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(NATURAL ENVIRONMENT RESEARCH COUNCIL)

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Final Report to Nature Conservancy Council

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DEVELOPMENT OF MONITORING OF SEABIRD POPULATIONS AND PERFORMANCE

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Restrictions: With the exception of Appendices 1-6, those wishing to quote this report should first consult both ITE (MP Harris) and NCC (PM Walsh).

Number of copies received: 70

General comments / background:

This is the third and final report of a project designed to review, develop, test and implement methods of monitoring seabirds. These methods are intended to provide information not only on seabird population changes but on other parameters including breeding output, adult survival rates and nestling diets. By covering such a range of parameters, the likelihood of detecting, and possibly identifying, adverse changes in the marine environment is improved. This will provide one of the few effective ways in which NCC can monitor the wider marine environment around Britain. The information collected is also essential for adequate assessment of the health of Britain's internationally important seabird populations.

This project is the seabird equivalent of integrated landbird monitoring being currently developed, partly under contract to NCC, by the British Trust for Ornithology (BTO). Both the BTO project and the seabird project are founded on the principle of using a co-operative approach between a co-ordinating agency and numerous volunteers and professional workers to provide a cost-effective method of fulfilling NCC's responsibilities and commitments to monitor Britain's bird populations.

Almost all of the methods developed or reviewed during this project can be used by reserve wardens or volunteer workers with limited time and funds available for seabird monitoring. In addition, more detailed programmes of work, to be carried out at small numbers of 'key-site' colonies, have been established. During the project, cooperation with other interested organisations and with a network of seabird volunteers around Britain has been steadily extended. The project was designed to provide the basis of a review by NCC CSD of its future plans for seabird monitoring.

Previous reports in this series (CSD reports nos. 737 and 821) summarised progress made during 1986 and 1987, including data collected with the support of CSD funds and relevant publications by the contractee. Major study colonies included the Isle of May, Fair Isle, Canna, and Skomer; less comprehensive information was collated for a wide range of other colonies.

In this final report, further data summaries (for 1986-88) and publications are included. Full details are appended of the 'low input' methods developed, which will allow the breeding success of selected seabirds to be assessed with minimum effort.

It should be noted that this project deals primarily with widespread, wholly-marine seabirds - i.e., in general, species other than skuas, Larus gulls and terns. The latter groups are less suitable as general 'marine monitors,' being either localised in distribution (skuas), feeding inland or on a very broad range of food types (gulls), or highly subject to localised breeding failures due to disturbance, predation etc. (terns). Many such species are already the subject of ongoing monitoring by NCC regions and the Royal Society for the Protection of Birds (RSPB).

Comments on report's recommendations:

The recommendations made by the contractee (pp. 3-4 of this report) do not necessarily represent the shared opinion of NCC. However, most of these recommendations have been adopted fully (some since an early stage in the 1986-89 project) and form the basis of NCC's formalised Seabird Monitoring Programme (project Bi503, initially funded April 1989 to March 1992). Some clarifications of individual recommendations, and the extent to which they have been followed, are given below.

1. Population-monitoring of breeding seabirds (in particular, fulmars, kittiwakes and auks) continues to be encouraged by NCC, through a combination of Regional wardens, contracted work at key sites, ongoing monitoring by CSD in Orkney (and, from 1990, St Kilda), and contacts with other organisations. The latter include the Seabird Group, which jointly administers the Seabird Colony Register, a database of whole-colony counts, funded by NCC as part of the SMP.

2. Attempts to improve the representativeness of population sample-plots are to a large extent dependent on other organisations. Where NCC funding is involved, every attempt is being made to change over to a system of randomly-selected plots; already achieved for the Isle of May and Fair Isle, and to be implemented when plots are established at St Kilda in 1990.

3. Monitoring data are being collated by the SMP coordinator (1989-92) and stored in computer databases; an annual report on short-term population changes and breeding success (the first dealing with 1989, CSD report no. 1071) will be widely circulated to contributors and to other interested individuals and organisations.

4. 'Key sites' are now in place on the Isle of May, Fair Isle and Skomer, funded as part of the SMP, with a composite key site for northwest Scotland being formed by Handa, Canna and St Kilda. Population-monitoring of NCC sample plots on Orkney mainland continues triennially, with monitoring of breeding output funded annually on an expanded scale. Some NCC regions have also provided funds towards some of the above. Results from all of these sites are circulated as individual CSD reports.

5. Monitoring of breeding success is directed primarily towards kittiwake, fulmar, shag, guillemot and puffin (with some NCC monitoring of other species by reserve wardens).

6. Productivity-monitoring methods presented in this report are being widely circulated among volunteers and reserve wardens, and colony-coverage is being steadily expanded.

7. The monitoring work of other organisations continues to be encouraged, and NCC's cooperation with them to be strengthened; production of the annual seabird monitoring report is jointly undertaken with RSPB and Shetland Oil Terminal Environmental Advisory Group.

8. Through informal contacts with individuals and organisations in Northern

Ireland and the Republic of Ireland, seabird monitoring there is encouraged; results are collated and help to place British results in a wider context.

9. Adult survival rates of a small number of species are being monitored at the four key sites mentioned during 1989-91.

10. No attempts are currently being made by NCC to assess immature survival rates; however, cooperation with research organisations may yield useful information for some species.

11. To asstant in assessment of population parameters, NCC continues to subsidise ringing of selected seabird species by BTO ringers.

12-13. As found during 1986-89, it is proving difficult to obtain adequate samples of seabird food from colonies away from the key sites, especially on the west coast. Efforts continue to improve this situation.

14. Collection of weight/wing-length data for nestlings is undertaken as part of the CSD-funded work at several key-site colonies, but is not actively encouraged at other colonies.

15. A further review of the usefulness (or otherwise) of weighing chicks will be undertaken during 1991, building on section 8 of the present report.

16. Radio-telemetry studies of seabird foraging are not currently funded as part of the SMP; however, these techniques are being used as part of a NERC-funded study by Glasgow University of seabirds and sandeels in Shetland waters.

17. Computerisation of data during the 1989-92 project will concentrate mainly on population-monitoring counts (especially of sample plots) and breeding productivity data; whole-colony counts are already stored routinely in a separate database, the Seabird Colony Register, and, with appropriate 'quality-coding', form a further useful source of population-monitoring data.

18. During 1989-92, funds for the Seabird Monitoring Programme are being directed primarily towards (a) in-house coordination and data-collation, (b) organisations contracted to monitor seabirds at specific key-sites, and (c) volunteers monitoring breeding success at other colonies (administered through a contract with the Seabird Group); general subsidies of seabird-ringing are separately funded by NCC.

Specific comments on report sections:

3 (monitoring numbers): Although population monitoring of seabirds has been routinely undertaken since the early 1970s at a range of colonies, there have been several recent improvements in recommended methodologies. Some of these improvements derive from the work of the contractee, and the project as a whole has been invaluable in disseminating such information to seabird workers.

4 (establishment of biological monitoring programmes at key sites): During this contract, suitable schemes were established, or substantially revised, on the Isle of May, Fair Isle, Skomer, and Canna/Handa. The report stresses the importance of establishing more comprehensive monitoring on St Kilda NNR, as another contribution to a 'northwest Scotland' composite key-site.

5 (monitoring breeding success): Suitable methods were developed and tested by the contractee, and are now used at a wide range of study colonies. Summaries of 1986-88 results here include a paper (now published in Journal of Applied Ecology) on kittiwake breeding success. The importance of monitoring

breeding success has become increasingly clear in recent years, as the breeding success of a range of species in Shetland has declined (with 1988 being the worst year yet). By having a network of monitoring sites in place, the true geographical scope of such events can be assessed, and similar (or less marked) events elsewhere are more likely to be detected.

6 (adult survival rates): Satisfactory scheme are now in place for several species and colonies. The report stresses the difficulty of obtaining realistic survival estimates without a major commitment of time and effort; this effectively restricts the technique to professional ornithologists. Monitoring immature survival rates and recruitment is even more difficult.

7 (food of young seabirds): This aspect has been adequately covered at a small number of colonies only, and data are summarised here and in appendices. It has proved difficult to encourage sampling at additional colonies where seabirds are regularly ringed, despite the ease with which food samples can be obtained in many cases.

8 (growth of chicks): The potential use of measurements of nestling weights in relation to wing-length as a method of assessing growth-rates is assessed here for several species. Practical difficulties in obtaining usable (or any) data from seabird ringers are considered; the technique would seem most applicable to colonies subject to ongoing, detailed monitoring. For kittiwake and shag, possible relationships between growth-rates, breeding success and food are unclear (see also section 5.3.1 for kittiwake). More information is needed for guillemot and puffin. In general, the report concludes that brood attendance and apparent breeding success are more worthwhile parameters to record on single-date visits during the nestling period. However, continuing work on growth-rates on Fair Isle is encouraged, in view of apparent recent changes in conditions around Shetland.

9 (radiotelemetry): Fuller details of work on the Isle of May is given in CSD reports 828 and 928 (by Dr Sarah Wanless).

10 (automatic data handling by NCC): Monitoring counts, details of breeding success, chick measurements, and adult survival rates are most amenable to this (counts being the immediate priority). The most straightforward data are the monitoring counts, but even these will need some 'screening' to ensure that compatible methods are being used.

11 (amateur involvement): This has proved most successful as a means of increasing coverage of kittiwake colonies for productivity-monitoring, and less successful for other species (and for dietary studies). The importance of contact with a central coordinator is stressed.

Appendix 1: Population studies of Puffins on Dun, St Kilda (part-funded by NCC) are summarised for the period 1977-87. This work will form the basis for continued monitoring of this important population on a triennial basis.

Appendices 2-6: These provide details of methods developed or refined by the contractee to allow efficient assessment of breeding output of selected species. Two published papers are included.

Appendices 7-9: Food samples collected during 1988 and calorific values of fish collected in 1987 are summarised; an in-press paper on Hermaness food studies 1973-88 (partly funded by NCC) is included.

Appendices 10-12: Chick weight/wing-length data collected under this project are tabulated for 1986-8.

Appendices 13-14: 1987-88 fieldwork on Canna and 1988 work on Hermaness, both part-funded by NCC through this project, are summarised in 'independent' reports.

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cc Karen Mossman - for the file
Ornithology daybook

CONTENTS

RECOMMENDATIONS

1 Monitoring of numbers of kitiwakes, fulmars and auks must continue as many populations which until recently were increasing are now declining.

2 Attempts should be made to increase the representativeness of sample plots.

3 A computerised data-base of monitoring counts should be set up and and funds found for an organiser who should (a) encourage counters, (b) collect and process data, and (c) prepare an annual report of changes in numbers and breeding success.

4 NCC should organize and fund a biological monitoring scheme to consist of (a) key sites at the Isle of May NNR, Fair Isle, Skomer NNR and a group of three sites (St Kilda NNR, Canna, Handa), in the north-west and (b) a series of smaller studies by wardens and volunteers scattered around the rest of the country. These schemes are already in operation and should continue.

5 Biological monitoring should concentrate on kittiwake, fulmar, shag, guillemot and where possible puffin. Other species should be followed only where accurate results can be obtained with available resources. Breeding success gives probably the best indication of condition around the coast and measurement of this for a range of species should be given priority.

6 Instructions for monitoring the breeding success of kittiwake, shag, guillemot, puffin and shag are presented. These have been field-tested and should be used in the future.

7 Other organisations (e.g. SOTEAG, RSPB) should be encouraged to maintain their monitoring studies at the present levels.

8 NCC should seek the co-operation of ornithologists in Northern Ireland and Ireland and encourage them to participate in seabird monitoring.

9 Estimation of adult survival rates although extremely desirable, will be extremely difficult to achieve. Unless separate specific research projects are initiated, NCC should restrict its schemes to Isle of May (puffin, guillemot, razorbill, kittiwake, shag, herring and lesser black-backed gulls), Skomer (puffin, guillemot, razorbill, kittiwake, herring and lesser black-backed gulls), Fair Isle (kittiwake, puffin) and Canna (kittiwake).

10 Estimation of immature survival rates is extremely difficult and should be the responsibility of research organisations and universities.

11 BTO ringers should continue to be encouraged (by subsidies) to ring <u>both</u> adult and young seabirds. Colour-ringing should be discouraged and restricted to clearly defined projects with attainable aims.

12 More information should be collected on the diet of young seabirds, especially at colonies in the west of Britain.

13 The use of pellets gave a very biassed assessment of the diet of the shag. Before pellets are used to describe the diet of any seabird, the results obtained should be validated by feeding trials.

14 Weights and measurements of chicks collected haphazardly are unlikely to be useful for monitoring feeding conditions. Collection of the data should continue only at the main study sites and attempts made to weigh a sample of chicks twice during the period of rapid growth.

15 There is an urgent need for a rigorous statistical review of the usefulness of weighing chicks.

16 Radio-telemetry is the best available method to study the foraging of individual seabirds and should be encouraged.

17 NCC should computerize the seabird monitoring counts before investing time and money in developing automatic data handling facilities for other topics.

18 NCC funding should be channelled to (a) the organisations and groups collecting data at the key sites, (b) the expenses of volunteers who monitor nesting success at other sites, (c) ringers who collect food samples and (d) general subsidies for rings for both adult and young seabirds.

2 INTRODUCTION

2.1 Background

Britain's coasts hold a high proportion of the world breeding population of some species of seabird (e.g. about 70% of gannets and 20% of razorbills). In European terms, Britain holds the majority of several species and British seas are critically important as feeding areas for these birds.

There were indications in the early 1980s that, in certain areas, increased industrial catching of previously unexploited small fish might be having serious effects on the breeding productivity of certain seabird species, but more rigorous data were required. Apart from the intrinsic need (and NCC's international commitments) to monitor and conserve seabird populations, seabirds provide one of the few ways in which we can monitor easily and cheaply the health of the wider marine environment, though it will remain difficult to understand the changes taking place.

A highly desirable feature of a monitoring programme is that it should monitor population processes (productivity, mortality) as well as population size. Monitoring of such processes may identify a problem before this becomes apparent in terms of population density, as seabird populations consist of long-lived individuals and include large immature components, leading to considerable buffering of the size of the breeding population in the short term. Biological monitoring may also indicate the areas in which to look for causes should a decline appear. If monitoring can also check some possible causes, such as food supply (e.g. via schedules of bringing food to young), this is an additional advantage.

In 1986 NCC and ITE initiated a joint project to develop methods of monitoring seabird breeding performance. The work has concentrated on cliff and burrowing nesting species.

A major effort has been made to present data as published papers. Data from 1986 and 1987 and copies of published papers can be found in the two previous reports (April 1987 and 1988) and are not repeated here. Publications are listed in Section 13.

2.2 Objectives

2.2.1 To develop and test methods (suitable for use by volunteers, wardens, etc) of monitoring by sample counts breeding colonies of kittiwakes, razorbills, guillemots, puffins, shags and other seabirds.

2.2.2 To develop methods (of similarly wide applicability where feasible) of monitoring the breeding productivity, annual adult survival, immature survival and feeding conditions of the species listed above.

2.2.3 To specify the observations, and other data-collection required to implement (1) and (2) at particular sites, and to design any necessary forms and a data handling system.

2.2.4 To establish, over the period of the study, monitoring programmes using the above technique at selected sites around Britain: possibly the Isle of May, Skomer, Fair Isle and St Kilda.

2.2.5 To encourage the implementation of such a monitoring programme (or elements of it) at other sites.

3 MONITORING NUMBERS

3.1 The numbers of many species of cliff- and island-nesting seabirds in Britain have increased dramatically this century but some of the increases have now slowed down or stopped. In some northern areas populations are declining. Monitoring of numbers of kittiwakes (nests), fulmars (occupied sites), razorbills and guillemots (individual birds) and puffins (burrows) must continue.

3.2 Methods. There is now general agreement for each species on the units to be counted (i.e. nests, birds, sites, etc.). However, the problem of ensuring that the plots which are counted provide a representative sample of the colony remains. This is unfortunate as there are tried and tested ways of improving methods.

3.2.1 Guillemot

Harris, Wanless & Rothery (1983) recommended that monitoring plots for assessing changes in numbers of guillemots should be dispersed randomly through the colony and presented a method of so-doing. Following much argument, RSPB concluded after an NCC contract that a random method of plot selection is to be preferred when establishing new schemes and a gradual change over to random plots at colonies where plots were not selected in this way (Mudge 1988). As far as I know, little progress has been made in implementing these recommendations in guillemot monitoring.

3.2.2. Kittiwake

Heubeck, Richardson & Dore (1986) assessed the effectiveness of using study plots to monitor the overall changes of the kittiwake population of Shetland. They had some misgivings about the use of plots and suggested that a more appropriate method for monitoring kittiwake populations would be to make an annual single count of delimited sections of coastline, as opposed to colonies, during the latter half of incubation. This censuses total breeding numbers rather than extrapolating to total numbers from arbitrarily selected study plots. The scheme to monitor kittiwake on the Isle of May has been altered to this format; the numbers of nests in the old study plots are recorded separately to allow comparison with the longer series of counts. There is much to recommend this approach.

3.2.3 Puffin

The changes in numbers of occupied burrows on Dun, St Kilda 1977-87 were assessed using randomly positioned quadrats. The method proved efficient and indicated that the population showed an overall increase by 18% during 1977-87, though at a variable rate (Appendix 1).

3.3 Results and analyses. Results are collected piecemeal by the various agencies concerned but there is a great need for (a) a UK data-base of monitoring counts to augment the NCC/Seabird Group data-base on the Seabird Colony Register, (b) a person to run it, and (c) an annual report on changes in seabird numbers. Moves are underway towards these goals (below).

3.4 Collaboration between monitoring bodies. M L Tasker convened a meeting of interested parties at Aberdeen on 27 October 1988 to discuss future collaboration in monitoring seabirds in Britain. This section is based on his memorandum produced after that meeting.

3.4.1 Current monitoring schemes organized by SOTEAG, RSPB, ITE and NCC were reviewed briefly. Errors in lists of current monitoring locations and species which had been sent out with meeting papers were identified; revised lists of monitoring projects will be issued by NCC in due course.

3.4.2 There was agreement that a comprehensive integrated seabird monitoring scheme including both numbers and breeding performance parameters would be very useful to all agencies present. There was agreement with the NCC plan for a monitoring co-ordinator (this subject to NCC funding).

3.4.3 There was agreement that the integrated monitoring programme should focus on kittiwake, guillemot, some species of terns and fulmar at those sites where these species would be easy to monitor. Other species e.g. puffin, gulls, Manx shearwaters, should be added where possible.

3.4.4 The 'four' main NCC sites (Isle of May, Fair Isle, Skomer and St Kilda/Canna/Handa) were agreed as key sites. SOTEAG's Shetland monitoring will continue, as well as RSPB's tern and reserve monitoring. Several sites were identified where NCC's wardens might produce more useable data; these included Hermaness, St Kilda and Rhum. Mark Tasker was to approach the Department of the Environment (Northern Ireland) to ascertain their interest in a monitoring scheme.

3.4.5 The production of a series of documents on monitoring methods was identified as a priority. These would aim to provide simple, clear instructions to volunteers, wardens etc. It was agreed that strict standardisation was not necessary for breeding performance monitoring as agencies are most interested in knowing of a good, intermediate or poor breeding season.

3.4.6 It was agreed that an annual meeting to discuss monitoring and population changes would be useful.

3.4.7 If an integrated monitoring scheme is established it would be desirable if an annual report could be produced. This would encourage the participants to maintain their involvement. The agencies present at the meeting agreed that their monitoring data would be available for such a report.

4 ESTABLISHMENT OF BIOLOGICAL MONITORING PROGRAMMES AT KEY SITES

4.1 Detailed comprehensive schemes are now in operation on the Isle of May NNR (this study hopefully to continue under contract to ITE), Skomer NNR (NCC contract to Edward Grey Institute, Oxford University) and on Fair Isle (NCC contract to Fair Isle Bird Observatory Trust). The locations of these colonies are shown in Fig. 4.1. These studies must continue to be funded.

4.2 The siting of a study area in the northwest continues to be a problem. St Kilda NNR is the obvious choice but there are severe travel and logistic problems in undertaking monitoring studies there. At present NCC contribute towards the expenses of R Swann for his long-running study on Canna and this is producing extremely valuable results on kittiwake, guillemot, shag and other species. In 1988, I installed guillemot and razorbill productivity study plots on Handa, where kittiwake success and numbers of cliff-nesting species were already being monitored by RSPB.

The only seabird monitoring work currently being undertaken by NCC on St Kilda is on kittiwake productivity. Given that St Kilda is a

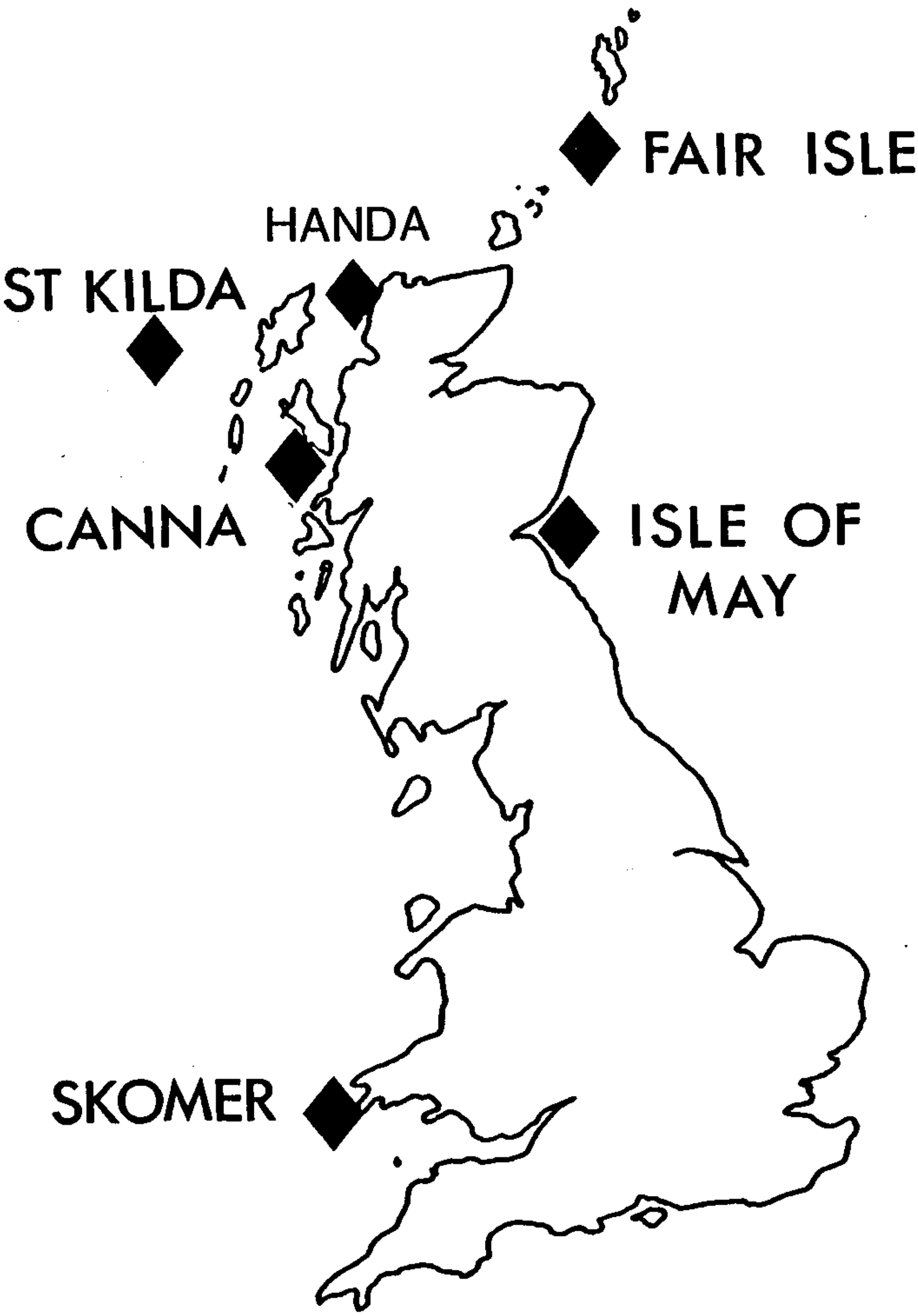

Fig. 4.1. Locations of the key biological monitoring sites.

National Nature Reserve and is a seabird breeding area of the highest international importance it is surprising and surely unacceptable, that monitoring of seabird numbers, receives such a low priority. At the very least breeding success of puffin, fulmar and kittiwake must be monitored and some attempt made to determine the food of a range of chick species. These projects should be possible within the normal workload of the warden. If not, provision should be made for a contract worker to collect the data.

4.3 It is impossible to get standardized coverage at all colonies due to varying practical difficulties and species present. Therefore NCC should support the study of the species which can be efficiently and accurately covered at each specific colony. However, other things being equal work should concentrate on kittiwake, guillemot, puffin, fulmar and shag which represent a range of different feeding strategies.

4.4 Wardens, volunteers, ringers and other workers should be encouraged to undertake work, especially on breeding success, at other colonies. Such people have made a major contribution to the study of kittiwake productivity (see next section).

5 MONITORING BREEDING SUCCESS

5.1 Methods. Low input methods have been developed for kittiwake, guillemot, shag, fulmar and puffin. All have been field tested by both professionals and volunteers and been shown to be efficient. Instruction sheets to be issued to fieldworkers are given as Appendices 2-6.

5.2 Coverage. In 1988, schemes were in place to monitor breeding success of kittiwake (33 colonies), guillemot (5), shag (7), puffin (3), fulmar (14), razorbill (2), black guillemot (1), and gannet (1). These totals involved NCC, RSPB, SOTEAG, ITE and several universities.

5.3 Results

5.3.1 Kittiwake. The whole of a recent draft paper is produced below as it illustrates the potential of biological monitoring studies.

BREEDING SUCCESS OF BRITISH KITTIWAKES RISSA TRIDACTYLA IN 1986-88: EVIDENCE FOR CHANGING CONDITIONS IN THE NORTHERN NORTH SEA

M.P. HARRIS AND S. WANLESS

INTRODUCTION

Many seabirds feed in the upper trophic levels of marine food webs and are both numerous and conspicuous. In comparison to other top marine predators e.g. whales, seals and fish, seabirds are relatively easy to study and thus can be used as indicators or monitors of change in the marine environment. Seabirds have been widely used to monitor the incidence of pollutants e.g. organochlorines, heavy metals, oil and plastics, throughout the world's oceans (Bourne 1976, Morris 1980, Anon 1983, Stowe & Underwood 1984). They also have a potential use as indicators of changes in fish stocks and as such can provide a widespread economical method where conventional fishery research surveys are unavailable (Ashmole & Ashmole 1968, Furness & Monaghan 1987, Cairns 1988). Several recent studies have illustrated the feasibility of this approach e.g. Anderson & Gress (1984), Ricklefs *et al.* (1984), Barrett *et al.* (1987), Montevecchi *et al.* (1988).

