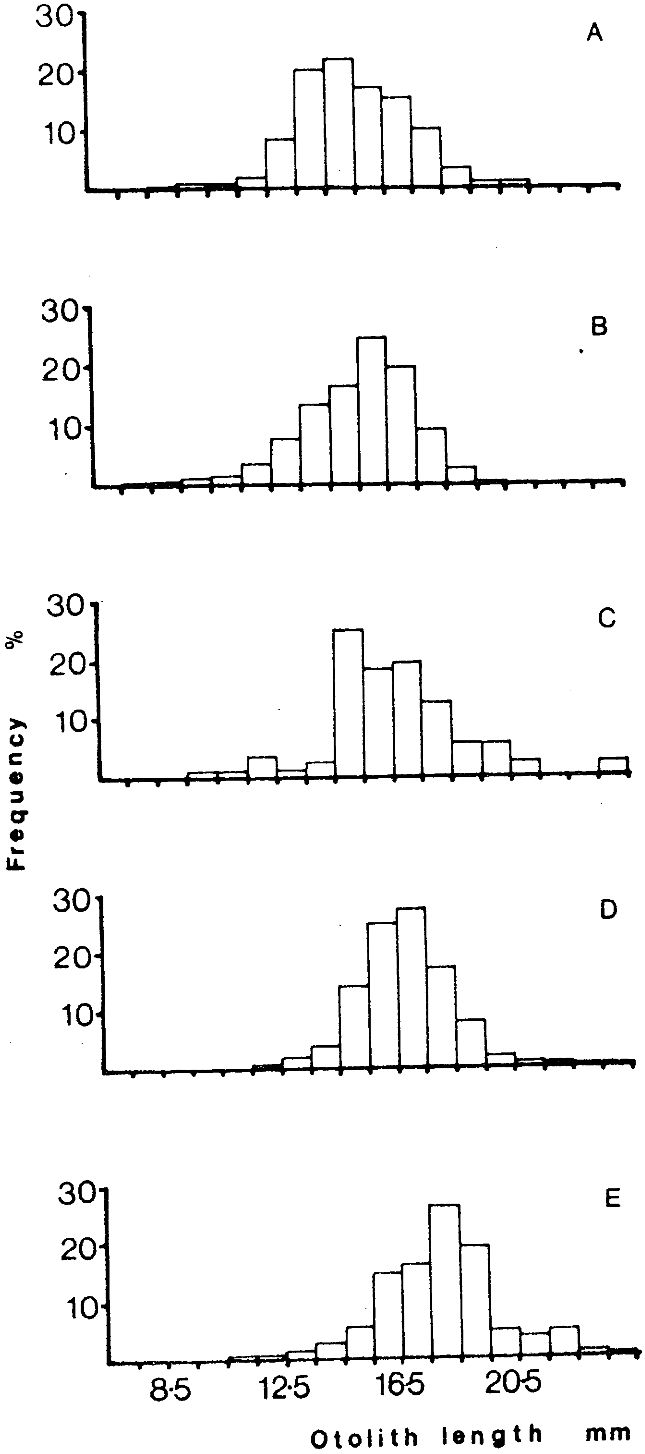

Fig. 6.1 Frequency of Whiting otolith lengths in pellets regurgitated by (A) breeding Great Skua (n = 329), (B) non-breeding Great Skua (n = 1189), (C) breeding Great Black-backed Gull (n = 88), (D) non-breeding Great Black-backed Gull (n = 1211) and (E) breeding Herring Gull (n = 208).

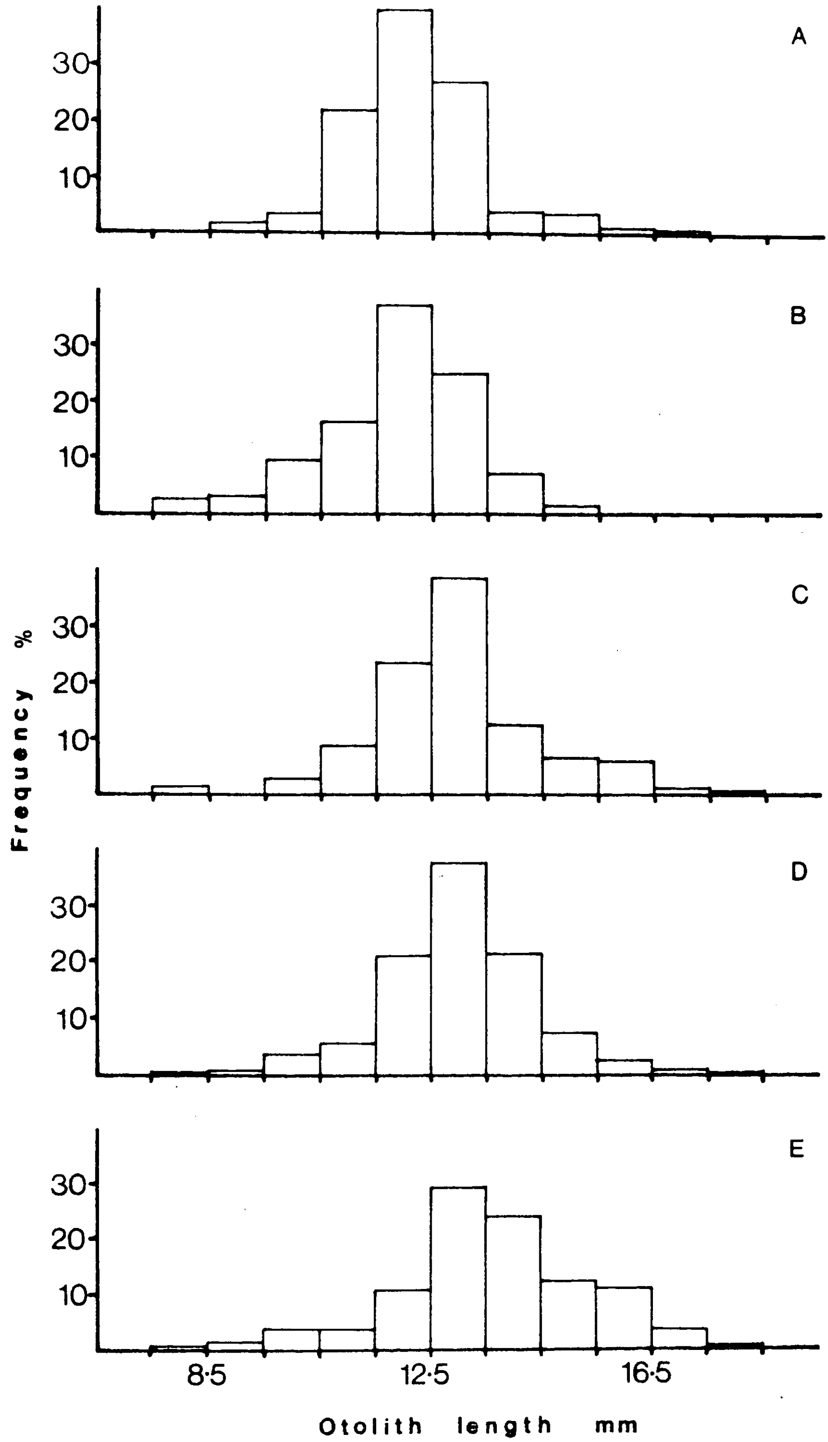

Fig. 6.2 Frequency of Haddock otolith lengths in pellets regurgitated by (A) breeding Great Skua (n = 222), (B) non-breeding Great Skua (n = 794), (C) breeding Great Black-backed Gull (n = 211), (D) non-breeding Great Black-backed Gull (n = 1036) and (E) breeding Herring Gull (n = 164).

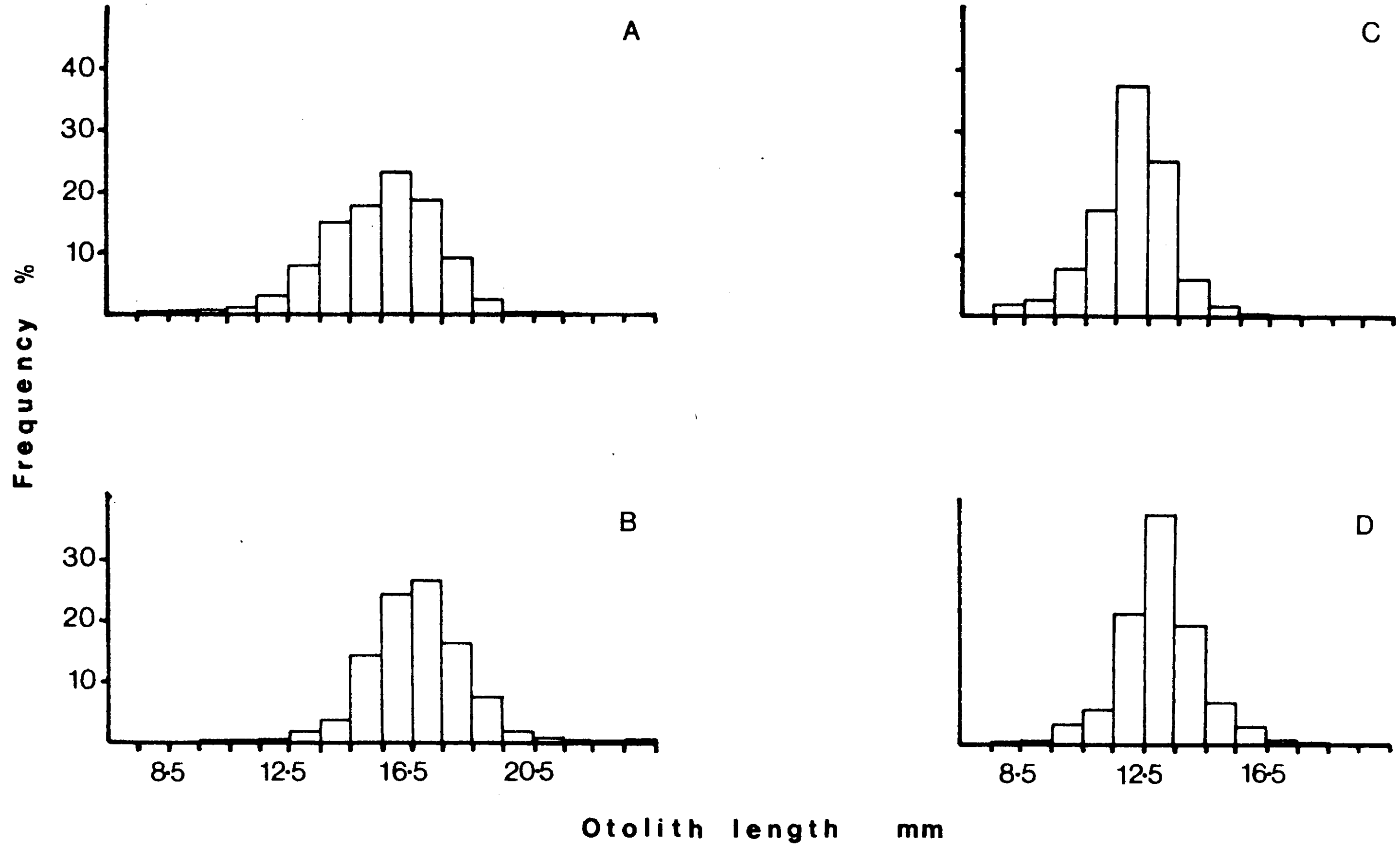

Fig. 6.3 Frequency of otolith lengths of Whiting consumed by (A) Great Skua (n = 1518) and (B) Great Black-backed Gull (n = 1299) and of Haddock consumed by (C) Great Skua (n = 1016) and (D) Great Black-backed Gull (n = 1247).

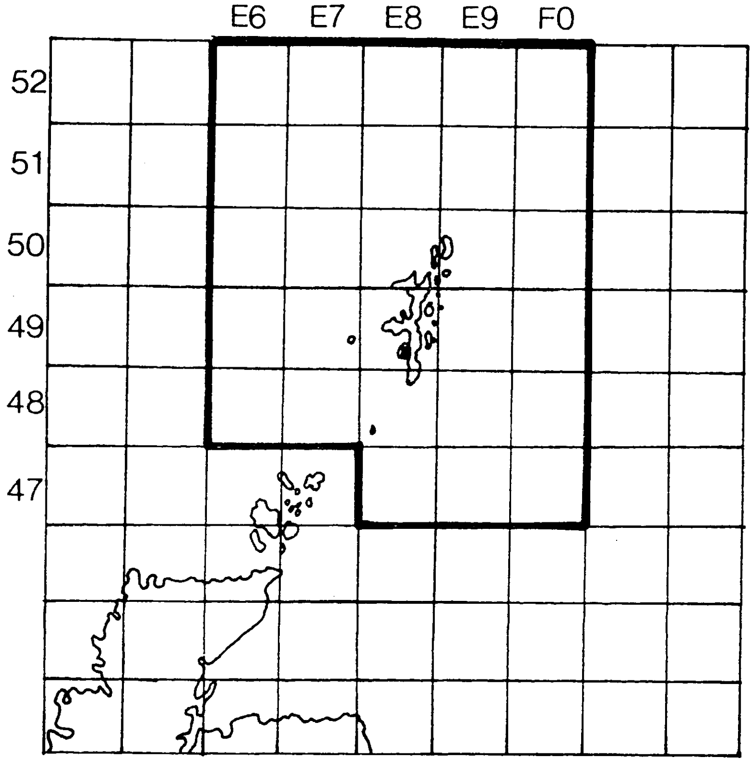

Fig. 7.1 Area of sea included in Shetland fishing zone (bounded by thick line). (Taken from Jermyn & Robb, 1980.)

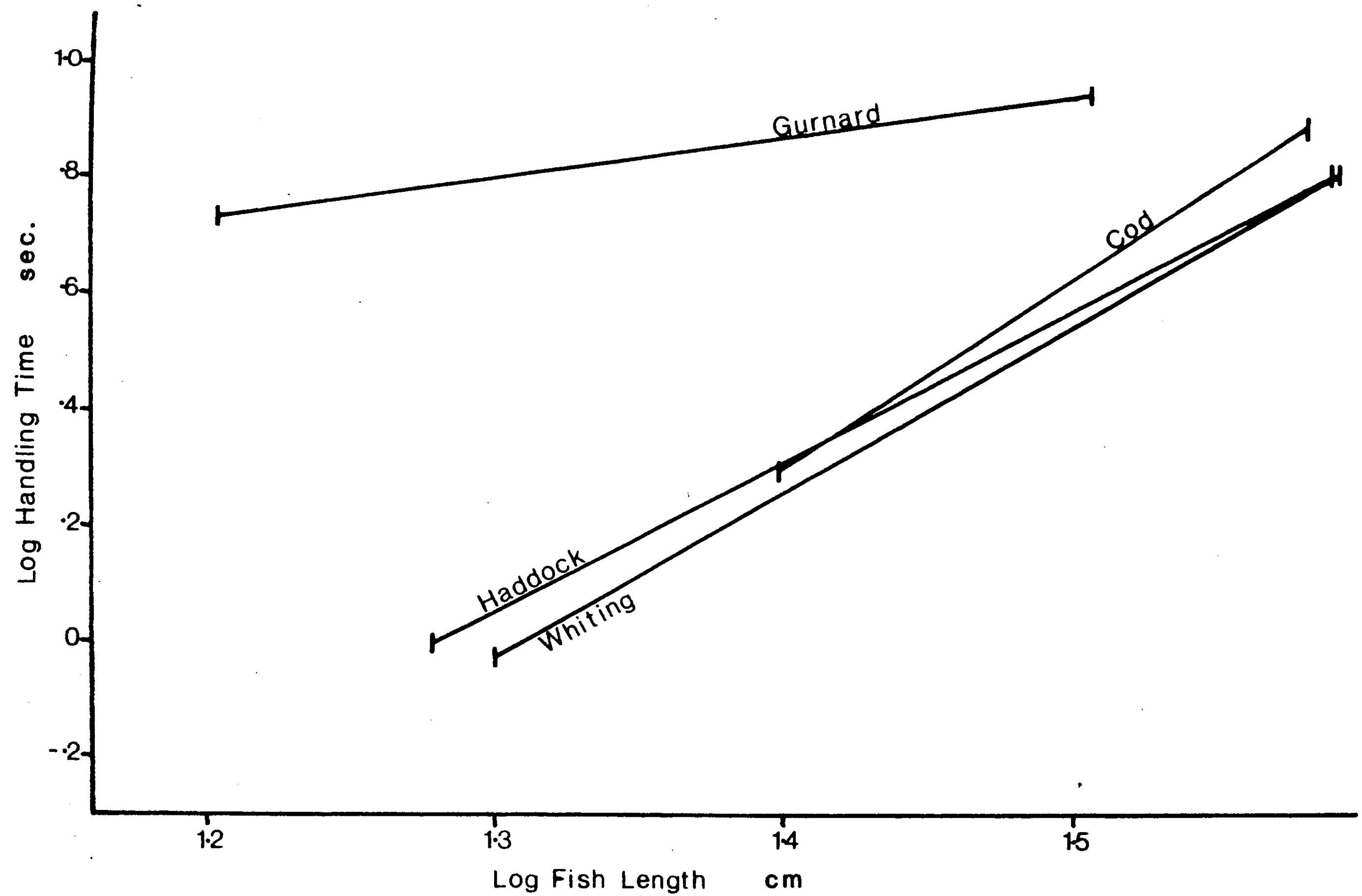

Fig. 8.1 Change in log handling time with increasing log fish length, for fish swallowed by adult Great Black-backed Gulls behind whitefish trawlers in Shetland 1985.

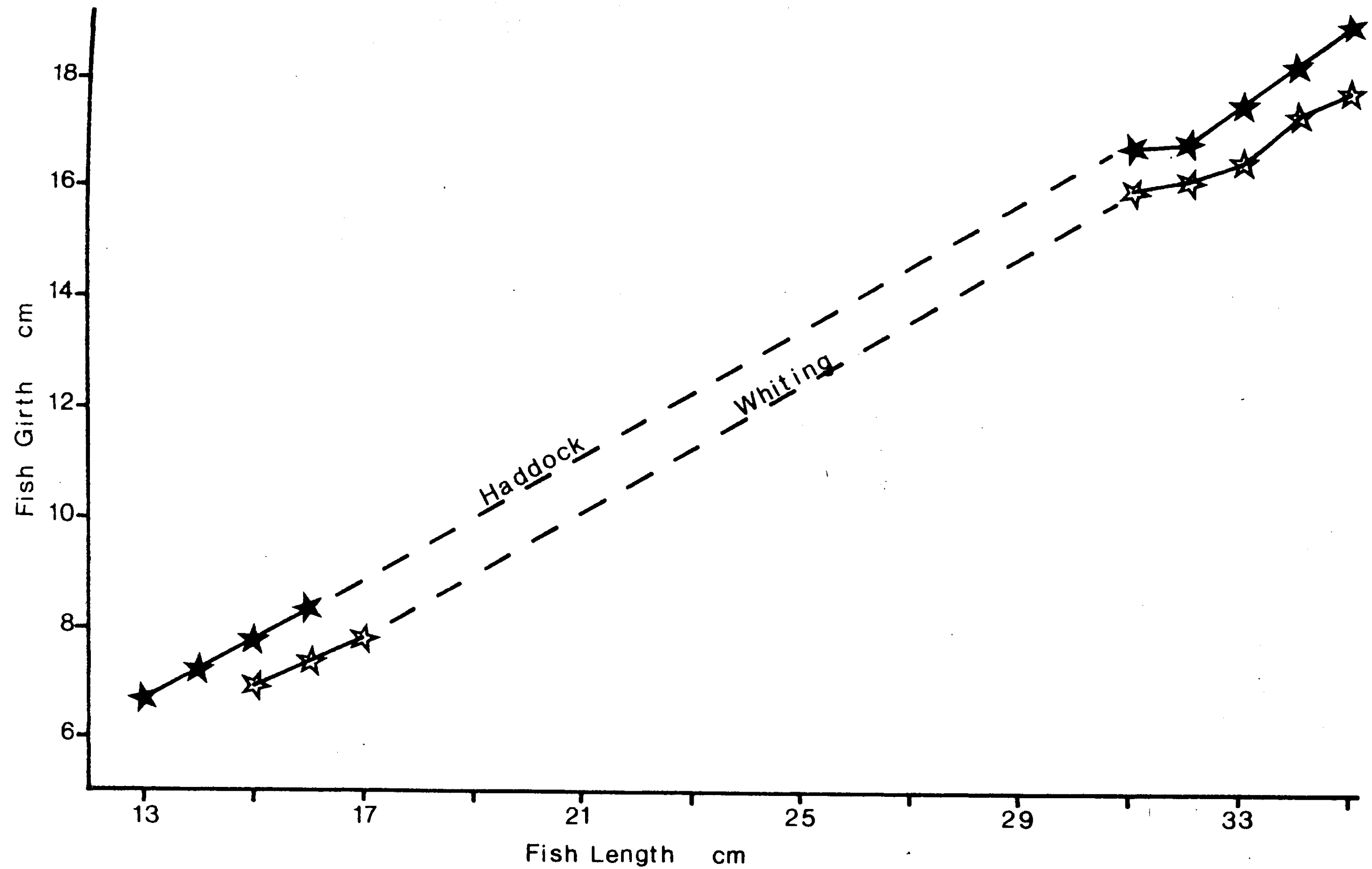

Fig. 8.2 Change in fish girth with increasing fish length for Haddock and Whiting. (DAFS data, Jermyn *in litt.*)

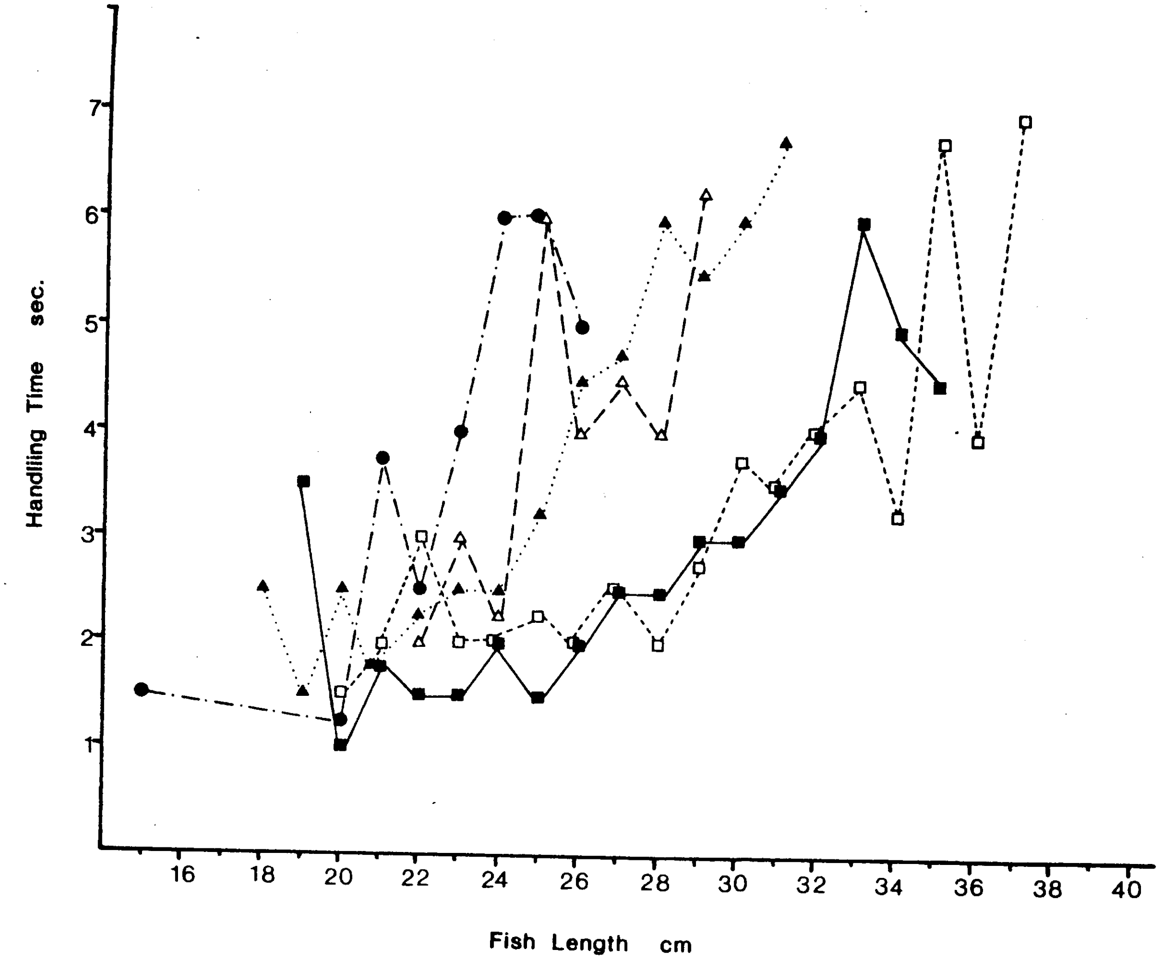

Fig. 8.3 Median handling times of Haddock of increasing length by Gannet (□), Great Black-backed Gull (■), Great Skua (▲), Herring Gull (△) and Fulmar (●).
Points representing one long fish (2cm or more longer than the length of the previous fish taken) have been excluded.