In the present study we collected data on the breeding success of kittiwakes *Rissa tridactyla* (L.) at 36 British and one Irish colony between 1986 and 1988. In this species the number of young fledging from a nest can be measured accurately and is likely to be a good index of food availability during the breeding season. Several other factors also enhance the kittiwake's suitability as a monitoring species: (a) it is common and widespread, (b) it breeds on cliffs and the nests and young can be counted easily without causing disturbance to the birds or danger to the observer, (c) it has a clutch of up to three eggs so that there is potential for variation in breeding success, (d) it suffers occasional breeding failures which have been attributed to food shortages (e.g. Barrett & Schei 1977, Heubeck *et al.* 1987, Murphy *et al.* 1982, Hatch 1987), (e) it relies heavily on a single prey type, sandeels *Ammodytes* spp. (Cramp & Simmons 1982), which is also important for many other seabirds and commercial fish species, (f) a 'short-cut' method is available to measure breeding output (Harris 1987) and (g) much is known of its population trends and biology (e.g. Coulson 1974, 1983, Coulson & Thomas 1985). Our aim was to assess whether a survey such as this could be used to describe spatial and temporal patterns in the marine environment.

METHODS

The colonies where data were collected in at least one year between 1986 and 1988 are shown in Fig. 1. Colonies are numbered sequentially from Fetlar (1) in the north to Handa (36) clockwise around the coast. Observers checked the success of all visible nests in small colonies or in several clearly defined areas (plots) containing 50 or more nests dispersed through large colonies (details in Harris 1987). Plots were positioned randomly or systematically at Fair Isle (9), Fowlsheugh (15), the Isle of May (16) and Marsden Rock (20), and haphazardly in the remaining colonies. The positions of nests were marked on large photographs and their state and/or the

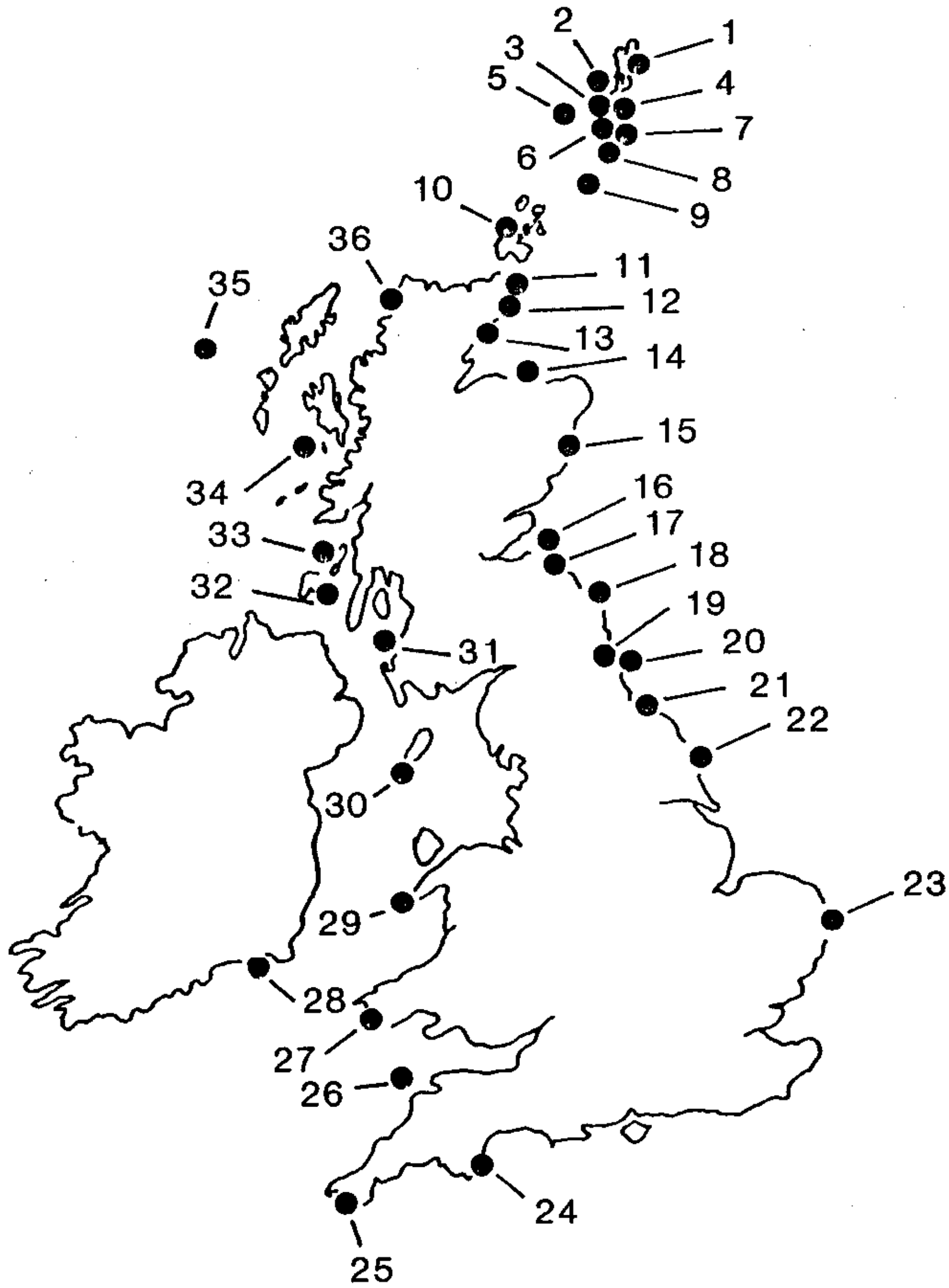

Fig. 5.1 Locations of kittiwake colonies where breeding success was monitored in 1986-88. The colonies were Fetlar(1), Eshaness (2), Westerwick (3), Noss (4), Foula (5), Kettlaness (6), Troswickness (7), Sumburgh Head (8), Fair Isle (9), Marwick Head (10), Skirza (11), Iresgeo (12), An Dun (13), Covesea (14), Fowlsheugh (15), Isle of May (16) , Dunbar (17), Farne Islands (18), North Shields (19), Marsden Rock (20), Saltburn (21), Bempton (22), Lowestoft (23), Berry Head (24), Trewavas Head (25), Lundy (26), Skomer (27), Dunmore East (28), Bardsey (29), Calf of Man (30), Ailsa Craig (31), Islay (32), Colonsay (33), Canna (34), St Kilda (35) and Handa (36).

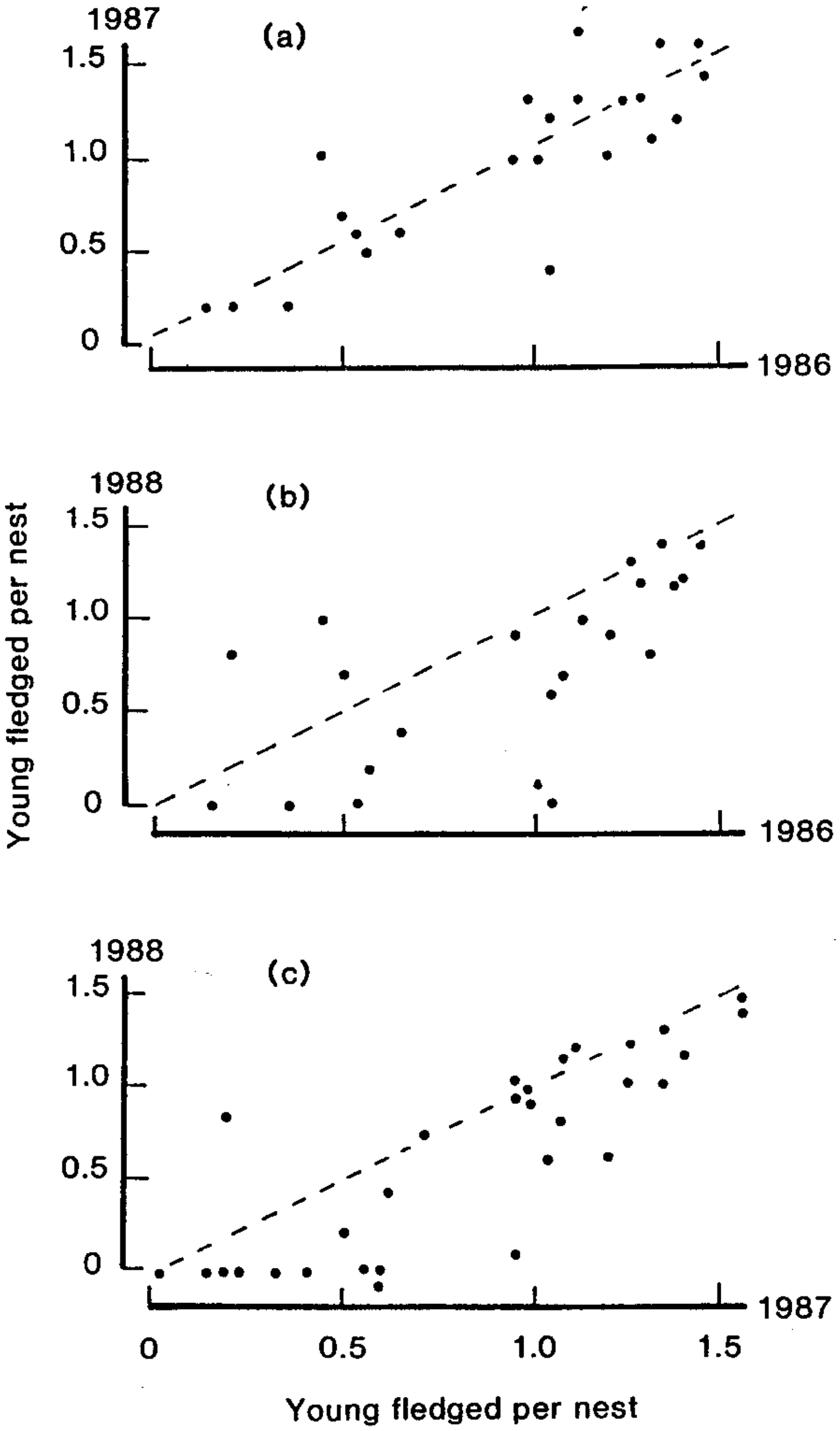

Fig. 5.2 Breeding success of kittiwake colonies followed in (a) 1986 and 1987, (b) 1986 and 1988, and (c) 1987 and 1988. The dotted line indicates no change.

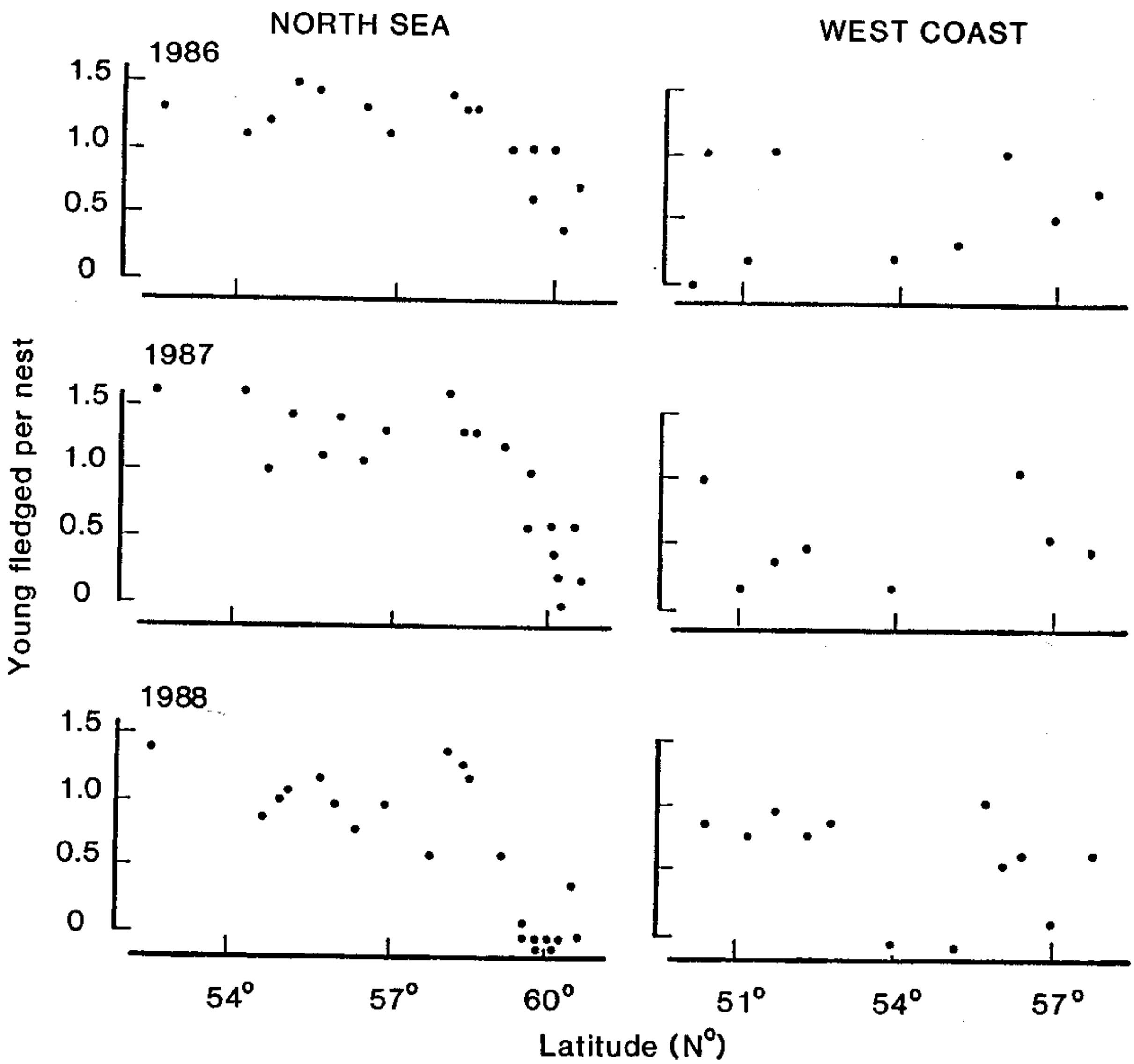

Fig. 5.3 Breeding success of kittiwakes at colonies in the North Sea and west coast in 1986, 1987 and 1988 in relation to latitude.

Table 5.1 Breeding success (young fledged completed nest^{-1}) of kittiwakes in 1986-88

Colony	1986 Nests (plots)	1986 Breeding success	1987 Nests (plots)	1987 Breeding success	1988 Nests (plots)	1988 Breeding success	Source
North Sea							
1 Fetlar	No data		103(2)	0.08-0.23	96(2)	0	RSPB (M.A. Peacock)
2 Eshaness	107(1)	0.65	291(2)	0.64-0.65	288(2)	0.41-0.50	Heubeck (1988a,b, 1989), Heubeck *et al.* (1987)
3 Westerwick	No data		133(2)	0.01-0.05	113(2)	0	Heubeck (1988a,b, 1989), Heubeck et al. (1987)
4 Noss	139(1)	0.35	423(4)	0.27±0.03	328(4)	0	Harvey & Suddaby (1986), Thomson & Cable (1987), Cable & Bird (1988)
5 Foula	?	Moderate	?	Low	?	0	Furness (1989)
6 Kettlaness	No data		261(1)	0.56	229(1)	0	Heubeck (1988a,b, 1989)
7 Troswickness	143(2)	11.04-1.06	227(2)	0.39-0.44	210(2)	0	Heubeck (1988a,b, 1989), Heubeck *et al.* (1987)
8 Sumburgh Head	262(4)	0.55±0.09	378(4)	0.60±0.05	3194	0.01	Heubeck (1988a,b, 1989), Heubeck *et al.* (1987)
9 Fair Isle	1034(5)	1.03±0.05	1497(10)	0.97±0.03	1415(10)	0.08±0.01	Riddiford & Osborn (1986, 1987), Riddiford & Silcocks (1988)
10 Marwick Head	58(2)	0.77-1.34	70(2)	0.95-1.43	77(2)	0.58-0.69	Beveridge (1986), Ward (1987), Thomas (1988)
11 Skirza	218(1)	1.29	217(1)	1.26	216(1)	1.20	Aspinall (1986), Parsons 1988), Evans (1989)
12 Iresgeo	285(3)	1.27±0.16	261(2)	1.24-1.40	252(2)	1.30	" " " "
13 An Dun	182(2)	1.44-1.58	208(2)	1.46-1.55	291(2)	1.39	" " " "
14 Covesea	No data		No data		185(*)	0.62	K. Wheeler
15 Fowlsheugh	100(1)	1.13	351(8)	1.26±0.05	342(7)	1.00±0.05	RSPB (H. Thurgate, R.G. Raynor)
16 Isle of May	1133(16)	1.33±0.04	1291(15)	1.09±0.06	1278(15)	0.82±0.08	Pers. obs.
17 Dunbar	No data		341(*)	1.39	380(*)	1.05	S.R.D. da Prato
18 Farne Islands	No data		676(10)	1.11±0.09	775(11)	1.17±0.08	National Trust
19 North Shields	78	1.40	76	1.34	68	1.16	
20 Marsden Rock	No data		No data		598(8)	0.96±0.06	D. Turner
21 Saltburn	232(3)	1.19±0.02	146(4)	1.00±0.06	160(4)	0.93±0.05	K. Ferry
22 Bempton	285(6)	1.13±0.23	364(6)	1.55±0.04			RSPB (M. Davies, P. Philp)
23 Lowestoft	90(*)	1.34	91(*)	1.56	107(*)	1.43	B.J. Brown
West Coast							
24 Berry Head	119(3)	0.96±0.17	118(3)	0.99±0.19	125(3)	0.86±0.19	K. Partridge
25 Trewavan Head	No data		126(*)	0.04	No data		P. McCartney
26 Lundy	243(1)	0.22	191(1)	0.22	138(1)	0.79	D. Dickins
27 Skomer	152(3)	0.45±0.09	206(3)	0.97±0.08	204(4)	0.98±0.09	C.M. Perrins
28 Dunmore East	267(2)	0.00-1.07	258(2)	0.85-0.96	245(2)	0.73-0.85	D. McGrath & P. Walsh
29 Bardsey	?	poor	82(1)	1.09	103(1)	0.85	Bardsey Bird & Field Observatory (P. Jenks, T. Collins)
30 Calf of Man	166(1)	0.15	109(2)	0.09-0.30	238(3)	0.04±0.01	Calf of Man Bird Observatory (D. Walker)
31 Ailsa Craig	?	poor	93(2)	0.30-0.41	561(3)	0.03	B. Zonfrillo
32 Islay	No data		No data		68(2)	1.09-1.18	M.A. Ogilvie
33 Colonsay	No data		458(4)	1.05±0.07	486(3)	0.57±0.18	J. Clarke
34 Canna	187(1)	0.57	280(1)	0.50	368(2)	0.03-0.36	Swann & Ramsay (1986,1987)
35 St Kilda	142(2)	0.41-0.63	189(2)	0.62-0.85	293(4)	0.65±0.09	J. Evans, J. Babb, D. Miller
36 Handa	286(4)	1.09±0.13	No data		243(4)	0.69±0.09	RSPB (C.L.P. Self, R. Ascroft)

Notes: 1. * indicates all visible nests in the colony were checked
2. If two plots were checked the range of success is given, otherwise the figure is mean ± S.E. (unless $<$ 0.01 when it is omitted). The number of plots checked is given in brackets after the total of nests
3. Colony locations are shown in Fig. 1

number of large young present were assessed visually in (a) late May and early June when most birds had laid and (b) in mid-July just before the young fledged. All very large young were assumed to have fledged. Where possible or needed, an additional later check was made to determine the survival of late chicks. Where small chicks were still present at the last check, 50% were assumed to have fledged. Field trials indicated that this short-cut method could have over-estimated true success by up to 13% (Harris 1987). At Ailsa Craig (31), Skirza (11), Iresgeo (12), and An Dun (13) the estimates of success were based on the mean of several counts of nests in June and a single count of large chicks in July in several plots. Figures for Foula (5) come from checks of nests late in the season (Furness 1983, 1989) and for North Shields (19) from all-season studies (J.C. Coulson unpubl. data).

Throughout this paper success is expressed as the mean number of young fledged completed nest^{-1} (defined as where an adult was seen apparently incubating or where the nest appeared capable of holding eggs). Where several plots were counted in a colony there were often large and significant (χ^2-tests) differences in the proportion of successful and unsuccessful nests in the plots; colony success was, therefore, calculated as the mean ($\pm$ S.E.) of the plot totals rather than the weighted mean.

The diet of chicks was assessed on the Isle of May, Fair Isle and two Caithness colonies (Iresgeo, Inver Hill) by collecting regurgitations produced by adults and chicks caught for ringing. A few samples were collected at other locations. Reasonably intact fish were assigned to 2 cm length classes. On Fair Isle, Isle of May and Iresgeo weights and wing measurements were taken for a sample of chicks each year.

Details of sources are given in the Appendix; longer runs of data and more detailed observations were extracted from the annual reports and log-books of the Bird Observatories on Bardsey (29) and the Calf of Man (30) and for Shetland from Heubeck (1987, 1988, 1989) and Heubeck *et al.* (1987) and for Lowestoft from Brown (1984 updated). In many analyses, colonies were divided into those bordering the North Sea (Shetland south to Lowestoft; colonies 1-23 in Fig. 1) and those on the west coast of Britain (including south-east Ireland) (colonies 24 - 36). For convenience, Fair Isle and Foula are not considered as parts of Shetland.

RESULTS

Breeding success

Details of sample sizes and annual successes are given in the Appendix. Over the three years kittiwake breeding success varied greatly from zero (several colonies in 1988) to 1.56 young fledged completed nest^{-1} (Lowestoft in 1987). Breeding success at each colony was generally very similar in 1986 and 1987 (Fig. 2), with the mean difference in 23 colonies being only 0.022 $\pm$ 0.05, but was much lower in 1988. The differences between values for colonies monitored in 1986 and 1988 (mean $\pm$ S.E. = -0.19 $\pm$ 0.08, n = 23), and 1987 and 1988 (-0.22 $\pm$ 0.05, n = 29) were both significantly below the no-change level ($\underline{t}$ = 2.39, $\underline{P}$ $<$0.05; $\underline{t}$ = 4.59, $\underline{P}$$<$0.001, respectively). In 1988, birds at 10 of the colonies monitored reared either no young or virtually no young at all. The only colony to have a markedly higher success in 1988 was Lundy (26) where breeding success was the highest recorded since 1982 (D. Dickins, pers. comm.).

There were also some differences in breeding success in relation to geographical area. In the North Sea in 1986 and 1987 there was a significant negative relationship between breeding success and latitude for colonies between An Dun and Shetland with latitude explaining 68% and 83% of the variation in breeding success in the two years respectively (Fig. 3). However, south of An Dun (58°00'N) there was no obvious relationship between success and latitude. In 1988, when most Shetland colonies failed completely and colonies elsewhere showed a marked reduction in breeding success, there was a significant north-south trend in success over the whole range (Fig. 3). Success declined by 0.18 chicks fledged completed nest^{-1} for every 1° shift north, and latitude explained 60% of the variation in breeding success. Successes at Iresgeo, Skirza and An Dun were higher than predicted from their latitude, possibly because they were all checked earlier (7 July) than most other colonies (mid to late July) which could have led to their breeding success being over-estimated although a later check did not discover any dead chicks. (It is possible, however, that conditions off the extreme north east of Scotland may have been good as kittiwakes on Auskerry off east Orkney also had a successful season (A.D.K. Ramsay pers. comm.).) Removing the three Caithness colonies from the regression increased the amount of variation explained to 86%. In 1988 the Calf of Man and Ailsa Craig produced virtually no young but in contrast to the North Sea, no systematic pattern of breeding success with respect to latitude was apparent amongst the west coast colonies (Fig. 3).

No attempt was made to determine the reasons why individual nests were unsuccessful but particularly when breeding success was low, most observers made a general assessment of when and at what stage breeding failed. The data suggested that in Shetland birds failed progressively earlier each year. Thus, in 1986 and 1987, moderate to severe post-fledging mortality was reported in mid to late July, whilst in 1988 most losses occurred when birds had small to medium-sized chicks at the end of June (reference in Appendix). In 1988 failures occurred first in Shetland and then spread sequentially south to reach Fair Isle, Marwick Head (10), Handa and St Kilda (35) in mid to late July. However, not all failures followed this pattern and at the west coast colonies of Calf of Man, Ailsa Craig and Canna (34), many birds apparently never laid (as no eggs were seen) and/or nests failed mainly during incubation or at or soon after hatching. Some nests at Castlerock, Coleraine, Northern Ireland failed when young died just before they were expected to fledge (S.H. Guthrie pers. comm.).