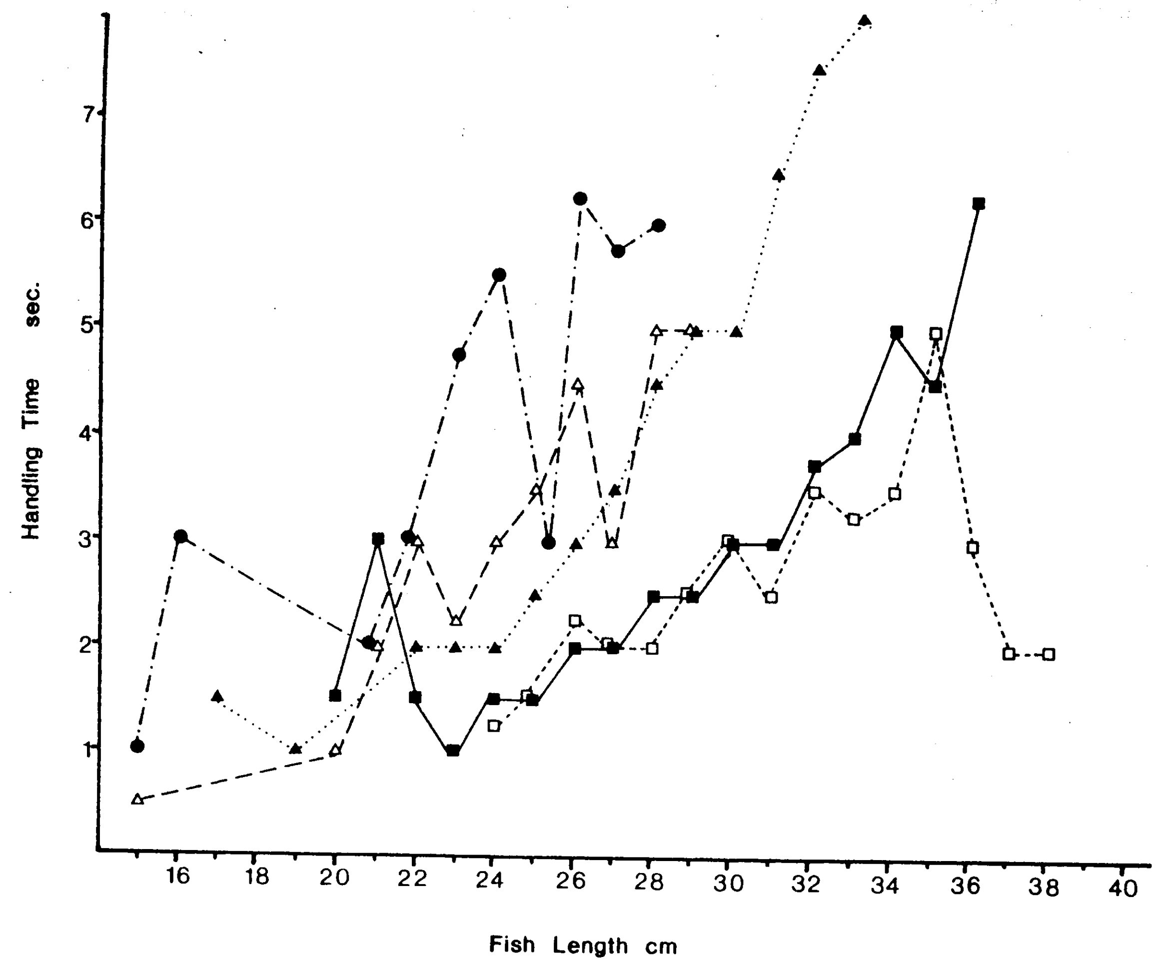

Fig. 8.4 Median handling times of Whiting of increasing length by Gannet (□), Great Black-backed Gull (■), Great Skua (▲), Herring Gull (△) and Fulmar (●).
Points representing one long fish (2cm or more longer than the length of the previous fish taken) have been excluded.

TABLE 2.1 : Increase in the Fulmar population in Shetland

Year	Number of occupied sites	Source
1879	24	Fisher, 1966
1889	75	Fisher, 1966
1899	405	Fisher, 1966
1909	1516	Fisher, 1966
1919	4367	Fisher, 1966
1929	8871	Fisher, 1966
1939	17741	Fisher, 1966
1949	29262	Fisher, 1966
1959	35857	Fisher, 1966
1969/70	116865	Cramp et al, 1974
1978	>150000	Berry & Johnston, 1980
1986	213300	Seabird Colony Register, NCC

TABLE 2.2 : Increase in the Fulmar population on the Isle of Noss

Year	Number	Source	Comments
1946	>1000[1]	Perry, 1948	
1949	1200	Fisher, 1966	By interpolation
1954	1500	Fisher, 1966	By interpolation
1964	2000	Fisher, 1966	By interpolation
1969	2080	Nicholl, 1976	
1970	4839	Nicholl, 1976	
1976	3320	Nicholl, 1976	Many August counts lowered the AON's due to chick loss.
1982	6085	Dore & Willcox, 1982	

1 : Refers to breeding pairs. All other counts are of apparently occupied nests. (AON's)

TABLE 2.3 : Increase in the Gannet populations on Noss and Hermaness

Year	Noss	Hermaness	Source
1935	800 pairs	1000 pairs	Wynne-Edwards et al, 1936
1939	1830 pairs	2611 pairs	Fisher & Vevers, 1943
1946	3150 pairs	-	Fisher & Vevers, 1951
1949	-	3750 pairs	Fisher & Vevers, 1951
1969	4300 pairs	5894 pairs	Cramp et al, 1974
1978	4500 pairs	5500 pairs[1]	Berry & Johnston, 1980
1982	4863 pairs	-	Dore & Willcox, 1982
1984	5231 nests	-	Dickson & Tyler, 1984
1984/5		8100 nests	Wanless et al, 1986

1 : probably an underestimate

TABLE 2.4 : Change in the Great Skua population in Shetland. Totals for 1920 to 1985 from Furness, 1986 and for 1986 from the Seabird Colony Register.

Year	Number of Pairs
1920	190
1930	423
1940	727
1950	1312
1960	2018
1970	3755
1980	4939
1985	5000
1986	4252

TABLE 2.5 : Decrease in the Herring Gull population on Noss

Year	Number	Source
1887	>1000 pairs	Raeburn, 1888, Evans & Buckley 1899
1946	Several 100 pairs	Perry, 1948
Late 1960s & early 1970s	400-500 pairs	Willcox et al 1983, Harris 1976
1980	162 pairs	Butler, 1980
1982	130 clutches	Dore & Willcox, 1982
1983	175 clutches	This study
1984	128 clutches	This study
1985	89 clutches	This study
1986	88 "	Seabird Colony Register, NCC

TABLE 2.6 : Changes in the numbers of breeding pairs of Great Black-backed gulls on Noss since 1946

Year	Numbers of pairs	Source
1946	150	Perry, 1948
1955	200	Tewnion, 1956
1974	304	Harris, 1976
1980	210	Butler, 1980
1983	140	This study
1984	136	This study
1985	89	This study
1986	84	Seabird Colony Register, NCC

2.7 : Status of Scavanging seabirds in Shetland. Data drawn from references quoted in the text and previous tables.

Species	Overall Changes in Shetland Breeding Population	Major Colonies
Fulmar	1878 first bred, 12 pairs Foula. Increased, spreading to all islands 1986 c. 213300 breeding pairs	Ubiquitous
Gannet	1914 first recorded to breed on Noss. 1917 first recorded to breed on Hermaness. Increased steadily 1986 c. 15600 breeding pairs	Hermaness, Noss
Great Skua	1774 c. 10 pairs bred, Foula and Saxavord. Fluctuating population, always low, until 1900. Since 1900 huge increases. 1986 c. 4250 breeding pairs.	Foula, Unst Noss, Fetlar
LBbG	Probably decreasing. 1986 c. 520 breeding pairs	Unst, Sumburgh
Herring Gull	Decreasing. 1986 c. 5335 breeding pairs	Sumburgh, Noss Fair Isle, Fetlar
GBbG	Fluctuating populations. 1986 c. 3360 breeding pairs.	Ramna Stacks, Unst, Noss, Fetlar, Papa Stour

TABLE 4.1: Distribution of laying dates for Herring Gulls 1983 and 1984, Isle of Noss. Laying date refers to date that first egg in clutch was laid.

	1983				1984	
Period	n^1	%	n^2	%	n	%
27.04-03.05	14	9.5	14	10.0	9	8.2
04.05-10.05	48	32.7	48	34.3	45	40.9
11.05-17.05	47	32.0	46	32.9	31	28.2
18.05-24.05	23	15.7	23	16.4	16	14.5
25.05-31.05	7	4.8	6	4.3	6	5.5
01.06-07.06	3	2.0	2	1.4	3	2.7
08.06-14.06	4	2.7	1	0.7	0	0.0
15.06-21.06	1	0.7	0	0.0	0	0.0
Total n	147		140		110	

n refers to number of clutches

1 includes known replacement clutches in 1983

2 excludes known replacement clutches in 1983

TABLE 4.2: Constants used in the determination of egg volume in previous studies of Herring Gulls.

Constant (k)	Source
0.5190	Paludan, 1951
0.5084	Barth, 1967
0.4760	Harris, 1964

TABLE 4.3: Parental attendance at nest sites and number of feeds per brood per hour (n feeds) for Herring Gulls at Papil Geo, Noss 1983.

Observation			% time with adults			
Date	n hours	time	0	1	2	n feeds
12.06.83	13	0600-1900	0.6	69.2	30.2	0.48
15-16.06.83	6.5	2300-0600	3.1	71.6	25.3	0.19
16.06.83	4.5	1900-2330	4.4	72.8	22.8	0.40
23.06.83	4	1500-1900	8.8	63.7	27.5	0.20
24.06.83	3.5	1000-1330	41.1	35.6	23.3	0.0
06.07.83	5	1400-1900	67.5	19.8	12.7	0.0
10.07.83	5	0830-1330	37.3	44.4	18.3	0.08
13-14.07.83	9.5	2250-0800	62.3	32.9	4.8	0.11

TABLE 4.4: Parental attendance at nest sites and number of feeds per brood per hour (n feeds) for Herring Gulls at Papil Geo, Noss 1984.

Observation			% time with adults			
Date	n hours	time	0	1	2	n feeds
09.06.84	6	1400-2000	0	52.7	47.3	0.63
11.06.84	6	0200-0800	0.7	74.7	24.7	0.40
15.06.84	6	0800-1400	3.3	65.3	31.3	0.64
16.06.84	3.5	2000-2330	15.6	73.3	11.1	0.19
22.06.84	8	1100-1900	31.3	60.1	8.6	0.31
23.06.84	4.5	1900-2330	13.2	74.6	12.3	0.52
27.06.84	5	0600-1100	24.6	60.3	15.1	0.17
02.07.84	4	1930-2330	28.4	67.7	3.9	0.08

TABLE 4.5: Mean duration time in minutes of adult Herring Gull departures from nest sites in 1983.

Date	12.6	15-16.6	16.6	23.6	6.7	10.7	13-14.7
Duration	88	77	45	56	15	75	60
Sample size	23	8	3	4	1	1	3
Standard error	19.6	34.3	30.0	23.0	0.0	0.0	0.0

TABLE 4.6: Mean duration time in minutes of adult Herring Gull departures from nest sites in 1984.

Date	9.6	11.6	15.6	16.6	22.6	23.6	27.6	2.7
Duration	40	70	38	46	112	45	75	70
Sample size	15	16	27	19	15	19	7	3
Standard error	5.6	10.7	4.8	6.4	18.8	8.0	28.3	40.9

TABLE 4.7: Hatching rates and survival of Herring Gull chicks on Noss, 1983 and 1984. Causes of egg loss are included.

	1983		1984	
	Number	%	Number	%
Clutches	152		113	
C3	103	67.8	74	65.5
C2	37	24.3	32	28.3
C1	12	7.9	7	6.2
Eggs	395		293	
Hatched	277	70.1	210	71.7
Eggs addled	23	5.8	11	3.8
Eggs lost	95	24.1	72	24.6
to predators	40		58	
bad weather	21		0	
Fulmar at nest	6		7	
eider at nest	0		2	
died at hatching	2		2	
? (Unknown)	26		3	
Chicks alive at 10 days*	187	67.5	162	77.1
20 days	160	57.8	119	56.7
30 days	120	43.3	75	35.7
Chicks died/predated	54	19.5	57	27.1

* Percentages refer to number of chicks hatched.

TABLE 4.8: Number of Herring Gull chicks known to be dead or alive at 10, 20, 30 and greater than 30 days of age, Noss 1983 and 1984. Percentages are of total number of deaths at known ages.

		Dead		Alive	Died	
Year	Age	n	%	n	n	%
1983	10 days	41	75.9	187	16	8.6
	20	8	14.8	160	10	6.3
	30	3	5.6	120	6	5.0
	>30	2	3.7			
1984	10 days	38	66.7	162	18	11.1
	20	12	21.1	119	6	5.0
	30	4	7.0	75	2	2.7
	>30	3	5.3			

(Died refers to chicks alive at x days that subsequently died).

TABLE 4.9: Distribution of laying dates for Great Skuas 1983 and 1984, Isle of Noss. Laying date refers to date that first egg in clutch was laid.

	1983		1984	
Period	n	%	n	%
08.05-14.05	11	22.0	22	31.4
15.05-21.05	23	46.0	34	48.6
22.05-28.05	14	28.0	10	14.3
29.05-04.06	2	4.0	4	5.7
Total number	50		70	

TABLE 4.10: Linear regressions for weight vs wing length (>50mm and <160mm) for Arctic Skua chicks on Foula 1976-1983.

Year	Linear regression equation	n	r	s.e.
1976	weight = 34.525 + 1.922 wing	50	0.928	3.670
1977	weight = 26.424 + 2.047 wing	59	0.960	2.433
1978	weight = 72.905 + 1.583 wing	41	0.910	3.202
1979	weight = 21.439 + 2.027 wing	195	0.947	1.569
1980	weight = 27.167 + 1.955 wing	72	0.965	2.074
1981	weight = 10.968 + 2.092 wing	57	0.965	2.221
1982	weight = 20.299 + 2.006 wing	83	0.949	2.082
1983	weight = 36.982 + 1.972 wing	43	0.900	4.246

TABLE 4.11: Hatching rates and survival of Great Skua chicks on Noss 1983 and 1984. Causes of egg loss are included.

	1983		1984	
	Number	%	Number	%
Clutches	50		70	
n C2	45		66	
n C1	5		4	
Eggs laid	95		136	
Chicks hatched	78	82.1	115	84.6
Eggs addled	14	14.7	14	10.3
Eggs failed when hatching	3	3.2	0	0.0
Eggs predated/lost	0	0.0	7	5.2
Chicks alive at 10 days	50	64.1	75	65.2
Chicks fledged	42	53.8	51	44.4
Chicks probably fledged	0	0.0	9	7.8
Chicks of unknown fate	5	6.4	9	7.8
Chicks died/predated	31	39.7	46	40.0

TABLE 4.12: Distribution of laying dates for Fulmar 1983-1984, Isle of Noss, calculated by assuming 51 days of incubation.

	1983		1984	
Period	n	%	n	%
07.05-11.05	4	5.1	5	6.0
12.05-16.05	23	29.5	22	26.5
17.05-21.05	30	38.5	35	42.2
22.05-26.05	15	19.2	16	19.3
27.05-31.05	4	5.1	3	3.6
01.06-05.06	2	2.6	1	1.2
06.06-10.06	0	0.0	1	1.2

TABLE 4.13a: Parental attendance at nest sites and number of feeds per chick per hour (n feeds) for Fulmars at Papil Geo, Noss 1983.

Date	Observation n hours	time	% time with 0, 1 or 2 adults present 0	1	2	n feeds
13-14.07.83	9.5	2300-0830	0.0	93.0	7.0	0.0
18-20.07.83	48	2200-2200	8.3	89.1	2.6	0.03
31.07.83	11	1030-2130	85.5	13.6	0.9	0.07
02.08.83	7	0430-1130	89.3	8.0	2.7	0.09
03.08.83	1	0330-0430	97.8	2.2	0.0	0.0
10.08.83	16.5	0500-2130	79.8	19.4	0.8	0.1
24.08.83	15.5	1530-2100	89.9	10.1	0.0	0.09

TABLE 4.13b: Parental attendance at nest sites and number of feeds per chick per hour (n feeds) for Fulmars at Papil Geo, Noss 1984.

Date	Observation n hours	time	% time with 0, 1 or 2 adults present 0	1	2	n feeds
12.07.84	15	0800-2300	0.0	89.9	10.1	0.060
29.07.84	17.5	0500-2230	71.7	26.9	1.4	0.082
19.08.84	16	0500-2100	93.5	6.4	0.15	0.025

TABLE 4.14: Minimum durations (in hours) of adult Fulmar departures, Noss 1983 (n = 121) and 1984 (n = 26).

Minimum time	2	4	6	8	10	12	14	16	18	48
1983 n	17	18	36	15	15	4	10	4	1	1
1984 n	2	3	1	1	6	4	4	5	0	0

TABLE 4.15: Differences, expressed by chi^2, between chick feed rates in 1983 and 1984. All differences were significant ($p<0.001$). 1983a includes 12 hours of darkness, when no feeds were observed. 1983b excludes those 12 hours of darkness. 1984a includes 5 nests with dye-marked adults. 1984b includes 20 nests.

	1984a	1984b
1983a	33.4	35.5
1983b	27.4	27.6

TABLE 4.16: Hatching and fledging success for Fulmar 1983-1984, Isle of Noss. Causes of egg and chick loss are included.

	1983		1984	
	n	%	n	%
Nests (= eggs laid)	81		83	
Chicks hatched	54	66	65	78.3
Eggs lost	27	33	18	21.7
addled	0		3	
lost 'early'	12		0	
failed at hatching	2		0	
unattended	2		0	
presumed preyed	11		15	
Breeding success		56.8		51.8
Chicks fledged	46	85.0	43	66.2
Chicks predated	4	7.4	20	30.8
Chicks died	4	7.4	2	3.1

Breeding success refers to fledging success from egg stage, therefore some early egg losses are not included. Thus number of chicks fledged, from those hatched, gives the most reliable estimate of breeding success.

TABLE 4.17: Mean and median laying dates for Herring Gull eggs.

Site	Mean	Median	Source
Rhode Island	7-10 May		Erwin (1971)
Isle of may		16-18 May	Parsons (1971)
Skokholm		10 May	Davis (1975)
Gull Island, Newfoundland	10-14 May		Haycock and Threlfall (1975)
Isle of Noss	12-14 May	11-12 May	This study (1983 and 1984)

TABLE 4.18: Breeding success of Herring Gulls, comparing Noss with literature sources.

Site	Hatching rate (%)	Chicks fledging per pair	Source
Skomer	64	0.6	Harris (1964)
Walney Island	67	c1.0	Brown (1967)
Rhode Island	67-82	-	Erwin (1971)
Skokholm	51-79	0.6 -0.7	Davis (1975)
Gull Island, Newfoundland	63-73	<1.0	Haycock and Threlfall (1975)
Isle of May	64-70	0.67-0.91	Parsons (1975)
Isle of Noss	70-72	0.66-0.83	This study (1983 and 1984)

TABLE 4.19: Peak laying periods for Fulmar eggs, from Fisher (1952).

	Most eggs laid
Small British colonies	25 May - 7 June
Large British colonies	20 - 29 May
St Kilda	12 - 22 May
Faeroe	mid - late May
Iceland	16 - 20 May
Bear Island	late May - early June
Franz Josef Land	by mid June
Greenland and the Canadian Arctic	early June
Pacific	late May - early June

TABLE 4.20: Breeding success of Fulmars, comparing Noss with literature sources.