During the day one or other of the kittiwake pair is normally present with the chicks although the young may be left unattended at night (Barrett 1978, Galbraith 1983). However, at some colonies where breeding success was low observers remarked on the unusually high proportion of unattended young. The effect appeared to get gradually more pronounced in Shetland over the three years and was first

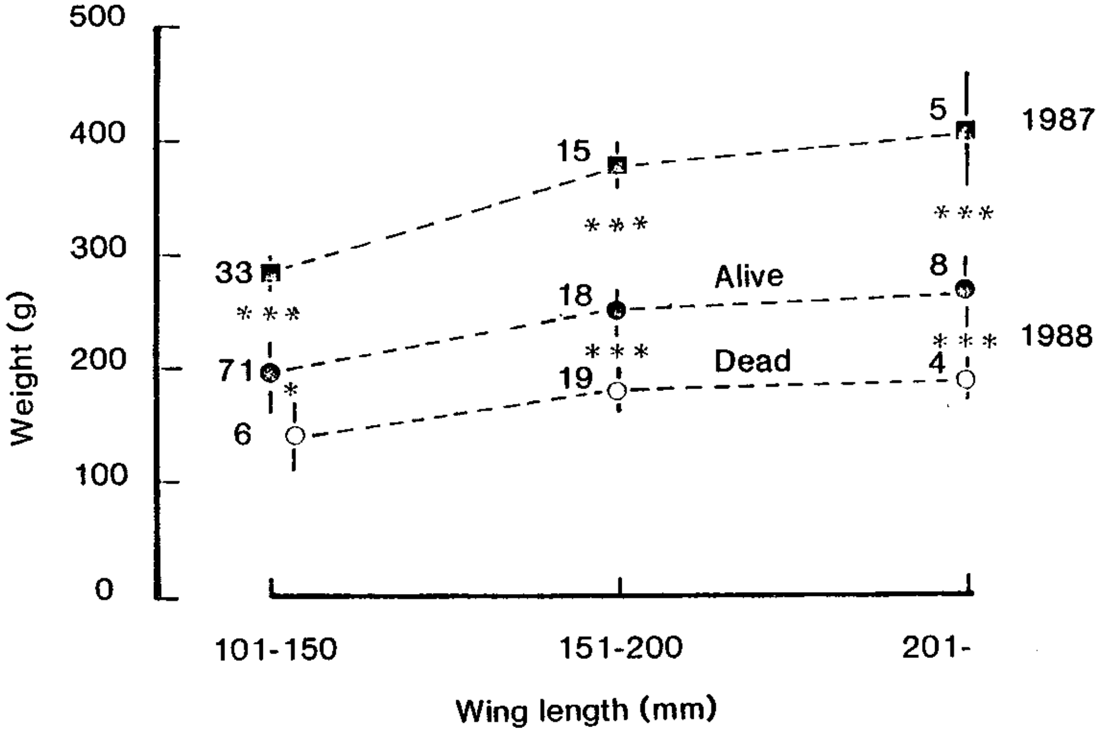

Fig. 5.4 Mean weights (and 95% confidence intervals) of kittiwake chicks on Fair Isle in 1987 (squares) and 1988 (circles) in relation to wing length. Numbers indicate sample sizes. Differences between adjacent samples for each wing length were all significant (*, *** = $P < 0.05$, $P < 0.001$, respectively).

remarked on by observers as being common outside Shetland in 1988, e.g. Fair Isle, Iresgeo, Isle of May, Handa. Few quantitative data are available but on the Isle of May 49% of 1272 broods checked between 0900-1800 h on 1-10 July 1988 were unattended which was significantly higher than the 13% of 306 broods recorded over the same period in 1986 (χ^2 = 133, $P<0.001$). We have been following seabirds on these cliffs since 1981, and 1986 was the first year that we recorded chicks being left. In 1988 broods of two were more than twice as likely to be unbrooded as single chicks (69% compared to 31%, n = 606 and 666, respectively, χ^2 = 181, $P<0.001$). Similarly at Iresgeo in 1988, 19% of 93 broods were unattended on 16 July and 23% of 326 broods were unguarded on 20 July (S. Mackay, pers. comm.).

Chick weight

The widespread reports of chick deaths and parental neglect strongly suggested that food shortage was at least partly responsible for some of the breeding failures. We therefore examined all our available data on chick weights and wing lengths for evidence of retarded growth in years when breeding success was low. The only colony to show such an effect was Fair Isle where chicks in 1988 had significantly lower weights for given wing lengths than chicks measured in 1986, or 1987. Furthermore, freshly dead chicks were significantly lighter than live chicks (Fig. 4). On the Isle of May and Iresgeo there were no annual differences in chick weights.

Food

Sandeels were by far the most important item in the chicks' diet being present in 89% of 194 regurgitations collected in 1986-88 and making up about 90% of the total biomass (Table 2). The proportion of sandeels in the diet of chicks on Fair Isle was slightly lower in 1988. Furness (1989) found an even more marked difference on Foula where the proportion in 1988 was only 67% compared to 100% between 1977 and 1982. In contrast, the only samples for a west coast colony, Canna, consisted mainly of two species of *Trisopterus*. Thus, there was suggestion of a link between a reduced amount of sandeel in the chicks' diet and lower breeding success but many more data are required to elucidate this. The majority of the measurable sandeels in the regurgitations were less than 10 cm long (Fig. 5) which corresponds to the 0-group age class (fish hatched in the current year) although some longer sandeels (1-group or older) were also present. On both the Isle of May and Fair Isle, fewer 0-group fish were taken in 1988, when success was low, compared to 1986, when more chicks were produced. In Caithness, more than 90% of sandeels regurgitated by kittiwakes in 1988 were 0-group size and chick production there was markedly higher than expected from colony latitude. Thus there also appeared to be a link between the availability of 0-group sandeels and breeding success but again more data are needed to elucidate this.

DISCUSSION

From the beginning of this century until about 1969 the kittiwake population in Britain increased at an average rate of 3-4% p.a. (Coulson 1974). The increase continued, albeit at a lower rate, between 1969 and 1979 in colonies bordering the North Sea but the numbers of breeding pairs in south-west and north-west England, Wales,

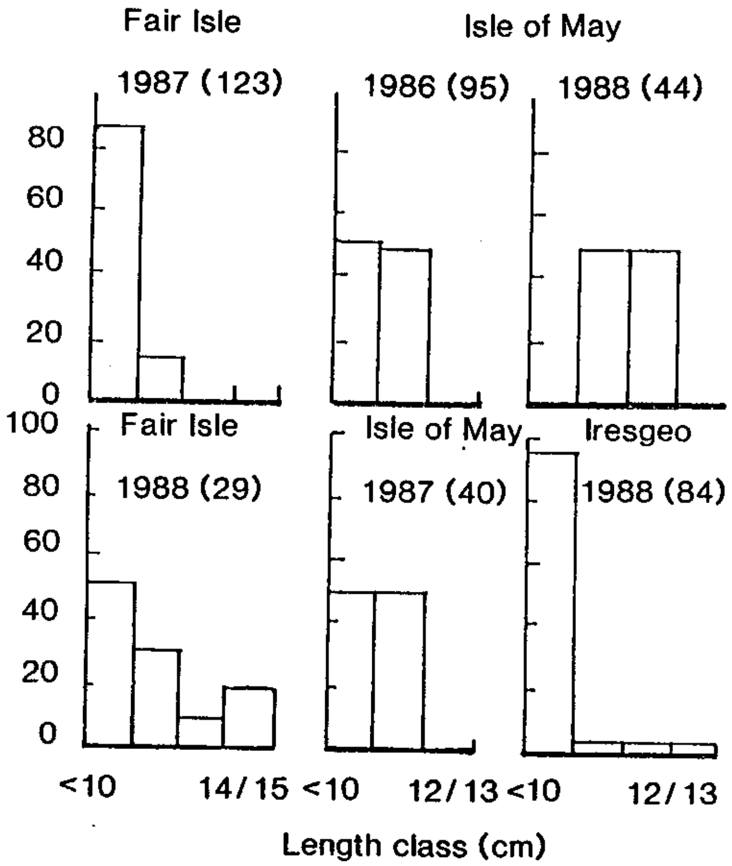

Fig. 5.5 Length distribution (in 2 cm categories) of sandeels regurgitated by kittiwakes at Fair Isle, Iresgeo and Isle of May in 1986-88. The numbers measured are given in brackets.

Table 5.2

The food of kittiwake chicks at various colonies expressed as (1) % occurrence in the number of regurgitations and (2) the % biomass.

	Sample Size Regurgitations	Items	Total Wt(g)	Sandeels (1)	Sandeels (2)	Clupeidae (1)	Clupeidae (2)	Gadidae (1)	Gadidae (2)	Crustacea (1)	Crustacea (2)
Isle of May, Fife											
1986	35	105	312	97	98	0		0		9	14
1987	17	80	165	94	95	6	3	0		6	1
1988	32	92	354	79	94	11	6	0		0	
Iresgeo and Inver Hill, Caithness											
1987	8	?	?	100	100	0		0		0	
1988	15	c.100	169	100	9	0		7	5	0	
Fair Isle											
1986	24	151	404	100	100	0		0		0	
1987	34	211	721	100	100	0		0		0	
1988	8	32	108	87	98	0		0		13	<1
Sumburgh, Shetland											
1987	2	12	65	50	69	0					
1988	1	1	3	0		0		100	100	0	
Canna, Inner Hebrides											
1987	7	15	150	14	20	0		83	80	0	
1988	6	20	120	0		0		83	80	17	5
Faraid Head, Sutherland											
1986	1	?		100	100	0		0		0	
Sule Skerry, Orkney											
1986	4	?		100	100	0		0		0	

Additional items (and relevant % in diet): Fair Isle, 1988 on unidentified fish (13%, 3%, 2%); Canna, 1988, 3 small probable wrasse Labridae (17%, 15%); Sumburgh, 1987, one mackerel *Scomber scombrus* L. (50%, 31%).

Table 5.3 Timing of the main period of failure in 1988 for colonies where breeding success was low

Colony	Fledged/ completed nest	Main period and stage of loss
1. Fetlar	0	Chick stage
2. Eshaness	0.45	Early July; medium to large young
3. Westerwick	0	Mid-June; eggs small young
4. Noss	0	Chick stage
5. Foula	0	Mid-July; medium to large young
6. Kettlaness	0	End-June; small to medium young
7. Troswickness	0	End-June; small to medium young
8. Sumburgh Head	0.01	End-June; medium young
9. Fair Isle	0.08	Middle third July; medium young
10. Marwick Head	0.63	Mid- and late-July
30. Calf of Man	0.04	Many pairs did not lay, few hatched
31. Ailsa Craig	0.03	Probably failed during incubation, or at hatching
33. Colonsay	0.57	Some eggs deserted, young died early July
34. Canna	0.20	More than half pairs apparently did not lay, many eggs did not hatch and many young died early/mid July
35. St Kilda	0.65	First half July
36. Handa	0.69	Late July; large young or after fledging

Notes. 1. Only colonies where success was 0.7 young fledged completed nest^{-1} are considered. No information was available for Covesea.

2. Numbers before colony names refer to their locations as shown in Fig. 1.

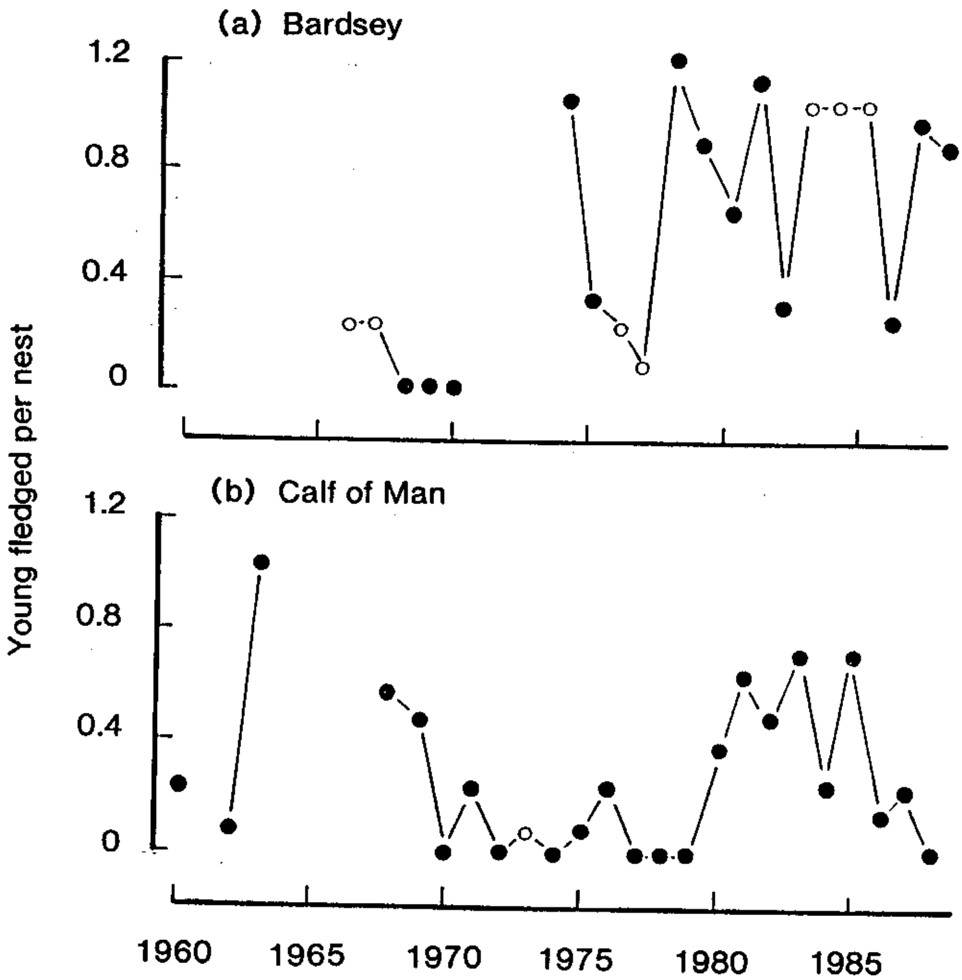

Fig. 5.6 Breeding success of kittiwakes on (a) Bardsey and (b) Calf of Man in 1960-88. Open circles indicate estimates based on general assessments of success scored as good (1.0), moderate (0.8), poor (0.2) or very poor (0.1). (Data from Bird Observatory records.)

south-west Scotland and southern Ireland declined (Coulson 1983). During the 1980s decreases in numbers continued in Orkney, Shetland and south-east Ireland and probably Caithness (Heubeck 1986; McGrath & Walsh 1985; Mudge 1986; Benn et al. 1987). However with a few notable exceptions, e.g. Coulson & Thomas (1985), Brown (1984), McGrath & Walsh (1985) very little published information on breeding success was available.

The data collected 1986-88 indicated spatial and temporal variation in kittiwake reproductive success in Britain. In 1986 low chick production in the North Sea was confined to Shetland but by 1988 breeding success had also declined in colonies well south in the North Sea and the situation in Shetland had deteriorated to such an extent that all the chicks at some colonies died. Although very poor breeding seasons have been recorded periodically in Alaska and Norway (Barrett & Schei 1977; Barrett & Runde 1980; Johansen 1978; Murphy et al. in press) until recently such events have not been a feature of British North Sea colonies. Long term studies at North Shields and Lowestoft indicate that chick production at colonies in the southern North Sea has been consistently high since at least the early 1960s (Coulson & Thomas 1985; Brown 1984) and seriously reduced breeding success was not recorded in Shetland until 1985 (Heubeck & Ellis 1986). The 1986-88 survey also showed that chick production was markedly lower on the west coast of Britain in 1988 with complete breeding failures at some colonies; there was a) no latitudinal trend in success was apparent, and b) results from Bardsey and the Calf of Man indicate that chick production on some parts of the west coast has frequently been low in the past (Fig. 6). In contrast, recent breeding failures on Canna are a new phenomenon, at least in the last 15 years (R.L. Swann & A.D.K. Ramsay, pers. comm.).

A marked feature of the recent failures in the North Sea has been that most losses occurred during the chick stage. This contrasts with the situation described by Coulson & Thomas (1985) at North Shields where the comparatively small annual variations in reproductive output were due mainly to changes in clutch size, hatching success, and to a lesser extent to changes in chick survival and where in general, fledging success was much higher than hatching success. The phenology of failures in Shetland and the north-east coast of Britain was also different to that on the west coast where failures on the Calf of Man, Ailsa Craig and Canna were apparently caused by birds not laying or nests failing mainly during incubation or soon after hatching.

In the North Sea changes in the extent and severity of the breeding failures were tracked by changes in the timing of the main period of loss. Thus in Shetland losses in 1988 occurred earlier than in 1986 or 1987 (Heubeck 1989). Within 1988 failures were recorded first in Shetland (where most pairs failed) and then spread sequentially south to reach Fair Isle (a few young reared), Marwick Head (chicks died just prior to fledging) and Handa (where most losses did not occur until just prior to or after fledging).

Food shortage

Within the North Sea the evidence that food shortage was responsible for the low breeding success is mostly circumstantial, but taken as a whole, compelling. First, kittiwakes in Britain appear to rely heavily on small to medium-sized sandeels on which to rear their young (Pearson 1968; Cramp & Simmons 1982; Galbraith 1983; Coulson & Thomas 1985, this study) and sandeel stocks around Shetland are known to have declined in recent years (below). Second, there was a marked increase in the amount of time that adults spent away from the nest which resulted in chicks frequently being left unattended. Although some chicks were taken by predators or died during periods of bad weather, the ultimate factor was parental neglect. Such behaviour strongly suggests food shortage during chick rearing and this was borne out by chicks being significantly underweight on Fair Isle in 1988. Barrett & Runde (1980) noted that on Runde, Norway, in a year when breeding success was low, only 35% of broods had an adult present.

Third, several other seabird species which also depend on sandeels to feed their young similarly reared few or no chicks in Shetland and nearby islands in 1988. The species affected tended to be small-sized, inshore, surface feeders e.g. arctic tern Sterna paradisaea Pont., puffin Fratercula arctica (L.), arctic skua Stercorarius parasiticus (L.) and great skua Catharacta skua (Brünn) (Ewins 1985; Monaghan et al. 1989; Furness 1989; Heubeck 1989; Harris & Riddiford 1989; Martin in press). A link between breeding failures of kittiwake and arctic tern has been noted previously in Norway (Barrett & Schei 1977). The amount of time a species has to spend foraging to rear a typical brood decreases with adult body size; thus small species such as the kittiwake which spend a high proportion of their time finding food for their young will be more susceptible to breeding failures during periods of food shortage since they cannot increase the amount of time spent foraging (Pearson 1968; Furness & Monaghan 1987). Finally, similar conclusions were drawn from similar data collected during widespread breeding failures of kittiwakes and puffins in Norway in the 1970s (Barrett & Schei 1977; Barret & Runde 1980; Lid 1981; Anker-Nilssen 1987). Here detailed pathological, microbiological, toxicological, endocrinological, enzymological and parasitological examinations failed to find evidence that the deaths had been due to anything but starvation (references in Anker-Nilssen 1987).

The stocks of sandeels in Shetland have declined in recent years and this has been attributed to (a) possible overfishing by a local fishery which started in 1974 and reached a peak in 1982 (Royal Society for the Protection of Birds, press release 3 August 1988)and (b) natural factors (Kunzlik 1989). The available data from fishery research tends to support the latter as, although sandeel numbers have certainly declined, the spawning stock in 1986 (the last year data are available) was still more than 60% the maximum recorded (in 1984) (details in Kunzlik 1989). It appears as though a series of poor recruiting year classes resulted in a decrease of smaller sandeels on which many seabird species depend for food for their young. Kunzlik postulated that adverse environmental factors could be influencing the survival of larvae and/or the transport of larvae into and out of the Shetland area. Our findings that the situation in Shetland, although being more severe, is part of a more widespread change which extends further south into the North Sea into areas where no sandeel fishing occurs supports Kunzlik's environmental hypothesis.

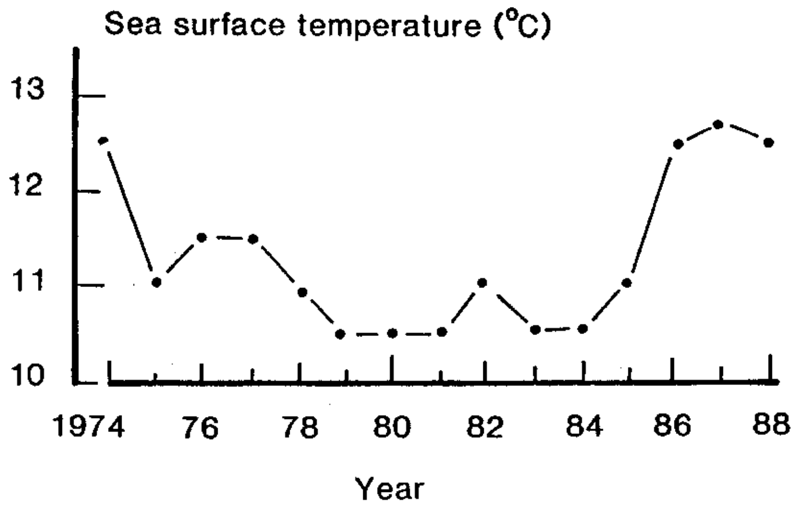

Fig. 5.7 Sea surface temperatures around Shetland in early July 1974-88. (Data from charts issued by Deutsches Hydrographisches Institut.)

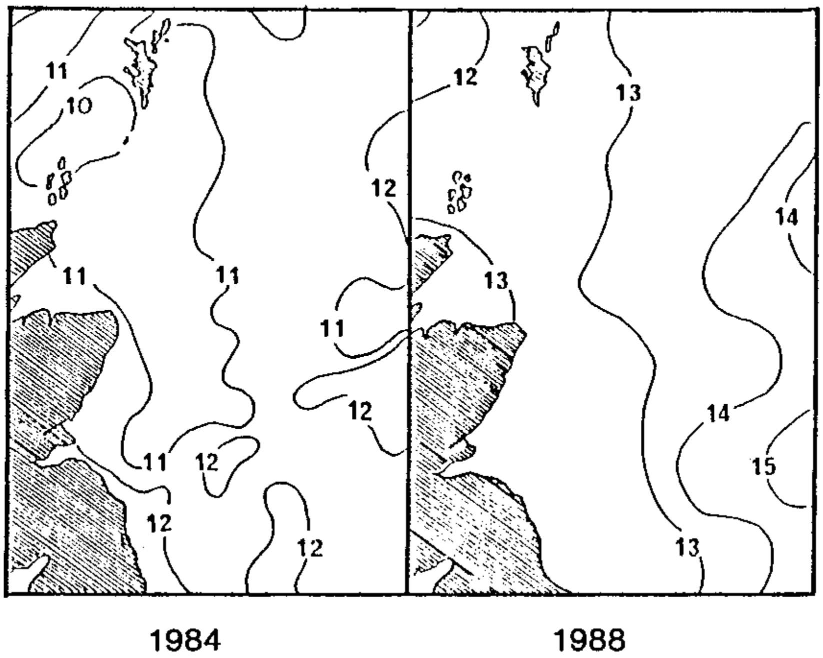

Fig. 5.8 Sea surface temperatures in the northern North Sea during the first weeks of July 1984 and 1988. (Data from charts issued by Deutsches Hydrographisches Institut.)

Environmental changes

As yet it is not possible to link these recent changes in kittiwake breeding success to any specific environmental change. However, major changes have occurred in the North Sea and north-east Atlantic during the last 20-30 years. These include a gradual increase in northerly airflow and storminess, a progressive delay in the initiation of the spring phytoplankton bloom, a long term decrease in zooplankton abundance (particularly in the west central North Sea), an increase in the numbers of the dinoflagellate Ceratium fusus (particularly in the waters around Shetland between 1985 and 1987) and an increase in herring Clupea harengus L. stocks (Colebrook 1985, 1988; Dickson et al. 1988; Saville & Bailey 1980, updated). Between 1985 and 1988 the summer sea surface temperatures around Shetland increased to levels not recorded since 1974 (Fig. 7) and in July of recent years warm water has extended down the east coast of Scotland (Fig. 8). It may well be that temperature per se is not the controlling factor since kittiwake breeding success was, in general, higher in colonies in the southern North Sea where July sea surface temperatures were 4-5^{o}C higher than around Shetland. However, changes in temperature are likely to be associated with varying degrees of penetration of Atlantic waters into the North Sea (Hart 1974) and thus indicative of more profound oceanographic changes. Changes in water temperature and salinity have been implicated with past changes in the abundance of sandeel larvae around Shetland and Orkney (Hart 1974).

In Alaska, kittiwake breeding success is very variable, failure of a colony to produce any young in a year is common and breeding failure is considered to have occurred only when production is less than 0.1 young per pair being produced (Hatch 1987). Hatch found no consistent relationship between kittiwake productivity and sea surface temperature in the Gulf of Alaska and concluded that it was unlikely that any single environmental factor will prove to be a good predictor of seabird success. The same probably holds for the North Sea as the highest recorded successes in recent years have been in the southern North Sea where sea temperatures are highest.

Coulson & Thomas (1985) found a positive correlation between the breeding success of kittiwakes at North Shields and the size of the North Sea herring stocks. They suggested that in general an increase in herring abundance would lead to improved breeding success of kittiwakes since immature herring are an important part of the kittiwake's diet early in the breeding season. The spawning stock biomass of North Sea herring increased five-fold between 1981 and 1988 but this was not accompanied by high kittiwake breeding success in Shetland. However, although adult herring are now found in relative abundance around Shetland, juvenile fish of the size fed by most seabird species to their chicks do not occur within 50-100 km of the archipelago and are thus largely outwith the normal foraging range of many of the seabirds during the chick rearing period (Pearson 1968; Kunzlik 1989). Indeed the poor recruitment of sandeels could be at least partly due to predation by herring since larval sandeels form a major part of the herring's diet (Hardy 1924).

Few chicks were fledged at some west coast colonies in 1988 but these failures seem unrelated to those in the North Sea, as they occurred at different times of the season and with no obvious geographical pattern. This is not unexpected since the oceanography of the two areas is very different. Interpretation of the results from the west are hindered by the almost complete lack of knowledge about the diet of kittiwake chicks there.

Although breeding success may not be the most sensitive measure of breeding performance (Hunt et al. 1986), surveys such as the one described here provide a useful and relatively cheap method of monitoring changes in the marine environment. However the detailed interpretation of the results is dependent on fundamental research into the population dynamics, ecology and behaviour of both seabirds and their prey undertaken at the same time.

References cited are listed in Section 14.