Place of study	% hatching	% fledging	% BS	Source
Sands of Forvie, Aberdeenshire	54.4	83.9	45.6	Mougin (1967)
Sands of Forvie, Aberdeenshire	-	-	52.9	MacDonald (1977)
Prince Leopold Island, N Canada	72.9	66.5	48.5	Nettleship (1977)
Eynhallow, Orkney (28 years)	-	-	16.0-52.0	Dunnet et al (1979)
Semidi Islands, Alaska	22.1-69.2	67.4-73.8	14.9-51.0	Hatch (1979)
Isle of Noss*	66.0-78.3	68.2-85.0	51.8-56.8	This study

* Maximum values for hatching and breeding success, as early egg losses not accounted for (see text).

BS refers to breeding success.

TABLE 5.1 : Diet of Herring Gull chicks, Noss 1983-1985 and mainland (M/L) Shetland 1985, obtained from chick regurgitates. Data are presented as the % of regurgitates in which food item appeared.

	Noss			M/L	Total	
Food	1983	1984	1985	1985	n	%
Sandeel	41.2	18.9	15.4	0.0	45	23.4
Whitefish	29.4	61.3	53.9	77.8	101	52.6
Intertidal invertebrates	11.8	2.8	0.0	0.0	9	4.7
Bird	3.9	0.9	3.9	0.0	4	2.1
Terrestrial invertebrates	25.5	8.5	7.7	11.1	25	13.0
Human waste	7.8	13.2	19.2	11.1	24	12.5
Other[1]	5.9	0.0	0.0	0.0	3	1.6
Total number of regurgitates	51	106	26	9	192	

[1] Other = squid (2), Herring gull egg (1)

TABLE 5.2a: Observed (O) and expected (E) frequencies of Sandeel and Whitefish in Herring Gull chick regurgitates early ($\leq$ 25 June) and late ($>$ 25 June) in the season, Noss 1983.

		Early	Late	Total
Sandeel	O	14	7	21
	E	11.7	9.3	21
Whitefish	O	6	9	15
	E	8.3	6.7	
Total		20	16	36

TABLE 5.2b: Observed (O) and expected (E) frequencies of Sandeel and Whitefish in regurgitates from young ($\leq$15 days) and old ($>$15 days) Herring Gull chicks, Noss 1983.

		Young	Old	Total
Sandeel	O	9	12	21
	E	8.2	12.8	
Whitefish	O	5	10	15
	E	5.8	9.2	
Total		14	22	36

TABLE 5.3a: Observed (O) and expected (E) frequencies of Sandeel and Whitefish in Herring Gull chick regurgitates early ($\leq$25 June) and late ($>$25 June) in the season, Noss 1984.

		Early	Late	Total
Sandeel	O	19	1	20
	E	10.6	9.4	
Whitefish	O	26	39	65
	E	34.4	30.6	
Total		45	40	85

TABLE 5.3b: Observed (O) and expected (E) frequencies of Sandeel and Whitefish in regurgitates from young (≤ 15 days) and old (> 15 days) Herring Gull chicks, Noss 1984.

		Young	Old	Total
Sandeel	O	18	2	20
	E	12	8	
Whitefish	O	33	32	65
	E	39	26	
Total		51	34	85

TABLE 5.4: Observed (O) and expected (E) frequencies of Sandeel and Whitefish in Herring Gull chick regurgitates early (≤ 25 June) and late (> 25 June) in the season, Noss 1985.

		Early	Late	Total
Sandeel	O	3	1	4
	E	1.3	2.7	
Whitefish	O	3	11	14
	E	4.7	9.3	
Total		6	12	18

TABLE 5.5a: Diet of adult Herring Gulls, Noss 1983-1985 and mainland (M/L) Shetland 1985, determined from the % occurrence of food items in regurgitated pellets.

Food	Noss 1983	Noss 1984	Noss 1985	Noss Total	M/L 1985 East	M/L 1985 West	Total n	Total %
Sandeel	0.1	0.0	0.0	+	0.0	0.0	4	+
Whitefish	2.5	5.7	1.4	2.8	18.3	13.4	608	6.0
Intertidal invertebrates	95.2	91.7	96.5	94.9	71.8	80.9	9220	90.6
Bird	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
Human waste	0.0	0.0	0.0	0.0	0.0	0.0	0	0.0
Other[1]	2.2	2.6	2.1	2.2	9.9	5.6	350	3.4
Total number of pellets	3895	1477	2152	7524	760	1898	10182	

Presence in less than 0.1% of pellets indicated by +

[1] Details of other foods in Appendix III

TABLE 5.5b : Diet of adult Herring Gulls, Noss 1983-1985 and mainland (M/L) Shetland 1985, determined from the % occurrence of food remains.

Food	Noss 1983	Noss 1984	Noss 1985	Noss Total	M/L 1985	Total n	Total %
Sandeel	0.0	0.0	0.0	0.0	0.0	0	0.0
Whitefish	0.0	0.0	0.0	0.0	0.0	0	0.0
Intertidal invertebrates	99.7	97.8	98.9	99.1	99.9	5755	99.6
Bird	0.3	2.0	1.1	0.9	+	21	0.4
Human waste	0.0	0.2	0.0	+	+	2	+
Other[1]	0.0	0.0	0.0	0.0	0.0	0	0.0
Total number of food remains	1308	600	277	2185	3593	5778	

Presence in less than 0.1% of food remains indicated by +

[1] Details of other foods in Appendix III

TABLE 5.6: Diet of Great Skua chicks, Noss 1983-1985 and on Hermaness, Unst 1985, obtained from chick regurgitates. Data are presented as the % of regurgitates in which the food item appeared. In all cases only one type of food appeared in each regurgitate.

	Noss			Total		
Food	1983	1984	1985	n	%	Hermaness
Whitefish	100	60	66.7	12	70.6	33.3
Sandeel	0	40	0.0	4	23.6	0.0
Seabird	0	0	33.3	1	5.9	66.7
Total number of regurgitates	4	10	3	17		3

TABLE 5.7a: Observed (O) and expected (E) frequencies of Sandeel, whitefish and bird in Great Skua chick regurgitates early (June) and late (July) in the season, Noss 1983-1985.

		Early	Late	Total
Sandeel	O	1	3	4
	E	1.4	2.6	
Whitefish	O	6	7	13
	E	4.6	8.4	
Bird	O	0	3	3
	E	1.0	2.0	
Total		7	13	20

TABLE 5.7b: Observed (O) and expected (E) frequencies of Sandeel, whitefish and bird in regurgitates from young ($\leq$15 days) and old ($>$15 days) Great Skua chicks, Noss 1983-1985.

		Young	Old	Total
Sandeel	O	1	3	4
	E	1.6	2.4	
Whitefish	O	6	7	13
	E	5.2	7.8	
Bird	O	1	2	3
	E	1.2	1.8	
Total		8	12	20

TABLE 5.8: Diet of breeding Great Skuas on Noss 1983-1985 and on Hermaness, Unst 1985. Data are presented as the % of pellets in which the food item appeared.

	Noss			Total		Hermaness	
Food	1983	1984	1985	n	%	n	%
Whitefish	50.8	57.0	22.8	675	40.4	8	19.5
Sandeel	0.7	1.0	1.0	15	0.9	0	0.0
Seabird	45.0	34.5	60.2	817	48.9	31	75.6
Rabbit	2.7	5.9	7.0	89	5.3	0	0.0
Other[1]	0.7	1.7	9.0	75	4.5	2	4.9
Total number of pellets	551	409	711	1671		41	

[1] Details of other foods in Appendix III

TABLE 5.9: Diet of non-breeding Great Skuas on Noss 1983-1985 and Hermaness, Unst 1985. Data are presented as the % of pellets in which the food item appeared.

	Noss			Total		Hermaness	
Food	1983	1984	1985	n	%	n	%
Whitefish	63.8	62.0	56.3	2156	61.7	27	65.9
Sandeel	9.3	9.3	12.5	348	10.0	0	0.0
Seabird	25.6	21.6	21.6	824	23.6	13	31.7
Rabbit	0.7	1.8	4.8	64	1.8	0	0.0
Other[1]	0.6	5.4	4.9	101	2.9	1	2.4
Total number of pellets	1759	1020	714	3493		41	

[1] Details of other foods in Appendix III

TABLE 5.10: Decrease with season in the occurrence of Sandeel (SE) in the diet of non-breeding Great Skuas, Noss 1983-1985.

	1983		1984		1985	
Date	% SE	n	% SE	n	% SE	n
3/5	-	0	-	0	9.1	44
10/5	-	0	-	0	-	0
17/5	9.5	21	6.5	62	-	0
24/5	-	0	15.4	143	32.4	32
31/5	25.0	216	27.3	47	47.1	87
7/6	33.7	107	19.2	176	12.9	70
14/6	24.8	101	17.6	94	-	0
21/6	16.2	179	0.0	57	11.9	84
28/6	9.5	84	0.0	158	8.9	101
5/7	3.3	214	6.3	0	6.9	72
12/7	0.0	105	0.0	44	-	0
19/7	-	0	0.0	87	0.0	99
26/7	-	0	0.0	54	0.0	44
2/8	1.8	57	0.0	33	0.0	57
2/8	0.2	675	-	0	0.0	24
Total number of pellets		1759		1020		714

n refers to total number of pellets examined.

TABLE 5.11: Diet of Fulmar chicks, Noss 1983-1985. Data are presented as the % of regurgitates in which the food item occurred.

				Total	
Food	1983	1984	1985	n	%
Whitefish and offal[1]	72.2	55.5	64.4	140	61.7
Sandeel[2]	25.0	33.7	34.4	75	33.0
Plankton	2.8	10.9	8.9	20	8.8
Crab	0.0	0.0	1.1	1	0.4
Other[3]	0.0	5.9	7.8	13	5.7
Total number of regurgitates	36	101	90	227	

[1] Includes whitefish, Herring/Mackerel, Garfish and offal

[2] Sandeel may also include very small fish, such as tiny Norway Pout

[3] Other; details of other foods in Appendix III

TABLE 5.12: Diet of adult Fulmars, Noss 1983-1985. Data are presented as the number of regurgitates in which the food item occurred.

Food	1983	1984	1985	Total n	Total %
Whitefish and offal	1	36	12	49	94.2
Sandeel[1]	3	4	2	9	17.3
Plankton	0	2	0	2	3.9
Total number of regurgitates	4	36	12	52	

[1] Sandeel may also include small fish such as tiny Norway Pout

TABLE 5.13: Diet of breeding Great Black-blacked Gulls, Noss 1985

Food	Pellets n	Pellets %	Food Remains n	Food Remains %
Other shellfish[1]	0	0.0	210	100
Mussel	36	5.6	0	0
Fish	200	31.3	0	0
Rabbit	238	37.2	0	0
Bird	136	21.3	0	0
Guillemot egg	30	4.7	0	0
Total number of food samples	640		210	

[1] Details in Appendix III

TABLE 6.1a: Fish species identified from otoliths found in pellets regurgitated by adult Great Skuas, Noss 1983-1985.

	Breeding Great Skua				Non-breeding Great Skua			
Fish	1983	1984	1985	%	1983	1984	1985	%
Whiting	14	50	77	48.6	80	110	119	22.8
Haddock	24	21	47	31.7	109	95	151	26.1
Cod	1	1	4	2.1	1	6	0	0.5
Saithe	2	0	0	0.7	1	2	4	0.5
Poor Cod[1]	0	0	0	0.0	5	4	0	0.7
Norway Pout	8	5	12	8.6	131	148	48	24.1
Herring	0	0	1	0.4	14	0	0	1.0
Redfish	0	0	0	0.0	8	8	7	1.7
Ling	2	0	0	0.7	0	1	0	0.1
Torsk	0	0	0	0.0	5	5	1	0.8
Lesser Argentine	0	0	2	0.7	7	3	4	1.0
Blue Whiting	0	0	0	0.0	5	2	0	0.5
Flatfish	0	0	0	0.0	1	2	0	0.2
Sandeel	6	0	13	6.6	102	60	109	20.0
Total n	57	77	156		469	446	443	

[1] Could possibly include Bib

% Refers to data for the three years combined

TABLE 6.1b: Fish species identified from otoliths found in pellets regurgitated by breeding Great Black-backed Gulls and Herring Gulls, Noss 1983-1985.

	Great Black-backed Gull				Herring Gull			
Fish	1983	1984	1985	%	1983	1984	1985	%
Whiting	14	1	63	24.8	13	14	31	3.7
Haddock	32	0	156	59.9	6	6	24	33.3
Cod	6	2	4	3.8	1	0	3	3.7
Saithe	1	2	3	1.9	0	0	0	0.0
Norway Pout	0	0	7	2.2	0	0	0	0.0
Herring	0	0	0	0.0	1	0	0	0.9
Redfish	0	0	6	1.9	0	0	0	0.0
Ling	1	0	1	0.6	3	0	3	5.6
Torsk	4	0	7	3.5	0	0	0	0.0
Flatfish	0	0	0	0.0	1	0	0	0.9
Sandeel	0	0	0	0.0	2	0	0	1.9
Unidentified	0	0	4	1.3	0	0	0	0.0
Total n	58	5	251		27	20	61	

Unidentified: includes two otoliths similar to Redfish otoliths and two that are probably Monkfish otoliths

% refers to data for the three years combined

TABLE 6.2: Median otolith in mm, and equivalent fish lengths in cm, occurring in pellets regurgitated by (A) breeding and non-breeding Great Skuas, and (B) breeding Great Black-backed Gulls (GBb Gull) and breeding Herring Gulls on Noss 1983-1985. Sample sizes as in Table 6.1.

(A)

	Breeding Great Skua		Non-breeding Great Skua	
Fish species	otolith length	fish length	otolith length	fish length
Whiting	15.5-16.5	27.6-29.0	14.5-15.5	26.2-27.5
Haddock	11.5-12.5	24.0-26.0	11.5-12.5	24.0-26.0
Cod	9.5-10.5	25.0-28.8	11.5-12.5	32.9-36.8
Norway Pout	5.5-6.5	11.1-13.5	6.5-7.5	13.6-16.1
Sandeel	3.0-3.2	16.0-16.7	2.8-3.0	15.2-15.9

(B)

	Breeding GBb Gull		Breeding Herring Gull	
Fish species	otolith length	fish length	otolith length	fish length
Whiting	15.5-16.5	27.6-29.0	17.5-18.5	30.6-32.0
Haddock	12.5-13.5	26.1-28.0	12.5-13.5	26.1-28.0
Cod	11.5*	32.9	12.5-13.5	36.9-40.8
Norway Pout	6.5-7.5	13.6-16.1	-	-
Sandeel	2.8-3.0	15.2-15.9	-	-

* Median fell between two otolith length classes so intermediate value given

TABLE 6.3: Fish species identified from otoliths regurgitated by breeding (br) and non-breeding (non-br) Great Skuas (GS) and Great Black-backed Gulls (GBbG), Foula 1975, 1976, 1980-1985

Bird Species	Year	Whiting	Haddock	Cod	Saithe	NP*	Poor Cod	Red-fish	Torsk	Sand-eel
Non-br GS	1975	141	108	0	0	29	6	0	0	2
	1980	108	106	0	0	11	0	0	0	13
	1981	136	31	0	0	2	0	0	0	3
	1982	134	17	3	0	0	0	1	0	0
	1983	86	18	1	0	4	0	0	0	91
	1984	34	10	0	0	2	0	0	0	6
	1985	240	146	0	0	11	0	0	0	70
	%	55.9	27.7	0.3	0.0	3.8	0.4	0.1	0.0	11.8
Br GS	1975	95	107	0	0	20	0	0	0	1
	1980	4	3	0	0	0	0	0	0	3
	1983	5	2	0	0	0	0	0	1	3
	1984	24	1	0	0	0	0	0	0	0
	1985	59	17	0	0	0	0	0	0	0
	%	59.2	37.7	0.0	0.0	5.8	0.0	0.0	0.3	2.0
Non-br GBbG	1975	36	37	0	0	0	0	9	0	0
	1976	225	263	0	0	3	0	37	0	0
	1980	110	122	0	2	0	0	1	0	1
	1981	47	37	2	0	0	0	0	0	0
	1982	75	41	0	0	0	0	0	0	0
	1983	301	157	0	0	1	0	6	0	0
	1984	71	21	0	0	4	0	0	1	0
	1985	28	21	0	0	0	0	0	0	0
	%	53.8	42.1	0.1	0.1	0.5	0.0	3.2	0.1	0.1
Br GBbG	1980	3	5	0	0	0	0	0	0	0
	1983	4	7	0	0	0	0	0	0	0
	1985	1	2	0	0	0	0	0	0	0
	%	36.4	63.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*NP: refers to Norway Pout

TABLE 6.4: Median otolith lengths in mm and equivalent fish lengths in cm (in parentheses) occurring in pellets regurgitated by breeding and non-breeding Great Skuas and Great Black-backed Gulls on Foula 1975, 1976, 1980-1985.

Abbreviations and sample sizes (for totals) as in Table 6.3, except for Sandeel otoliths found in faecal pellets of breeding Great Black-backed Gulls, where n = 193.

Bird Species	Whiting	Haddock	Cod	Norway Pout	Sandeel
Br	14.5-15.4	11.5-12.4	-	6.5-7.5	2.4-2.6
GS	(26.2-27.5)	(24.0-26.0)	-	(13.6-16.1)	(13.6-14.3)
Non-br	15.5-16.4	11.5-12.4	9.5-10.4	6.5-7.4	2.4-2.6
GS	(27.6-29.0)	(24.0-26.0)	(25.0-28.8)	(13.6-16.1)	(13.6-14.3)
Br	16.0*	13.5-14.4	-	-	2.0-2.2
GBbG	(28.4)	(28.1-30.0)	-	-	(12.0-12.8)
Non-br	16.5-17.4	12.5-13.4	13.5	7.5	-
GBbG	(29.1-30.6)	(26.1-28.1)	(40.8)	(16.2)	-

* where median falls between two otolith length classes, intermediate value given

TABLE 6.5: Species of fish identified from otoliths regurgitated by gulls on mainland Shetland.

Abbreviations as in Table 6.3 and LBbG refers to Lesser Black-backed Gull. T/S refers to Trondra and Scalloway gulls, mixed species.

Fish	Br HG 1983	Br HG 1985	Non-br HG 1985	Br LBbG 1985	Br GBbG 1985	Non-br GBbG 1985	Br HG/ LBbG 1985	Loafing gulls 1985	T/S gulls 1985
Whiting	2	147	6	42	1	319	41	8	63
Haddock	20	109	6	35	9	337	9	19	47
Cod	0	5	0	0	0	11	2	1	8
Saithe	0	0	0	0	0	4	0	0	2
Norway Pout	0	3	0	1	0	2	0	0	1
Redfish	0	0	0	0	0	6	0	0	0
Plaice	0	0	0	0	0	1	0	0	0
Sandeel	0	0	0	0	0	1	0	0	0
Ling	0	4	0	0	0	0	0	0	0
Flatfish	0	0	0	0	0	1	0	0	0
Blue Whiting	0	1	0	0	0	0	0	0	0
Total	22	269	12	78	10	681	52	28	123

TABLE 6.6: Median otolith lengths in mm and equivalent fish lengths in cm (in parentheses) occurring in pellets regurgitated by gulls on mainland Shetland.

Sample sizes and abbreviations as in Table 6.5

	Whiting	Haddock	Cod
Br HG	-	13.5	-
1983	-	(28.1)	-
Br HG	17.5-18.5	13.5-14.5	-
1985	(30.6-32.0)	(28.1-30.0)	-
Br LBbG	14.5-15.5	11.5-12.5	-
1985	(26.2-27.5)	(24.0-26.0)	-
Br LBbG/HG	14.5-15.5	11.5-12.5	-
1980	(26.2-27.5)	(24.0-26.0)	-
Non-br GBbG	16.5-17.5	12.5-13.5	12.5-13.5
1985	(29.1-30.5)	(26.1-28.0)	(36.9-40.7)
Loafing gulls	17.5	14.5-15.5	-
1985	(30.6)	(30.1-32.1)	-
T/S gulls	17.5-18.5	13.5-14.5	12.5-13.5
1985	(30.6-32.0)	(28.1-30.0)	(36.9-40.7)

Table 7.1: Mean maximum ($\pm$se) bird numbers per trip attending whitefish trawlers in Shetland 1984

Date	n	Fulmar	Great Skua	GBbG	HGull	Gannet	Kittiwake	LBbG	Other
08-09.07.84	3	173	6	+	0	5	8	1	+AS
		(63.6)	(2.3)	+	-	(3.4)	(4.4)	(0.6)	+
17.07.84	7	471	7	27	71	+	2	2	+AS
		(59.6)	(2.5)	(10.2)	(71.4)	+	(0.6)	(1.6)	+
24.07.84	7	600	20	140	22	0	6	1	0
		(95.6)	(7.5)	(56.2)	(13.8)	-	(2.8)	(0.9)	-
13.08.84	6	967	15	+	0	+	+	0	+SS,S,P
		(82.3)	(2.6)	+	-	+	+	-	+

n refers to number of hauls
+ indicates a mean value of less than 1
AS refers to Arctic Skua
SS refers to Sooty Shearwater
S refers to Shag
P refers to Puffin

Table 7.2: Mean maximum ($\pm$se) bird numbers attending whitefish trawlers in Shetland 1985, in the pre-breeding season (March), during the breeding season (April-July) and in the post breeding season (August and September)

Season	n	Fulmar	Great Skua	GBbG	HGull	Gannet	Kittiwake	LBbG	Other
March	6	850	0	143	1633	5	7	+	+
		(160.7)	-	(33.8)	(323.2)	(2.2)	(3.0)	+	+
April-July	92	498	11	240	33	8	2	5	+
		(36.7)	(1.1)	(19.0)	(6.8)	(2.7)	(0.6)	(0.6)	+
August-September	53	423	11	207	31	6	+	+	+
		(35.6)	(1.6)	(33.3)	(18.7)	(2.3)	+	+	+

n refers to number of hauls
+ indicates a mean value of less than 1

Table 7.3: Percentage of adults in flocks of gulls and Gannets following whitefish trawlers in Shetland 1985. Percentages are approximations for each trip, where data were available.

Date	GBbG	LBbG	HGull	Kittiwake	Gannet
30.4.85	80	100	100	0	100
8.5.85	90	90	50	95	95
14.5.85	80-90	95	-	-	-
20-21.5.85	-	85	-	-	-
10-12.6.85	75-80	95	-	-	70
17-19.6.85	80-85	-	85	-	-
19-21.6.85	85	-	-	-	-
24-26.6.85	80-90	-	90	-	75
22.7.85	90	-	-	-	75
24.7.85	75-80	-	80-90	-	90
29.7.85	80-95	-	-	-	75
31.7.85	70-80	-	-	-	55
7-9.8.85	90	-	90	0	-
12.8.85	-	-	-	-	100
18-21.8.85	90	-	90	-	90-95
27.8.85	80-90[1]	-	-	-	60
2.9.85	70-80[1]	-	70[1]	100	90
5.9.85	50	-	-	-	100
9.9.85	70	-	-	75	100
10.9.85	70	-	-	80	80

1: half of the non-adult birds were juveniles

Table 7.4: Changing bird numbers, during the gutting and discarding process following the final haul, behind whitefish boats in Shetland as the boats neared the shore.