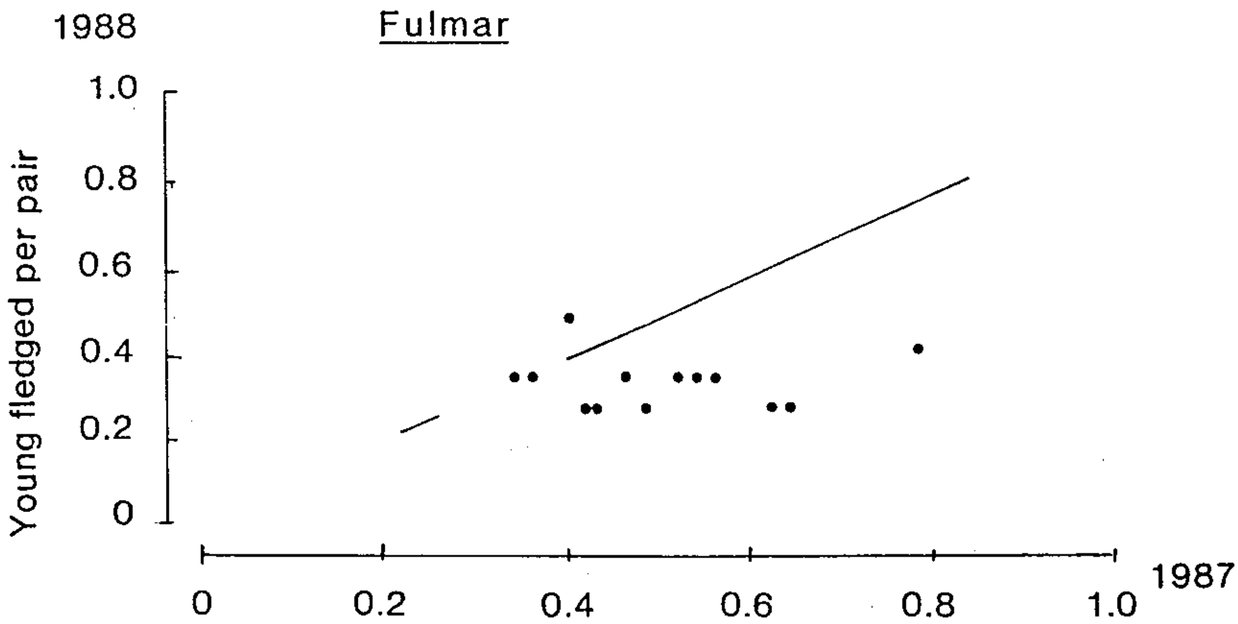

Fig. 5.9. Breeding success (young fledged per pair laying) of fulmars at the same colony in 1987 and 1988. The 'no change' line is shown.

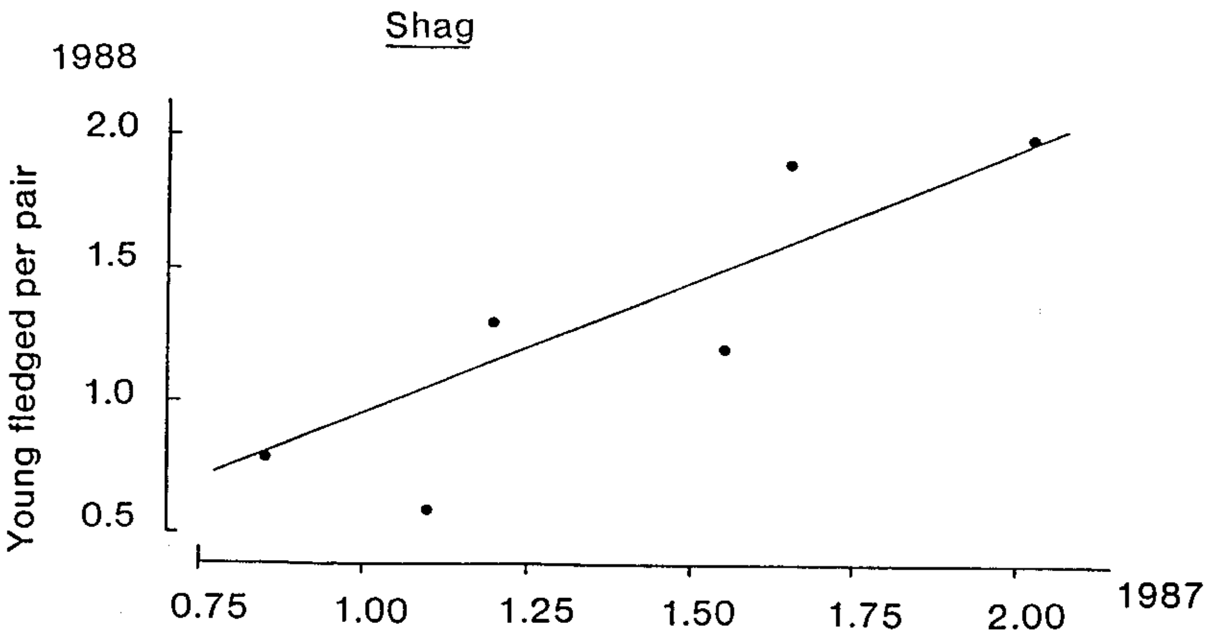

Fig. 5.10. Breeding success (young fledged per nest) of shags at the same colony in 1987 and 1988. The 'no change' line is shown.

Table 5.4. **Breeding success of fulmar 1986-88**

	1986		1987		1988	
	Sites (plots)	Fledged/ site	Sites (plots)	Fledged/ site	Sites (plots)	Fledged site
Eshaness, Shetland	219(4)	0.49±0.10	246(4)	0.55±0.10	?	0.36
Noss, Shetland	?	0.54	?	0.42	?	0.27
Troswickness, Shetland	830(6)	0.56±0.03	385(4)	0.39±0.10	?	0.46
Sumburgh, Shetland	48(2)	0.46-0.61	48(2)	0.53-0.75	?	0.30
Foula, Shetland	?	Good	?	Good	?	Poor
Fair Isle	548(5)	0.48±0.05	494(5)	0.54±0.03	453(5)	0.38±0.04
Iresgeo, Caithness	?	0.41	641(5)	0.35±0.05	562(5)	0.34±0.03
An Dun, Caithness	?	0.43	520(5)	0.34±0.05	667(5)	0.34±0.03
Isle of May	79(11)	0.53±0.10	69(9)	0.47±0.11	64(10)	0.31±0.09
Tantallon, Lothians	no data		101(3)	0.51±0.13	116(3)	0.37±0.10
Farne Is.	43(1)	0.49	31(2)	0.67-0.90	119(5)	0.39±0.06
Guernsey, Herm & Jethou	12(3)	0.50	23(3)	0.17	no data	
Bardsey, Gwynedd	no data		30	0.60	no data	
Calf of Man	no data		no data		52(2)	0.22-0.67
Colonsay	no data		73(2)	0.38-0.52	72(2)	0.27-0.43
Canna	39(2)	0.20-0.48	48(2)	0.46-0.77	50(2)	0.13-0.49
Uig, Lewis	no data		825(11)	0.41±0.03	56(2)	0.14-0.43

Notes: 1) Sources are listed in Table 5.1. Additional sources were C M Reynolds (Uig), M Hill (Channel Islands)

2) Success is expressed as the number of large young present in August in defined parts of the colony divided by the count of apparently incubating birds in the same area in late May or June. Where more than one area was checked the number of plots checked is given in brackets after the total of nests. If two plots were checked the range of success is given, if more then the mean±SE is shown.

Table 5.5. Breeding success of shag, 1986-88.

	Nests (plots)	Fledged/ nest	Nests (plots)	Fledged/ nest	Nests (plots)	Fledged nest
Sumburgh, Shetland		good		good	167	1.44
Foula		good		?		good
Fair Isle	68	1.47	64	1.20	64	1.30
Isle of May	223	0.75	288(14)	1.09±0.14	221(14)	0.61±0.09
Farne Islands			291(10)	1.56±0.13	328(9)	1.22±0.18
Guernsey	no data		79(8)	0.85±0.24	26(4)	0.77±0.28
Bardsey, Gwynedd	no data		29	1.76	no data	
Calf of Man	no data		no data		25% of normal	
Colonsay	no data		37(3)	1.64±0.16	29(3)	1.90±0.10
Canna	13	1.17	50	2.02	46	2.04

Notes: 1. Sources are given in Table 5.1. Additional data from M Hill (Guernsey), Okill (1989; Sumburgh)
2. Success is expressed as young fledged (or very large young present) per completed nest where a bird recorded as 'incubating'. On Canna every nest had eggs present.
3. Where more than one area was checked the number of plots is given in brackets after the total of nests. If two plots were checked, the range of success is given, if more the mean±S.E. is presented.

Table 5.6. Breeding success of gannet, guillemot, razorbill, puffin and black guillemot, 1986-88.

	Nests (plots)	Fledged/ nest, site or burrows	Nests (plots)	Fledged/ nest, site or burrows	Nests (plots)	Fledged/ nest, site or burrow
Gannet						
Fair Isle (incubating bird)	124	0.68	107	0.48	126	0.78
Guillemot						
Fair Isle (occupied site)		good		good	107(2)	0.77-0.80
Foula (impression)		good		good		good
Rest of Shetland (impression)		good		good		good
Marwick Head (site)	67	0.71	73	0.70	64	0.78
Isle of May (egg laid)	785(5)	0.82±0.02	800(7)	0.76±0.02	732(6)	0.85±0.02
Farne Islands (egg laid)	57(2)	0.47-0.74	86(2)	0.54±0.85	70(3)	0.79±0.02
Handa (site)	no data		no data		92(2)	0.76±0.88
Razorbill						
Foula (impression)		good		good		poor
Rest of Shetland (impression)		normal		normal		normal
Isle of May (egg)	84(5)	0.72±0.06	64(4)	0.71±0.12	98(5)	0.70±0.05
Handa (site)	no data		no data		114(2)	0.82±0.86
Puffin						
Hermaness, Shetland (impression)	very poor		very poor		very poor	
Foula (impression)	poor		poor		poor	
Fair Isle (egg laid)	no data		93	0.70	71	0.75
Isle of May (egg laid)	136	0.80	176	0.93	157	0.88
Skomer, Dyfed (occupied burrow)	40	0.87	62	0.76		
Black Guillemot						
Fair Isle (occupied site)	no data		24	0.58	14	0.57

Notes. 1. Sources given in Table 5.1. Additional data from Martin (in press), Okill (1989).

2. Where more than one area was checked, the number of plots followed is given in brackets after the total of nests. If two plots were checked the range of success is given, if more than two the mean is shown.

5.3.2 Fulmar. Details are given in Table 5.4. There was a small but not statistically significant reduction in breeding success between 1986 and 1987 but a significant reduction of 30% between 1987 and 1988 (Fig. 5.9).

5.3.3 Shag. Breeding success varied greatly (Table 5.5) but there was no significant change between 1987 and 1988 (Fig. 5.10). There were too few data to compare 1986 and 1987.

5.3.4 Other species. Breeding success of puffin, guillemot, razorbill and gannet remained high (Table 5.6).

6 ADULT SURVIVAL RATES

6.1 Coverage. Data were collected from the Isle of May (puffin, guillemot, razorbill, shag and kittiwake. Survival of herring and lesser black-backed gulls will be monitored starting in 1989, Skomer (puffin, razorbill, herring and lesser black-backed gulls; data to be supplied separately in C M Perrins' report to NCC; adult and immature survival of guillemots is being followed by T R Birkhead), Canna (kittiwake), Fair Isle (kittiwake, puffin, black guillemot and shag), Hermaness (shag, gannet).

6.2 Data are given in Table 6.1.

6.3 The survival of puffins on the Isle of May averaged 95.6% 1973-81 but then declined to average 87.6% 1981-88. Survival of adults on Skomer showed a similar decline and there was a significant positive correlation between the two survival rates over the 13 seasons where data were available (r_s = 0.63 P 0.05). This correlation is unexpected as puffins from the two colonies winter in different areas. Factors influencing winter survival appear to be acting over a wide area.

6.4 Survival rates of other species on the Isle of May were high but survival of shags between 1987 and 1988 was lower than anticipated. There are as yet too few data from elsewhere for any meaningful comparisons to be made.

6.5 My attempts to get amateurs and wardens to measure adult survival showed that worthwhile data are only likely to come from dedicated professional ornithologists. Despite some ringers being keen and willing to colour-ring birds, they just do not have the time to search for colour-rings in the years following the initial ringing. Such searchs are best made early in the season before birds lay; few

Table 6.1 Annual survival rates of adult seabirds 1987-1988.

	Alive 1987	Seen 1988	% 1987-88	% Survival 1986-87
1. Isle of May				
Guillemot				
Breeding	353	323	91.5	97.3
Nonbreeding	32	24	75.0	50.0
Total	385	347	90.1	95.1
Razorbill				
Breeding	67	59	88.1	92.7
Nonbreeding	9	6	66.7	75.0
Total	76	65	85.5	91.5
Puffin				
Breeding	163	124	76.1	81.2

Note: It is very difficult to find every bird each year so this figure is certainly too low. However, including birds missing in 1987 but seen in 1988 only increased the survival 1986/87 to 84.3%.

	Alive 1987	Seen 1988	% 1987-88	% Survival 1986-87
Kittiwake				
Breeding				
Low light	81	70	86.4	95.7
Tarbet	83	71	85.5	96.5
Total	164	141	86.0	96.1
Shag				
Breeding	172	133	77.3	91.4
Oystercatcher				
Adults	62	55	88.7	92.1
2. Fair Isle				
Shag	104	40	38.5	82.1
Kittiwake	108	38	35.2	80.4
Black Guillemot	11	8	72.7	-
Puffin	140	109	77.9	85.3

Note: The kittiwake figure is unrealistic due to the checks for rings being made after some birds had lost eggs or chicks.

non-professionals have spare time then. Amateurs should be discouraged strongly (or perhaps even banned) from colour-ringing adult seabirds unless they have well formulated and attainable aims.

6.6 Fair Isle B.O. had difficulties in resighting colour-ringed shags and kittiwakes. The survival rates recorded (38% for shag, 35% for kittiwake) are unrealistically low. In the case of the shag the difficulties in finding shags if they move even to the next bay are unsurmountable. This study should stop. A serious attempt must be made to find colour-ringed kittiwakes in April/May 1989; if this proves to be impractical this work should also stop. There is little point in continuing with colour-ringing black guillemots as the sample sizes will always be very small. Colour-ringing of puffins should continue.

6.7 Experience has shown that a sample of about 150 individually colour-ringed birds is (a) large enough to yield useful results, and (b) small enough to be manageable logistically.

6.8 Several amateurs have colour-ringed seabird chicks to try and measure recruitment. Some have obtained useful data on age of first breeding, but in general, studies of recruitment require a full-time professional ornithologist. Recruitment studies should remain the responsibility of research organisations and universities supported by NCC and other grants.

7 FOOD OF YOUNG SEABIRDS IN 1988

7.1 As in 1986 and 1987, Fair Isle, the Isle of May and Canna were covered fairly adequately as regards sampling the food of young, but in general it is difficult to get ringers to collect fish. Details of diet and measurements of prey are given in Appendix 7.

7.2 Sandeels were by far the commonest prey for the young of most species but some species in Shetland appeared to have been forced to switch to other prey. Changes in the food of seabirds at Hermaness NNR have been documented in detail by A R Martin (in press) who has been partly funded by this project. His paper on this is included as Appendix 8.

TABLE 7.1. Diet (% by number) of young seabirds on Fair Isle in 1986-88. The figure in brackets after the number of fish is the number of regurgitations or fish loads examined.

	Range of sampling dates	Total No. of fish in samples	% of samples which contained					
			Sandeel	Sprat or Herring	Gadidae	Butter -fish	Fishing offal or waste	Other items
Fulmar								
1986	24/7-11/8	?(24)	4	0	0	0	96	0
1987	/7- /8	?(14)	29	0	0	0	65	6
1988	1/7-10/8	?(37)	3	0	0	0	94	3
Shag								
1986	25/6-8/7	32(11)	100	0	0	0	0	0
1987	/ - /7	394(35)	100	0	0	0	0	0
1988	3/7-30/7	36(11)	93	0	0	0	0	7
Razorbill								
1986	24/6-16/7	26(26)	100	0	0	0	0	0
1987	-	31(31)	97	3	0	0	0	0
1988	3/7-30/7	4(4)	75	25	0	0	0	0
Guillemot								
1986	15/6-1/7	47(47)	96	4	0	0	0	0
1987	/6- /7	30(30)	100	0	0	0	0	0
1988	14/6-8/7	89(89)	99	0	1	0	0	0
Black Guillemot								
1987	6/7-12/7	51(51)	37	0	0	61	0	2
1988	11/7-4/8	40(40)	0	0	15	48	0	37
Kittiwake								
1986	5/7-8/7	151(24)	100	0	0	0	0	0
1987	/6- /7	211(34)	100	0	0	0	0	0
1988	26/6-9/7	29(8)	94	0	0	0	0	6

7.3 The food of some young seabirds on Fair Isle in 1986-88 by M.P. Harris & N.J. Riddiford

7.3.1 During the 1980s numbers of some species of seabird in the main part of Shetland have declined and breeding success has been low (Heubeck et al 1986, Shetland Bird Report 1987, Heubeck 1988, Monaghan et al. 1989, Furness 1989). In 1988, few young were reared by arctic terns, kittiwakes, great skuas and arctic skuas (Heubeck 1988). The reasons for these failures are unclear but changes in food supply have been suggested (Heubeck & Ellis 1986, Martin in press, Monaghan et al 1989). This report summarizes what is known about the food brought in for chicks of thirteen species o seabird on Fair Isle between 1986 and 1988 and presents more detailed information on the diet of puffin chicks for seven years between 1974 and 1988. References cited here are listed in section 14.

7.3.2 Food samples obtained were (a) regurgitations produced by young herring gulls, lesser black-backed gulls, great black-backed gulls, kittiwakes, great skuas, arctic skuas, fulmars and shags caught for ringing,(b) loads of fish dropped by puffins caught in mist-nets, (c) fish found in colonies of guillemot, razorbill, black guillemot, arctic and common tern and (d) fish identified during observations from a hide of young guillemots (4 days in 1988) and black guillemots (4 days in 1987, 8 days in 1988). Fish or regurgitations were usually weighed, and the sandeels *Ammodytes* spp. were also measured (length to tip of tail) or, if partly digested assigned to 2 cm categories by reference to intact fish and then deep frozen for later examination. No fish from kittiwakes or shags were measured in 1987. Chick diet is expressed as percentage (by numbers) of specific items in the regurgitations or fish examined. Very few regurgitations contained more than a single item and those which did are mentioned below.

Breeding success was determined by (a) regular checks of nests without disturbing the birds, using numbered photographs or diagrams, or (b) for puffin and black guillemot by checks of burrows after birds had laid and before the young fledged.

7.3.3 Details of the main food items fed to chicks, and the ranges of sampling dates are given in Tables 7.1 and 7.2. As the diet of seabird chicks can vary within a season and dropped fish may be unrepresentative of those actually eaten, conclusions which are based on small samples, should be treated with caution. Nevertheless the general differences in diet between years are clear.

TABLE 7.2. Weight (g) and composition of loads of fish taken from puffins on Fair Isle in 1974-88. In 1988, the fish under sprat could have been a juvenile herring and there were also two Norway pout and one unidentified flatfish.

	Range of sampling dates (days) sampled	Mean weight ±SE (n)	Total fish	% Total fish: Sandeels large	Sandeels small	Whiting	Sprat	Rockling	Saithe
1974	10/7-14/7(3)	?	47	64	11	25	0	0	0
1975	15/6-24/7(6)	?	117	32	45	0	10	13	0
1976	16/6-27/7(10)	6.2±0.5(61)	212	88	6	0	0	3	3
1977	15/7-27/7(5)	7.3±0.6(42)	277	5	89	1	4	1	0
1986	27/6-23/7(6)	7.0±0.8(20)	44	26	70	2	0	2	0
1987	/6- /7( )	4.6±0.4(27)	32	22	78	0	0	0	0
1988	2/7-21/7(5)	6.0±0.6(34)	116	7	22	50	1	1	0

Fulmar: Offal and small fish, probably from trawler discards, made up at least 65% of the diet each year. Fish identified included Trisopterus sp. (probably Norway pout T. esmarkii) (3), whiting Merlangius merlangus (2), probable hake Merluccius merluccius (1), unidentifiable Gadidae (1) and a cartilaginous fish; sandeels were important only in 1987. Other items were a minute 'shrimp' and a whelk operculum.

Shag: All the regurgitations contained sandeels and one sea-scorpion Taurulus bubalis was also recorded. In 1986 all the sandeels measured were between 10 and 13 cm long (Fig.7.1). A much greater size range was apparent in 1988.

Kittiwake: Except for a 1 cm-long 'shrimp' and an unknown fish in the same sample, all regurgitations consisted entirely of sandeels. Like shags, kittiwakes regurgitated more large sandeels in 1988 than in 1986 (Fig. 7.1).

Guillemot: Sandeels made up 98% of the 166 fish identified; the exceptions were two sprats Sprattus sprattus and one Trisopterus sp. The mean lengths cm±S.E. (and sample sizes) of sandeels were 12.9 ± 0.5 (45) in 1986, 13.7 ± 0.1 (30) in 1987 and 11.1 ± 1.4 (8) in 1988. Thus guillemots brought in smaller sandeels in 1988.

Razorbill: This species often carries several fish at a time for the chick so it is not known how many loads the 61 fish represented. All the items were sandeels except for two 11 cm long fish which were either sprat or herring Clupea harengus.

Puffin: In the six years between 1974 and 1987 for which data were available sandeels were by far the commonest prey and made up 75-100% of the fish fed to chicks (Table 7.2). However, in 1988 sandeels formed only about 30% of the diet and Gadidae, mainly whiting with a few Norway pout, were the main prey. The only other year in which whiting formed a major component of chick diet was 1974. Despite the changes in species composition the weights of whole loads in 1988 were similar to these in previous years.

Sandeels of several different age classes are eaten by seabirds and these can be divided into the 0-group (those hatched in the current calendar year and usually less than 10 cm long) and older fish (usually longer than 10 cm). The mean sizes of the two groups taken from puffins in each year are shown in Fig. 7.2. 1976 and 1977 were unusual in that very few larger sandeels were taken even though there appeared to be good numbers of these size-classes recruiting into the Shetland sandeel populations (Kunzlik 1989). The few 4-6 cm long sandeels in 1976 came presumably from a late-spawning stock.

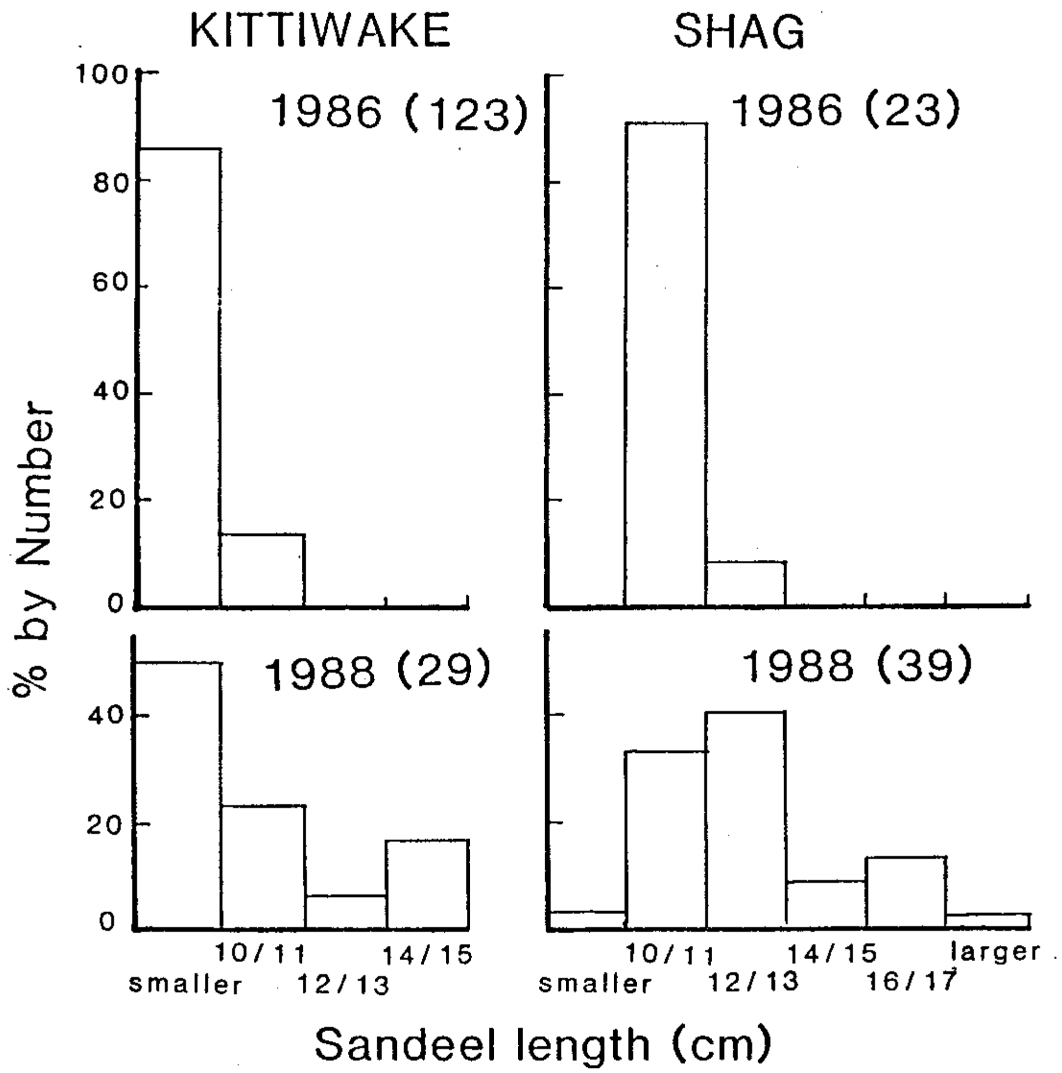

Fig. 7.1. Size distribution (in 2 cm categories) of sandeels regurgitated by kittiwake and shag on Fair Isle in 1986 and 1988. The numbers of fish measured are given in brackets.

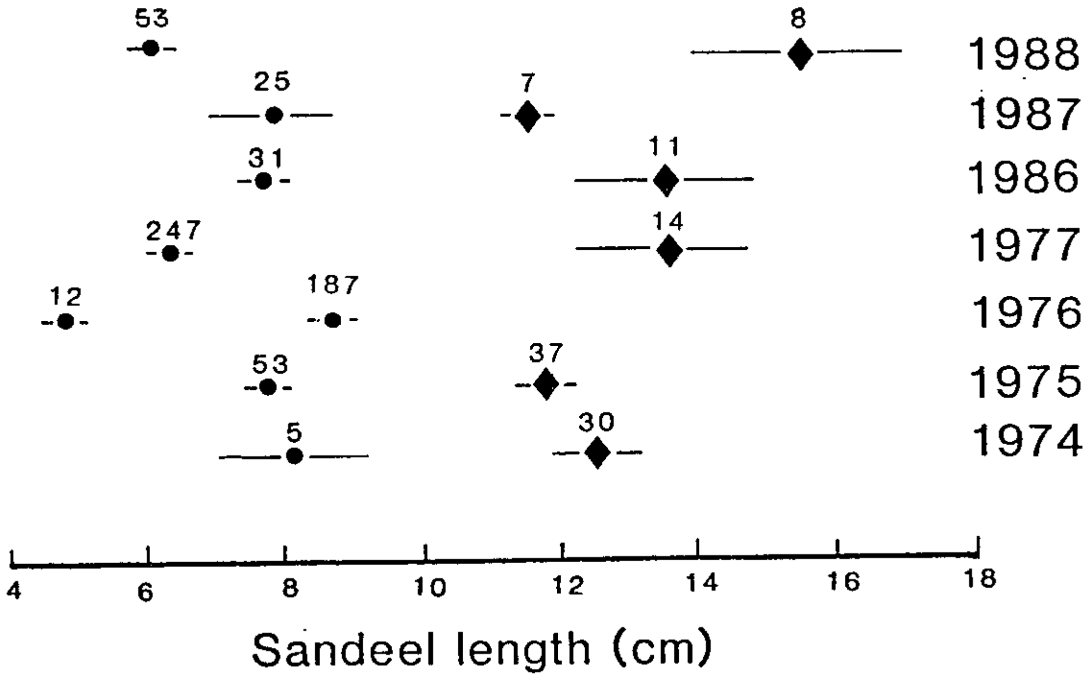

Fig. 7.2. Mean values ±2SE of the two sizes of sandeels brought ashore by puffins on Fair Isle, 1974-88. The sample sizes are also shown.

Table 7.3. Breeding success of seabirds on Fair Isle, 1986-88.

	Chicks reared/pair laying					
	1986		1987		1988	
Species	pairs	young/pair	pairs	young/pair	pairs	young/pair
Fulmar	548	0.47	494	0.53	453	0.38
Gannet	124	0.68	107	0.48	126	0.78
Shag	64	1.30	64	1.20	68	1.47
Kittiwake	1034	1.02	1497	1.00	315	0.09
Black Guillemot		?	25	0.48	14	0.57
Puffin		?	93	0.70	71	0.75
Arctic Tern		?	211	0.00	345	0.003
Common Tern		?	37	c.0.50	59	0.03

Black guillemot: Butterfish Pholis gunnellus were the commonest food of chicks in both 1987 and 1988. Although sandeels were the other main item in 1987 none were recorded in 1988 and their place was apparently taken by long-spined sea-scorpion Myoxocephalus scorpius (5), sea-scorpion (5), Yarrell's blenny Chirolophis ascanii (1) and a single minute rockling. All but three of the sea-scorpions were found lying in the colony, so many of these fish may have been too spiny or awkward for the chicks to swallow. Three flatfish were recorded in 1988 and one in 1987.

Other seabirds: In 1986 no data were collected for species other than those mentioned above and the only additional record for 1987 was of five 5-6 cm sandeels dropped by common terns. In 1988 arctic terns brought in three sandeels 9-11 cm long. Regurgitations from arctic skua chicks collected between 24 June-14 July contained sandeels (3), other small fish (1), and the stomach of a bird (1). Those of great skua chicks collected between 3 July-6 August contained mammalian or bird flesh (5, one also had a piece of fish), young rabbit (1) and probable trawler discards (3). Young great black-backed gulls regurgitated fish flesh (1) and a 10-12 cm sandeel (1) on 5 July. Lesser black-backed gull chicks regurgitations collected between 6 June-18 July contained a 14 cm Gadidae (1) and toast and fish offal together (1), whilst young herring gulls handled on 6 June-18 July regurgitated sandeels (3), fish discards (3), the remains of a guillemot egg (1), a whole guillemot chick (1) and a small oily fish.

7.3.4 In 1986 the four species monitored had relatively successful breeding seasons (Table 7.3). In 1987 fulmars, shags and kittiwakes showed little change in breeding success from the previous year but gannets Sula bassana fledged markedly less young. Arctic terns fledged no young at all. There was a wide disparity in the breeding success of the various species in 1988. Chick production was high for gannets and shags but there was almost a total failure among kittiwakes and the two species of tern. Of the remaining species fulmars fledged fewer young than in the previous two years, whereas breeding success was slightly higher in the black guillemot and puffin.

7.3.5 During the study sandeels were present to a greater or lesser degree in the chick diet of all the species of seabird sampled. The importance of sandeels during chick rearing is well known and has previously been demonstrated in a wide range of seabirds at colonies around Britain (e.g. Pearson 1968, Furness 1983, Ewins 1985, 1986, Harris & Wanless 1986). The only notable difference in the diet of any species on Fair Isle and elsewhere was that of the fulmar. In 1986-88 sandeels made up only 3-29% of the chick diet which was a much lower proportion than the 72% recorded on Foula, Shetland between 1978 and 1982 (Furness & Todd 1984) and 47% recorded on Yell, Shetland in 1984 and 1985 (Fowler & Dye 1987); it was, however, similar to the 3% on Foula in 1988 (Furness 1989).

Clearly 1988 stands out as a very odd breeding season. Kittiwakes, common terns and arctic terns all nested in record numbers (pers. obs.) but failed almost completely to raise their young. Fulmars did moderately well and gannets, shags and auks reared good numbers of chicks. Sandeels formed a much smaller proportion of the diet of puffin chicks and were completely absent from that of black guillemot chicks in 1988 (Table 7.1). Although the sizes of sandeels taken from puffins in 1988 were not markedly different to previous years (Fig. 7.2), kittiwakes and shag regurgitations contained a higher proportion of large sandeels in 1988 than 1986 (Fig. 7.1).

In contrast, the mean size of sandeels found in the guillemot colonies was lower in 1988 compared to either 1986 or 1987. However the situation in the guillemot is confused by the fact that an unknown proportion of these fish would have been used for display and such fish are generally smaller than those fed to for chicks (Harris & Wanless 1985). Many of the 1988 fish may have been for display. There was nothing unusual in the measurements of sandeels from Puffins in 1988

The large difference in breeding success between the various species in 1988 is consistent with the idea that there was a shortage of small sandeels at or near the sea surface. This would be expected to have a catastrophic effect on kittiwakes and terns which feed in the top few centimetres of the water column. For these species there was apparently no alternative source of food and their young starved. In contrast, species which feed by pursuit-diving could either still find sandeels of a suitable size, e.g. shag and guillemot, or could switch to an alternative prey species e.g. puffin and black guillemot. From studies on the Isle of May it is clear that the diet of young puffins can change quite considerably over a period of years (Harris 1984). However, on the Isle of May the alternatives to sandeels, namely herring and sprats are of much higher energy value than the whiting which formed a large part of the chicks diet on Fair Isle in 1988. On St Kilda, Western Isles, young puffins which received a high proportion of whiting in their diet in the wild had relatively low fledging weights, and captive chicks fed ad lib. on a diet exclusively of whiting could not be reared successfully (Harris & Hislop 1978). Although the increased proportion of whiting did not apparently have an adverse effect on breeding success of Fair Isle puffins, at Hermaness, Unst, puffins in 1987 and 1988 brought in small loads of very small rockling and gadoids; chicks were found dead in this colony and breeding success was probably very low (Martin in press). It therefore seems likely that an increased dependence on whiting during chick rearing would ultimately result in a lower breeding success of Fair Isle Puffins.

Gannets on Fair Isle were more successful in 1988 than in the two previous years. This species feeds by plunge diving so can exploit prey lower in the water column than either kittiwakes or terns although it cannot dive as deeply as the pursuit-divers. It is also a much more efficient flier than the auks or shag and has a potential foraging range in excess of 100 km which is considerably more than the estimated 30 km for auks and 15-20 km for shags (Pearson 1968, Nelson 1978, Bradstreet & Brown 1985, Tasker et al 1987). The diet of gannet chicks on Fair Isle was not sampled but it can apparently rear its young successfully on a wide range of fish species. Studies in Shetland and elsewhere have shown that the relative importance of sandeel, mackerel Scomber scombrus and herring can change over a period of years (Wanless 1984, Martin in press). The current recovery of herring stocks in the North Sea (Saville & Bailey 1980, updates from ICES Reports) is likely to be advantageous for the gannet, which can take adult herring. It may, however, be detrimental to seabird species which depend on small sandeels as herring are major predators of sandeel larvae (Hardy 1924).

The biomass of spawning sandeels (i.e. 2 or more years old), around Shetland increased through the 1970s to a peak in 1984 and then declined; the decline in numbers of 0-group sandeels was much more marked with a reduction of maybe 80% between 1982 and 1985 and the sparse data suggest that very few were present in 1988 (details in Kunzlik 1989). There is disagreement as to whether these changes are natural (Kunzlik 1989) or a result of the Shetland sandeel fishery (RSPB Press release, Shetland Fishing News). Some support for the former comes from the finding that Kittiwakes in many colonies as far south as the Firth of Forth and the Irish Sea were also less successful in 1988 than they had been in 1987 (pers. obs.). This suggests that the events recorded in Shetland were part of a more widespread phenomenon which was also apparent in areas without a human sandeel fishery.

7.4 Calorific analyses of fish collected in 1987-88 confirmed the preliminary findings that food quality was good (Appendix 9). Sprats from guillemots on Canna were of extremely high calorific value.

7.5 On the Isle of May, feeding frequency of the young of the three species of auks was high and the food quality good.

7.6 In the puffin there is a significant negative correlation between the weight of a chick feed and the feeding frequency. The same may well occur in other species. Therefore, a realistic measure of feeding conditions of the chick needs estimates of both meal size and feeding frequency. The measurement of feeding frequency is time consuming, even for auks, and very difficult for shag and kittiwake which have several young and which may feed each several times after each foraging trip. Only research workers have sufficient time to obtain accurate results and NCC's monitoring will have to be restricted to describing what prey species young are fed rather than how much food they receive.

7.7 Many seabirds produce pellets which contain the undigested remains of prey. Otoliths from fish are common in pellets and can often be identified to species and their lengths used to estimate the size of the fish which they came from. Many workers have used otoliths to describe the diets of seabirds but few have checked the validity of their results.

7.7.1 The usefulness of pellets for assessing the diet of adult shags Phalacrocorax aristotelis

Several different methods are commonly used to investigate the diet of adult seabirds, (a) making direct observations of feeding birds, (b) examining stomach contents either by killing birds or flushing out the food from the stomach, and (c) examining the remains in regurgitated pellets. All these techniques have serious limitations and biases associated with the interpretation of the results. For instance observations of feeding birds will tend to record large, difficult to handle prey; soft-bodied prey will leave few, if any, traces in pellets. Some cormorants Phalacrocoracidae regurgitate mucus covered pellets which contain calcareous fish otoliths (sagittae) and bones, fragments of crustacea, cephalopod beaks which can often be identified to species, and stones. Even though it is known that some of the otoliths, which are composed of calcium carbonate, are completely digested in the acid conditions of the stomach[1,2], the relative proportions of the otoliths of different species in the pellets have been used to document the diet of several species of cormorant.[1,3,4]

Adult shags Phalacrocorax aristotelis visit colonies such as the one on the Isle of May, Firth of Forth, Scotland, throughout the year, and it is possible to collect large numbers of pellets. We were interested in annual and seasonal changes in the food of these shags but, bearing in mind the warning of Hartley[5] who stressed that pellets alone should not be used in food studies until preliminary trials had established their quantitative and qualitative adequacy, we wished to check whether the remains of the prey species could be detected in the pellets with equal, or at least predictable, accuracy. Two studies of stomach contents of shags collected in Scotland[6,7], and our own observations of food regurgitated by adult and young shags, indicated that sandeels Ammodytidae (mainly Ammodytes marinus), Clupeidae (mainly sprat Sprattus sprattus and herring Clupea harengus) and Gadidae were likely to make up most of the diet. We therefore fed captive shags known numbers of known size sandeel, herring, sprat and cod Gadus morhua, and examined the contents of the pellets that they produced to determine (a) what proportion of the otoliths from these fish were recovered, and (b) whether or not the measurements of the otoliths gave an accurate indication of the size of the fish that had been eaten.

7.7.2 Two adult male and 2 adult female shags were caught at their nest-sites prior to breeding, marked with colour-rings, and kept (under licence) in captivity out-of-doors from 30 May until 28 June. They were then released, apparently in good condition. Each bird was weighed when it was caught and when it was released. The 2 males and the 2 females were kept together in adjacent pens 4.2 x 2.0 x 2.2 m. Each pen contained rocks and artificial ledges, a feeding tray, water and a supply of grit. Each bird had its own favourite perch, and in general pellets were found below these perches, so that many pellets could be assigned to an individual bird. However, for analyses the pellets from a pen were combined. Each morning, the pens were searched thoroughly for pellets and then hosed clean and the shags fed.

Birds were fed a single species of fish each day. All fish came from northeast Britain and were deep frozen until needed. They were of fairly uniform size (Table 7.4). Each fish was measured (snout to tip of tail to nearest 5 mm) and the total weight of fish put into each pen recorded. Fish were sprinkled with coarse sand (to encourage pellet formation). For the first few days birds were force-fed, but then they eagerly ate all fish presented. During the total time they were in captivity each male and female ate a mean of 288 and 267 g fish/day - which was 16-18% of the initial weight of the birds. These figures agree well with the published figures of daily intakes of 16-17% adult weight by long-tailed cormorants *P. africanus* and white-breasted cormorants *P. carbo lucidus*.[8,9] Pellets were not produced regularly until the birds had been in captivity for 9 days so Day 1 of the experiment was set at 8 June. The experiment ended on Day 21. For convenience, a meal and the pellets produced within 24 hr of the meal are given the same day number.

7.7.3 Pellets were produced overnight, or early in the morning. Twice one female produced a pellet when it was about to start feeding. Each pellet collected was put in a strong solution of a biological washing powder (Biotex) which dissolved the mucus but left the otoliths, sand and the few fish bones present. The treatment had no demonstrable effect on the length of otoliths, the means $\pm$SD of 30 measured before and after 48 hr soaking were 2.52 ± 0.26 and 2.47 ± 0.28 mm, respectively ($t = 0.75$, n.s.). Otoliths were removed and identified. Each fish has two otoliths but no attempt was made to pair up otoliths, rather we counted the number found and compared the counts with twice the number of fish fed. The lengths of samples of otoliths removed from fish and from the pellets collected the first day after a change of food species were measured to the nearest 0.05 mm under a dissecting microscope. Fish lengths (FL) were back-calculated from the otolith length (OL) or otolith width (OW) using published formulae[10,11] -

Sandeel FL (mm) = $8.776 + 51.91$ OL (mm)
Herring FL (mm) = $-8.50 + 58.46$ OL (mm)
Sprat FL (mm) = $-25.28 + 137.24$ OW (mm)
Cod FL (mm) = $9.883\ \mathrm{OL}^{1.439}$ (mm)

7.7.4 **Birds:** The birds took readily to captivity, became relatively tame and once they were kept two to a pen did not try to escape. The weights of the 2 males at capture/on release were 1760/1625 g and 1800/1575 g, and the 2 females were 1440/1205 and 1560/1330 g. Although all birds were lighter after the experiment the difference could well have been due to them not having been fed for 24 hr prior to the second weighing or to using up fat laid down in preparation for breeding prior to capture.

7.7.5 **Pellets:** Most days, each bird produced one pellet (Table 2). All but one pellets contained some otoliths, the one which didn't was one of two produced by a bird on a single day. One female produced pellets rather irregularly whilst on a few occasions three pellets were recovered from 2 birds of either sex

Table 7.4. Measurements of the total length (mm) of samples of the fish fed to shags

Species	Number	Mean	S.D.	Range
Sandeel	283	157	21	120-205
Herring	292	134	9	110-165
Sprat	263	165	17	120-220
Cod	65	188	23	110-245

in one day. It is not clear whether such irregularities in pellet production also occur in wild birds or whether they were due to captivity. The species of fish eaten did not influence the number of pellets produced (pooling sexes, $X^2_3 = 1.5$, n.s.). When the species of fish fed was changed the pellets produced later that day contained only otoliths from the new species. However, if a pellet was not produced, then some otoliths from that day were sometimes found in pellets produced after the next meal, i.e. 25-48 hr later (Table 2). No otoliths were found in faeces.

7.7.6 **Otoliths recovered:** There was great variation in the proportions of ingested otoliths which were recovered from the pellets with regard to species eaten, the sex of the bird, and day (Table 7.5). The recovery rate was highest for the relatively large otoliths from cod (73%) and lowest for the smaller and more delicate otoliths from sprat (22%). This was not unexpected as herring otoliths dissolve much faster in acid (and so presumably in stomachs) than do those from the gadoid haddock *Melanogrammus aeglefinus*.[12] Measurements and weights of otoliths suggest that those from Ammodytidae will dissolve at an intermediate rate.[13] For each fish species, the recovery rate was consistently higher for the two males, presumably because one of the females occasionally failed to produce a pellet and so completely digested a higher proportion of the otoliths. Considering only the days when both birds in a pen produced a pellet, there were significant differences in the proportions of otoliths ingested which were recovered from males and females for both sprat (male $X^2_5 = 24.0$, female $X^2_5 = 34$; $P < 0.001$) and sandeel (male $X^2_5 = 56$, $P < 0.001$, female $X^2_5 = 31$, $P < 0.001$). There were too few data for tests to be made for herring and cod.

7.7.7 **Otolith length:** The lengths of otoliths of sandeels and herring from pellets were significantly smaller than those from a sample of the fresh fish (Table 7.6). Calculation of the lengths of fish from the measurements of otoliths in pellets produced within 24 hr of the birds having been given a change of fish gave very inaccurate estimates of the sizes of the fish that were eaten (Figure 7.3). The smaller otoliths had presumably been completely digested. Assuming this, a comparison of the distributions of the known and calculated fish in Figure 7.3 suggests that the otoliths had been completely digested for most sandeels below 16 cm long, herring below 14 cm and sprat and cod below 19 cm.

7.7.8 DISCUSSION: The possibility of using pellets to assess the diet of the shag is attractive. Large numbers of pellets are easily collected in a systematic way throughout the year without disturbance to the birds; vast numbers of otoliths can be assembled and identified. However, opinion varies as to the usefulness of cormorant pellets. Ainley *et al.*[3] considered that they were equivalent to stomach samples in terms of what they indicated about diet, Duffy & Laurenson[2] showed that some otoliths of fish eaten by cape cormorants were completely digested but still considered that pellets were ideal for long-term studies of changes in the marine environment, and they have been used for such[4].

The results of our feeding trials were unambiguous. Many otoliths were completely digested, the proportion varied between prey

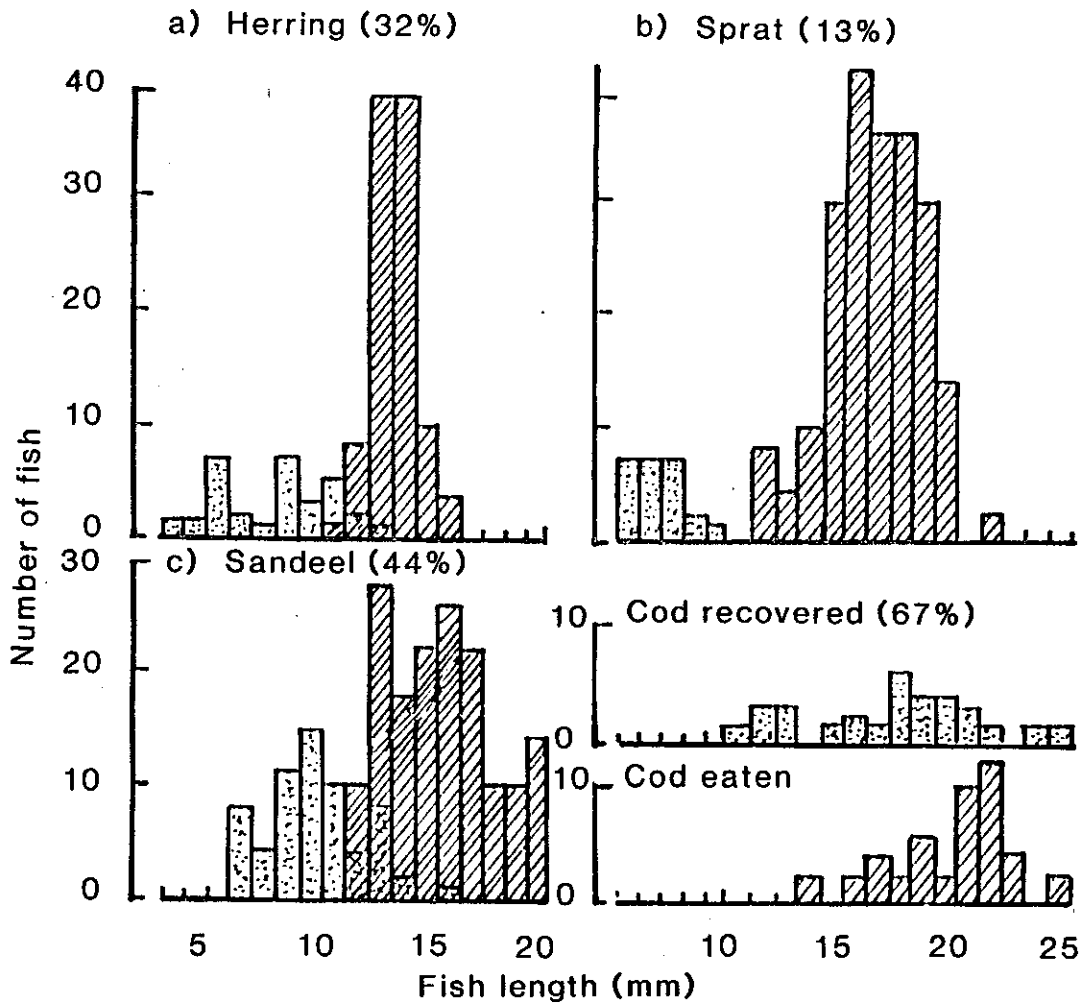

Fig. 7.3. The distribution of fish length of a) herring, b) sprat, c) sandeel and d) cod fed to shags (cross-hatched) compared with the distribution calculated from fish otoliths (stippled) recovered from pellets produced within 24 hr of the feeds. The percentages are the recovery rates for otoliths during these particular days.

Table 7.5. Details of fish fed to two male and two female *Shags, the number of pellets produced and the fish otoliths they contained.

Day	Fish eaten	MALES Pellets produced	MALES Otoliths swallowed	MALES Otoliths recovered	MALES %	FEMALES Pellets produced	FEMALES Otoliths swallowed	FEMALES Otoliths recovered	FEMALES %
1	Sandeel	1	126	65	52	1	138	28	20
2	Sandeel	1	130	65	50	1	116	22	19
3	Sprat	2	70	9	13	2	44	7	16
4	Sprat	2	58	25	43	2	54	17	31
5	Sprat	2	42	22	52	2	66	1	2
6	Cod	2	28	25	89	1	22	6	27
7	Cod	2	24	24	100	2	22	20	91
8	Cod	1	16	15**	94	0	22	8***	36
9	Herring	2	102	17	17	2	90	19	21
10	Herring	3	104	30	29	2	76	10	13
11	Herring	2	108	26	24	3	104	29	28
12	Sandeel	2	160	73	46	1	112	43	38
13	Sandeel	3	136	77	57	2	156	69	44
14	Sandeel	2	170	132	78	1	184	46	25
15	Sprat	2	42	7	17	2	48	7	15
16	Sprat	2	54	8	15	2	44	12	27
17	Sprat	2	52	16	31	2	28	3	11
18	Sandeel	1	172	58	34	1	210	5	23
19	Sandeel	2	176	76	43	0	168	0	0
20	Sandeel	2	138	89	64	2	162	27	17
21	Sandeel	2	164	101	62	1	140	35	25
Totals									
9	Sandeel	16	1372	736	54	10	1386	275	20
6	Sprat	12	318	87	27	12	284	47	17
3	Cod	5	68	64	94	3	66	34	52
3	Herring	7	314	73	23	7	270	58	21

*number of fish eaten is half the number of otoliths

**includes 7 in a pellet from Day 9

***all in a pellet from Day 9

Table 7.6. Measurements (mm) of otoliths dissected from fish and taken from pellets produced within 24 hours of birds first being fed on sandeel and herring

	From fish			From pellets					
	Number	Mean	S.D.	Number	Mean	S.D.	% decrease in size	t	P
Sandeel	30	2.525	0.258	73	2.006	0.320	-20	7.8	<0.001
Herring	30	2.367	0.102	30	1.608	0.421	-32	9.6	<0.001

species, measurements of otoliths which were recovered would, if taken at face value, have given very biassed estimates of the sizes of the prey eaten. These results agree with the results obtained by previous workers on the diet of both marine birds and mammals,[1, 2, 12-15] and do not inspire confidence in the use of pellets to describe the sizes of fish eaten by shags. Although it might be possible to calculate better correction factors to allow for differential rates of digestion of otoliths, or to use otolith thickness as a better predictor of original otolith, and therefore fish size[15], or to measure only apparently undigested otoliths,[14, 15] such refinements are of limited value when it is suspected that some species and/or age classes of prey cannot be detected at all.

7.7.9: The results of our experiments gave us confidence that, if the shags were feeding on larger Ammodytidae, Clupeidae, and Gadidae, we would detect some remains in the pellets and be able to say, for example, that 'x% of pellets collected in a certain month contained Ammodytidae'. Further, we might calculate approximate correction factors for different species and so convert the results to 'y% of the fish of species represented in the pellets were Ammodytidae'. However, the otoliths of smaller individuals of these species, and of much larger individuals of species which have small or easily digested otoliths,[10, 13] may be completely digested so that it may never be possible to say that 'z% of the diet was Ammodytidae'. Two studies of the stomach contents of Scottish shags have been made and both have found a wide range of fish.[6,7]. Assuming that any otolith with a length of less than 3 mm (equivalent to a sandeel 16 cm long) would be completely digested and that the digestibility of otoliths of other families is similar to that of Ammodytidae, at least 15% of the individual fish recorded in these studies would have gone undetected had pellets been used instead of part-digested stomach contents. The main families (and the species eaten commonly by shags) overlooked would be Zoarcidae (eel pout or viviparous blenny *Zoarces viviparus*), Pholidae (butterfish *Pholis gunnellus*), Labriidae (wrasse spp.), Callionymidae (dragonet *Callionymus lyra*) and Gasterosteidae (sea stickleback *Spinachia spinachia*).