	More than 2 miles from shore		Less than 2 miles from shore		
Date	Fulmar	HGull	Fulmar	HGull	Chi^{2*}
17.07.84	500	0	50	500	867.8
29.07.85	600	10	10	300	831.2
09.08.85	300	150	10	800	667.8
02.09.85	500	0	0	800	1300.0

* $P < 0.001$ in all cases

Table 7.5: Mean (±se) bird numbers behind a sandeel boat in Shetland 1984

Date	n	Fulmar	Great Skua	GBbG	HGull	Gannet	LBbG	Other
18.07.84	7	+	+	7 (2.3)	60 (15.3)	+	2 (0.9)	2 (0.8)

n refers to numbers of hauls
Other includes Kittiwake, Arctic Tern, Black Guillemot
+ refers to a mean value of less than 1

Table 7.6: Maximum bird numbers for individual hauls behind sandeel trawlers, observed from Noss (N) or a Zodiac inflatable (Z) in Shetland 1984

Date	Time	Fulmar	Great Skua	GBbG	HGull	Gannet	LBbG	Gull*	Fulmar/ Gull*
06.08.84	2115 Z	70	0	40	0	0	1	-	-
07.08.84	0945 N	80	2	20	0	0	0	-	-
11.08.84	1440 N	100	40	50	20	30	0	-	-
23.08.84	1205 N	25	0	+	+	25	+?	25	-
	1915 N	+	6	+	+	25	+?	-	200
26.08.84	0930 N	30	2	20	20	0	6	-	-
	1020 N	+	12	+	+	75	+?	-	30
	1630 N	30	0	+	+	30	+?	20	-
	1640 N	+	0	+	+	20	+?	-	40
27.08.84	1400 Z	50	12	50	25	25	0	-	-
	1430 Z	50	12	75	+	100	0	-	-
	1445 Z	50	0	50	0	75	0	-	-
	1500 Z	12	3	75	10	20	0	-	-

+ indicates presence in unknown numbers
+? indicates possible presence in small numbers amongst group of gulls
* explained in full in text (3.4.1.a); refers to flocks of mixed species

Table 7.7a: Mean numbers of birds observed behind whitefish trawlers in different seasons during aerial counts in Shetland 1984 and 1985

Seasons as follows: pre-breeding = March; breeding = April to July; post-breeding = August and September; non-breeding = October

Season	Mean number of birds per boat	Number of boats	± SE
Post-breeding 1984	481	16	183.0
Pre-breeding 1985	810	8	368.5
Breeding 1985	881	43	274.7
Post-breeding 1985	787	19	163.5
Non-breeding 1985	1500	1	

Table 7.7b: Mean numbers of birds observed behind whitefish trawlers near (< 15 miles) and far (≥ 15 miles) from land, during aerial counts in Shetland 1984 and 1985

	Less than 15 miles from land	Greater than or equal to 15 miles from land
Mean number of birds per boat	621	1050
Number of boats	54	33
± se	147.1	260.7

Table 7.8a: Mean number ($\pm$se) of each bird species observed behind whitefish trawlers in different seasons during aerial counts in Shetland 1984 and 1985

Season	n	Fulmar	GBbG	Great Skua	Gannet	Kittiwake	Unidentified*
Post-breeding 1984	16	379	101	1	+	0	0
		(145.2)	(67.6)	(0.7)	-	-	-
Pre-breeding 1985	6	852	0	0	2	10	650^{1}
		(491.9)	-	-	(1.1)	(8.1)	(350.0)
Breeding 1985	40	861	29	2	4	0	670^{2}
		(287.7)	(13.2)	(1.3)	(2.5)	-	(438.4)
Post-breeding 1985	16	471	(45)	1	43	0	2000^{3}
		(222.9)	(28.4)	(0.7)	(23.6)	-	(0.0)
Non-breeding 1985	1	1500	0	0	0	0	0
		(0.0)	-	-	-	-	-

+ indicates a mean value of less than 1

* explained in full in text (3.4.2); refers to flocks of mixed species

n refers to number of boats, except for boats with 'unidentified' birds behind them

where 1: n = 2

2: n = 3

3: n = 3

Table 7.8b: Mean numbers (±se) of each bird species observed behind whitefish trawlers, near (< 15 miles) and far (> 15 miles) from land, during aerial counts in Shetland 1984 and 1985

	Less than 15 miles from land	Greater than or equal to 15 miles from land
Fulmar	488 (± 144.4)	1008 (± 275.8)
GBbG	57 (± 25.7)	25 (± 12.0)
Great Skua	2 (± 1.1)	1 (± 0.7)
Gannet	17 (± 8.4)	1 (± 0.4)
Kittiwake	0	2 (± 1.6)

Table 7.9: Total hauls and proportions of catches discarded and approximate proportions of discards consumed by seabirds behind whitefish trawlers in Shetland 1985. Data from each haul have been summed to give total catches for each trip

	Total haul		Discarded		Discards consumed	Market landings
Date	Boxes	Weight (kg)	Boxes	%	%	Boxes
18.03.85	58	2578	9	15.5	90-100	49
30.04.85	16	711	4	25	75	12
08.05.85	29	1289	9	31	45	20
13.05.85	80	3556	12	15	50-60	68
14.05.85	90	4000	6	7	75	84
20-21.05.85	85	3778	10	13	85-90	75
10-12.06.85	110	4890	20	18	70	90
17-19.06.85	161	7157	27	17	80-85	134
19-21.06.85	96	4267	18	19	80-90	78
24-26.06.85	145	6445	57	39	90	88
22.07.85	54	2400	5	9	>90	49
24.07.85	39	1734	7	18	90-100	32
29.07.85	85	3778	8	9	>90	77
31.07.85	60	2667	10	17	>90	50
05-07.08.85	123	5467	43	35	90	80
07-09.08.85	59	2623	19	32	>90	40
12.08.85	35	1556	12	34	50-60	23
18-21.08.85	146	6490	73	50	60-65	73
27.08.85	65	2889	53	82	50-60	12
29.08.85	145	6445	21	14.5	80	124
05.09.85	71	3156	18	25	90-100	53
09.09.85	71	3156	32	45	75	39
10.09.85	68	3023	33	49	75	35
Totals	1891	84055	506	26.8	74-78% (376-394 boxes)	1385

Table 7.10: Landings of demersal fish, in 100kg units, caught by UK vessels in Shetland waters 1983-1985, in inner and outer zones. Data supplied by DAFS

	1983	1984	1985
Inner			
50E7	7	3001	5060
50E8	17219	11626	17826
50E9	79274	46215	32824
49E7	27575	30544	25708
49E8	32411	27552	28947
49E9	43390	35359	16903
48E7	4560	17634	19445
48E8	91721	78774	57331
48E9	42695	66247	26027
Outer			
52E6	0	0	0
52E7	0	106	0
52E8	0	6	0
52E9	723	0	413
52F0	0	0	554
51E6	0	0	0
51E7	0	156	566
51E8	521	5989	9688
51E9	1777	6804	8916
51F0	469	2553	4707
50E6	101	0	268
50F0	10442	13783	10693
49E6	236	565	5244
49F0	40736	46097	29258
48E6	5860	8941	11003
48F0	26497	28406	26572
47E8	25416	39041	22025
47E9	4640	10255	19999
47F0	58276	53148	29596

Table 7.11: Monthly landings of demersal fish, in 100kg units, caught by UK vessels in Shetland waters 1983-1985, in inner and outer zones. Data supplied by DAFS

	1983		1984		1985	
	Inner	Outer	Inner	Outer	Inner	Outer
Jan	15480	10811	20485	17129	22026	20628
Feb	40192	28718	42519	40746	32190	29806
Mar	53757	42300	55859	46547	24077	25622
Apr	42976	17112	32353	22892	15807	15243
May	31980	8315	21414	11992	18639	10456
June	30820	6119	19591	7163	22148	7607
July	21400	9427	22543	6856	19705	6981
Aug	26552	12469	26653	15234	14000	5802
Sept	27016	11896	25223	12073	17427	8915
Oct	14247	8672	20405	9776	20650	19435
Nov	23416	12652	18332	10217	15627	13638
Dec	11016	7203	12292	15225	7775	15369

Table 7.12: Landings of demersal fish, in tonnes, caught by UK vessels in Shetland waters 1973-1985. Data supplied by DAFS

Year	Inner Zone	Outer Zone	Total
1973	91251	38209	129460
1974	36870	16286	53156
1975	33236	13658	46893
1976	38668	11853	50521
1977	44501	85003	53001
1978	33196	14197	47393
1979	23967	18270	42197
1980	26426	16802	43228
1981	26838	16413	43251
1982	30064	15805	45869
1983	33885	17569	51455
1984	31767	21585	53352
1985	23007	17950	40957

Table 7.13: Total landings, in tonnes, of demersal fish caught during summer and winter months by UK vessels in Shetland waters 1983-1985 and calculated weights in tonnes, of discards and offal available to seabirds

		Inner Zone			Outer Zone		
Season	Year	Landings	Discards	Offal	Landings	Discards	Offal
Summer	1983	18074	6597	2259	6534	2385	817
Winter	1983	15811	5771	1976	11036	4028	1379
Total	1983	33885	12368	4235	17570	6413	2196
Summer	1984	14778	5394	1847	7621	2782	952
Winter	1984	16989	6201	2124	13964	5097	1746
Total	1984	31777	11595	3971	21585	7879	2698
Summer	1985	10773	3932	1347	5500	2008	688
Winter	1985	12234	4466	1529	12450	4544	1556
Total	1985	23007	8398	2876	17950	6552	2244

TABLE 7.14: Calorific values of fish and offal, determined during this study and taken from the literature.

Fish species	Fish length (cm)	n	KJ g^{-1} (wet weight) Mean	$\pm$ s.e.	Source
Offal (Saithe)	28 -29.5	3	7.2	0.06	This study
Offal (Whiting)	18 -28	6	12.6	0.78	This study
Offal (Saithe and Whiting)	18 -28	9	10.8	1.03	This study
Saithe (whole)	28 -29.5	2	5.2	0.06	This study
Whiting (whole)	18 -28	5	5.8	0.83	This study
Saithe (whole)	3.7- 4.3	8	5.1	0.21	Harris and Hislop, 1978
Whiting (whole)	4.0- 6.4	3	4.1	0.32	Harris and Hislop, 1978
Saithe (gutted)	29.5	1	4.9	0.0	This study
Whiting (gutted)	18 -28	5	4.4	0.05	This study
Cod (fillet)	-	3	3.2	-	Paul and Southgate, 1975
Haddock (fillet)	-	-	3.1	-	Paul and Southgate, 1975
Plaice (whole)	-	8	3.8	-	Paul and Southgate, 1975

TABLE 7.15: Number of Shetland seabirds capable of gaining sufficient food behind whitefish trawlers to satisfy their energy demands, assuming that only Fulmars consumed offal (90% of all made available) and that only Great Black-backed Gulls consumed discarded fish (75% of all made available). Landings from 1984 and 1985 (see Table 7.13) have been used.

	1984		1985	
	Fulmar	GBbG	Fulmar	GBbG
Summer				
Inner zone	83000	56000	61000	41000
Outer zone	43000	29000	31000	21000
Total	126000	85000	92000	62000
Winter				
Inner zone	96000	65000	69000	47000
Outer zone	79000	53000	71000	47000
Total	175000	118000	140000	94000

TABLE 7.16: Mean numbers of seabirds associated with fishing boats in different areas. Minimum and maximum counts are given in parentheses. Summer includes April to July; winter includes October to February. Sources and number of counts (n) are supplied at the bottom of the table.

Bird	Irish Sea[1] Summer	Irish Sea[1] Winter	Clyde[2] Winter	N Rona[3] Summer	E Scotland[4] Winter	Shetland[5] Summer	Shetland[6] Summer
Fulmar	23	3	+	155	1)	485	72
	(0-100)	(0-30)	(0-3)		(0-4)	(10-2500)	(0-6000)
Gannet	11	6	6	5	15	9	3
	(0-50)	(0-50)	(0-167)		(0-51)	(0-200)	(0-100)
GBbG	213	251	241	15	2	234	19
	(0-800)	(10-900)	(0-1340)		(0-24)	(10-1000)	(0-300)
LBbG	2	+	3	1	2	6	0
	(0-10)	(0-1)	(0-88)		(0-28)	(0-20)	
HGull	5	16	6	90	87	30	0
	(0-30)	(0-60)	(0-80)		(0-380)	(0-400)	
Kittiwake	75	78	24	35	0	3	0
	(0-200)	(2-400)	(0-285)			(0-50)	
Great Skua	+	+	+	0	0	12	1
	(0-6)	(0-6)	(0-1)			(0-50)	(0-20)

1 Watson (1981) n = 18 in summer, n = 32 in winter
2 Hudson and Ensor, unpublished data n = 149
3 Boswall (1960)
4 Anstey (1984) n = 18
5 This study, trawler observations n = 72
6 This study, aerial observations n = 40
\+ indicates a mean value of less than 1

TABLE 8.1: Numbers and median lengths of fish discarded from whitefish trawlers in Shetland 1985.

Fish species	Number discarded	% of all discards	Median discard length (cm)	Number known to be consumed	% of these discarded*
Whiting	2589	34.0	29	1657	64.0
Haddock	2859	37.6	28	1691	59.2
Cod	88	1.2	32	56	63.6
Saithe	37	0.5	39	3	8.1
Norway Pout	36	0.5	16	24	66.7
Hake	1	-	-	0	(0.0)
Ling	7	0.1	-	0	(0.0)
Mackerel	4	0.1	-	3	(75.0)
Horse Mackerel	9	0.1	30	5	(55.6)
Herring	15	0.2	25	3	(20.0)
Lesser Argentine	10	0.1	21.5	6	(60.0)
Red Gurnard	565	7.4	25	172	30.4
Grey Gurnard	199	2.6	32	118	59.3
Skate	3	-	-	0	(0.0)
Angler	3	-	-	0	(0.0)
Dragonet	1	-	-	0	(0.0)
Witch	90	1.2	25	3	3.3
Megrim	22	0.3	28	0	0.0
Plaice	14	0.2	26.5	0	(0.0)
Lemon Sole	321	4.2	23	20	6.2
Long Rough Dab	732	9.6	21	32	4.4
Totals	7605			3793	49.4

* % based on $n < 20$ in parentheses

TABLE 8.2: Mean percentage values of offal consumed by Fulmars (as a percentage of all offal consumed by seabirds) behind whitefish trawlers in Shetland 1985.

n Fulmars	500	300	250	350	275	125	165	200	200
Fulmars as a % of all seabirds present	70.4	72.2	73.5	66.7	66.3	24.0	29.7	21.4	32.0
n GBbG	150	75	75	150	100	350	350	700	200
n HGulls	0	5	10	10	20	0	20	20	200
n Other birds	60	30	5	15	20	45	20	15	25
n Counts	8	22	3	3	9	7	8	3	4
Mean % of offal taken by Fulmars	99.0	94.1	91.9	86.4	81.9	77.8	70.6	61.5	35.1
± s.e.	0.36	1.67	6.15	3.99	4.82	4.71	3.60	5.78	1.21
Mean % of offal taken by other seabirds	1.0	5.9	8.1	13.6	18.1	22.1	29.4	38.5	64.9

n refers to number of

TABLE 8.3: Mean number of pieces of offal consumed per bird present for Herring Gulls and Great Black-backed Gulls, behind whitefish trawlers in Shetland 1985.

	Herring Gull			Great Black-backed Gull		
Offal	0.434	0.128	0.394	0.038	0.018	0.007
s.e.	0.061	0.024	0.132	0.006	0.008	0.015
n	23	14	5	25	14	5

Offal refers to mean number of pieces swallowed per bird present.

n refers to number of counts.

TABLE 8.4: Numbers of each fish species, following experimental discarding from Shetland whitefish trawlers in 1985, seen to be swallowed by seabirds.

Bird	Whiting	Haddock	Cod	Gurnard	Saithe	N.P.	F.f.	Total	%
Adult GBbG	1025	1126	48	99	2	9	46	2355	62.3
Intermediate GBbG	67	96	0	9	0	0	0	172	4.6
Immature GBbG	110	102	0	10	0	1	3	226	6.0
Adult Gannet	129	140	6	167	1	0	2	445	11.8
Non-adult Gannet	4	3	0	0	0	0	0	7	0.2
Adult HGull	44	38	2	2	0	5	2	93	2.5
Non-adult HGull	2	11	0	0	0	1	0	14	0.4
Adult LBbG	11	11	0	2	0	0	1	25	0.7
Non-adult LBbG	1	6	0	0	0	0	0	7	0.2
Great Skua	228	118	0	0	0	0	1	347	9.2
Fulmar	36	40	0	1	0	8	0	85	2.3
Total number:									
swallowed	1657	1691	56	290	3	24	55	3776	
discarded	2589	2859	88	764	37	36	1179	7552	
expected to be swallowed	1294.5	1429.5	44	382	18.5	18	589.5		

N.P. refers to Norway Pout
F.f. refers to flatfish

TABLE 8.5: Numbers of each fish species, following experimental discarding from Shetland whitefish trawlers in 1985, seen to be picked up and then dropped by seabirds.

Bird	Whiting	Haddock	Cod	Gurnard	Saithe	N.P.	F.f.	Total	%
Adult GBbG	20	24	17	33	0	0	19	113	35.5
Intermediate GBbG	1	5	0	2	0	0	1	9	2.8
Immature GBbG	1	3	1	5	0	0	2	12	3.8
Adult Gannet	5	4	0	21	0	0	0	30	9.4
Non-adult Gannet	2	0	0	3	0	0	0	5	1.6
Adult HGull	16	31	0	3	0	0	0	50	15.7
Non-adult HGull	0	6	0	0	0	0	0	6	1.9
Adult LBbG	5	15	0	1	0	0	0	21	6.6
Non-adult LBbG	3	1	0	0	0	0	0	4	1.3
Great Skua	26	34	0	6	0	0	0	66	20.8
Fulmar	2	0	0	0	0	0	0	2	0.6
Total number:									
dropped	81	123	0	74	0	0	22	318	
expected to be dropped	139.5	142.4	4.7	24.4	0.3	2.0	4.6		
% of all discarded	3.13	4.30	20.50	9.69	0.0	0.0	1.87		

N.P. refers to Norway Pout
F.f. refers to flatfish

TABLE 8.6: Chi^2 values and significance levels, comparing numbers of fish dropped by different bird species in Shetland 1985 (degrees of freedom in parentheses).

	Adult GBbG	Non-adult GBbG	Adult Gannet	Adult HGull	Great Skua
Adult GBbG	-	NS 4.33(4)	*** 20.95(4)	*** 44.48(4)	NS 0.04(1)
Adult Gannet			-	*** 37.42(2)	NS 0.52(1)
Adult HGull				-	NS 0.92(1)
Great Skua					-

TABLE 8.7a: Numbers of each fish species, kleptoparasitised by each bird species behind whitefish trawlers in Shetland 1985. (N.P. refers to Norway Pout; F.f. refers to flatfish).

Bird	Whiting	Haddock	Cod	Gurnard	Saithe	N.P.	F.f.	Total	%
Adult GBbG	146	161	6	16	0	0	6	335	62.4
Intermediate GBbG	5	3	0	0	0	0	0	8	1.5
Immature GBbG	15	19	0	1	0	0	1	36	6.7
Adult Gannet	29	12	1	12	0	0	0	54	10.1
Non-adult Gannet	2	1	0	0	0	0	0	3	0.6
Adult HGull	2	3	0	0	0	0	0	5	0.9
Non-adult HGull	0	0	0	0	0	0	0	0	0.0
LBbG	0	0	0	0	0	0	0	0	0.0
Great Skua	48	43	0	1	0	1	1	94	17.5
Fulmar	1	1	0	0	0	0	0	2	0.4
All birds	248	243	7	30	0	1	8	537	
% kleptoparasitised (as % of all discards)	9.6	8.5	8.0	3.9	0.0	2.8	0.7	7.11	
Expected (proportional to n swallowed)	235.6	240.5	8.0	41.2	0.4	3.4	7.8		

TABLE 8.7b: Numbers of each fish species kleptoparasitised from each bird species behind whitefish trawlers in Shetland 1985.

Bird	Whiting	Haddock	Cod	Gurnard	Saithe	N.P.	F.f.	Total	%
Adult GBbG	80	73	5	9	0	0	6	173	32.2
Intermediate GBbG	4	5	1	2	0	0	0	12	2.2
Immature GBbG	8	15	0	0	0	0	1	24	4.5
Adult Gannet	17	10	1	11	0	0	0	39	7.3
Non-adult Gannet	0	0	0	0	0	0	0	0	0.0
Adult HGull	21	30	0	0	0	0	0	51	9.5
Non-adult HGull	1	6	0	0	0	0	0	7	1.3
LBbG	11	14	0	1	0	1	0	27	5.0
Great Skua	71	56	0	7	0	0	1	135	25.1
Fulmar	35	34	0	0	0	0	0	69	12.9
All birds	248	243	7	30	0	1	8	537	

TABLE 8.8a: Percentages of fish swallowed, dropped or stolen by and from each bird species. Percentages are of the total number of fish handled by seabirds behind whitefish trawlers in Shetland 1985.

Bird	Swallowed	Dropped	Stolen by	Stolen from	Total number handled
Adult GBbG	79.1	3.8	11.3	5.8	2977
Intermediate GBbG	85.6	4.5	4.0	6.0	201
Immature GBbG	76.0	4.0	12.0	8.0	300
Gannet	77.6	5.9	9.8	6.7	593
HGull	48.0	24.5	2.2	25.3	229
LBbG	38.1	29.8	0.0	32.1	84
Great Skua	54.1	10.3	14.6	21.0	642
Fulmar	54.7	1.2	1.2	42.9	161
Total numbers	3793	318	538	538	5187

TABLE 8.8b: Difference, expressed by chi^2, between the expected and observed number of fish stolen by and from each age class and species of bird in Shetland 1985.