7.7.10: The use of pellets to assess the diet of a seabird species assumes that there is an equal chance of getting a sample from every individual in the population, however that is defined. Present information suggests that a bird usually produces one or two pellets per 24 hr, normally at night[1,2], but it is not known whether the production of pellets (or the proportion of otoliths ingested getting into the pellet) is influenced by the quantity, quality or prey species consumed. Blue-eyed shags *P. atriceps* fed on an inadequate diet failed to produce pellets[16], and in little penguins *Eudyptula minor* the proportion of otoliths digested was inversely related to meal size[15]. Thus it is likely that pellet production is influenced by food intake. If sandeels were to become less numerous, shags might change their feeding behaviour. If they moved outside their normal feeding or roosting areas, pellets would become unobtainable, or they might switch to other species or other sizes of food. If the diet was small, bottom living species, such as viviparous blenny or butterfish, many otoliths would be too small to resist digestion or perhaps no pellets would be produced. A further potential source of error is if the production of pellets varies through the year. On the Isle of May there are marked differences in the ease with which pellets can be found. In 1986, R. Forbes (personal coummunication) noted that pellets were hard to find once chicks had hatched, whereas we found few in May 1988 prior to the birds laying. It is unclear whether these rather unsystematic observations indicated normal physiological changes or were due to changes in diet.

7.7.11: For pellets to provide a meaningful description of the diet we therefore have to be certain that by using them we are not seriously biassing our results. Clearly there is a need for a detailed study of pellet production both in the field and the laboratory. Only when some of the fundamental questions, including why do cormorants and some other seabirds produce pellets? have been answered should pellets be used for general diet studies.

This paper will appear in Bird Study in 1989.

8 GROWTH OF CHICKS

8.1 The young of some seabird species are easily weighed in large numbers and it is possible to construct composite weight growth curves from series of 'spot' or one-off weighings, assuming that some measurement of the chick can be correlated with age.

The aims of this work were to -

(a) assess the feasibility of using spot measurements to construct growth curves for kittiwake, shag and guillemot.
(b) assess if bird-ringers could be persuaded to weigh chicks on a regular and systematic basis.
(c) determine if it was possible to detect a reduction in the growth of chicks before a decline in breeding success, i.e. to use weight as an indicator of feeding conditions.

8.2 Chicks were weighed and their wings were measured at a selection of Scottish colonies in 1986-88. Growth of seabirds normally follows a sigmoid pattern - a short period of slow growth, a period of rapid growth where weight increase (expressed as g/increase in age or wing length) is linear, and then a period prior to fledging (or in the guillemot, leaving the colony) when weight remains fairly stable. Wing length was used as an indicator of age as several studies have shown a linear relationship between wing length and age, and (b) wing length is little affected by food shortage until birds are near starvation.

Preliminary analyses confirmed a consistent linear relationship between weight and wing length for young of kittiwake, shag and guillemot between wing lengths of 40-130 mm, 40-160 mm and 20-43 mm respectively. I, therefore, compared the slopes of these linear regressions between brood sizes, years and colonies using analyses of covariance (ANCOVA). It was found impossible to weigh large shag or kittiwake chicks without causing them to fledge prematurely so no data were available for chicks near their peak weights. However, I compared samples of weights of guillemot chicks with wing length $\geqslant$ 60 mm i.e. when weight was more or less stable using t-tests or analysis of variance (ANOVA).

For convenience kittiwake and shag chicks in broods of one, two or three young are referred to as b/1, b/2 and b/3, respectively. Guillemots only lay a single egg. Brood size was that recorded at the time of weighing; chicks with dead siblings present were not weighed. Raw data are presented in Appendices 10-12.

8.3 Kittiwake

Chicks were weighed on the Isle of May and Fair Isle in 1986-88 and at Canna (R Swann) and Ashy Geo, Caithness (S Mackay) in 1987-88.

There was no significant difference between the growth rates of b/1 and b/2 chicks at any colony or in any year (Table 8.1). Of the 7 possible comparisons of growth rates between years at a single colony, only one (b/2 on Canna in 1987 and 1988) was significant. In 1987, chicks were weighed at all four colonies, comparing growth rates at the colonies there were no significant differences in the growth rates of either b/1 or b/2 ($F_{3,32}$ = 0.12, ns, $F_{3,107}$ = 1.9, ns. respectively).

Table 8.1. Growth of young kittiwakes in broods of one (b/1) and two (b/2) chicks

		Brood size								
		b/1				b/2				
Isle of May	Breeding success	n	Slope	SD	R^2	n	Slope	SE	R^2	
1986	1.33	30	2.02	0.10	93	77	1.71	0.10	79	$F_{2,129}$ = 2.55, n.s.[5]
1987	1.09	9	1.60	0.33	76	23	1.58	0.14	87	$F_{1,28}$ = 0, n.s.
1988	0.82	28	1.57	0.22	65	51	1.56	0.13	73	$F_{1,75}$ = 0, n.s.
	$F_{2,61}$ = 1.73 n.s.					$F_{2,173}$ = 0.25, n.s.				
Fair Isle										
1986	1.03	8	1.96	0.14	97	16	1.77	0.18	88	$F_{1,20}$ = 0.5, n.s.
1987	0.97	19	1.71	0.18	84	37	1.56	0.10	88	$F_{1,52}$ = 0.6, n.s.
	$F_{1,23}$ = 0.7, n.s.					$F_{1,39}$ = 1.31, n.s.				
Canna										
1987	0.50	6	2.12	0.60	76	27	2.33	0.18	87	$F_{1,29}$ = 0.73, n.s.
1988	0.03	9	1.61	0.31	79	44	1.67	0.17	69	$F_{1,49}$ = 0.03, n.s.
	$F_{1,11}$ = 0.4, n.s.					$F_{1,67}$ = 6.26 $P < 0.02$				
Caithness										
1987	1.32		no data			15	1.99	0.21	88	
1988	1.30		no data			19	1.60	0.47	40	
						$F_{1,30}$ = 0.63 n.s.				

1). Growth is increase in weight (g) per mm increase in wing length
2). Breeding success is the main mean number of young fledged per completed nest in the colony as a whole
3). R^2 is %.
4). F-values refer to comparisons between years (down columns) or brood size (across columns).
5). Isle of May 1986; there were 28 b/3, slope = 2.12 ± 0.22, R^2 = 79%.

Table 8.2 Rates of increase in weight of shag chicks with wing lengths 40-160 mm (by analysis of covariance) 40-160 mm.

Isle of May	Breeding Success	One young (b/1) n	Slope	SE	R^2(%)	Two young (b/2) n	Slope	SE	R^2(%)	Three young (b/3) n	Slope	SE	R^2(%)	
1986	0.75	20	7.74	0.76	85	44	8.29	0.51	86	77	7.87	0.36	86	$F_{2,135}$ = 0.3, ns
1987	1.09	7	8.69	0.62	98	14	8.58	0.53	96	27	8.6	0.78	83	$F_{2,42}$ = 0.1, ns
1988	0.61	19	8.60	0.60	93	46	8.65	0.41	91	44	9.23	0.32	95	$F_{2,103}$ = 0.7, ns
		$F_{2,40}$ = 0.6, ns				$F_{2,110}$ = 0.7, ns				$F_{2,142}$ = 37 P = 0.03				
Fair Isle														
1987	1.20	no data				47	9.18	0.25	97	52	9.34	0.37	93	$F_{1,95}$ = 0.1, ns
1988	1.30	no data				20	10.20	0.78	91	21	8.45	1.13	75	$F_{1,37}$ = 1.7, ns
						$F_{1,69}$ = 0.8 ns				$F_{1,63}$ = 2.3 ns				

Inter-colony comparisons:- b/2 1987; $F_{1,101}$ = 45, $P < 0.05$ 1988; $F_{1,62}$ = 2.6, ns
b/3 1987; $F_{1,92}$ = 0.05, ns 1988; $F_{1,61}$ = 0.61, ns

Note: Breeding success is young fledged per nest where a bird was seen apparently incubating (Table 5.5).

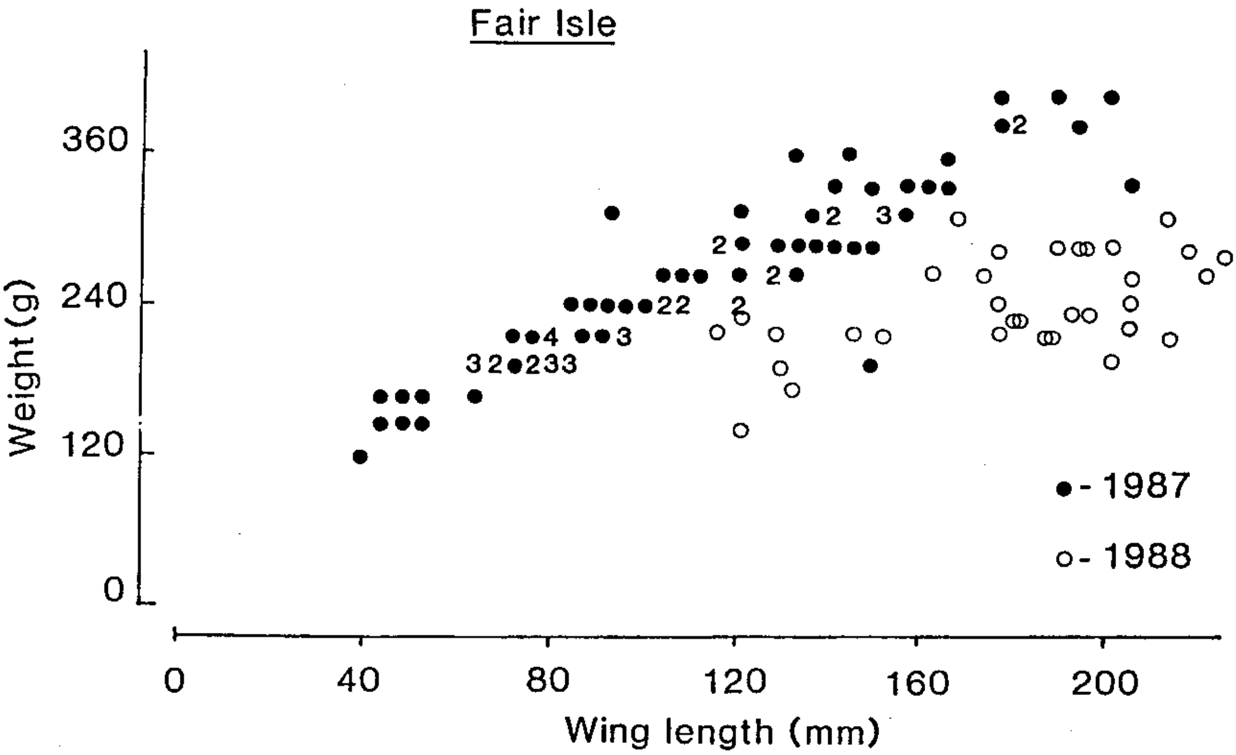

Fig. 8.1. Weights of young kittiwakes at Fair Isle in 1987 (closed circles) and 1988 (open circles, numbers represent the number of similar points).

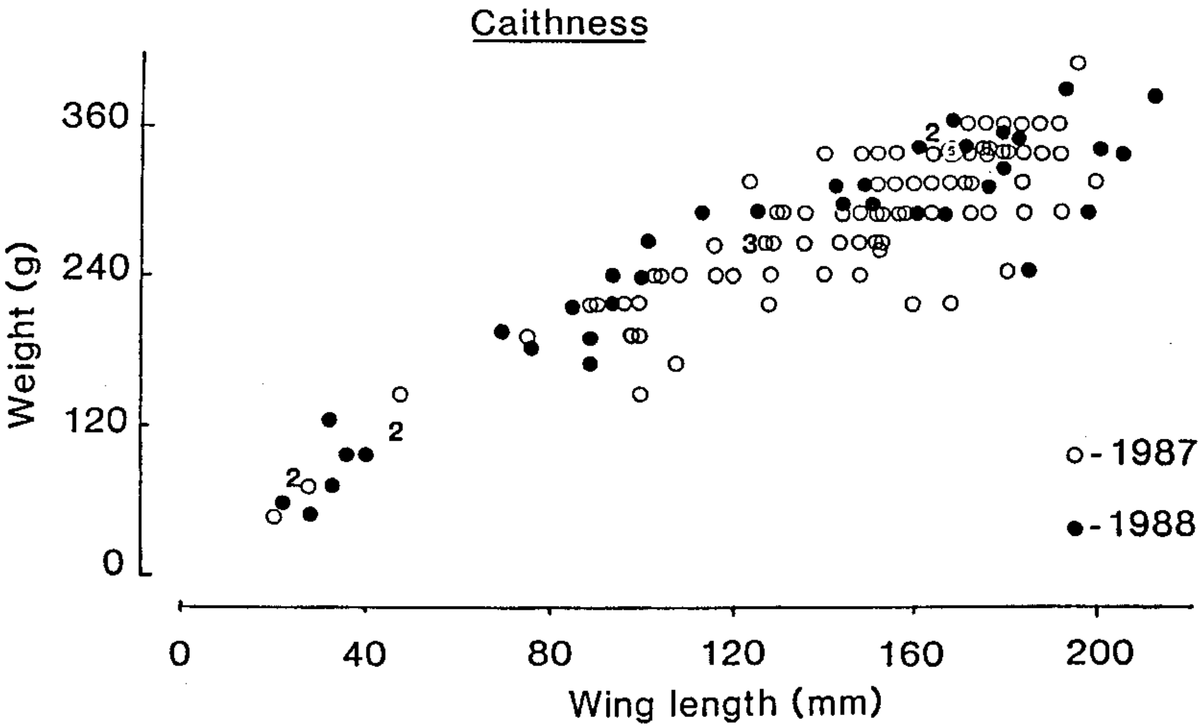

Fig. 8.2. Weights of young kittiwakes at Caithness in 1987 (closed circles) and 1985 (open circles, numbres represent the number of similar points).

Breeding success was markedly lower in 1988 than in 1987 (Section 5.3.1) but only among b/2s on Canna was growth significantly slower in 1988. No small chicks were weighed on Fair Isle in 1988, as all were dead when the colonies were visited, but the weights of large chicks were significantly lower than in 1987 (Fig. 8.1; also Fig. 5.4).

In Caithness there was no difference in the rate of weight increase of chicks in 1987 and 1988 (Fig. 8.2) yet in 1988, S MacKay noted that 19-23 % of the broods did not have an adult present, which suggested that they were having difficulty finding food.

8.4 Shag

Chicks in broods of b/1, b/2 and b/3 were weighed on the Isle of May in 1986-88 and in broods of b/2 and b/3 on Fair Isle in 1987-88 (Table 8.2).

There were no significant differences in growth rates of b/1, b/2 and b/3 in any year or place but b/3 individuals on the Isle of May showed significant differences between years. This was mainly because the rate of growth in 1986 was significantly lower than in either 1987 or 1988 ($t = 7.8$, $P < 0.001$, $t = 11.1$, $P < 0.001$, repectively). The ranking of growth rates of b/3 in different years (1986, 1987, 1988) was not consistent with the ranking of breeding success (1988, 1986, 1987).

In 1987, b/2 young on Fair Isle grew significantly faster than those on the Isle of May but there was no significant difference between b/3 in 1987, or b/2 or b/3 in 1988.

8.5 Guillemot

Chicks were weighed on the Isle of May each year 1982-88 and at 8 other colonies in 1987.

There was no significant difference between the rates of weight increase of chicks on the Isle of May over the 7 years (Table 8.3a). However, there was a significant difference in the weights of large chicks with those in 1982 and 1983 being markedly light and those in 1984-86 being heavy (Table 8.3b). The annual values of rates of weight increase and weight of large chicks were not significantly correlated with either breeding success or calculated food intake of chicks (Table 8.4).

In 1987 there was no significant difference in the rates of weight increase of chicks at the 4 colonies where sufficient small chicks were weighed (Table 8.5); however, there were substantial differences in the weights of large chicks among the 8 colonies with those from the Flannan Isles being very heavy and those from Fair Isle being very light (Table 8.6). There were few small chicks weighed at either Fair Isle or the Flannan Isles but even excluding these two colonies the ANOVA was still significant ($F_{5,374} = 7.1$, $P < 0.001$). The importance, if any, of these differences is unknown.

Chicks were weighed at Compass Head (Shetland) and Fair Isle, 30 km apart, in both 1987 and 1988. There was no significant difference

Table 8.3. Weights (g) of young guillemots on the Isle of May, 1982-88.

(a) Weight increase (g/mm increase in wing length) over the period of linear weight increase (wing length up to 43 mm) based on least squares regressions.

Year	Chicks (n)	Slope[1)]	SE of slope	R^2
1982	22	6.3	0.8	76%
1983	27	6.1	1.0	59%
1984	92	6.0	0.5	57%
1985	64	4.4	0.6	44%
1986	83	6.1	0.5	61%
1987	57	6.3	0.8	54%
1988	136	5.6	0.4	57%

ANCOVA $F_{6,467} = 1.08$, n.s.

(b) Weight of chicks with wing length 60 mm

	n	Mean	S.E.	Range
1982	16	249.2	5.4	203-300
1983	40	249.5	3.4	200-295
1984	45	262.1	3.5	216-303
1985	15	261.7	5.8	216-304
1986	52	264.5	3.8	171-334
1987	84	251.7	2.7	188-320
1988	40	250.4	3.7	204-294

ANOVA $F_{6,286} = 3.10$, $P < 0.01$

Table 8.4. Breeding success, food intake of chick, rate of weight increase and weight of large chicks for guillemots on the Isle of May, 1982-88.

Year	Breeding success (fledged/pair laying)	Food intake (kJ/day)	Weight increase (g/mm)	Weight of large young (g)
1982	0.79	354	6.3	249
1983	0.77	386	6.1	250
1984	0.71	295	6.0	262
1985	0.82	244	4.4	261
1986	0.80	269	6.1	265
1987	0.79	319	6.3	252
1988	0.85	396	5.6	250

Spearman Rank correlations between columns were all not significant ($P > 0.05$)

Table 8.5. Rate of weights increase (g/mm increase in wing length) of young guillemots over the period of linear weight increase (wing up to 43 mm), at four colonies in 1987.

Colony	Chicks (n)	Slope[1)]	SE of slope	R^2
Isle of May, Firth of Forth	57	6.3	0.8	54%
Fair Isle, Shetland	22	7.7	0.7	85%
North Sutor, Ross & Cromarty	11	6.6	1.4	72%
Canna, Inner Hebrides	17	7.9	0.7	89%

ANCOVA $F_{3,105} = 1.96$, n.s.

Table 8.6. Weights (g) of guillemot chicks with wing lengths 60 mm or more in 1987.

Colony	n	Mean	SE
Isle of May	84	251.1	2.8
North Sutor Ross & Cromarty	21	257.0	5.4
Ceann Ousdale and Inver Hill Caithness	128	270.8	2.2
Fair Isle	12	234.3	8.1
Compass Head Shetland	39	269.1	3.4
Sule Skerry	46	261.4	4.5
Flannan Is	10	311.8	3.9
Canna, Inner Hebrides	62	269.4	3.6

ANOVA $F_{7,394} = 12.2$ $P < 0.001$

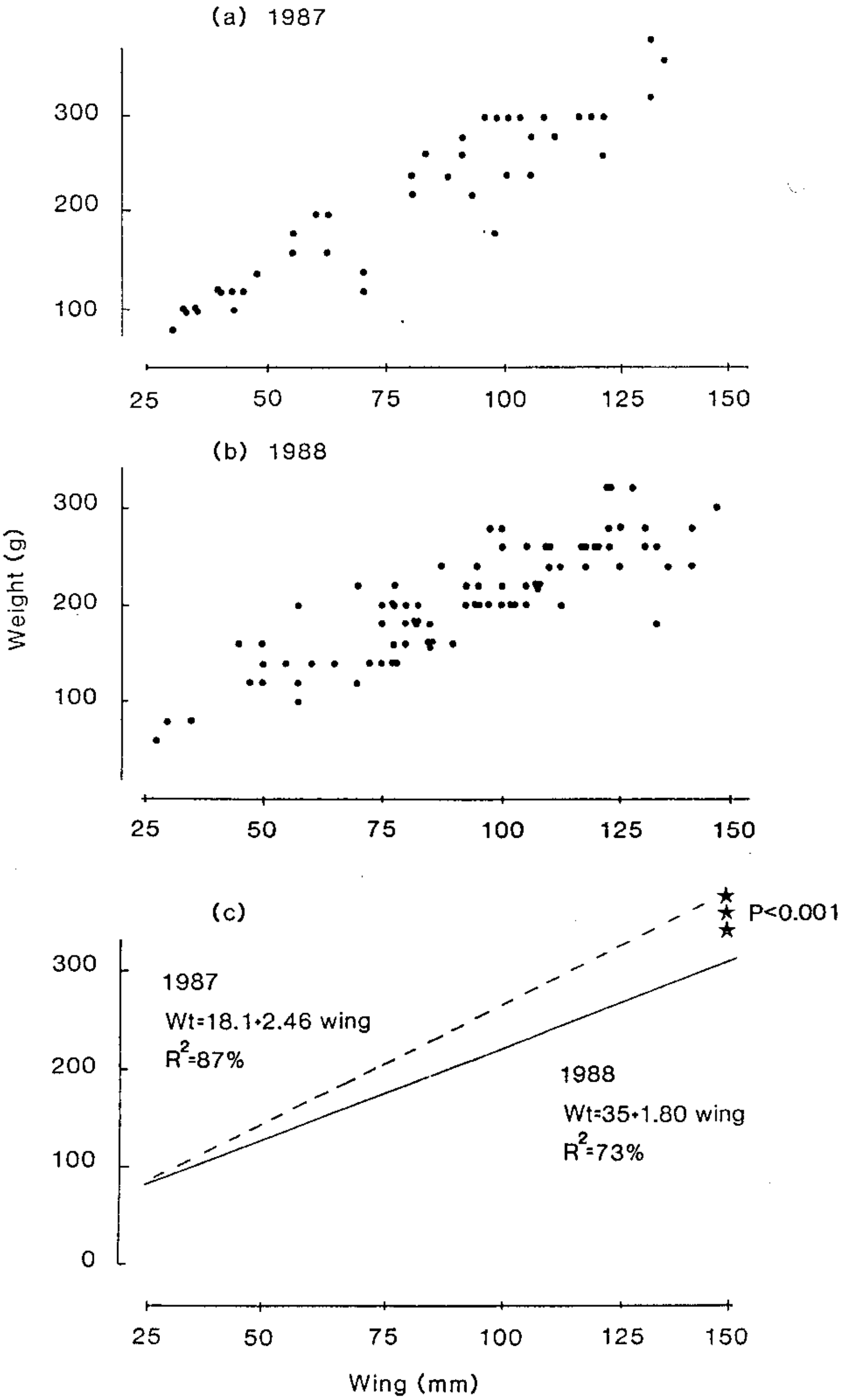

Fig. 8.3. Weights of young puffins on Fair Isle in (a) 1987 and (b) 1988. The overall linear regressions are compared in (c).

between the years in the growth rate or weights of large chicks on Fair Isle but at Compass Head, where only large chicks were weighed, chicks in 1988, (n = 31, mean ± SE = 255 ± 4 g) were significantly lighter than chicks in 1987 (n = 39, mean = 269 ±4; t = 2.74, $P < 0.01$).

8.6 Puffin

Chicks of various ages were weighed on Fair Isle in 1987 and 1988 (Fig. 8.3). The weights showed a linear increase up to the time of fledging (when the wing length is about 130-135 mm). The rate of growth in 1988 was significantly slower than in 1987 ($F_{1,122} = 11.8$, $P < 0.001$). Although the nesting success was similar in the two years (Table 7.3), in 1988 N Riddiford (pers. comm.) noted a few young of near fledging age outside their burrows during the day which made no attempt to retreat into their burrows. Chicks in 1988 were fed many small whiting, so the adults may have been having difficulty feeding young and those outside burrows could have been starving.

8.7 Conclusions

8.7.1 It is possible to weigh large numbers of younger chicks of many species without causing undue disturbance. However, weighing takes time and is rather messy. With a few marked exceptions it proved impossible to cajole, bully or even bribe ringers to weigh chicks mainly because weighing reduced the numbers of birds which they ringed.

8.7.2 It is difficult to ensure the collection of comparative data from one year to the next. Many ringers have fixed dates for ringing so that if breeding is early, late or even synchronized in a particular year their weighings may not give the data needed for analysis.

8.7.3 There is a potential problem that birds from different colonies may vary in size. Therefore, weights and rates of growth are probably most useful in comparing growth rates between years at a particular colony rather than comparing several colonies within the same year.

8.7.4 Interpretation of the results is difficult but in neither the kittiwake nor the shag did chicks grow fast in years when breeding success was high or vice versa. Neither was growth correlated with food intake in the guillemot. The relationship between growth and condition may well not be clear cut, e.g. Coulson & Thomas (1985) found that in the kittiwake b/3 chicks grew slightly slower than b/1 and b/2 chicks but still fledged successfully by slightly lengthening the fledging period.

8.7.5 The available evidence suggests that the unsystematic weighing and measuring chicks is an ineffective way of determining feeding conditions for kittiwake and shag. More data are needed for guillemot and puffin in years when breeding success is less good.

8.7.6 Recording brood size (including nests where breeding has failed) and the amount of time 'off-duty' birds spend at their nests appear to be more useful indicators of feeding conditions than chick growth rates.

8.7.7 Ricklefs, Duffy & Coutler (1984) weighed and measured blue-footed booby chicks at 13 localities. They reweighed the chicks after 5 days and found differences in the growth rate which they linked with differences in oceanographic conditions. Bertram & Karser (1988) weighed a series of chicks of rhinoceros auklet twice during their development and suggested that variation in growth rate within and between years was related to the availability of sandeels. This approach might be developed for burrow nesting puffins but it would be difficult to make two weighings of young of the other species without much additional manpower and risking severe disturbance to the colony.

8.7.8 Further study of the growth of seabirds and of the methods for analysing data are desirable but these are specialized research topics. There is little to be gained by continuing to collect weights of seabird chicks on a sporadic basis for monitoring purposes. Time would be better spent in collecting chick production data.

8.7.9 Conditions around Shetland appear to be changing rapidly. therefore chicks should continue to be weighed on Fair Isle. Some young should be weighed twice about 5 days apart during the period of linear weight increase. A sample of young puffins and guillemots of all ages should also be weighed, and 30 young should be weighed twice during the first two-thirds of the fledging period (say up to a wing length of 110 mm).

9 RADIO-TELEMETRY

9.1 The work progressed extremely well and full details can be found in the relevant publications and in Dr S Wanless's NCC report.

9.2 We can now follow seabirds on a 24hr/day basis and determine when and where shags and auks feed and how much time the various components of foraging take.

9.3 We hope to extend this work in future years and at other colonies such as Shetland, if funds can be made available.

10 AUTOMATIC DATA HANDLING BY NCC

10.1 There are obvious advantages and attractions in this but only certain aspects of the monitoring work covered in this contract lend themselves to this treatment.

10.2 Aspects which do are -

a) Monitoring counts of birds or nests
b) Details of nesting success
c) Measurements of chicks
d) Survival rates of adults (although these will have to be updated each year, as well as adding a new year's data, to allow for 'missing' birds being found again).
e) Standardized report production using work processors

10.3 Aspects which do not are -

a) Food of chicks, as given the range of birds, fish and observers this will always be an untidy data set.

10.4 At a meeting with M L Tasker and J Riggal it was decided that NCC's priority must be to collect and store the annual monitoring counts. This is now a very heterogenous and unwieldy data set, and it continues to grow rapidly. The data collected under the present contract can remain in paper files for the immediate future.

11 AMATEUR INVOLVEMENT

11.1 Even given finanical inducements, volunteers were reluctant to offer help. A list of volunteers and the types of data which they collected are given in Appendix 20. Some of the people also supplied data for the Seabird Colony Register.

11.2 It is obvious that only in a) the case of monitoring kittiwake nesting success and, b) some specific ringers who are prepared to collect fish and measure young, can we rely on amateur help for anything but the shortest of studies.

11.3 The efficient use of amateur help demands the personal contact between the organiser and the fieldworker. The network of 34 kittiwake sites in 1988 included only 14 amateurs, but these were essential to the total coverage, especially in the south and west. I had, on average, 5-6 written or telephone contacts with each during the year. (Several of the professional wardens also needed considerable encouragement.) Without these contacts no scheme will flourish. If NCC wants this work to continue it will have to engage/contract a suitable person as organiser.

12 CO-OPERATON WITH OTHER BODIES AND ASSISTANCE GIVEN

12.1 Much help was given by RSPB staff, wardens, and contract workers, SOTEAG (M Heubeck), EGI, FIBOT, National Trust (Farne Islands Watchers) and NCC staff. Hopefully this fruitful co-operation will continue.

12.2 I gratefully acknowledge the following people for invaluable assistance during the study and various un-named wardens and ringers who contributed counts, measurements and food samples.

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Monitoring of Puffin burrows on Dun, St Kilda, 1977–1987

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The numbers of burrows of Puffins were counted in fixed, randomly positioned quadrats on Dun, St Kilda in 6 years during 1977–87. The use of fixed sampling quadrats substantially reduced the variance of the estimates of population changes obtained and also saved time. The breeding population increased by 18% during 1977–87, though at a variable rate.

St Kilda has by far the largest concentration of Puffins *Fratercula arctica* in Britain so that a change in numbers there has a great influence on the total population. The bulk of the quarter of a million pairs breed on Boreray and Soay, islands which are difficult of access so that monitoring of changes in numbers on a regular basis is not practical. However, the population of *c.* 40 000 pairs on the smaller island of Dun has been followed since 1971. Initially the numbers of burrows in fixed transects running across the colony were counted. These transects were positioned for ease of surveying and counting, although they did appear to cross areas of different burrow density, but in 1977 a scheme using permanent, randomly positioned, circular quadrats was set up. The change was made because of the lack of objectivity in the siting of the transects and the time needed to install and check them and also to improve the precision of the estimates of population sizes and population changes. This paper documents the changes in the numbers of burrows in the main part of the colony over 11 breeding seasons and assesses the usefulness of the new monitoring scheme.

METHODS

A description, a photograph and the history of this colony have been given by Harris & Murray.[1] For the monitoring scheme, a surface plan of the main colony was made, allowing for the slope of the ground, and the area was divided into 4 sections, or 'strata', where the burrow density was obviously different. Fifty-six quadrats were allocated to the strata in proportion to the area of each. (The allocation of the numbers to strata could also have been made on the basis of the variances of the density of burrows but these were not known at the time.) Points were selected at random within each stratum and plotted using a numbered grid superimposed on the plan; these points were then located in the field and marked with wooden stakes. The numbers of occupied burrows (as indicated by fresh digging or droppings) were counted in circular quadrats of 30 m^2 centered on these points in May 1977, 1978, 1979, 1980, 1984 and 1987. The area covered by the quadrats was 2.3% of the area being monitored. The number of quadrats counted was limited by the time available for regular monitoring, and the size by the area in which burrows could be easily and accurately counted. A burrow falling on the boundary was included if half or more of its entrance fell within the quadrat. Counts were made even if the quadrat fell on terrain where burrowing was impossible. Over the years 12 stakes were dug out by the birds or otherwise lost. Each lost point was re-surveyed, but, given the rough and steep ground, it may well have been in a slightly different position. Shortage of time resulted in 3 quadrats not being counted in 1984. In 1977 and 1979 counts were made by Stuart Murray; all others were by MPH. Comparison in 1978 indicated no significant differences in counts made by these 2 counters.[2]

The analysis follows that for a stratified random sampling scheme.[3] To estimate the number in each stratum, one divides the mean number per quadrat in that stratum by 30 (the area of each quadrat) and multiplies by the total area of the stratum; the sum of the estimates for the 4 strata gives the estimate of total numbers. Mathematically this estimate is thus

$$\sum \bar{x}_i \cdot A_i/30$$

where $\bar{x}_i$ is the mean number per quadrat in the ith stratum and A_i is the area of the stratum. The variance of this estimate is

$$\sum s_i^2 \cdot A_i^2/900n_i$$

where n_i is the number of quadrats in the ith stratum and s_i^2 the between-quadrat variance. When the overall density is required, the above estimates are divided by A and A^2, respectively, where A is the total area of the population. To estimate changes from one year to the next the same expressions are used but with differences in quadrat counts in successive years being used as the data rather than the counts themselves.

This approach allows for the correlation between counts of the same quadrat in different years which increases the precision of the estimated change, since the variance of the difference between two counts is $2V(1-r)$ where V is the variance of a single count and r is the correlation. Figure 1 shows that the correlation was generally large and positive in this study, often exceeding 0.9 for counts made within 5 years of each other. For $r = 0.90$, the variance of the estimated change is one-tenth that obtained if quadrat locations were changed each year (when $r = 0$); the corresponding standard error is reduced by a factor 0.33. For longer timespans, the correlation decreased; this might have been due to a real change in the colony or an increasing effect of repositioning quadrats. We cannot evaluate the relative importance of these two factors.

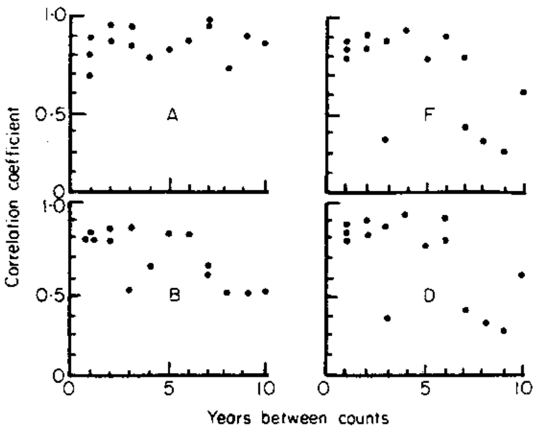

Figure 1. Correlation coefficients between years in burrow counts in quadrats in the 4 strata in relation to numbers of years between counts. There is a tendency for the correlations to decrease as the time intervals widen.

RESULTS AND DISCUSSION

The estimated total population of the area monitored and the estimates of burrow density in each of the 4 strata are given in Table 1. From 1977–87, the estimated population size increased by 18% from 25 000 to 29 600 burrows. Within this period there were both significant increases and significant decreases between successive surveys. The low number of occupied burrows in 1978 has been attributed to birds not breeding that season.[2] The proportion of these occupied burrows actually used for breeding has changed little overall: of 59 marked burrows checked in both 1977 and 1987, 55 and 55, respectively, had adults or eggs present. (In 1978, 49 of these burrows showed signs of occupancy.) The pattern of changes in the 4 strata was generally similar but most of the increase in numbers occurred as a result of increases in density in B and F. The density dropped in F between 1984 and 1987 but the change was not significant ($t_{49} = 1.06$). In 1975, when the last full survey had been made, there were 40 000 occupied Puffin burrows on Dun and 70% were in the present monitoring area. If the changes in the area monitored reflected the changes in the whole of Dun, and 70% of Dun's Puffins were in the area, the total population in 1987 would have been 42 000 occupied burrows.

Table 1. Estimates of density (burrows/m^2) in each stratum and of total population in the survey area in 1977–87. Standard errors are shown in parentheses. Note that only 14 and 16 quadrats were counted in B and F, respectively, in 1984. Asterisks indicate significant changes between successive surveys

Stratum	*Area (m^2)*	*Numbers of quadrats*	*1977*	*1978*	*1979*	*1980*	*1984*	*1987*
A	12 263	10	0.157	0.090	0.210	0.123	0.170	0.160
			(0.049)	(0.043)	(0.055)	(0.044)	(0.053)	(0.062)
B	24 683	16	0.502	0.367	0.421	0.442	0.629	0.612
			(0.079)	(0.052)	(0.062)	(0.083)	(0.100)	(0.104)
D	14 804	13	0.141	0.080	0.136	0.133	0.151	0.144
			(0.043)	(0.027)	(0.041)	(0.053)	(0.045)	(0.045)
F	21 832	17	0.396	0.306	0.365	0.363	0.608	0.478
			(0.059)	(0.056)	(0.055)	(0.069)	(0.101)	(0.C82)
Total burrows	73 582	56	25 000	18 000	22 900	22 300	33 100	29 600
			(2500)	(1890)	(2150)	(2710)	(3430)	(3290)
Change in total			−7000*	+4900*	−600	+10 800*	−3500	
			(1560)	(1080)	(1540)	(2270)	(3200)	

The original aim of the monitoring scheme was to be able to assess changes in numbers with a known statistical accuracy. This has been successful. The use of fixed quadrat points has removed the labour-intensive work of re-surveying on randomly positioned points each season and also substantially increased the precision of the method: for the estimated changes between successive surveys, the standard errors are 50, 38, 45, 52 and 68% of those that would have been obtained had the quadrats been randomly repositioned each season. It must, however, be borne in mind that such a scheme does not allow for the extent of the colony changing with time or for the possibility that repeat sampling might cause disturbance to burrows or birds in the quadrats. Each year we checked the occupation of burrows on either side of the boundary of the area to confirm that the colony had not substantially changed its extent in recent years since the area was defined and we assume that one visit to a quadrat every 3–4 years had caused little adverse effect to the burrows being monitored. If change of area or damage is detected the dispersion and number of the quadrats should be changed.

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Appendix 2: Instruction for determining an index of breeding productivity of guillemots

1. Introduction

Several schemes monitor changes in the numbers of seabirds at breeding colonies by making repeated annual counts of birds or their nests (e.g. Stowe 1982). The Guillemot (Uria aalge) is considered to be a key species as it appears to be susceptible to both oil and chemical pollution (Bourne 1976). In a review of monitoring data collected on Guillemots at 27 British and Irish colonies, Rothery et al. (1988) concluded that the schemes provided good descriptions of long-term changes in numbers of birds but they did not lead to a greater understanding of the biological processes involved. They urged that biological data should also be collected.

Breeding success is of fundamental importance to the understanding of population dynamics. At one extreme it is possible to obtain a very crude estimate of breeding success by visiting a colony during the chick-rearing period and assessing whether there are few or many young present in relation to either how many adults are present or on past knowledge of the colony. At the other extreme, very detailed daily observations can be made of relatively small groups of birds to determine how many pairs lay and how many young leave the colony (Birkhead and Nettleship 1980). This method is extremely time consuming and Gaston and Nettleship (1981) concluded that 3 hours per day were needed to determine the breeding success of 80 pairs of Brunnich's Guillemot (U. lomvia). Few monitoring schemes can invest this input of time over a period of up to 3 months.

Here I describe a method for determining an index of breeding productivity for Guillemots which takes less time than a detailed study over the whole breeding season but provides a more objective assessment than casual observations made during normal monitoring counts. The method is a refinement of that used by Drury et al. (1981) and Murphy et al. (1986) who expressed the numbers of sea-going chicks as a fraction of the average number of full-grown Guillemots present in study plots from 7 days before the first egg hatched until the first chick left. My index is the number of young which fledge divided by the number of site holding pairs present during late incubation or early chick-rearing.

2. Suggested method

2.1 Select several study plots dispersed through the colony where the birds can be viewed from the same level or from above.

2.2 Take photographs when the birds are incubating or brooding small young. Good, large-scale photographs are essential. Make large prints.

2.3 Delimit the area to be checked on the photographs. Tape on transparent overlays so that photographs can be annotated.

2.4 View the area from where the photographs were taken late in the incubation or early in the chick rearing period. In Britain this is early June. Plot the positions of, a) birds with an egg, b) birds with a chick, c) birds sitting tight, and d) pairs which regularly attend a site which appears capable of supporting an egg (bearing in mind that some eggs are laid on most unsuitable sites).

2.5 Make several visits, including some when large numbers of Guillemots are present, until you are satisfied that you have found most occupied sites. Record any chicks without an adult in attendance.

2.6 Number the active sites and note their contents every 1-2 days (or, as second best, commence such checks before the young are near fledging). Any young leaving when aged 15 days or more old and/or well feathered can be considered as having been reared successfully.

2.7 Present the results as x young fledged from y active (i.e. a, b, c above) and z inactive (d) sites as found on the dates of the first checks.

2.8 Make notes if you have any reason to suppose that the season, or the results, may have been atypical.

2.9 Follow the same areas each year.

3. Tests

The method was field-tested by 9 observers on the Isle of May in 1986 and 1987, and on Fair Isle and Skomer in 1987. The results are shown in Tables 1-3. Active sites are those where a bird had an egg, a chick, or was sitting tight on each check; inactive sites are those where two birds, apparently paired, were present and will have included failed pairs and nonbreeding pairs holding sites. All observers recorded most active sites (mean = 97%, s.e. = 0.8) but a much lower proportion of relatively few inactive sites (mean = 52%, s.e. = 8). They also recorded a few extra inactive sites which had not been occupied during the laying period.

The index of productivity (total number of young fledged as shown by later daily checks/total of active and inactive sites) found by each observer was higher than the traditional estimate of productivity (number of young fledged/number of pairs laying). The range was 3-28% and the mean 11% (s.e. = 3).

Measurements of breeding success are useful for a variety of purposes. The highest accuracy is required for modelling the population dynamics of a specific colony, but for Guillemots this may take up to 4 months of daily checks. The inevitable loss of accuracy resulting from any short-cut or low-input method may, however, be small compared to other components of the model which are themselves even more difficult to obtain. One such factor is the proportion of the young reared at the colony which return to breed there. In the Kittiwake (Rissa tridactyla), approximately three-quarters of the birds breeding at a colony may have been reared elsewhere (Porter and Coulson 1987). Another is the proportion of the young which actually survive to breeding age. The breeding success of Isle of May Guillemots has been very high in recent years yet the population declined significantly between 1986 and 1987, apparently because the post-fledging survival of several age classes has been low (Harris and Wanless 1988). It could be argued that additional time needed to improve the estimates of breeding success obtained by this low input method would be better used to obtain estimates of post-fledging and adult survival which will have a great effect on population dynamics. At the other extreme, an index of success may be needed to assess how well the adults are performing. The method described here will give an objective estimate of the number pairs present in an area and an indication of their breeding output.

4. Limitations

The main limitation of the method is the lack of direct measure of the number of pairs which actually laid. The index of breeding productivity is very sensitive to differences in colony attendance and behaviour by non-active pairs. Severe food shortage could presumably result in few young being reared and few inactive sites being occupied; the index would be as high as when success was high and failed and many nonbreeders were present. I know of no detailed study of Guillemot biology and behaviour made when breeding success was very low but Murphy et al. (1986) found no obvious relationship between the average numbers of Guillemots at an Alaskan colony and the suitability of conditions for breeding there for a wide range of breeding successes. Similarly Bakken (1986) found that even in a year when breeding success at a Norwegian colony was only 0.17 young per pair, the numbers of birds attending the colony remained high. However, the uncertainty of the usefulness of the index in times of low productivity remains. It would be prudent to check the same study plots in each year and to note the numbers of birds and unattended chicks present. It should then be obvious if anything untoward had occurred.

5. Young fledged

Another limitation, and one which applies to all estimates of breeding success is the difficulty in deciding which young fledge. Young Guillemots leave the breeding ledges when partly grown and unable to fly. The length of time spent at the breeding site, i.e. the 'fledging' period, varies greatly. For instance, on the Isle of May most young appeared to fledge successfully when aged 15-30 days, with an overall mean of 1300 periods being 21.9 days (s.e. = 0.3). Further, the length of the period declines from 23-25 days for the earliest chicks to 19-21 days for the latest (Wanless and Harris 1988). The only feasible way of recording breeding output is to number the breeding sites on the photograph and to check chicks every 1-2 days and make some arbitrary decision as to a minimum fledging age. Some chicks appear to be capable of swimming when 15 days old and both Gaston and Nettleship (1981) and Harris and Wanless (1988) took the pragmatic view that young murres disappearing when aged 15 days or more old when reasonably well feathered had left successfully. A proportion of such young chicks will have perished rather than fledged, but generally chick survival is high at this stage.

6. Siting of study plots

The use of monitoring plots to assess biological parameters for colonies or populations assumes that the results obtained are representative of the colony or population under consideration. The positioning of plots poses formidable statistical and logistical problems and it is unlikely that any but the most thorough monitoring schemes will have the resources to allow adequate replication of study plots. Further, relatively few parts of the colony may be amenable to detailed study so that any objective method of siting plots (e.g. random (Harris et al. 1983) or stratified positioning) will be difficult to carry out. Most schemes will probably be forced to adopt a more pragmatic approach but even so attempts must be made to reduce the chances of the plots(s) being atypical. On the Isle of May, a 6 year study found no systematic difference in the productivity of murres in five plots situated in the main part of the colony (Harris and Wanless 1988) but a plot in a recently colonised area followed in 1987 had a fledging success of 0.66 young per pair laying. This compared with a mean of 0.78 (S.E. = 0.015) for the five plots in the main part of the colony in 1987. On Skomer Birkhead (1978) found that Guillemots breeding at a low density had a lower productivity than those at a high density. Therefore, the temptation to have study plots solely in areas where study is easy, e.g. where pairs are at low density in isolated groups or at the fringes of colonies, must be resisted. At some colonies, Guillemots nest in large groups at a high density. Our experience has shown that productivity of such groups can be determined if the group can be viewed from above. Therefore, such groups must be considered even if they are ruled out after detailed inspection. If possible, the productivity of several plots, of say 50 pairs, dispersed through the colony should be followed.

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TABLE 1

The numbers of occupied sites of guillemots found during one hour checks compared to the actual totals in two areas on the Isle of May
Percentage values are shown in brackets.

	1986			1987			
	Area A			Area A		Area B	
	Actual	Observer 1	Observer 2	Actual	Observer 3	Actual	Observer 2
Number of checks		5	5		3		4
Active sites	109	109 (100)	109 (100)	70	68 (97)	116	114 (98)
Failed sites	7	5 (71)	6 (86)	5	3 (60)	5	5 (100)
Nonbreeding sites	15	11 (73)	10 (67)	8	3 (37)	13	8 (62)
Extra sites	-	1	3	-	1	-	2
Total sites	131	126 (96)	128 (98)	83	75 (90)	134	129 (96)
No. of young fledged	100	-	-	64	-	100	-
No. fledged/pair laying	0.86	-	-	0.85	-	0.83	-
No. fledged/site holding pair	0.76	0.79	0.78	0.77	0.85	0.75	0.78
% estimates too high	-	4	3	-	10	-	4

TABLE 2

The numbers of occupied sites of guillemots found by one hour long checks compared to the actual total. Percentage values are shown in brackets.

	Actual	Observer 4	5	6	7[a]
Active sites	115-116	107(93)	113(97)	107(93)	113(97)
Inactive sites[b]	27-28	21(75)	15(56)	8(29)	19(70)
Extra sites	-	6	3	3	3
Total site-holding pairs	143	134	131	118	137
No. fledged/occupied site[c]	0.71	0.80	0.86	0.91	0.82

a) based on one 30 min check; other observers watched for 5 one hour periods
b) includes failed and nonbreeding pairs
c) true success was 0.77/pair laying

TABLE 3

The number of occupied sites of guillemots found by one hour long checks compared to the actual total on Fair Isle. Percentage values are shown in brackets.

	Actual	Observer 8	Observer 9
Active sites	131	128(98)	124(95)
Inactive sites[a)]	33	5(15)	4(12)
Total site-holding pairs	164	133(81)	128(78)
No. fledged/occupied site[b)]	0.63	0.78	0.81
% estimate too high	-	24	28

a) includes 11 failed and 22 nonbreeding pairs
b) true success was 0.73/pair laying

Appendix 3: Instruction forms and background information for monitoring the breeding success of kittiwakes

Instructions

Aims

To determine within clearly defined areas:

1. The number of pairs which breed. We include nests where birds appear to be incubating when most pairs have laid.
2. The number of young raised by each pair. We assume that all large young present just before the first young fledge will survive to fly. We need to know that, for instance, 3 pairs raised three young (f/3) 20 f/2, 30 f/1 and 25 f/0.
3. If possible, we would also like to know the number of additional pairs which had sites with even the smallest amount of nest-material.

Method

1. Selection of study plots is important if we are to minimize bias and ensure that what we are recording is representative of the colony. Having said that, we fully realize that objective choice is sometimes limited. In small colonies we may have to follow all the visible nests, in large colonies we would prefer to follow at least 5 groups of nests (say 50+ in each) dispersed through the colony. We suggest dividing the colony into 5 very roughly equal lengths, and having one study plot in each section. Only plots which are clearly visible from a safe vantage point should be selected.
2. Photograph each group in black-and-white using a long lens if necessary. This is best done when birds have nests - say during May. Nests/pairs should be clearly distinguishable on the prints which should be as large as possible (full-plate or A4).

   Do not stint on the photographs. Film is cheap and decent photos save on time (and temper) later. Better to have several prints to cover the area than one distant view. Photographs can be used for several years, as nest-sites change little, by using transparent overlays. For instance, those used in photocopying machines.

3. If photographs cannot be taken, make a good, large scale, unambiguous drawing of the cliff and mark on the nests. This is far less desirable than photographs but usable.
4. Take the print into the field and delimit the study area with a felt-tip pen. Then mark each nest and nest-site, either with a cross or a number. In the latter case, try and number adjacent nests/sites consecutively as this makes record-keeping easier.
   If the nests are numbered, you can use a check-sheet (as attached). If not numbered, cellotape on an overlay and write on this using a different coloured permanent pen (e.g. Staedtler Lumocolor) for each visit.
5. Best results come from regular (7 or 10-day) checks but two carefully timed visits, soon after the birds have finished laying (end-May) and immediately prior to fledging (late-July), can produce useful data. Make sure that all nests checked the first visit are rechecked and contents noted. Add any additional nests, even those only partly completed.
6. Such a scheme can be used to monitor annual changes in the number of nests and chick production.
7. The Institute of Terrestrial Ecology and the Nature Conservancy Council are attempting to collect data on the biology of selected species around Britain. Your data could be invaluable to us. Please let us have a copy of your results.

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PLACE: ISLE OF MAY (Area 2)

Date	'56 23.5	10.6	20.7								Remarks
Time	17.00 GMT	11.00	18.00								
No.											
1	c/o	I	b/2								young medium
2	I	I	f/1								
3	I	c/2	O								Nest gone
4	c/o	I	b/1								small
5	c/3	c/3	f/2								
6	I	I	f/1								
7	I	✓2	✓2								Nest probably fell-off
8	I	O									Wave-washed
9	I	I	f/1								
10	I	I	O								Failed
11											
12											
13											
14											
15											
16											
17											
18											
19											
20											
21											
22											
23											
24											
25											

c/3, c/2, c/1 =clutch-size- c/o = good nest but no eggs
I = sitting tight, contents not seen
b/3, b/2, b/1 = brood size with remark of large, medium or small
f/3, f/2, f/1 = can probably fly
✓1, ✓2 = trace of nest, one or two birds present

Suggestions for selecting plots for monitoring kittiwake nesting success

1. As with all monitoring, the problem is to reduce the chances that the samples you choose are atypical of the colony as a whole.

2. If the colony is small, try and check all the visible nests. Even in a large colony, the higher proportion of the population checked the better.

3. If the colony is large, sample areas (called plots) must be chosen. Virtually all studies of colonial seabirds have shown that many aspects of biology vary within the colony, and often the laying or productivity of pairs are clumped, e.g. some groups of birds breed early/late, have high/low productivity, etc.

4. This causes problems in sampling but it is far better (on both statistical and practical grounds) to choose many relatively small plots scattered throughout the colony than one or two large plots. A plot containing 50-100 nests is considered a reasonable size.

5. Two methods for dispersing these plots have been used

(a) **Random position.** This is not haphazard. Go along the colony and find all the groups of 50-100 nests which can be checked accurately and safely. Include all the areas used by birds for nesting and try not to bias the plots to top/bottom, centre/edge of the colony. Plots can abutt each other. Draw rough diagrams of where these plots are. When you get to the end of your defined colony, give each plot a number, say 1-32. Then decide how many you can check (remembering the more the merrier!). Let's say 6. Then choose six of the 32 numbers by using a table of random numbers or writing numbers on cards and then pulling six of the 32 out of a hat. Record how many plots you choose from (i.e. 32).

(b) Divide the colony into say 4 or 5 aproximately equal parts (either by cliff top length or number of nests) and pick (say) 2 plots in each area. Have the same number of plots in each area. Again, try not to bias the choice towards top or bottom areas. If the cliffs are not too high, the plots should span from the cliff-top to sea. This method is probably not as good as (a) but has been used where the number of possible plots is small.

6. Whatever method you use, document exactly how you made your choice.

7. If you are constrained absolutely just to check specific plots for any reason (safety, time, only places not to disturb birds or the public), say so.

8. It is not necessary to use the same plots each season as we are not comparing counts but breeding output.

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A Low-input Method of Monitoring Kittiwake *Rissa tridactyla* Breeding Success

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ABSTRACT

The nesting success of six groups of kittiwakes was determined as 0·98–1·59 young fledged per pair building a nest by marking nest-sites on photographs and visually checking them every 3–4 days. Only over a week did a count of large young present approximate to the total number fledging. The results of checks of 10 other groups of nests on single dates in May and July were thought to have overestimated breeding output by 13%. This was considered accurate enough for monitoring purposes. A method for monitoring breeding output using photographs and 2–4 checks a year is detailed.