Bird	Expected number stolen by or from	Observed number stolen by	Observed number stolen from	χ^2
Adult GBbG	254	335	173	51.6
Intermediate GBbG	10	12	8	0.8
Immature GBbG	30	24	36	2.4
Gannet	49	58	40	3.3
HGull	31.5	5	58	44.6
LBbG	13.5	0	27	27.0
Great Skua	114.5	94	135	7.3
Fulmar	35.5	2	69	63.2

TABLE 8.9a: Mean lengths, in cm, of Haddock swallowed by seabirds and difference from mean length (27.59cm) discarded from whitefish trawlers in Shetland 1985.

Bird	Mean length swallowed	n	± s.e.	d	Significance
Adult GBbG	27.94	1126	0.082	35.86	***
Intermediate GBbG	27.94	96	0.289	1.19	NS
Immature GBbG	26.93	102	0.235	2.74	**
Adult Gannet	28.88	140	0.290	4.53	***
Adult HGull	25.61	38	0.395	4.97	***
Intermediate HGull	24.71	7	0.993	-	-
Immature HGull	23.50	4	0.957	-	-
Adult LBbG	25.36	11	0.717	3.10	**
Great Skua	25.49	118	0.271	7.58	***
Fulmar	22.95	40	0.360	12.75	***
All discards	27.59	2859	0.056		

TABLE 8.9b: Mean lengths, in cm, of Whiting swallowed by seabirds and difference from mean length (28.59cm) discarded from whitefish trawlers in Shetland 1985.

Bird	Mean length swallowed	n	± s.e.	d	Significance
Adult GBbG	28.59	1025	0.078	0.00	NS
Intermediate GBbG	28.43	67	0.303	0.52	NS
Immature GBbG	28.52	110	0.235	0.29	NS
Adult Gannet	31.01	129	0.250	41.51	***
Adult HGull	26.11	44	0.415	5.92	***
Intermediate HGull	26.50	2	0.500	-	-
Adult LBbG	27.00	11	1.027	1.55	NS
Great Skua	27.39	228	0.161	7.07	***
Fulmar	24.14	36	0.565	7.84	***
All discards	28.59	2589	0.053		

TABLE 8.10a: Mean lengths, in cm, of Haddock dropped by seabirds in Shetland 1985 and differences from mean lengths (A) discarded and (B) swallowed.

Bird	Mean length dropped	n	± s.e.	(A) d	(A) Significance	(B) d	(B) Significance
Adult GBbG	29.50	24	0.694	2.743	**	2.232	*
Adult HGull	28.71	31	0.345	3.210	**	5.917	***
Adult LBbG	28.73	15	0.345	3.265	**	3.771	***
Great Skua	28.50	34	0.414	2.178	*	6.078	***

TABLE 8.10b: Mean lengths, in cm, of Whiting dropped by seabirds in Shetland 1985 and differences from mean lengths (A) discarded and (B) swallowed.

Bird	Mean length dropped	n	± s.e.	(A) d	(A) Significance	(B) d	(B) Significance
Adult GBbG	30.50	20	0.738	2.581	*	2.573	*
Adult HGull	29.38	16	0.836	0.943	NS	3.503	***
Great Skua	31.27	26	0.286	9.213	***	11.820	***

TABLE 8.11a: Increase in the percentage of fish dropped by, or stolen from, adult Herring Gulls and Great Skuas with increasing fish length. n refers to the total number of fish swallowed, dropped by or stolen from a bird, for each size class of fish.

Fish length (cm)	Herring Gull Haddock % dropped	Herring Gull Haddock n	Herring Gull Whiting % dropped	Herring Gull Whiting n	Great Skua Haddock % dropped	Great Skua Haddock n	Great Skua Whiting % dropped	Great Skua Whiting n
≤ 20	-	0	0.0	2	-	0	-	0
21	-	0	50.0	2	-	0	-	0
22	0.0	4	0.0	3	0.0	22	0.0	3
23	0.0	4	0.0	4	0.0	12	33.3	9
24	11.1	9	0.0	2	0.0	7	0.0	16
25	57.1	7	22.2	9	50.0	8	0.0	18
26	50.0	10	22.2	18	30.4	23	0.0	40
27	33.3	6	28.6	7	20.0	30	4.9	41
28	69.2	13	62.5	8	29.6	27	6.5	31
29	68.8	16	70.0	10	55.0	20	26.0	50
30	100.0	9	100.0	4	84.0	25	34.6	26
31	66.7	3	100.0	6	83.3	6	52.9	34
32	100.0	5	100.0	2	100.0	3	73.3	15
33	-	0	-	0	100.0	1	77.8	9
34	-	0	-	0	100.0	1	100.0	2
35	-	0	-	0	-	0	100.0	1

TABLE 8.11b: Percentage of fish dropped by, or stolen from, adult Great Black-backed Gulls for fish of increasing length. (n as in Table 8.11a).

Fish length (cm)	Haddock		Whiting	
	% dropped	n	% dropped	n
⩽20	11.1	9	0.0	2
21	0.0	6	0.0	2
22	4.5	22	0.0	3
23	0.0	49	12.5	8
24	1.7	58	4.8	21
25	2.6	77	3.1	64
26	2.3	88	1.0	97
27	3.0	134	0.7	140
28	1.6	190	2.9	205
29	6.7	179	5.6	179
30	7.9	165	3.3	120
31	5.3	113	6.9	87
32	7.3	55	6.9	58
33	5.0	20	15.1	53
34	16.7	6	11.8	17
35	28.6	7	35.7	14
36	-	0	0.0	5
37	-	0	-	0
38	0.0	1	-	0
39	-	0	50.0	2

TABLE 8.12a: Mean fish lengths, in cm, of Haddock stolen from seabirds in Shetland 1985 and differences from mean lengths (A) discarded and (B) swallowed.

Bird	Mean length stolen from	n	± s.e.	(A) d	(A) Significance	(B) d	(B) Significance
Adult GBbG	28.45	73	0.295	2.869	**	1.674	NS
Immature GBbG	28.93	15	0.636	0.533	NS	2.951	**
Adult Gannet	28.10	10	0.836	0.609	NS	0.882	NS
Adult HGull	28.67	30	0.402	2.661	**	9.641	***
Adult LBbG	27.93	14	0.577	0.595	NS	2.808	**
Great Skua	28.30	56	0.345	2.034	*	6.405	***
Fulmar	24.71	34	0.506	5.661	***	2.835	**

TABLE 8.12b: Mean fish lengths, in cm, of Whiting stolen from seabirds in Shetland 1985 and differences from mean lengths (A) discarded and (B) swallowed.

Bird	Mean length stolen from	n	± s.e.	(A) d	(A) Significance	(B) d	(B) Significance
Adult GBbG	29.31	80	0.302	2.350	*	2.312	*
Adult Gannet	33.12	17	0.878	5.149	***	2.393	*
Adult HGull	28.62	21	0.4951	0.121	NS	3.884	***
Adult LBbG	30.09	11	0.5947	2.512	*	2.604	**
Great Skua	29.86	71	0.222	5.565	***	9.010	***
Fulmar	27.34	35	0.404	3.070	**	7.357	***

TABLE 8.13a: Mean fish lengths, in cm, of Haddock stolen by seabirds in Shetland 1985 and differences from mean lengths (A) discarded and (B) swallowed.

Bird	Mean length stolen	n	± s.e.	(A) d	(A) Significance	(B) d	(B) Significance
Adult GBbG	28.14	161	0.209	2.538	*	0.890	NS
Immature GBbG	27.42	19	0.480	0.352	NS	0.918	NS
Adult Gannet	29.50	12	0.839	2.271	*	0.786	NS
Great Skua	26.40	43	0.540	2.193	*	1.506	NS

TABLE 8.13b: Mean fish lengths, in cm, of Whiting stolen by seabirds in Shetland 1985 and differences from mean lengths (A) discarded and (B) swallowed.

Bird	Mean length stolen	n	± s.e.	(A) d	(A) Significance	(B) d	(B) Significance
Adult GBbG	29.10	146	0.197	2.494	*	2.404	*
Immature GBbG	28.07	15	0.665	0.779	NS	0.638	NS
Adult Gannet	32.35	29	0.632	5.926	***	2.103	*
Great Skua	28.58	48	0.333	0.030	NS	3.219	**

TABLE 8.14: Maximum and minimum lengths, in cm, of Haddock and Whiting observed to be swallowed by seabirds behind whitefish trawlers in Shetland 1985.

Bird	Haddock Max	Haddock Min	Whiting Max	Whiting Min
Adult GBbG	38	19	39	20
Intermediate GBbG	33	20	34	23
Immature GBbG	32	21	35	23
Adult HGull	31	22	30	15
Intermediate HGull	27	20	27	26
Immature HGull	25	20	25	25
Adult LBbG	31	22	33	21
Adult Gannet	39	20	38	24
Great Skua	31	18	35	17
Fulmar	30	15	29	14

Max = Maximum

Min = Minimum

TABLE 8.15: Regression equations of log handling time (y) on log fish length (x) for fish swallowed behind whitefish trawlers in Shetland 1985.

Bird	Fish	Regression equation	n	r^2*	Significance
Adult GBbG	Haddock	y = 2.5789.x - 3.30095	1126	27.44	***
	Whiting	y = 2.82743.x - 3.70017	1025	26.52	***
	Cod	y = 3.22879.x - 4.21944	48	40.67	***
	Gurnard	y = 0.66385.x - 0.06682	99	2.46	NS
Intermediate GBbG	Haddock	y = 1.66344.x - 1.87064	96	13.24	***
	Whiting	y = 1.21721.x - 1.25039	67	5.32	*
Immature GBbG	Haddock	y = 1.83415.x - 2.15444	102	9.42	***
	Whiting	y = 1.71894.x - 1.94126	110	8.39	**
Adult Gannet	Haddock	y = 2.24518.x - 2.79989	140	24.94	***
	Whiting	y = 1.643.x - 1.96031	129	5.74	**
	Gurnard	y = 1.9836.x - 2.00882	167	23.04	***
Adult HGull	Haddock	y = 3.4828.x - 4.31446	38	38.41	***
	Whiting	y = 3.12135.x - 3.91448	44	40.53	***
Great Skua	Haddock	y = 3.72529.x - 4.63495	118	43.35	***
	Whiting	y = 3.91701.x - 5.01646	228	37.56	***
Fulmar	Haddock	y = 3.9188.x - 4.74077	40	47.47	***
	Whiting	y = 2.53769.x - 2.84821	36	38.32	***

* r^2 refers to the percentage variation in handling time explained by increase in fish length.

TABLE 8.16b: Comparisons for Shetland seabirds of different age and species between rates of change of handling times with increasing length of Whiting.

Species being compared	F	Degrees of freedom	Significance
Adult GBbG : Intermediate GBbG	3.6078	2 : 1086	*1
Adult GBbG : Immature GBbG	2.5129	2 : 1129	NS
Intermediate GBbG : Immature GBbG	0.1713	2 : 171	NS
Adult GBbG : Adult Gannet	3.5263	2 : 1148	*2
Adult GBbG : Adult HGull	0.1473	2 : 1063	NS
Adult GBbG : Great Skua	5.1285	2 : 1247	*3
Adult GBbG : Fulmar	0.2038	2 : 1055	NS
Adult Gannet : Adult HGull	1.2534	2 : 167	NS
Adult Gannet : Great Skua	6.5100	2 : 351	*3
Adult Gannet : Fulmar	0.5476	2 : 159	NS
Adult HGull : Great Skua	0.6850	2 : 266	NS
Adult HGull : Fulmar	0.2530	2 : 74	NS
Great Skua : Fulmar	2.6307	2 : 258	NS

1 Intermediate GBbG had the greater slope.
2 Adult GBbG had the greater slope.
3 Great Skua had the greater slope.

TABLE 8.16c: Comparisons for Shetland seabirds between rates of change of handling times with increasing length of Haddock and Whiting.

Consumer species	F	Degrees of freedom	Significance
Adult GBbG	0.0106	2 : 206	NS
Intermediate GBbG	0.1653	2 : 157	NS
Immature GBbG	0.8235	2 : 2145	NS
Adult Gannet	0.4277	2 : 263	NS
Adult HGull	0.0701	2 : 76	NS
Great Skua	0.0708	2 : 340	NS
Fulmar	1.1520	2 : 70	NS

TABLE 8.17: Log handling times for Haddock, Whiting and Cod of 28cm length, plus standard errors and 95% confidence limits.

Bird	Fish	Log h.t.	n	$\pm$ s.e.	95% confidence limits[1]
Adult GBbG	Haddock	0.4312	1126	0.0055	0.4204 - 0.4420
	Whiting	0.3917	1025	0.0056	0.3807 - 0.4027
	Cod	0.4533	48	0.0300	0.3945 - 0.5121
Intermediate GBbG	Haddock	0.5367	96	0.0199	0.4977 - 0.5757
	Whiting	0.5112	67	0.0240	0.4642 - 0.5582
Immature GBbG	Haddock	0.4999	102	0.0219	0.457 - 0.5428
	Whiting	0.5464	110	0.0200	0.5072 - 0.5856
Adult Gannet	Haddock	0.4493	140	0.0177	0.4146 - 0.484
	Whiting	0.4174	129	0.0237	0.3709 - 0.4639
Great Skua	Haddock	0.7563	118	0.0207	0.7157 - 0.7969
	Whiting	0.6522	228	0.0133	0.6261 - 0.6783
Adult HGull	Haddock	0.7259	38	0.0298	0.6675 - 0.7843
	Whiting	0.6027	44	0.0300	0.5439 - 0.6615
Fulmar	Haddock	0.9306	40	0.0298	0.8722 - 0.9890
	Whiting	0.8243	36	0.0384	0.7490 - 0.8996

1 Where 95% confidence limits do not overlap, then mean handling times are significantly different.

TABLE 8.18a: Median handling times, in seconds, of Haddock of different lengths, swallowed by seabirds behind whitefish trawlers in Shetland 1985. Sample sizes are in parentheses.

Fish length (cm)	Adult GBbG		Adult Gannet		Adult HGull		Great Skua		Fulmar	
15	-		-		-		-		1.5	(1)
16	-		-		-		-		-	
17	-		-		-		-		-	
18	-		-		-		2.5	(1)	-	
19	3.5	(3)	-		-		1.5	(2)	-	
20	1.0	(5)	1.5	(2)	-		2.5	(5)	1.25	(2)
21	1.75	(6)	2.0	(1)	-		1.75	(8)	3.75	(4)
22	1.5	(21)	3.0	(4)	2.0	(4)	2.25	(6)	2.5	(9)
23	1.5	(49)	2.0	(5)	3.0	(4)	2.5	(12)	4.0	(10)
24	2.0	(57)	2.0	(7)	2.25	(8)	2.5	(7)	6.0	(7)
25	1.5	(75)	2.25	(4)	6.0	(3)	3.25	(4)	6.0	(3)
26	2.0	(86)	2.0	(4)	4.0	(5)	4.5	(16)	5.0	(3)
27	2.5	(130)	2.5	(15)	4.5	(4)	4.75	(24)	-	
28	2.5	(187)	2.0	(15)	4.0	(4)	6.0	(19)	-	
29	3.0	(167)	2.75	(18)	6.5	(5)	5.5	(9)	-	
30	3.0	(152)	3.75	(20)	-		6.0	(4)	12.0	(1)
31	3.5	(107)	3.5	(17)	5.0	(1)	6.75	(1)	-	
32	4.0	(51)	4.0	(11)	-		-		-	
33	6.0	(19)	4.5	(7)	-		-		-	
34	5.0	(5)	3.25	(6)	-		-		-	
35	4.5	(5)	6.75	(2)	-		-		-	
36	-		4.0	(1)	-		-		-	
37	-		7.0	(1)	-		-		-	
38	8.5	(1)	-		-		-		-	
39	-		-		-		-		-	
Total n		(1126)		(140)		(38)		(118)		(40)

TABLE 8.18b: Median handling times, in seconds, of Whiting of different lengths, swallowed by seabirds behind whitefish trawlers in Shetland 1985. Sample sizes are in parentheses.

Fish length (cm)	Adult GBbG		Adult Gannet		Adult HGull		Great Skua		Fulmar	
15	-		-		0.5	(1)	-		1.0	(1)
16	-		-		-		-		1.0	(1)
17	-		-		-		1.5	(1)	3.0	(1)
18	-		-		-		-		-	
19	-		-		-		1.0	(1)	-	
20	1.5	(2)	-		1.0	(1)	-		-	
21	3.0	(2)	-		2.0	(1)	-		2.0	(1)
22	1.5	(3)	-		3.0	(3)	2.0	(1)	3.0	(3)
23	1.0	(7)	-		2.25	(4)	2.0	(6)	4.75	(4)
24	1.5	(20)	1.25	(2)	3.0	(2)	2.0	(16)	5.5	(7)
25	1.5	(62)	-		3.5	(7)	2.5	(18)	3.0	(4)
26	2.0	(96)	2.25	(6)	4.5	(14)	3.0	(40)	6.25	(4)
27	2.0	(139)	2.0	(9)	3.0	(5)	3.5	(39)	5.75	(8)
28	2.5	(199)	2.0	(10)	5.0	(3)	4.5	(29)	6.0	(1)
29	2.5	(169)	2.5	(9)	5.0	(3)	5.0	(37)	9.0	(1)
30	3.0	(116)	3.0	(15)	-		5.0	(17)	-	
31	3.0	(81)	2.5	(21)	-		6.5	(16)	-	
32	3.75	(54)	3.5	(14)	-		7.5	(4)	-	
33	4.0	(45)	3.25	(22)	-		8.0	(2)	-	
34	5.0	(15)	3.5	(12)	-		-		-	
35	4.5	(9)	5.0	(2)	-		13.0	(1)	-	
36	6.5	(5)	3.0	(3)	-		-		-	
37	-		2.0	(1)	-		-		-	
38	-		2.0	(3)	-		-		-	
39	3.0	(1)	-		-		-		-	
Total n		(1025)		(129)		(44)		(228)		(36)

TABLE 8.18c: Median handling times, in seconds, for median fish lengths, in cm, consumed by Great Black-backed Gulls, Gannets, Herring Gulls and Great Skuas.

Fish	GBbG		Gannet		HGull		Great Skua	
species	h.t.	m.f.l.	h.t.	m.f.l.	h.t.	m.f.l.	h.t.	m.f.l.
Haddock	2.5	28	2.75	29	5.0	25.5*	4.5	26
Whiting	2.5	28	3.5	32	4.5	26	3.5	27
Cod	4.0	31	-	-	-	-	-	-

* Mid-value taken between 25cm and 26cm and 4 seconds and 6 seconds.

h.t. = handling time, in seconds.

m.f.l. = median fish length, in cm.

TABLE 8.19: Regression equations of log handling time (y) on log fish length (x) for Haddock and Whiting dropped by or stolen from adult birds behind whitefish trawlers in Shetland 1985.

Bird	Regression equation	n	r^2	Significance
GBbG	$y = - 0.28237.x + 0.84048$	105	0.18	NS
Gannet	$y = - 0.73043.x + 1.53224$	14	2.07	NS
HGull	$y = + 0.00269.x + 0.37201$	85	< 0.01	NS
Great Skua	$y = - 1.19581.x + 2.26966$	135	1.4	NS
LBbG	$y = - 0.74090.x + 0.54975$	18	< 0.01	NS
Fulmar	$y = - 2.50963.x + 3.99091$	32	8.23	NS

Note: The Gulls and Gannets are all adults.

TABLE 8.20: Numbers of fish picked up following dropping, or directly kleptoparasitised from other birds, behind whitefish trawlers in Shetland 1985.

Victim/Victor	Adult GBbG	Non-adult GBbG	Great Skua	Gannet	Totals	
Adult GBbG	75H	10H	17H	2H	104)	
	81W	11W	8W	5W	105)	228
	18C	1C	0C	0C	19)	
Non-adult GBbG	17H	9H	3H	0H	29)	
	5W	3W	5W	0W	13)	44
	2C	0C	0C	0C	2)	
HGull	42H	2H	3H	0H	47)	
	28W	0W	2W	0W	30)	77
LBbG	18H	4H	2H	0H	24)	
	10W	2W	4W	0W	16)	40
Gannet	2H	2H	1H	5H	10)	
	2W	0W	0W	18W	20)	31
	0C	0C	0C	1C	1)	
Great Skua	36H	3H	24H	7H	70)	
	36W	0W	38W	10W	84)	154
Fulmar	20H	3H	9H	1H	33)	
	20W	1W	8W	4W	33)	66
Totals	210H	33H	59H	15H	317)	
	182W	17W	65W	37W	301)	640
	20C	1C	0C	1C	22)	
	412	51	124	53	640	

H = Haddock W = Whiting C = Cod

TABLE 8.21: Observed (O) and expected (E) frequency of kleptoparasitism by seabirds feeding behind whitefish trawlers in Shetland 1985.

Victim/Victor		Adult GBbG	Non-adult GBbG	Gannet	Great Skua	Totals
Adult GBbG	O	174	22	7	25	228
	E	146.8	18.2	18.9	44.2	
Non-adult GBbG	O	24	12	0	8	44
	E	28.3	3.5	3.6	8.5	
Herring Gull	O	70	2	0	5	77
	E	49.6	6.1	6.4	14.9	
LBbG	O	28	6	0	6	40
	E	25.8	3.2	3.3	7.8	
Gannet	O	4	2	24	1	31
	E	20.0	2.5	2.6	6.0	
Great Skua	O	72	3	17	62	154
	E	99.1	12.3	12.8	29.8	
Fulmar	O	40	4	5	17	66
	E	42.5	5.3	5.5	12.8	
Totals		412	51	53	124	640

TABLE 8.22: Calorific values (in kJg^{-1}) of Haddock and Whiting consumed by Great Black-backed Gulls and other seabirds behind whitefish trawlers, following controlled discarding in Shetland 1985.

	GBbG	Other bird species	Total	%consumed by GBbG
Haddock	1456740	357365	1814105	80.3
Whiting	1249520	452455	1701975	73.4

Note: Calorific values determined from:

Total weight of fish consumed (g) x 5 kJg^{-1}
where total weight of fish calculated for each size class of fish length using:

$W = a\ L^b$ (From Jermyn in litt.)

where W = gutted weight (g)
L = fish length (cm)
and $W \times 1.125$ = round weight
for Haddock $a = 0.0157$
$b = 2.8268$
Whiting $a = 0.0093$
$b = 2.9456$

APPENDIX I

Conversion from wing length (in mm) to chick age (in days) for Herring Gull chicks, Noss 1983 and 1984

Age	Wing Length	N	± S.E.	Age	Wing Length	N	± S.E.
1	26	102	0.10	25	180	18	7.17
2	27	66	0.17	26	190	20	6.28
3	28	80	0.22	27	198	17	5.81
4	30	51	0.26	28	205	16	10.04
5	32	62	0.37	29	218	14	8.02
6	34	46	0.44	30	244	15	4.24
7	36	61	0.61	31	233	10	8.59
8	39	53	0.65	32	241	12	7.66
9	42	40	0.96	33	254	13	6.06
10	48	41	1.70	34	265	18	5.67
11	54	27	3.06	35	274	12	4.55
12	59	41	2.00	36	275	10	3.99
13	66	23	2.70	37	290	14	5.58
14	74	37	2.72	38	294	11	7.51
15	88	29	3.93	39	293	5	15.91
16	86	28	3.98	40	310	10	8.29
17	95	33	4.08	41	315	3	6.49
18	110	29	3.82	42	306	6	9.00
19	128	27	4.25	43	317	3	8.35
20	125	25	5.88	44	323	6	12.06
21	144	12	7.61	45	-	0	-
22	161	23	4.71	44	349	2	3.50
23	158	15	6.00	47	337	1	-
24	172	18	5.64				

Conversion from wing length (in mm) to chick age (in days) for Great Skua chicks, Noss 1983 and 1984

Age	Wing Length	N	± S.E.	Age	Wing Length	N	± S.E.
1	25	80	0.13	25	158	4	16.61
2	27	35	0.26	26	173	14	3.58
3	28	47	0.23	27	185	5	11.21
4	29	33	0.24	28	187	12	4.30
5	31	27	0.37	29	187	13	5.56
6	33	25	0.42	30	201	8	7.10
7	35	27	0.69	31	215	7	9.27
8	37	13	0.70	32	224	10	4.88
9	40	19	0.74	33	236	5	7.56
10	41	17	1.05	34	238	5	9.08
11	46	17	1.22	35	251	8	4.86
12	50	10	2.34	36	259	7	12.77
13	54	6	2.17	37	265	4	6.47
14	65	16	3.26	38	269	8	4.35
15	67	20	2.61	39	275	6	5.55
16	78	11	3.81	40	283	5	5.19
17	84	8	5.13	41	301	8	5.66
18	104	10	3.68	42	302	8	5.07
19	96	5	8.72	43	304	4	6.56
20	119	14	4.60	44	312	4	9.15
21	117	9	6.35	45	315	7	5.23
22	139	13	3.84	46	317	4	5.01
23	144	10	6.88	47	318	3	5.86
24	153	12	5.69	48	337	2	12.50

Conversion from wing length (in mm) to chick age (in days) for Fulmar chicks, Noss 1983 and 1984

Age	Wing Length	N	± S.E.	Age	Wing Length	N	± S.E.
1	28	26	0.22	25	150	19	1.22
2	29	20	0.19	26	163	11	3.75
3	31	19	0.27	27	165	13	2.34
4	32	27	0.24	28	175	12	2.37
5	34	10	0.67	29	179	18	1.52
6	36	19	0.65	30	188	8	3.52
7	39	12	0.82	31	190	16	1.96
8	42	21	0.46	32	198	5	1.36
9	46	10	1.16	33	206	17	1.93
10	46	19	0.75	34	211	9	3.80
11	53	11	0.58	35	221	12	1.53
12	55	15	0.86	36	230	5	3.01
13	59	12	2.19	37	231	13	1.93
14	64	10	2.14	38	235	8	3.22
15	72	10	2.56	39	240	11	1.03
16	77	14	1.40	40	251	5	5.01
17	83	13	1.19	41	257	3	4.67
18	94	11	2.60	42	259	4	3.94
19	98	12	1.28	43	259	5	3.76
20	105	8	3.95	44	269	2	5.50
21	115	16	1.80	45	271	1	-
22	126	11	4.92	44	275	2	0.50
23	134	11	3.16	47	282	1	-
24	141	17	1.91				

APPENDIX II

Mean weights (in g) with increasing wing length (in mm) for Herring Gull chicks from broods of varying size, Noss 1983.

Brood	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
1	Mean Weight	73	150	223	201	348	373	465	561	636	659
	± 2 s.e.	6.6	21.8	30.4	39.3	18.4	-	51.4	67.8	-	30.2
	n	14	9	8	3	3	1	4	6	1	5
2	Mean Weight	78	151	206	310	350	401	439	495	544	656
	± 2 s.e.	5.6	13.5	18.1	43.7	36.1	23.5	26.0	46.4	45.4	36.1
	n	48	30	18	6	7	9	8	10	10	13
3	Mean Weight	77	139	222	342	318	383	453	518	581	635
	± 2 s.e.	4.8	7.4	14.3	52.5	24.0	19.0	41.6	36.6	62.2	34.0
	n	41	63	27	6	2	9	7	7	9	12

Brood	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359
1	Mean Weight	817	745	790	794	929	811	867	850	1065	1045
	± 2 s.e.	-	71.4	23.0	133.0	224.8	57.9	173.6	91.0	-	-
	n	1	4	2	5	4	5	7	2	1	1
2	Mean Weight	662	680	712	796	817	838	885	891	882	865
	± 2 s.e.	69.0	59.7	67.8	150.8	49.7	56.4	49.8	77.5	72.7	30.0
	n	8	5	10	4	14	13	17	6	7	2
3	Mean Weight	677	725	801	743	847	918	849	911	1014	-
	± 2 s.e.	62.0	49.3	69.7	86.6	126.4	83.0	105.7	177.2	313.0	-
	n	9	15	9	11	6	13	10	8	2	0

Mean weights (in g) with increasing wing length (in mm) for Herring Gull chicks, Noss 1983-1985.

Year	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
1983	Mean Weight	77	145	221	306	343	389	447	514	581	645
	± 2 s.e.	3.2	6.4	11.0	33.6	18.4	13.0	19.0	28.2	38.0	19.0
	n	106	109	59	18	16	22	27	26	26	35
1984	Mean Weight	72	141	228	301	330	378	426	490	540	595
	± 2 s.e.	2.0	4.9	9.3	10.7	9.7	11.7	16.0	18.7	19.9	30.2
	n	253	177	82	44	35	38	45	47	32	29
1985	Mean Weight	69	120	217	305	354	392	467	505	512	615
	± 2 s.e.	3.8	11.6	14.2	28.4	38.2	45.6	35.9	39.8	65.2	47.4
	n	35	32	20	8	7	7	5	7	5	8
Total	Mean Weight	72	134	213	299	331	377	430	493	546	605
	± 2 s.e.	1.9	4.8	9.8	14.1	14.7	14.6	16.4	19.2	26.4	29.0
	n	394	318	161	70	58	67	77	80	63	72

Year	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359
1983	Mean Weight	678	734	760	777	841	860	876	904	915	978
	± 2 s.e.	36.8	35.6	39.4	58.0	47.0	36.6	46.4	68.6	79.8	112.8
	n	23	28	25	23	31	40	44	24	16	8
1984	Mean Weight	668	689	767	768	789	859	869	876	923	977
	± 2 s.e.	33.5	28.0	50.7	41.6	37.2	37.4	48.4	101.9	39.9	180.5
	n	30	28	17	23	24	20	21	9	7	3
1985	Mean Weight	606	734	669	766	853	833	931	896	905	-
	± 2 s.e.	68.3	44.3	89.8	81.6	83.3	58.4	57.9	100.2	150.0	-
	n	6	11	8	13	7	9	7	4	3	0
Total	Mean Weight	654	715	748	771	822	856	867	897	916	978
	± 2 s.e.	32.3	20.7	30.8	32.5	29.5	24.8	40.0	51.2	51.7	90.8
	n	59	67	50	59	62	69	72	37	26	11

Mean weights (in g) with increasing wing length (in mm) for Herring Gull chicks, Inchmarnock 1983 and mainland Shetland 1985.

Year	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
Inch	Mean Weight	-	180	243	263	334	345	429	478	561	576
	n	-	1	2	2	4	3	11	10	9	13
Total	Mean Weight	72	121	218	298	348	383	445	477	546	639
	n	60	46	29	13	8	12	11	11	11	12
M/L	Mean Weight	75	124	220	286	310	371	426	429	573	686
	n	25	14	9	5	1	5	6	4	6	4

Year	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339
Inch	Mean Weight	627	703	803	823	-	-	-	-	-
	n	11	19	9	2	0	0	0	0	0
Total	Mean Weight	624	736	720	772	852	846	942	896	905
	n	11	17	18	17	12	11	10	4	3
M/L	Mean Weight	646	740	761	791	851	908	968	-	-
	n	5	6	10	4	5	2	3	0	0

Inch = Inchmarnock
Total = Noss + Shetland mainland sites (named in text)
M/L = Mainland (Shetland)

Mean weights (in g) with increasing wing length (in mm) for Great Skua chicks, Noss 1983-1985

Year	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
1983	Mean Weight	77	153	253	359	427	480	572	662	756	822
	± 2 s.e.	3.0	10.8	18.4	20.4	10.8	23.9	22.1	22.8	22.3	37.7
	n	105	66	35	13	19	22	24	35	23	16
1984	Mean Weight	73	158	262	349	398	442	542	629	735	775
	± 2 s.e.	1.7	8.1	11.0	13.0	24.6	20.8	18.8	27.2	35.4	32.3
	n	194	117	49	26	12	17	21	18	22	25
1985	Mean Weight	74	146	232	339	421	478	556	633	704	792
	± 2 s.e.	5.4	18.1	24.6	24.0	50.7	72.2	35.8	41.9	52.9	35.8
	n	29	21	7	6	4	3	7	12	7	13

Year	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359
1983	Mean Weight	911	992	1039	1077	1147	1176	1200	1231	1258	-
	± 2 s.e.	38.0	38.8	29.3	44.5	45.9	43.1	55.4	63.5	30.7	-
	n	25	24	20	21	21	28	13	14	12	0
1984	Mean Weight	881	926	987	1084	1116	1187	1182	1183	1149	1185
	± 2 s.e.	34.7	27.9	43.8	30.3	29.0	28.1	39.3	38.0	65.2	10.0
	n	25	24	17	23	26	27	21	25	7	2
1985	Mean Weight	859	911	989	1026	1039	1162	1190	1154	1233	1275
	± 2 s.e.	51.8	43.2	54.9	64.1	67.4	106.8	66.8	124.4	81.2	90.0
	n	13	16	15	18	11	17	12	8	10	2

Mean weights (in g) with increasing wing length (in mm) for Great Skua chicks, Noss and Hermaness 1985.

Place	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
H'ness	Mean Weight	63	87	-	380	400	475	570	645	643	725
	n	2	2	0	1	1	1	3	2	3	2
Total	Mean Weight	73	141	232	345	417	478	561	634	685	783
	n	31	23	7	7	5	4	10	14	10	15

Place	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359
H'ness	Mean Weight	834	998	1025	1081	1093	1096	1270	-	-	-
	n	4	5	8	10	7	8	1	0	0	0
Total	Mean Weight	853	932	1002	1046	1060	1141	1196	1154	1233	1275
	n	17	21	23	28	18	25	13	8	10	2

H'ness = Hermaness
Total = Noss and Hermaness weights combined

Mean weights (in g) with increasing wing length (in mm) for Great Skua chicks, Foula 1975-1984 and Noss 1983-1985

Place	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
Foula	Mean Weight	140	190	277	345	397	452	520	616	703	783
	± 2 s.e.	33.8	6.5	4.4	5.1	4.8	5.1	4.2	4.2	4.6	4.4
	n	9	179	433	384	408	425	993	1132	1155	1315
Noss	Mean Weight	74	155	256	350	416	464	558	648	740	793
	± 2 s.e.	1.5	6.1	9.5	10.1	12.1	16.6	13.9	16.6	19.5	20.9
	n	328	204	91	45	35	42	52	65	52	54

Place	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279	280-299	300-319	320-339	340-359
Foula	Mean Weight	853	922	978	1046	1082	1133	1171	1205	1212	1100
	± 2 s.e.	5.2	5.5	6.3	7.8	8.8	11.4	15.2	21.9	29.0	40.0
	n	1213	1129	964	711	548	371	253	115	62	2
Noss	Mean Weight	888	947	1008	1065	1113	1177	1189	1193	1223	1230
	± 2 s.e.	23.2	22.4	24.7	26.7	26.2	25.6	28.9	34.7	37.0	63.8
	n	63	64	52	62	58	72	46	47	29	4

Mean weights (in g) with increasing wing length (in mm) for coastal and inland chicks Fulmar chicks, Noss 1984 and 1985.

Site & Year	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
Inland 1984	Mean Weight	122	212	296	400	499	482	649	760	800	844
	± 2 s.e.	-	22.2	72.3	37.7	51.3	23.3	80.2	80.0	20.0	64.1
	n	1	4	3	5	3	3	4	2	2	5
Coastal 1984	Mean Weight	96	179	301	410	475	578	632	717	835	872
	± 2 s.e.	6.0	14.6	19.7	39.4	31.9	66.5	43.3	97.0	44.4	50.1
	n	36	43	26	15	12	7	16	5	17	21
Inland 1985	Mean Weight	135	177	309	475	467	480	698	800	853	865
	± 2 s.e.	30.0	43.0	31.9	70.9	83.9	-	49.2	134.0	98.9	97.4
	n	2	5	14	3	6	1	5	5	6	6
Coastal 1985	Mean Weight	89	199	302	381	488	566	676	788	839	912
	± 2 s.e.	26.5	24.5	18.1	20.9	31.7	43.2	45.4	50.0	50.4	58.5
	n	3	26	33	29	18	10	25	16	21	23

Site & Year	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279
Inland 1984	Mean Weight	985	1123	1020	1060	1160	1180
	± 2 s.e.	150.0	146.6	-	42.0	105.7	140.0
	n	2	4	1	5	5	2
Coastal 1984	Mean Weight	919	1068	1070	1088	1175	1243
	± 2 s.e.	32.0	51.7	59.7	43.6	66.1	327.5
	n	17	21	16	17	12	3
Inland 1985	Mean Weight	1030	1068	1038	1060	-	-
	± 2 s.e.	80.8	157.7	117.3	70.2	-	-
	n	4	5	4	3	0	0
Coastal 1985	Mean Weight	1010	1041	1035	1123	1075	-
	± 2 s.e.	46.9	54.7	37.3	116.4	50.0	-
	n	16	24	20	10	2	0

Mean weights (in g) with increasing wing length (in mm) for Fulmar chicks, Noss 1983 - 1985.

Year	Wing Range	20-29	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159
1983	Mean Weight	93	189	313	429	535	585	667	822	908	990
	± 2 s.e.	6.8	13.9	19.7	31.4	45.1	65.7	36.5	61.5	55.3	59.3
	n	32	46	28	19	7	9	25	19	14	17
1984	Mean Weight	97	182	300	408	480	549	635	729	832	867
	± 2 s.e.	6.0	13.7	18.7	30.6	27.2	54.5	37.4	71.0	39.9	42.0
	n	37	47	29	20	15	10	20	7	19	26
1985	Mean Weight	107	195	304	390	483	558	680	791	842	902
	± 2 s.e.	28.6	21.6	15.7	22.0	30.9	42.1	38.6	47.9	44.2	50.3
	n	5	31	47	32	24	11	30	21	27	29
Total	Mean Weight	96	188	305	406	499	563	664	794	854	910
	± 2 s.e.	4.5	9.1	10.2	15.8	16.8	30.3	22.1	35.0	27.5	30.6
	n	74	124	104	71	46	30	75	47	60	72

Year	Wing Range	160-179	180-199	200-219	220-239	240-259	260-279	280-299
1983	Mean Weight	1030	1103	1141	1201	1114	1059	1390
	± 2 s.e.	60.6	86.2	42.2	54.6	140.2	68.8	-
	n	21	22	20	19	14	7	1
1984	Mean Weight	926	1076	1067	1082	1173	1218	-
	± 2 s.e.	32.1	48.7	56.4	35.0	54.3	187.3	-
	n	19	25	17	22	17	5	0
1985	Mean Weight	1014	1046	1035	1109	1075	-	-
	± 2 s.e.	40.1	51.6	35.4	90.8	50.0	-	-
	n	20	29	24	13	2	0	0
Total	Mean Weight	992	1072	1079	1130	1142	1125	1390
	± 2 s.e.	29.1	35.5	27.3	34.8	65.5	95.2	-
	n	60	76	61	54	33	12	1

Mean weights (in g) with increasing wing length (in mm) for Fulmar chicks, Foula 1979 and 1983 and St Kilda 1981 and 1983.

Place	Wing Increment	30-39	40-49	50-59	60-69	70-79	80-99	100-119	120-139	140-159	160-179
Foula 1979	Mean Weight	210	352	418	550	605	643	813	847	855	1109
	n	2	3	10	10	9	16	20	13	12	4
Foula 1983	Mean Weight	-	-	-	-	-	582	709	829	922	978
	n	0	0	0	0	0	5	20	41	57	100
St Kilda 1981	Mean Weight	-	-	-	-	-	-	-	-	-	1000
	n	0	0	0	0	0	0	0	0	0	1
St Kilda 1983	Mean Weight	-	-	-	-	-	-	-	-	-	850
	n	0	0	0	0	0	0	0	0	0	2

Place	Wing Increment	180-199	200-219	220-239	240-259	260-279	280-299
Foula 1979	Mean Weight	1157	780	-	-	-	-
	n	3	1	0	0	0	0
Foula 1983	Mean Weight	1046	1071	1145	1169	1260	1260
	n	142	137	74	22	1	1
St Kilda 1981	Mean Weight	960	1155	1238	1184	1139	-
	n	2	9	24	18	4	0
St Kilda 1983	Mean Weight	1055	1061	1119	1182	1295	-
	n	12	21	31	12	1	0

APPENDIX III

Occurrence of food items in Herring Gull chick regurgitates, 1983 - 1985

Food Type	Noss 1983	Noss 1984	Noss 1985	Shetland mainland 1985
Fish	15	65	14	7
Sandeel	21	20	4	0
Mussel	3	1	0	0
Limpet	0	1	0	0
Starfish	1	1	0	0
Squid	2	0	0	0
Herring Gull chick	1	0	0	0
Guillemot chick	0	1	1	0
Fulmar	1	0	0	0
Herring Gull egg	1	0	0	0
Bread	1	7	1	1
Meat remains	2	7	3	0
Vegetable scraps	0	0	1	0
Raisins	1	0	0	0
Sea-slater	1	0	0	0
Sandhopper	1	0	0	0
Tipulid larvae	1	2	0	0
Noctuid larvae	0	1	0	0
Noctuid adult	0	1	1	0
Cyclorrhapha	6	1	1	0
Weevils	3	2	0	0
Geometridae larvae	3	2	0	1
Total number of regurgitates	51	106	26	9

Occurrences of hard food remains (F.R.) and of food items in pellets regurgitated by breeding Herring Gulls on Noss 1983-1985 and mainland Shetland (M/L) 1985.

Food Type	Noss 1983		Noss 1984		Noss 1985		M/L 1985	
	Pellet	F.R.	Pellet	F.R.	Pellet	F.R.	Pellet	F.R.
Fish	99	0	84	0	31	0	394	0
Sandeel	4	0	0	0	0	0	0	0
Mussel	3491	0	1348	0	2064	0	2031	349
Razorshell	0	164	0	68	0	13	0	81
Clam	0	0	0	0	0	0	0	10
Cockle	0	0	0	0	0	0	0	3
Limpet	0	675	0	275	0	170	0	1629
Common Dogwhelk	49	56	0	4	0	1	0	111
Common whelk	0	0	0	0	0	2	0	146
Topshell	0	0	0	0	0	0	0	3
Periwinkle	153	1	6	27	0	0	50	570
Horse Mussel	0	0	0	0	0	0	0	15
Barnacle	15	0	0	0	12	0	1	0
Sea Urchin	0	29	0	27	0	37	0	30
Scallop	0	6	0	2	0	0	0	3
Spider Crab	0	98	0	93	0	9	0	367
Shore Crab	0	6	0	5	0	2	0	136
Edible Crab	0	268	0	84	0	40	0	137
Starfish	0	1	0	1	0	0	0	0
Sea-slater	0	0	0	1	0	0	0	0
Weevils	0	0	2	0	0	0	0	0
Auk	0	2	0	1	0	0	0	0
Herring Gull chick	0	0	0	1	0	0	0	1
Snipe	0	0	0	1	0	0	0	0
Starling	0	0	0	9	0	3	0	1
Pipit	0	2	0	0	0	0	0	0
Guillemot egg	1	0	0	0	0	0	0	0
Fulmar egg	0	0	0	0	0	0	1	0
Herring Gull egg	1	0	0	0	0	0	1	0
Eider egg	0	0	0	0	0	0	1	0
Rabbit	0	0	3	0	1	0	8	0
Oats	82	0	34	0	44	0	171	0
Chop bone	0	0	0	1	0	0	0	1
Total number	3895	1308	1477	600	2152	277	2658	3593

Occurrence of food items in the diet of non-breeding Great Skuas 1983 - 1985.

Food Type	Noss 1983	Noss 1984	Noss 1985	Hermaness 1985
Fish	1122	632	402	27
Sandeel	164	95	89	0
Goose Barnacle	0	46	29	1
Sea Urchin	0	0	1	0
Limpet	1	0	0	0
Squid	1	0	0	0
Sea-slater	1	0	0	0
Kittiwake	339	168	92	4
Fulmar	7	3	0	0
Auk[1]	102	49	61	9
Black Guillemot	0	0	1	0
Herring Gull	2	0	0	0
Starling	0	5	0	0
Guillemot egg	1	0	2	0
Fulmar egg	1	0	0	0
Great Skua egg	0	0	2	0
Eider egg	5	2	0	0
Rabbit	12	18	34	0
Vegetation	1	2	1	0
Total number	1759	1020	714	41

1 : Auk could be either Razorbill or Guillemot

Occurrence of food items in the diet of breeding Great Skuas 1983 - 1985.

Food Type	Noss 1983	Noss 1984	Noss 1985	Hermaness 1985
Fish	280	233	162	8
Sandeel	4	4	7	0
Goose Barnacle	0	1	1	0
Razorshell	2	0	0	0
Kittiwake	204	84	309	9
Fulmar	1	3	1	0
Auk[1]	26	31	105	9
Black Guillemot	1	1	0	0
Puffin	0	0	0	7
Herring Gull	1	0	2	0
Arctic Skua	2	3	0	0
Great Skua	13	18	11	1
Seabird[2]	0	0	0	5
Eider duck	0	1	0	0
Oystercatcher	0	1	0	0
Snipe	0	0	0	1
Starling	0	0	0	1
Guillemot egg	0	0	4	0
Fulmar egg	2	0	0	0
Kittiwake egg	0	0	54	0
Eider egg	0	5	0	0
Rabbit	15	24	50	0
Vegetation	0	0	5	0

1 : Auk could be either Razorbill or Guillemot

2 : Species of seabird not identified

Occurrence of food items in food remains left by, and pellets regurgitated by, Great Black-backed Gulls, Noss 1985.

Food Type	Pellet	Food Remains
Limpet	0	153
Razorshell	0	14
Spider Crab	0	12
Shore Crab	0	22
Edible Crab	0	2
Sea Urchin	0	7
Mussel	36	0
Fish	199	0
Sandeel	1	0
Kittiwake	62	0
Snipe	1	0
Auk chick	71	0
Great Skua chick	1	0
Herring Gull chick	1	0
Guillemot egg	30	0
Rabbit	238	0
Total number	640	210

APPENDIX IV

Correlation coefficients and regressions between fish length or the cube root of fish weight and otolith length or maximum breadth for Haddock, Whiting and Norway Pout from DAFS Marine Laboratory, Aberdeen and Sandeel from Shetland (Furness & Hislop, 1981) and for Cod from the Clyde.

Fish	Sample	Regression equation	Correlation coefficient
Whiting	56	Fish length = 14.759 otolith length +47.492	+0.967
		Fish length = 60.838 otolith breadth +1.087	+0.913
		Fish weight = $(0.294$ otolith length $+0.854)^3$	+0.946
		Fish weight = $(1.235$ otolith breadth $-0.149)^3$	+0.909
Haddock	56	Fish length = 20.362 otolith length +6.191	+0.913
		Fish length = 59.847 otolith breadth +5.671	+0.922
		Fish weight = $(0.421$ otolith length $-0.011)^3$	+0.902
		Fish weight = $(1.241$ otolith breadth $-0.035)^3$	+0.914
Norway Pout	56	Fish length = 25.645 otolith length -30.415	+0.903
		Fish length = 38.696 otolith breadth +29.879	+0.835
		Fish weight = $(0.567$ otolith length $-0.866)^3$	+0.876
		Fish weight = $(0.853$ otolith breadth $+0.474)^3$	+0.807
Sandeel	28	Fish length = 39.928 otolith length +40.588	+0.965
		Fish weight = $(0.589$ otolith length $+0.569)^3$	+0.982
Cod	216	Fish length = 39.744 otolith length -128.101	+0.917
		Fish weight = $(0.8982$ otolith length $-3.2196)^3$	+0.928

Length and species of fish consumed by non-breeding Great Skuas, Noss 1983-1985 (8.5-9.5 implies > 8.5 and < 9.5)

Fish Species	Otolith length mm	1983	1984	1985	1983-85	≡Fish length cm
Whiting (n=309)	8.5 - 9.5	3	0	0	3	17.3 - 18.7
	9.5 - 10.5	5	2	3	10	18.8 - 20.2
	10.5 - 11.5	3	2	3	8	20.3 - 21.6
	11.5 - 12.5	8	6	4	18	21.7 - 23.1
	12.5 - 13.5	2	10	19	31	23.2 - 24.6
	13.5 - 14.5	7	8	25	40	24.7 - 26.1
	14.5 - 15.5	18	21	24	63	26.2 - 27.5
	15.5 - 16.5	8	24	25	57	27.6 - 29.0
	16.5 - 17.5	11	17	14	42	29.1 - 30.5
	17.5 - 18.5	8	10	2	20	30.6 - 32.0
	18.5 - 19.5	7	9	0	16	32.1 - 33.4
	19.5 - 20.5	0	1	0	1	33.5 - 34.9
Haddock (n=356)	7.5 - 8.5	6	7	4	17	15.9 - 17.8
	8.5 - 9.5	5	8	4	17	17.9 - 19.9
	9.5 - 10.5	13	16	20	49	20.0 - 21.9
	10.5 - 11.5	18	16	24	58	22.0 - 23.9
	11.5 - 12.5	36	15	53	104	24.0 - 26.0
	12.5 - 13.5	22	19	39	80	26.1 - 28.0
	13.5 - 14.5	9	12	6	27	28.1 - 30.0
	14.5 - 15.5	1	2	1	4	30.1 - 32.1
Cod (n=7)	8.5 - 9.5	1	0	0	1	21.0 - 24.9
	10.5 - 11.5	0	2	0	2	28.9 - 32.8
	11.5 - 12.5	0	4	0	4	32.9 - 36.8
Saithe	9.5 - 10.5	0	0	2	2	
	10.5 - 11.5	1	2	1	4	
	11.5 - 12.5	0	0	1	1	
Redfish	5.5 - 6.5	0	0	2	2	
	6.5 - 7.5	2	1	0	3	
	7.5 - 8.5	5	5	3	13	
	8.5 - 9.5	1	2	2	5	
N. Pout (n=327)	4.5 - 5.5	8	41	2	51	8.5 - 11.0
	5.5 - 6.5	40	50	8	98	11.5 - 13.5
	6.5 - 7.5	70	45	32	147	13.6 - 16.1
	7.5 - 8.5	13	12	1	26	16.2 - 18.7
	8.5 - 9.5	0	0	3	3	
	9.5 - 10.5	0	0	2	2	
Poor Cod/Bib	6.5 - 7.5	0	2	0	2	
	7.5 - 8.5	0	1	0	1	
	8.5 - 9.5	0	1	0	1	
	9.5 - 10.5	5	0	0	5	
	7.5 - 8.5	0	2	0	2	
Torsk	8.5 - 9.5	2	0	0	2	
	9.5 - 10.5	0	1	0	1	
	10.5 - 11.5	3	2	1	6	
	11.5 - 12.5	0	0	0	0	
Herring	4.5 - 5.0	5	0	0	5	
	? length	9	0	0	0	

Sandeel	1.8 - 2.0	2	1	1	4	11.2 - 11.9
	2.0 - 2.2	9	2	7	18	12.0 - 12.7
	2.2 - 2.4	11	4	9	24	12.8 - 13.5
	2.4 - 2.6	12	6	11	29	13.6 - 14.3
	2.6 - 2.8	8	12	16	36	14.4 - 15.1
	2.8 - 3.0	16	11	24	51	15.2 - 15.9
	3.0 - 3.2	28	10	28	66	16.0 - 16.7
	3.2 - 3.4	14	5	11	30	16.8 - 17.5
	3.4 - 3.6	1	8	2	11	17.6 - 18.3
	3.6 - 3.8	0	1	0	1	18.4 - 19.1
Ling	5.5 - 6.5	0	1	0	1	
Lesser Argentine	(n=14)					

Length and species of fish consumed by breeding Great Skuas, Noss 1983 - 1985

Fish Species	Otolith length mm	1983	1984	1985	1983-85	≡Fish length cm
Whiting (n=141)	9.5 - 10.5	0	0	1	1	
	10.5 - 11.5	0	0	0	0	
	11.5 - 12.5	0	2	0	2	
	12.5 - 13.5	1	2	9	12	
	13.5 - 14.5	0	5	11	16	
	14.5 - 15.5	1	6	16	23	
	15.5 - 16.5	2	8	20	30	
	16.5 - 17.5	2	11	14	27	
	17.5 - 18.5	6	8	3	17	
	18.5 - 19.5	2	8	0	10	
	19.5 - 20.5	0	0	0	0	
	20.5 - 21.5	0	0	3	3	
Haddock (n=92)						
	8.5 - 9.5	1	0	1	2	
	9.5 - 10.5	1	2	0	3	
	10.5 - 11.5	7	4	8	19	
	11.5 - 12.5	6	3	20	29	
	12.5 - 13.5	5	8	15	28	
	13.5 - 14.5	2	2	3	7	
	14.5 - 15.5	1	2	0	3	
	15.5 - 16.5	1	0	0	1	
Cod	7.5 - 8.5	1	0	0	1	17.0 - 20.9
	9.5 - 10.5	0	1	4	5	25.0 - 28.8
Saithe	10.5 - 11.5	1	0	0	1	
	11.5 - 12.5	1	0	0	1	
N. Pout (n=25)	4.5 - 5.5	0	3	0	3	
	5.5 - 6.5	3	2	7	12	
	6.5 - 7.5	5	0	5	10	
Ling	9.5 - 10.5	2	0	0	2	
Sandeel	2.2 - 2.4	1	0	0	1	
	2.4 - 2.6	3	0	3	6	
	2.6 - 2.8	1	0	0	1	
	2.8 - 3.0	0	0	1	1	
	3.0 - 3.2	0	0	8	8	
	3.2 - 3.4	1	0	1	2	
Herring	4.2	0	0	1	1	

Length and species of fish consumed by breeding Black-backed Gull, Noss 1983 - 1985

Fish Species	Otolith length mm	1983	1984	1985	1983-85
Whiting (n=78)	11.5 - 12.5	0	0	1	1
	12.5 - 13.5	0	0	1	1
	13.5 - 14.5	0	0	2	2
	14.5 - 15.5	6	0	14	20
	15.5 - 16.5	0	0	16	16
	16.5 - 17.5	3	1	9	13
	17.5 - 18.5	0	0	11	11
	18.5 - 19.5	0	0	5	5
	19.5 - 20.5	5	0	0	5
	20.5 - 21.5	0	0	2	2
	21.5 - 22.5	0	0	0	0
	22.5 - 23.5	0	0	0	0
	23.5 - 24.5	0	0	2	2
Haddock (n=188)	7.5 - 8.5	0	0	2	2
	8.5 - 9.5	0	0	0	0
	9.5 - 10.5	3	0	3	6
	10.5 - 11.5	4	0	11	15
	11.5 - 12.5	15	0	32	47
	12.5 - 13.5	3	0	70	73
	13.5 - 14.5	6	0	17	23
	14.5 - 15.5	1	0	9	10
	15.5 - 16.5	0	0	11	11
	16.5 - 17.5	0	0	1	1
Cod	10.5 - 11.5	6	0	0	6
	11.5 - 12.5	0	2	3	5
	12.5 - 13.5	0	0	1	1
Saithe	11.5 - 12.5	0	2	0	2
	12.5 - 13.5	1	0	3	4
Redfish	8.5 - 9.5	0	0	6	6
Ling	9.5 - 10.5	1	0	0	1
	10.5 - 11.5	0	0	1	1
N. Pout	4.5 - 5.5	0	0	2	0
	5.5 - 6.5	0	0	1	0
	6.5 - 7.5	0	0	3	0
	7.5 - 8.5	0	0	1	0
Torsk	10.5 - 11.5	0	0	2	0
	11.5 - 12.5	0	0	2	0
	12.5 - 13.5	0	0	1	0
	13.5 - 14.5	0	0	1	0
	14.5 - 15.5	0	0	1	0

Length and species of fish consumed by breeding Herring Gull, Noss 1983 - 1985

Fish Species	Otolith length mm	1983	1984	1985	1983-85	≡Fish length cm
Whiting	13.5 - 14.5	2	0	0	2	
(n=58)	14.5 - 15.5	0	1	0	1	
	15.5 - 16.5	3	1	3	7	
	16.5 - 17.5	2	5	5	12	
	17.5 - 18.5	0	1	14	15	
	18.5 - 19.5	4	6	6	16	
	19.5 - 20.5	0	0	0	0	
	20.5 - 21.5	0	0	3	3	
	21.5 - 22.5	2	0	0	2	
Haddock						
(n=36)	7.5 - 8.5	0	0	1	1	
	8.5 - 9.5	0	0	0	0	
	9.5 - 10.5	0	0	2	2	
	10.5 - 11.5	0	0	2	2	
	11.5 - 12.5	0	2	4	6	
	12.5 - 13.5	1	1	6	8	
	13.5 - 14.5	2	3	2	7	
	14.5 - 15.5	3	0	2	5	
	15.5 - 16.5	0	0	5	5	
Cod	11.5 - 12.5	0	0	1	1	32.9 - 36.8
	12.5 - 13.5	0	0	2	2	36.9 - 40.7
	16.5 - 17.5	1	0	0	1	52.8 - 56.6
Ling	9.5 - 10.5	2	0	2	4	
	10.5 - 11.5	1	0	1	2	
Herring	4.5 - 5.5	1	0	0	1	
Sandeel	1.4 - 1.6	1	0	0	1	
	2.2 - 2.4	1	0	0	1	

Length and species of fish con-sumed by non-breeding Great Skuas, Foula 1975 & 1976, 1980 - 1985.

Fish Species	Otolith length mm	1975	1980	1981	1982	1983	1984	1985	All Years
Whiting (n=879)	7.5 - 8.5	0	1	0	0	0	0	0	1
	8.5 - 9.5	0	0	0	0	0	0	1	1
	9.5 - 10.5	2	0	0	0	0	0	0	2
	10.5 - 11.5	5	0	0	0	0	0	2	7
	11.5 - 12.5	16	0	0	0	0	0	6	22
	12.5 - 13.5	38	0	0	0	0	0	24	62
	13.5 - 14.5	64	3	3	2	6	1	43	122
	14.5 - 15.5	14	31	10	11	15	5	47	133
	15.5 - 16.5	2	35	65	43	24	13	54	236
	16.5 - 17.5	0	24	38	63	22	7	38	192
	17.5 - 18.5	0	14	19	14	14	6	20	87
	18.5 - 19.5	0	0	1	1	4	2	5	13
	19.5 - 20.5	0	0	0	0	1	0	0	1
Haddock (n=436)	7.5 - 8.5	0	1	0	0	0	0	0	1
	8.5 - 9.5	2	2	1	0	0	0	1	6
	9.5 - 10.5	5	5	0	0	0	0	14	24
	10.5 - 11.5	16	21	2	0	1	2	25	67
	11.5 - 12.5	66	47	17	7	7	4	41	189
	12.5 - 13.5	18	26	6	3	8	2	53	116
	13.5 - 14.5	0	4	3	6	1	1	12	27
	14.5 - 15.5	1	0	2	1	1	1	0	6
Cod	9.5 - 10.5	0	0	0	3	0	0	0	3
	10.5 - 11.5	0	0	0	0	0	0	0	0
	11.5 - 12.5	0	0	0	0	1	0	0	1
N. Pout (n=59)	4.5 - 5.5	2	2	0	0	0	0	1	5
	5.5 - 6.5	11	4	0	0	0	0	4	19
	6.5 - 7.5	11	2	2	0	2	1	6	24
	7.5 - 8.5	5	2	0	0	0	1	0	8
	8.5 - 9.5	0	0	0	0	0	0	0	0
	9.5 - 10.5	0	1	0	0	0	0	0	1
	10.5 - 11.5	0		0	0	2	0	0	2
Sandeel (n=185)	1.6 - 1.8	0	0	0	0	5	0	0	5
	2.0 - 2.2	0	4	0	0	16	0	0	20
	2.2 - 2.4	1	2	0	0	17	1	7	28
	2.4 - 2.6	1	2	1	0	17	1	19	41
	2.6 - 2.8	0	3	1	0	11	2	12	29
	2.8 - 3.0	0	2	0	0	8	1	20	31
	3.0 - 3.2	0	0	1	0	8	1	7	17
	3.2 - 3.4	0	0	0	0	7	0	4	11
	3.4 - 3.6	0	0	0	0	1	0	1	2
Redfish	5.5 - 6.5	0	0	0	0	0	0	0	0
	6.5 - 7.5	0	0	0	0	0	0	0	0
	7.5 - 8.5	0	0	1	0	0	0	0	1
	8.5- 9.5	0	0	0	0	0	0	0	0
Poor Cod/Bib	6.5 - 7.5	1	0	0	0	0	0	0	1
	7.5 - 8.5	2	0	0	0	0	0	0	2
	8.5 - 9.5	3	0	0	0	0	0	0	3

Length and species of fish consumed by breeding Great Skuas, Foula 1975, 1980 - 1985.

Fish Species	Otolith length mm	1975	1980	1981	1982	1983	1984	1985	All Years
Whiting (n=187)	8.5 - 9.5	1	0	0	0	0	0	0	1
	9.5 - 10.5	0	1	0	0	0	0	0	1
	10.5 - 11.5	2	0	0	0	0	0	0	2
	11.5 - 12.5	4	0	0	0	0	0	0	4
	12.5 - 13.5	16	0	0	0	0	0	0	16
	13.5 - 14.5	40	1	0	0	0	4	6	51
	14.5 - 15.5	19	1	0	0	1	6	20	47
	15.5 - 16.5	12	1	0	0	1	4	8	26
	16.5 - 17.5	1	0	0	0	2	5	15	23
	17.5 - 18.5	0	0	0	0	1	4	10	15
	18.5 - 19.5	0	0	0	0	0	1	0	1
Haddock (n=130)	8.5 - 9.5	1	0	0	0	0	0	0	1
	9.5 - 10.5	3	0	0	0	0	0	1	4
	10.5 - 11.5	25	1	0	0	0	0	3	29
	11.5 - 12.5	49	1	0	0	0	0	8	58
	12.5 - 13.5	25	1	0	0	2	0	3	31
	13.5 - 14.5	1	0	0	0	0	0	0	1
	14.5 - 15.5	1	0	0	0	0	1	2	4
	15.5 - 16.5	1	0	0	0	0	0	0	1
	16.5 - 17.5	1	0	0	0	0	0	0	1
N. Pout (n=20)	4.5 - 5.5	4	0	0	0	0	0	0	4
	5.5 - 6.5	3	0	0	0	0	0	0	3
	6.5 - 7.5	8	0	0	0	0	0	0	8
	7.5 - 8.5	4	0	0	0	0	0	0	4
	8.5 - 9.5	1	0	0	0	0	0	0	1
Sandeel	2.0 - 2.2	0	1	0	0	0	0	0	1
	2.2 - 2.4	1	1	0	0	0	0	0	2
	2.4 - 2.6	0	1	0	0	1	0	0	2
	3.0 - 3.2	0	0	0	0	1	0	0	1
	3.2 - 3.4	0	0	0	0	1	0	0	1
Torsk	12.5 - 13.5	0	0	0	0	1	0	0	1
Unidentified		0	0	0	0	0	0	3	3

Length and species of fish consumed by non-breeding Great Black-backed Gull, Foula 1975, 1976, 1980-85

Fish Species	Otolith length mm	1975	1976	1980	1981	1982	1983	1984	1985	All Years
Whiting	12.5 - 13.5	0	3	1	0	0	0	0	2	6
(n=893)	13.5 - 14.5	0	7	0	0	0	1	9	4	21
	14.5 - 15.5	5	50	7	2	8	30	19	5	126
	15.5 - 16.5	11	66	42	19	24	52	14	6	234
	16.5 - 17.5	15	57	26	18	25	96	19	5	261
	17.5 - 18.5	3	28	20	3	12	82	8	3	159
	18.5 - 19.5	2	6	11	5	6	36	2	1	69
	19.5 - 20.5	0	6	3	0	0	4	0	2	15
	20.5 - 21.5	0	0	0	0	0	0	0	0	0
	21.5 - 22.5	0	2	0	0	0	0	0	0	2
Haddock	8.5 - 9.5	0	0	0	1	0	0	0	0	1
(n=699)	9.5 - 10.5	0	0	13	0	0	2	0	0	15
	10.5 - 11.5	0	0	4	0	1	16	2	2	25
	11.5 - 12.5	12	44	14	8	13	44	9	4	148
	12.5 - 13.5	15	120	42	4	18	41	7	11	258
	13.5 - 14.5	5	64	36	20	5	42	3	4	179
	14.5 - 15.5	5	26	11	0	2	9	0	0	53
	15.5 - 16.5	0	9	2	2	2	1	0	0	16
	16.5 - 17.5	0	0	0	2		2	0	0	4
	5.5 - 6.5	0	1	0	0	0	0	0	0	1
Redfish	7.5 - 8.5	4	6	0	0	0	0	0	0	10
	8.5 - 9.5	4	20	1	0	0	6	0	0	31
	9.5 - 10.5	1	7	0	0	0	0	0	0	8
	10.5 - 11.5	0	3	0	0	0	0	0	0	3
N. Pout	4.5 - 5.5	0	0	0	0	0	0	0	0	0
	5.5 - 6.5	0	0	0	0	0	0	2	0	2
	6.5 - 7.5	0	0	0	0	0	0	2	0	2
	7.5 - 8.5	0	2	0	0	0	0	0	0	2
	8.5 - 9.5	0	1	0	0	0	1	0	0	2
Torsk	11.5 - 12.5	0	0	0	0	0	0	1	0	1
Saithe	13.5 - 14.5	0	2	0	0	0	0	0	0	2
Sandeel	2.0 - 2.2	0	0	1	0	0	0	0	0	1
	10.5 - 11.5	0	0	0	0	0	2	0	0	2
Cod	12.5 - 13.5	0	0	0	1	0	0	0	0	1
	13.5 - 14.5	0	0	0	1	0	0	0	0	1

Length and species of fish consumed by breeding Great Black-backed Gull, Foula

Fish Species	Otolith length mm	1975	1976	1980	1981	1982	1983	1984	1985	All Years
Whiting (n=8)	10.5 - 11.5	0	0	1	0	0	0	0	0	1
	11.5 - 12.5	0	0	2	0	0	0	0	0	2
	12.5 - 13.5	0	0	0	0	0	0	0	0	0
	13.5 - 14.5	0	0	0	0	0	0	0	0	0
	14.5 - 15.5	0	0	0	0	0	0	0	1	1
	15.5 - 16.5	0	0	0	0	0	0	0	0	0
	16.5 - 17.5	0	0	0	0	0	4	0	0	4
Haddock (n=14)	10.5 - 11.5	0	0	0	0	0	2	0	1	3
	11.5 - 12.5	0	0	0	0	0	2	0	0	2
	12.5 - 13.5	0	0	0	0	0	0	0	1	1
	13.5 - 14.5	0	0	0	0	0	2	0	0	2
	14.5 - 15.5	0	0	2	0	0	1	0	0	3
	15.5 - 16.5	0	0	1	0	0	0	0	0	1
	16.5 - 17.5	0	0	1	0	0	0	0	0	1
	17.5 - 18.5	0	0	1	0	0	0	0	0	1
Sandeel	1.0 - 1.2	0	0	2	0	0	0	0	0	0
	1.2 - 1.4	0	0	12	0	0	0	0	0	0
	1.4 - 1.6	0	0	22	0	0	0	0	0	0
	1.6 - 1.8	0	0	68	0	0	0	0	0	0
	1.8 - 2.0	0	0	39	0	0	0	0	0	0
	2.0 - 2.2	0	0	25	0	0	0	0	0	0
	2.2 - 2.4	0	0	9	0	0	0	0	0	0
	2.4 - 2.6	0	0	5	0	0	0	0	0	0
	2.6 - 2.8	0	0	6	0	0	0	0	0	0
	2.8 - 3.0	0	0	2	0	0	0	0	0	0
	3.0 - 3.2	0	0	0	0	0	0	0	0	0
	3.2 - 3.4	0	0	0	0	0	0	0	0	0

Length and species of fish identified from otoliths regurgitated on mainland Shetland.

Place	Year	Bird	Fish	Otolith length	n
Hermaness	18.07.85	Breeding Great Skua	Whiting	14.5-15.5	2
		Non-breeding Great Skua	Whiting	15.5-16.5	2
			Haddock	10.5-16.5	2
			N. Pout	6.5-7.5	2
Bressay Mainland	1983	Breeding Herring Gull	Whiting	16.5-17.5	2
			Haddock	7.5-8.5	1
			(n=20)	10.5-11.5	3
				11.5-12.5	2
				12.5-13.5	4
				13.5-14.5	3
				14.5-15.5	2
				15.5-16.5	3
				16.5-17.5	2
Mainland	1985		Whiting	10.5-11.5	1
			(n=147)	11.5-12.5	1
				12.5-13.5	3
				13.5-14.5	4
				14.5-15.5	10
				15.5-16.5	23
				16.5-17.5	19
				17.5-18.5	39
				18.5-19.5	23
				19.5-20.5	10
				20.5-21.5	4
				21.5-22.5	8
				22.5-23.5	2
			L gadoid		2
			Haddock	8.5-9.5	2
			(n=109)	9.5-10.5	4
				10.5-11.5	1
				11.5-12.5	9
				12.5-13.5	36
				13.5-14.5	29
				14.5-15.5	13
				15.5-16.5	10
				16.5-17.5	4
				17.5-18.5	1
			Cod	11.5-12.5	2
				12.5-13.5	3
			Ling	9.5-10.5	2
				12.5-13.5	2
			N. Pout	5.5-6.5	2
				6.5-7.5	1
Brindister L. Mainland	1985	Non-breeding Herring Gull	Whiting	15.5-16.5	2
			(n=6)	16.5-17.5	4
			Haddock	12.5-13.5	2
			(n=6)	13.5-14.5	2
				14.5-15.5	2
W. Burra Mainland	1985	Breeding LBb Gull	Whiting	11.5-12.5	2
			(n=42)	12.5-13.5	7
				13.5-14.5	5
				14.5-15.5	11
				15.5-16.5	9
				16.5-17.5	4
				17.5-18.5	3
				21.5-22.5	1

Place	Year	Bird	Fish	Otolith length	n
			Haddock (n=35)	8.5-9.5	2
				9.5-10.5	1
				10.5-11.5	6
				11.5-12.5	14
				12.5-13.5	11
				13.5-14.5	0
				14.5-15.5	1
			N. Pout	6.5-7.5	1
Mainland	1980	Breeding HG/LBbG	Whiting (n=41)	10.5-11.5	2
				12.5-13.5	3
				13.5-14.5	10
				14.5-15.5	9
				15.5-16.5	8
				16.5-17.5	8
				17.5-18.5	1
			Haddock (n=9)	10.5-11.5	2
				11.5-12.5	3
				12.5-13.5	2
				13.5-14.5	2
			Cod	10.5-11.5	2
Mainland	1985	Non-breeding GBbG	Whiting (n=318)	11.5-12.5	5
				12.5-13.5	16
				13.5-14.5	27
				14.5-15.5	41
				15.5-16.5	66
				16.5-17.5	67
				17.5-18.5	45
				18.5-19.5	25
				19.5-20.5	6
				20.5-21.5	11
				21.5-22.5	5
				22.5-23.5	2
				23.5-24.5	2
			Haddock (n=337)	7.5-8.5	1
				8.5-9.5	3
				9.5-10.5	22
				10.5-11.5	30
				11.5-12.5	69
				12.5-13.5	132
				13.5-14.5	41
				14.5-15.5	23
				15.5-16.5	10
				16.5-17.5	4
				17.5-18.5	2
			Cod (n=11)	10.5-11.5	2
				11.5-12.5	2
				12.5-13.5	4
				13.5-14.5	2
				14.5-15.5	1
			Redfish	7.5-8.5	2
				8.5-9.5	4
			Saithe	11.5-12.5	1
				12.5-13.5	1
				13.5-14.5	2
			N. Pout	7.5-8.5	2
			Sandeel	3.0-3.2	1
			Plaice		1

Place	Year	Bird	Fish	Otolith length	n
Papa Stour	1985	Breeding GBbG	Whiting	14.5-15.5	1
			Haddock	11.5-12.5	1
			(n=9)	12.5-13.5	7
				13.5-14.5	1
Mainland	1985	Loafing GBbG/HG	Whiting	14.5-15.5	2
			(n=8)	16.5-17.5	2
				17.5-18.5	2
				21.5-22.5	2
			Haddock	9.5-10.5	1
			(n=19)	10.5-11.5	2
				11.5-12.5	1
				12.5-13.5	4
				13.5-14.5	1
				14.5-15.5	3
				15.5-16.5	5
				16.5-17.5	1
				17.5-18.5	1
			Cod	12.5-13.5	1
Trondra	1985	Loafing gulls	Whiting	13.5-14.5	1
			(n=44)	14.5-15.5	1
				15.5-16.5	2
				16.5-17.5	7
				17.5-18.5	13
				18.5-19.5	8
				19.5-20.5	1
				20.5-21.5	5
				21.5-22.5	6
			Haddock	9.5-10.5	1
			(n=30)	10.5-11.5	1
				11.5-12.5	1
				12.5-13.5	5
				13.5-14.5	7
				14.5-15.5	8
				15.5-16.5	7
			Cod	11.5-12.5	3
			(n=8)	12.5-13.5	4
				13.5-14.5	1
			Saithe	13.5-14.5	2
Scalloway Harbour	1985	Loafing gulls	Whiting	13.5-14.5	3
			(n=21)	14.5-15.5	2
				15-5-16.5	3
				16.5-17.5	2
				17.5-18.5	4
				18.5-19.5	5
				20.5-21.5	2
			Haddock	7.5-8.5	1
			(n=17)	10.5-11.5	1
				11.5-12.5	4
				12.5-13.5	5
				13.5-14.5	2
				14.5-15.5	2
				15.5-16.5	2
			N. Pout	7.5-8.5	1

Distribution of Haddock and Whiting otolith lengths found in Great Skua and Gull pellets. Combined data from Foula 1975, 1980-1985, Noss 1983-1985, Mainland Shetland 1980, 1983, 1985.

Fish	Otolith length mm	Breeding Great Skua	%	Non-breeding Great Skua	%	Breeding GBb Gull	%	Non-breeding GBb Gull	%	Breeding Herring Gull	%
Whiting	7.5-8.5	0		1	0.1	0		0		0	
	8.5-9.5	1	0.3	4	0.3	0		0		0	
	9.5-10.5	2	0.6	12	1.0	1	1.1	0		0	
	10.5-11.5	2	0.6	15	1.3	1	1.1	0		1	0.5
	11.5-12.5	6	1.8	40	3.4	3	3.4	5	0.4	1	0.5
	12.5-13.5	28	8.5	93	7.8	1	1.1	22	1.8	3	1.4
	13.5-14.5	66	20.1	162	13.6	2	2.3	48	4.0	6	2.9
	14.5-15.5	72	21.9	196	16.5	22	25.0	167	13.8	11	5.3
	15.5-16.5	56	17.0	295	24.8	16	18.2	300	24.8	30	14.4
	16.5-17.5	50	15.2	234	19.7	17	19.3	328	27.1	33	15.9
	17.5-18.5	32	9.7	107	9.0	11	12.5	204	16.9	54	26.0
	18.5-19.5	11	3.3	29	2.4	5	5.7	94	7.8	39	18.8
	19.5-20.5	0		1	0.1	5	5.7	21	1.7	10	4.8
	20.5-21.5	3	0.9	0		2	2.3	11	0.9	7	3.4
	21.5-22.5	0		0		0		7	0.6	10	4.8
	22.5-23.5	0		0		0		2	0.2	2	1.0
	23.5-24.5	0		0		2	2.3	2	0.2	1	0.5
Haddock	7.5-8.5	0		18	2.3	2	1.0	1	0.1	1	0.6
	8.5-9.5	3	1.4	23	2.9	0	0	4	0.4	2	1.2
	9.5-10.5	7	3.2	73	9.2	6	2.8	37	3.6	6	3.7
	10.5-11.5	48	21.6	127	16.0	18	8.5	55	5.3	6	3.7
	11.5-12.5	87	39.2	293	36.9	50	23.7	217	21.0	17	10.4
	12.5-13.5	59	26.6	196	24.7	81	38.4	390	37.7	48	29.3
	13.5-14.5	8	3.6	54	6.8	26	12.3	220	21.2	39	23.8
	14.5-15.5	7	3.2	10	1.3	13	6.2	76	7.3	20	12.2
	15.5-16.5	2	0.9	0		12	5.7	26	2.5	18	11.0
	16.5-17.5	1	0.5	0		2	1.0	8	0.8	6	3.7
	17.5-18.5	0		0		1	0.5	2	0.2	1	0.6

APPENDIX V

Mean (± s.e.) bird numbers per trip attending whitefish trawlers in Shetland 1985.

Date	n	Fulmar	Great Skua	GBbG	HGull	Kittiwake	Gannet	LBbG	Other	
		870	0	142	1840	8	6	+	0	
18.03.85	6	(178.6)	-	(41.4)	(317.2)	(3.4)	(2.5)	+	-	
		275	6	300	3	+	40	8	0	
30.04.85	2	(176.8)	(0.0)	(100.0)	(3.0)	+	(10.0)	(2.8)	-	
		280	10	29	+	5	9	3	+	BHG
08.05.85	5	(46.4)	(2.6)	(7.6)	+	(3.1)	(3.3)	(2.0)		
		671	16	257	3	+	2	3	0	
13.05.85	7	(335.6)	(4.8)	(55.8)	(1.3)	+	(1.0)	(1.4)	-	
		740	15	230	8	3	+	8	0	
14.05.85	5	(211.9)	(2.7)	(25.5)	(3.5)	(1.0)	+	(1.4)	-	
		307	22	137	1	1	3	7	0	
20-21.05.85	7	(56.1)	(7.1)	(39.6)	(1.0)	(0.7)	(2.1)	(1.8)	-	
		731	11	258	9	+	+	6	0	
10-12.06.85	13	(83.5)	(2.1)	(27.1)	(1.7)	+	+	(2.0)	-	
		339	1	531	44	+	32	4	0	
17-19.06.85	8	(90.4)	(0.4)	(110.6)	(22.9)	+	(24.3)	(1.8)	-	
		378	1	333	88	3	+	6	+	SP, BHG
19-21.06.85	9	(47.2)	(0.6)	(72.2)	(20.9)	(2.2)	+	(2.4)		
		330	1	162	57	8	21	5	+	BHG, SP, AT
24-26.06.85	11	(92.9)	(0.3)	(45.6)	(14.7)	(4.3)	(11.9)	(1.6)		
		533	19	133	10	6	2	4	+	SP
22.07.85	6	(66.7)	(3.2)	(24.7)	(3.3)	(0.9)	(0.4)	(1.0)		
		567	17	267	152	1	6	13	0	
24.07.85	6	(122.9)	(3.3)	(35.8)	(67.3)	(1.0)	(2.7)	(2.5)	-	
		600	15	120	8	1	2	3	3	SP
29.07.85	6	(57.7)	(2.2)	(20.8)	(3.0)	(0.7)	(0.6)	(0.6)	(1.9)	
		557	21	279	10	0	1	3	+	SS
31.07.85	7	(75.1)	(2.5)	(32.5)	(1.6)	-	(0.8)	(0.8)	+	
		530	13	56	4	0	+	+	+	SS, SP
05-07.08.85	10	(78.6)	(7.1)	(17.7)	(2.1)	-	+	+	+	
		147	2	192	133	+	2	2	0	
07-09.08.85	6	(65.7)	(1.1)	(47.2)	(94.1)	+	(1.0)	(1.1)	-	
		500	7	114	0	0	+	+	+	AS
12.08.85	5	(89.4)	(1.5)	(66.3)	-	-	+	+	+	
		433	13	11	3	+	31	0	0	
18-21.08.85	8	(80.9)	(4.1)	(3.6)	(2.5)	+	(12.2)	-	-	
		875	16	128	0	+	1	0	0	
27.08.85	4	(137.7)	(3.2)	(57.8)	-	+	(0.3)	-	-	
		417	10	217	267	2	3	0	1	SS
02.09.85	3	(136.4)	(3.2)	(142.4)	(266.7)	(1.0)	(2.1)	-	(0.3)	
		225	8	667	0	0	1	0	0	
05.09.85	6	(54.4)	(1.7)	(111.6)	-	-	(0.7)	-	-	
		383	10	333	0	+	5	0	+	SS, SP
09.09.85	6	(30.7)	(2.2)	(67.9)	-	+	(2.1)	-	+	
		380	15	290	0	1	2	0	+	SS
10.09.85	5	(86.0)	(2.7)	(100.5)	-	(0.4)	(1.1)	-	+	
Range		10-2500	0-75	0-1100	0-2000	0-50	0-200	0-20		

n refers to number of hauls per trip

+ indicates a mean value of less than 1

BHG = Black-headed Gull, SS = Sooty Shearwater, AS = Arctic Skua, SP = Storm Petrel, AT = Arctic Tern

Bird numbers around whitefish boats, observed from the air, Shetland 1984 and 1985.

Date	Area	Boat activity	Bird numbers
28.08.84	Burra Haaf, 6 miles out	Discarding	1000 Fulmars, 1000 GBbG
	Burra Haaf, 6 miles out	Trawling	100 Fulmars
10.09.84	8 miles E of N Yell	Steaming	0
	10 miles SE of Whalsay	Trawling	0
	10 miles SE of Whalsay	Trawling (3 boats)	0 at each
	10 miles SE of Whalsay	Trawling	20 Fulmars
	Burra Haaf, 6 miles out	Hauling	1000 Fulmars, 500 GBbG, 10 Great Skuas
	20 miles W of Burra	Discarding	1000 Fulmars, 5 GBbG, 5 Great Skuas
	20 miles W of Burra	Discarding	2000 Fulmars, 2 Gannets
	20 miles W of Burra	Trawling	100 Fulmars, 10 GBbG
	20 miles W of Burra	Steaming/trawling	300 Fulmars, 100 GBbG
	20 miles W of Burra	Steaming/trawling	30 Fulmars
	20 miles W of Burra	Steaming/trawling	20 Fulmars
	8 miles ESE of Foula	Steaming	500 Fulmars
14.03.85	15 miles NW of N Yell	Discarding	1500 Fulmars, 5 Kittiwakes, 5 Gannets
	25 miles NW of N Yell	Trawling	600 Fulmars, 50 Kittiwakes
	25 miles NW of N Yell	Steaming	0
	10 miles SE of Unst	Steaming slowly	300 birds (Fulmars and Kittiwakes)
15.03.85	20 miles NW of N Yell	Discarding	3000 Fulmars, 5 Kittiwakes, 5 Gannets
	20 miles NW of N Yell	Steaming	0
	20 miles N of Foula	Trawling	1000 birds (Fulmars and Kittiwakes)
	20 miles N of Foula	Trawling	10 Fulmars
29.04.85	Yell Sound, near land	Steaming	0
	3 miles W of Yell	Steaming/trawling	0
	8 miles NW of Yell	Steaming	20 Fulmars
	15-20 miles NW of Unst	Trawling (2 boats)	10 Fulmars
	Yell Sound, near land	Hauling	500 birds
	Yell Sound, near land	Steaming fast	0
	20 miles NW of Foula	Trawling	100 Fulmars
	5 miles W of Yell	Trawling	50 Fulmars, 25 GBbG
07.05.85	6 miles N of Yell	Trawling (2 boats)	300 Fulmars
	5 miles NW of N Mainland	Trawling	0
	3 miles W of N Mainland	Steaming/trawling	20 Fulmars
	6 miles W of Papa Stour	Trawling	10 birds
	2 miles W of W Mainland	Steaming fast	5 Fulmars
28.05.85	5 miles NW of N Mainland	Steaming/trawling	0
	2 miles E of N Yell	Steaming slowly	0
04.06.85	20 miles NW of N Mainland	Putting net out	1500 Fulmars, 200 GBbG, 5 Gannets
	20 miles NW of N Mainland	Steaming	2000 Fulmars, 300 GBbG, 5 Gannets, 5 Great Skuas
	25 miles NW of N Mainland	Trawling/idling	500 Fulmars, 5 GBbG, 5 Gannets, 5 Great Skuas
	15 miles W of N Mainland	Trawling	1500 Fulmars, 100 GBbG, 20 Great Skuas, 5 Gannets
	8 miles NW of N Mainland	Putting net out	200 Fulmars, 5 Gannets
	8 miles NW of N Mainland	Hauling	2500 Fulmars, 100 Gannets, 50 GBbG, 5 Great Skuas
	10 miles NW of N Mainland	Trawling/idling	250 Fulmars, 50 GBbG, 5 Gannets, 5 Great Skuas
12.06.85	10 miles E of N Unst	Steaming/trawling	? (Not a large flock)
	30 miles NE of Unst	Trawling	2000 Fulmars
	30 miles NE of Unst	Hauling	300 Fulmars, 1 Gannet
	30 miles NE of Unst	Steaming slowly	5500 Fulmars
	35 miles NE of Unst	Trawling	200 Fulmars
	35 miles NE of Unst	Trawling	6000 Fulmars
	2 miles W of N Yell	Discarding	1500 birds (Fulmars and Gulls)
	Yell Sound, near land	Steaming/trawling	? (Not a large flock)
27.06.85	10 miles W of Unst	Hauling) Close Trawling) together	8000 Fulmars, 400 GBbG, 50 Great Skuas, 20 Gannets
	10 miles W of Unst	Trawling	10 Fulmars
	12 miles W of Unst	Trawling) Close Trawling) together	400 Fulmars, 20 GBbG, 10 Gannets
	10 miles W of Unst	Trawling	? (Not a large flock)
	15 miles W of Unst	Stationary	300 Fulmars, 10 GBbG, 5 Gannets
	6 miles W of Unst	Trawling	20 Fulmars
16.07.85	15 miles NW of Unst	Steaming/trawling (2 boats)	? (Not a large flock)
	18 miles NW of Unst	Trawling	5 Fulmars
	20 miles NW of Unst	Steaming	0
	25 miles NW of Unst	Trawling	? (Not a large flock)
	25 miles WNW of Unst	Discarding	2500 Fulmars
30.07.85	2 miles S of Fetlar	Steaming	0
	2 miles S of Fetlar	Steaming	? (Not a large flock)
	15 miles W of Unst	Trawling	50 Fulmars
	15 miles W of Unst	Trawling	200 Fulmars, 1 Gannet
14.08.85	10 miles W of Unst	Trawling	20 Fulmars, 5 GBbG, 5 Gannets
	10 miles W of Unst	Trawling	10 Fulmars, 5 Gannets
	15 miles W of Unst	Trawling	20 Fulmars, 50 GBbG
22.08.85	4 miles E of Papa Stour	Trawling	20 Fulmars, 10 GBbG
03.09.85	6 miles S of Foula	Trawling	20 Fulmars
	6 miles W of Fitful	Discarding	2000 birds (mostly Fulmars, some Gulls)
	5 miles W of Fitful	Discarding	2000 birds (mostly Fulmars, some Gulls)
	5 miles W of Fitful	Steaming slowly	100 Fulmars
	5 miles W of Fitful	Trawling	0
	3 miles S of Fitful	Steaming fast	0
	Sumburgh, near land	Putting net out	100 Fulmars
	3 miles S of Bressay	Steaming	20 Fulmars
	4 miles NW of Out Skerries	Trawling	1200 Fulmars, 300 Gannets
	3 miles W of Fetlar	Steaming fast	20 Fulmars, 10 Gannets
17.09.85	4 miles NW of Out Skerries	Hauling - pair trawlers	1000 Fulmars, 250 Gannets, 250 GBbG, 10 Great Skuas
	4 miles N of Out Skerries	Hauling	2000 birds (mostly Fulmars, some Gannets)
	5 miles NE of Out Skerries	Net at surface	2000 Fulmars, 400 GBbG, 100 Gannets
	12 miles ENE of Out Skerries	Steaming slowly	3000 Fulmars, 20 Gannets, 5 Great Skuas
02.10.85	10 miles NW of Yell	Discarding	1500 Fulmars

APPENDIX VI

Number and size of fish discarded from Whitefish Trawlers in Shetland April - September 1985

Fish Length cm	WHITING	HADDOCK	COD	SAITHE	NORWAY POUT	HAKE	LING	MACKEREL	HORSE MACKEREL	HERRING	LESSER ARGENTINE	RED GURNARD	GREY GURNARD	SKATE	ANGLER	DRAGONET	WITCH	MEGRIM	PLAICE	LEMON SOLE	LONG ROUGH DAB
12					1																
13					3																
14	1				4						1									1	1
15	2	1			6						0	1					1			0	6
16	2	0			11						0	6					5			1	27
17	1	1			3						0	9					2			2	58
18	0	5			3					1	0	16					1			8	67
19	2	9			1					0	0	18					10			15	71
20	5	30			3					0	1	50					0	2		22	101
21	5	39			0					0	3	71					4	1	1	35	89
22	18	74			0					1	2	71	1				7	2	0	57	52
23	35	133			0				1	1	2	77	2				3	2	0	53	60
24	76	160	1		1				0	4	1	55	3		1		8	0	1	39	44
25	137	207	4						0	2		49	4		0		7	1	2	34	30
26	238	261	3						0	3		45	10		1		2	0	3	16	31
27	325	347	6						3	1		32	6			1	4	2	2	11	21
28	439	411	6						0	1		23	17				10	2	2	14	23
29	386	419	10						0	0		23	10				10	1	1	5	14
30	331	333	7						1	1		12	18				2	3	0	5	11
31	237	226	4	1					0			7	26				4	1	0	1	13
32	151	111	10	0				1	0				20				7	1	1	2	6
33	117	59	9	3				0	0				22				1	2	1		5
34	41	18	4	5				1	1				17		1		1	0			0
35	22	10	1	0				0	1				14	1			0	0			0
36	11	2	2	4				0	2				5				0	2			2
37	2	1	6	2				1					6				1				
38	4	1	9	1				0					9								
39	1	1	4	7				0					1								
40			2	2				0					1								
41				5				0					0								
42				2				1					3	1							
43				3		1	1						1	0							
44				1									3	1							
45				0																	
46				0																	
47				1																	
48																					
49																					
50																					
53																					
55																					
61																					
62																					
Total	2589	2859	88	37	36	1	7	4	9	15	10	565	199	3	3	1	90	22	14	321	732

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