INTRODUCTION

The numbers of kittiwakes *Rissa tridactyla* nesting in Britain and Ireland have increased dramatically this century (Coulson, 1983) but this increase may now have been reversed in some areas (e.g. Reynolds, 1985; Heubeck *et al.*, 1986). Kittiwake nests have been counted annually in fixed plots at many colonies (e.g. Stowe, 1982), and the biology of the species has been studied in detail at a colony at South Shields, Tyne & Wear since 1952 (Coulson & Thomas, 1985), but there are few such quantitative data on geographic variation in breeding success. Although such data are time-consuming to collect, they are essential if we are to understand the results of population monitoring. I report on a simple method of estimating breeding success

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which also allows the accurate monitoring of changes in numbers of nests from year to year.

METHODS

The field study was undertaken at the colony of *c.* 4000 pairs of kittiwakes on the Isle of May NNR, Fife, Scotland in 1986. Six groups of nests (or plots) were chosen for detailed study. These covered a range of habitat type and nest density. Two plots (nos. 1 and 2) were on inland cliffs above a fresh-water loch which had been colonised in the late 1970s. These two plots included all the nests in the two groups, whereas the other plots were parts of much larger concentrations of nests on sea-cliffs. The outcome of the breeding attempt at all nests within these defined areas from sea-level to cliff-top was followed.

The plots were photographed on 28 April, after pairs had started nest-building, from the spot where observations were to be made. All occupied nest-sites were numbered subsequently on the photographs and all sites were checked using binoculars or telescope about every four days from when the first egg was seen on the island (9 May) until the first young hatched, and then every three days until 13 August when virtually all the adults had left. New nests and sites were marked on the photographs as they were built or occupied respectively. On each check every nest was scored (on a check-sheet) for (a) state of development ('deserted', 'trace' with a few fragments of material, or 'complete' when it had a well-formed cup and could have held a clutch of eggs); (b) whether or not a bird appeared to be incubating or brooding; (c) the number and the state of development of the young; and (d) whether adults were present. Birds were not disturbed and no attempt was made to collect further data such as clutch-size. A complete nest with an adult present was equivalent to the 'apparently occupied nest' of typical June monitoring counts. In this paper 'nest' is used solely for a structure deemed capable of holding a clutch of eggs. Daily totals of nests include nests where adults were present and where eggs or young could be seen if the adults were absent. A chick was assumed to have fledged if it disappeared when its state of development was such that its wing tips projected well past its tail, all down had been lost and it was at least 36 days old. Younger chicks were unlikely to have been able to fly properly (Coulson & White, 1958). There were seven unfledged young present when observations finished. All appeared healthy and they were assumed to have fledged successfully.

Breeding success for each plot is expressed as the mean number of young fledging (a) per pair which laid (or where a bird was apparently incubating on at least two consecutive checks) and (b) per pair which had built a complete nest. It is conceivable that a pair failing early in the breeding season could have moved and made a new nest, but I had no evidence of this.

To monitor the efficiency of assessing breeding success by just two checks, an additional 10 plots dispersed around the Isle of May were also photographed. On 29 May, when—to judge by the plots studied intensively—most pairs were incubating, the position of each incubating pair and nest was marked separately (but not numbered) on a transparent overlay placed over the photographic prints of these additional plots. Each plot and each marked nest was checked again on 14 July, the day after the first young was seen flying. The number of young present was marked against each nest. The position and contents of new nests were added.

RESULTS

Laying

The first kittiwake egg was seen on 9 May, which compared with 1 May 1981, 4 May 1982, 6 May 1984, 9 May 1983 and 16 May 1985. Laying started a few days later in the plots (Table 1), and 50% of pairs with nests were incubating by 16–22 May, depending on the plot. Of the 426 nests where eggs were thought to have been laid, 414 (97%) of the clutches were started in May. One of the June layings was thought to be a replacement. The latest laying occurred between 27 June and 4 July.

The total number of nests present increased rapidly until early June but then stabilised at 95–97% of the season's total (Fig. 1). Twenty-five nests (6% of the total) were completed during June. Eighteen of these were at the two inland colonies.

TABLE 1
Timetable of Breeding Kittiwakes in the Study Plots

Plot	*Pairs incubating (n)*	*First egg*	*50% of n pairs incubating by*	*First young seen*	*Latest young left*
1	89	(14 May)[a]	19 May	10 June	7 August
2	74	(14 May)[a]	19 May	13 June	after 13 August
3	41	16 May	22 May	13 June	10 August
4	30	12 May	16 May	10 June	after 13 August
5	111	12 May	16 May	12 June	after 13 August
6	81	14 May	16 May	10 June	after 13 August

[a] First incubating birds, no eggs were seen.

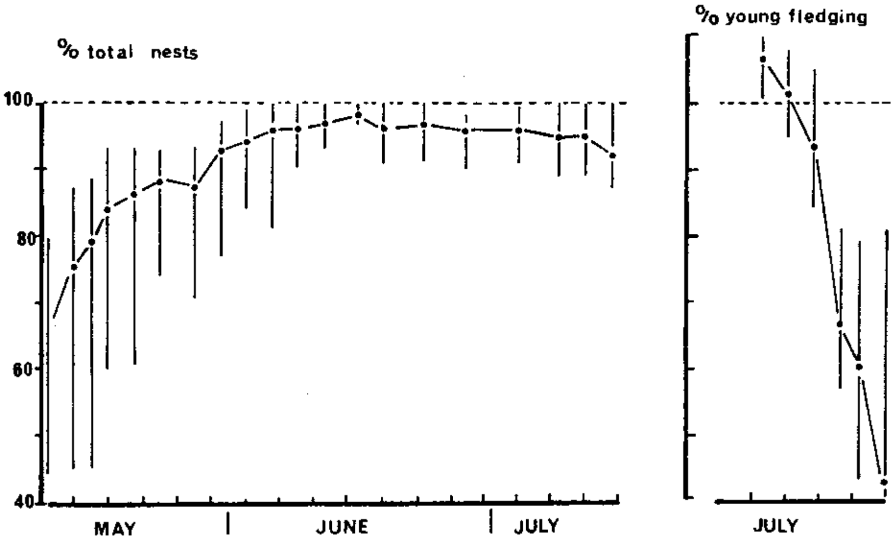

Fig. 1. Counts of nests and young kittiwakes present in nests at various dates expressed as a percentage of the total number of nests built and the total young fledging. The means and ranges of the six study plots are shown except for the first nest count where only the range of the three plots counted is indicated.

Fledging

The first young was seen flying on 13 July but none left the study nests until five days later. The number of young present on the nests declined quickly (Fig. 1) and only over a period of a week did a single count of all the young present approximate (±5%) to the number known to have fledged from these nests in 1986.

Breeding output

Breeding success was high and the majority of pairs reared two young (Table 2). In five of the study plots the mean production was 1·35–1·59 young fledged per pair building a nest (or 1·40–1·65 per pair incubating). The reason for the low success (0·98 and 1·02 fledged respectively) of the sixth plot was unknown as it was part of a large cliff group of kittiwakes which has had about the same number of nests for at least the last 20 years.

The chances of young present on any day fledging remained high at 90% up to 11 July, but then declined significantly to 75% for young still present at the end of July. This decline was described by the equation:

$$\% \text{ success (arcsin transformed)} = 88 - 0{\cdot}64 \text{ date in July}$$

$$(r = -0{\cdot}95,\ n = 7,\ P < 0{\cdot}01)$$

TABLE 2
Breeding Success of Kittiwakes on the Isle of May 1986

Plot	*Pairs laid*	*Other nests*	*Other regular sites*	*No. of pairs hatching (%)*	*Pairs fledging*					*Mean young fledged per*	
					0	*1*	*2*	*3*	*Total young*	*pair laying*	*pair and nest*
						young					
1	89	1	3	85 (96)	8	23	54	4	143	1·61	1·59
2	74	6	6	69 (93)	5	23	42	1	110	1·49	1·37
3	41	2	2	33 (80)	6	12	15	0	42	1·02	0·98
4	30	1	0	25 (83)	6	8	14	2	42	1·40	1·35
5	111	8	3	106 (95)	5	21	78	2	183	1·65	1·54
6	81	5	4	79 (98)	7	27	45	2	123	1·52	1·43

Production based on two checks

On 14 July the mean number of young per nest completed either in May or July varied from 1·03–1·55 depending on the monitoring plot (Table 3). Combining the plots on the first check there were 634 pairs incubating (which gave rise to 858 young alive on the second check) and an additional 70 completed nests (15 young). On the second check there were 3 new, completed nests (one young). Thus 874 young came from 707 nests known to have been completed. Assuming the same breeding timetable as found in the study plots, 7% of nests would have been missed and the count of young would have exceeded true production by 7%, i.e. the total production would have been 13% lower than the count (1·08 young/nest cf. 1·24 young/nest).

TABLE 3
Number of Young Present on 14 July at Nests which were Completed by 29 May 1986

Area	*Incubating in May young present in July*				*Complete nest in May young present in July*			*New nests in July (n)*	*Total young present*	*Young per completed nest (Mean)*
	0 (n)	*1 (n)*	*2 (n)*	*3 (n)*	*0 (n)*	*1 (n)*	*2 (n)*			
1	12	15	25	1	2	0	0	0	68	1·24
2	31	53	85	3	13	0	0	0	232	1·25
3	31	40	59	0	23	0	0	1	158	1·03
4	22	40	53	1	1	2	0	1	151	1·26
5	5	20	31	0	4	2	0	1[a]	85	1·35
6	1	2	6	0	1	1	0	0	15	1·36
7	4	7	14	0	6	0	2	0	39	1·18
8	3	5	14	0	3	3	1	0	38	1·31
9	3	8	29	2	4	1	0	0	73	1·55
10	0	3	6	0	1	0	0	0	15	1·50

[a] This nest had a single young, the other two new nests were empty.

DISCUSSION

The use of photographs to monitor breeding output proved extremely efficient, especially when the nests were not numbered but their position, state and number of young marked directly onto transparent overlays placed over the photos. If the same photographs are used each year, the photographs or overlays are also an extremely accurate way of monitoring changes in the numbers and distribution of pairs present.

It took me a single day to mark the nests of 1100–1200 pairs, dispersed between 16 parts of the island, on to the photographs and another day to check the number of young present near fledging. Because I had been regularly checking the intensively studied plots, I was probably fairly efficient at the task, but as a novice in 1985, I marked 760 nests on photographs in about 10 hours and later P. Ewins noted the number of large young produced at these same nests in about the same time. Large prints of high quality photographs are essential for efficiency. Areas 2 and 4 had 185 and 119 nests, respectively, in May and each area was covered by a single photograph. Checking each took about three times as long as area 3 (with 153 nests) which was covered by five photographs.

The temptation to follow either just small areas with well separated nests at the edges of colonies, or to check just a single plot in the centre of the colony, must be avoided, as kittiwakes breeding at the edge of a colony perform differently from those at the centre (Coulson, 1968) and nesting success varies greatly within a colony (Table 2). The areas to be followed should, if possible, be representative of the colony but this is extremely difficult, or possibly even impossible, to ensure. On the Isle of May I attempted to minimise the chances of the plots being unrepresentative by (a) having many plots and (b) by dividing the island into several approximately equal sized areas and dispersing the plots amongst these. I could have dispersed them randomly throughout the colony (see Harris *et al.*, 1983) or have sub-divided the island in some other way, e.g. by cliff-type. It is difficult to know the minimum number of plots which need to be studied to get an unbiased production figure. The number probably varies from colony to colony. The Isle of May scheme monitors about 30% of the total population distributed among 16 plots. This would seem adequate.

The estimates of breeding success based on two checks appeared to be 13% too high. Should we be satisfied with this or should we aim for greater precision, which would come from an increase in the numbers of checks? Kittiwake nesting success varies greatly, e.g. from 1·59 young fledged per nest built (this study) to virtually zero when pairs either do not lay or most nests fail early on (Johansen, 1978). For monitoring the general 'health' of the population there is little to be gained from greater accuracy. Indeed, if it were not for the chances of a breeding failure, with many birds leaving the colony early in the season, the count in May could be dispensed with and the breeding success expressed as the number of young present per completed nest occupied near fledging (e.g. Barrett, 1983).

The Isle of May has a large kittiwake population and nesting success was high in 1986. Are patterns of laying and fledging documented here likely to be typical? Several other studies have shown a similar stability of counts of completed (or apparently occupied) nests in mid-season. Richardson *et al.* (1981) recorded a maximum nest count at a Shetland colony on 22 June and six counts made between 5 June and 10 July all exceeded 95% of this. McGrath & Walsh (1985) followed nests in two colonies in Waterford and noted that numbers of nests remained above 95% and 90% respectively, of the maximum count from early June to late July. However, such a long period of stability of counts does not always occur. Heubeck (1986) followed four plots at Sumburgh, Shetland, in 1986. The maximum counts of active nests ranged between 86 and 95% of the total and the count of nests declined gradually from a peak in early June. Breeding success was low at 0·41–0·75 young fledged per nest where birds had been seen incubating. Presumably in even worse conditions kittiwakes may sometimes completely abandon small colonies (Barrett & Schei, 1977). Therefore, care must be exercised in interpreting counts of occupied nests in late June or July as the 'breeding population', since by then some pairs could have already failed and left the colony.

The start of laying varies considerably from year to year even at one colony. For instance, on the Isle of May first egg dates between 1981–86 varied from 1–16 May whereas on the Farne Islands, Northumberland, first egg dates between 1971–86 ranged from 15 April to 8 May (Hawkey & Hickling, 1972–86). The peak of laying might be more consistent, but the mean date of laying of experienced breeders at North Shields, Tyne & Wear, ranged from 15 to 25 May 1952–82 (Coulson & Thomas, 1985), and on Hornøy, Norway, there was a 10-day difference between both median and first egg dates in both 1980 and 1981 (Barrett, 1983). Timing of breeding also varies greatly from colony to colony. Barrett (1978) followed the pattern of laying at two neighbouring Norwegian colonies for three seasons; the differences in first egg dates and mean laying dates between the colonies in the same years were 2–17 and 0–9 days respectively. Thus, it is extremely difficult to predict the laying or fledging season of any colony.

The timing of nest checks is vital, especially if only two or three are made. In Britain, the plotting of completed nests on photographs is probably best done in early June, but two checks, about three weeks apart, in late May and mid-June are preferable. On the Isle of May two such checks missed only 1% of the annual total of completed nests. The timing is more important for

TABLE 4
Useful Indications of the Age of Kittiwake Chicks
(taken from Maunder & Threlfall, 1972)

Black tips to feathers of neck just visible at 9 days
Tail feathers erupt at 10 days
Black tips to upper wing coverts visible at 11 days
Black tips to vanes of tail feathers visible at 16 days
Most down lost but still some on top of head and back at 25–30 days
Wing tips equal length of tail at 30 days
Wing tips 1–2 cm longer than tail at 36 days
Wing tips 3–4 cm longer than tail at 40–45 days

determining the number of chicks fledging. Ideally, there should be two or three checks 5–7 days apart, straddling the main fledging period. If only one visit is possible, this should be during the week following the first fledging. If the date of this event cannot be determined directly it can be predicted approximately, either by adding 10 weeks (27 days incubating and 43 days fledging periods; Coulson & White, 1958) to the first egg date or by estimating the ages of the oldest chicks present using the criteria in Table 4. Kittiwake breeding success is so variable that even a few visits should give some indication if it was a 'good' or 'bad' season.

Suggested method of monitoring breeding output

(1) Decide the time available for the checks and thus the number of plots which can be covered. The initial check and plotting of 50–70 nests on photographs will take an hour or more, but later checks will be both quicker and easier. If the colony is small, the observer should try to check as many of the nests as possible. If it is large, the plots should be dispersed throughout the colony. Several small plots are more likely to be representative of the colony than one or two large plots and are relatively much quicker to check.

(2) Photograph the plots when the birds are present, preferably when they are on nests. Photographs can be used for several years as the same sites are normally used each season. *Good photographs are essential.* Have a maximum of 50–70 nests per print.

(3) Make large prints (A4 size is ideal) and tape on transparent overlays, and write on these using a suitable waterproof pen. [If this is not possible, the negatives can be mounted as slides and projected on to clean white paper, the nests, sites and prominent cliff-features marked, and photocopies made of these 'maps' (M. G. Richardson, pers. comm.).]

(4) Visit the colony in late May and mid June (or, if two checks are

impossible, once in early June) and mark on the overlays the position of (a) nests with birds incubating, (b) other completed nests, and (c) a bird with even a trace of nest material, using different symbols. If an overlay is not available or many visits are to be made, number the nests and pairs sequentially and note the state of each on a check-sheet. Do not waste time trying to determine clutch size.

(5) Determine or predict when the first fledging should occur. Make a visit as soon after this as possible and check each nest/site marked previously and add on any new nests. Mark the number of large young present alongside each nest on the overlay (using a different colour pen for each visit) or check-sheet. Note any young which are *not* near to fledging, i.e. with wing tips shorter than the tail. Do not waste time trying to determine the numbers of very small young in late broods. Try and return 5–7 days later and check these late nests. The more checks made, the better the result.

(6) When assessing how many young you think may fledge, remember that large young sometimes move between nests, that young in broods of two or three sometimes fledge several days apart and that fledged young may return for several days either to their own or other nests.

(7) Sketch the main features of the colony on to the overlay, label both picture and overlay fully (including the dates of the checks) and keep for future assessment of numbers and nest-sites.

(8) Present chick productions as the number of pairs which built complete nests which reared three, two, one or no young and, if possible, the numbers of other pairs which built only part-completed nests.

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Appendix 4. A method for monitoring the breeding success of the shag.

1. This is a straightforward procedure but an accurate result necessitates regular visits to a colony (high-input method). However, a few visits can produce a useful index for comparing success in different years. The methods can also be used for gannet and cormorant.

2. High-input method

2.1 This entails visiting the colony every 7-10 days from when birds start laying to check the progress of breeding at numbered nest-sites until the young are fully feathered. Some background data on the reasons for regular checks is given in the appended reprint.

2.2 The method can be used both for birds breeding on open cliff ledges and for these nesting under boulders.

2.3 Selecting plots for monitoring nesting success.

2.3.1 As with all monitoring, the problem is to reduce the chances that the samples you choose are atypical of the colony as a whole.

2.3.2 If the colony is small, try and check all the visible nests. Even in a large colony, the higher proportion of the population checked the better.

2.3.3 If the colony is large, sample areas (called plots) must be chosen. Virtually all studies of colonial seabirds have shown that many aspects of biology vary within the colony, and often the laying or productivity of pairs are clumped, e.g. some groups of birds breed early/late, have high/low productivity, etc.

2.3.4 This causes problems in sampling but it is far better (on both statistical and practical grounds) to choose many relatively small plots scattered throughout the coloncy than one or two large plots. A plot containing 10-20 nests is considered a reasonable size.

2.3.5 Two method for dispersing these plots have been used

(a) Random position. This is <u>not</u> haphazard. Go along the colony and find all the groups of nests which can be checked accurately and safely. Include all the areas used by birds for nesting and try not to bias the plots to top/bottom, centre/edge of the colony. Plots can abutt each other. Draw rough diagrams of where these plots are. When you get to the end of your defined colony, give each plot a number, say 1-20. Then decide how many you can check (remembering the more the merrier!). Let's say 6. Then choose six of numbers by using a table of random numbers or writing numbers on cards and then pulling six of the 20 out of a hat. Record how many plots you choose from (i.e. 20).

(b) Divide the colony into say 4 or 5 approximately equal parts (either by cliff top length or number of nests) and pick (say) 2 plots in each area. Have the same number of plots in each area. Again, try not to bias the choice towards top or bottom areas. If the cliffs are not too high, the plots should span from the cliff-top to sea. This method is probably not as good as (a) but has been used where the number of possible plots is small.

2.3.6 Whatever method you use, document exactly how you made your choice.

2.3.7 If you are constrained absolutely just to check specific plots for any reason (safety, time, only places not to disturb birds or the public), record this.

2.3.8 It is not necessary to use the same plots each season as we are not comparing counts but breeding output.

2.3.9 Photograph the plot, preferably when birds are at their nest-sites, and make large (A4) black-and-white prints. Tape over a transparent overlay, mark on the positions of the nests and number them. (It is possible to sketch the colony instead of photographing it but this often leads to confusion during later checks.)

2.3.10 If the nests are among boulders, mark the sites with numbered pegs.

2.4 Visit the area every 7-10 days and for each nest record the state of the nest (e.g. few sticks, complete platform), nest contents (if visible) of if a bird appears to be incubating or brooding. Pay particular attention to young at sites on open ledges as large young sometimes move away from the nests. You will have to assume that well feathered young which appear healthy will fledge successfully.

2.5 Express your results as both:-

(a) the total numbers of nests where eggs were seen plus those where birds appeared to be incubating which failed or fledged one, two, three or four chicks. Record the reasons for any losses, e.g. washed away, eggs did not hatch.

(b) the total number of young fledged/number of nests where were birds were definitely or probably incubating.

Do not pool results from plots as if there are significant differences between plots the colony mean production is the average of the plot means.

3. Low input method

3.1 In boulder colonies check nests during incubation, and near fledging when a search should also be made for additional sites. This will give a useful index of chick production.

3.2 Record the number and sizes of young in broods and empty nests during a visit when chicks are large, e.g. during ringing. Average brood size can be used as an index of breeding output (Aebischer, N.J. (1986), J. Anim. Ecol. 55: 613-629).

4. The following paper explains why regular checks are needed and lists some of the potential problems.

Bird Study (1987) **34**, 187–190

The effect of date on counts of nests of Shags *Phalacrocorax aristotelis*

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We made weekly counts of nests at a colony of Shags on the Isle of May. Numbers of nests increased to a peak in early June and then declined. The peak count of active nests was only 89% of the annual total in the area. Some sites were used by more than one pair. We confirmed the finding of Potts that a single count of occupied nests in early June is normally a good index of the breeding population, at least in northeast Britain. Occasionally, breeding is either very late or a large proportion of the population does not breed. Counts should, therefore, include an objective assessment of the timing of breeding and a subjective assessment of whether or not the number of birds present seems excessive given the number of nests present.

Shags *Phalacrocorax aristotelis* build large bulky nests, which successful pairs occupy for some 16–17 weeks. Where the birds nest on open ledges, these nests are easily counted and a single annual count made in early June is often used as a measure of the size of a breeding population (e.g. Cramp, Bourne & Saunders 1974). The timing is based on the work of Potts (1969) on the Farne Islands, Northumberland in 1963–67. We wished to confirm that this was the best time to make such counts, working at another colony 20 years later.

METHODS

Part of the nesting colony at the south end of the Isle of May NNR, Fife, where Shags nest on ledges on small cliffs and offshore stacks, was photographed in April 1986. Breeding density was high, with 290 sites being occupied along 100 m of coastline. As pairs started to breed, the position of each nest was marked on the photographs, a complete check of all nests being made approximately weekly from 12 May until 27 July 1986 by R.F. Each nest was categorized as (a) active (bird sitting tight whether or not eggs or young were seen, or an unattended brood of young), (b) full nest (well built but seen to be empty although apparently capable of holding eggs), (c) half-built (platform of nest material but insufficient to hold eggs), or (d) trace (a few fragments of material guarded by one or both adults). Active and full nests are the categories usually counted and combined together as 'nests' in widespread population censuses (e.g. Operation Seafarer, Seabird Colony Register). This check using photographs aimed to account for every nest present in the part of the colony that was being surveyed.

Approximately weekly, Sarah Wanless and M.P.H. independently mimicked a typical census count. They checked the whole area from all vantage points, constrained only by the need not to disturb incubating birds, and categorized all the nests they saw as above. Only nests with at least 1 adult (or a brood of young) present were counted. When both S.W. and M.P.H. made counts, we have used the mean of the 2 as the count for the day. The comparisons between these counts and those from the weekly check of photographically mapped nests were restricted to parts of the colony visible from these vantage points. In the presentation of the results below, the difference between counts made by 2 counters or by 2 methods is given as the mean and standard deviation of the individual differences between the 2 counts, always taking the same counter or method first, divided by the average of the 2 counts.

RESULTS

There was remarkably good agreement between the combined counts of active and full nests found by the counters and the checks of the area using photographs. On the 7 dates where both methods were used the mean difference was only 1.4% (s.d. 6.8). Thus, we conclude that S.W. and M.P.H. overlooked few nests and their counts are used throughout this paper.

On the 8 days when S.W. and M.P.H. made direct counts there was good agreement between their counts, the mean differences in the counts of active nests being 2.3% (s.d. 3.1). There was, however, a difference of 15% (s.d. 33) in the combined counts of trace and half-nests. We think that this results from (a) the difficulty of deciding when a pair started to build (e.g., whether a few pieces of seaweed had been brought there by the birds) and (b) pairs sometimes leaving the sites unattended at this stage. The mean difference in the total nest counts of the 2 observers was 3.2% (s.d. 2.9).

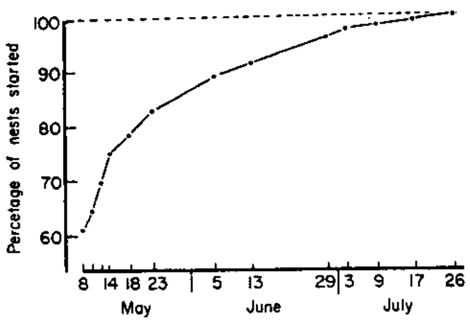

Figure 1. The proportion of the 290 nest-sites used by Shags on the Isle of May in 1986 which had a nest started by a given date. Data are from checks using photographs to ensure that no sites were overlooked.

Overall, 290 different nest sites were used during the period. Over 90% of the sites used had at least a trace of a nest by 13 June but 11 sites (4%) were not occupied for the first time until July (Fig. 1). No nest was started after 27 July. Of these 290 sites, 252 (87%) reached the active stage; of the rest, 13 reached the full nest stage, 15 the half-nest stage, and 6 never had more than a trace. (Four nests were almost hidden from view so the state that they reached is unknown.) Thirty sites were used on several different occasions and at 10 of these there were 2 successive active nests. Five of the 30 sites were used by individually recognizable pairs. One was used by 2 different pairs, both of which had active nests at that site some time during the season; 3 were used by 2 different pairs, though only 1 nest reached the full stage; and 1 was used twice by the same pair. One male deserted his nest and 5 eggs about 10 June after being colour-ringed, moved 85 km to the Farne Islands, and bred again in the same season, successfully rearing a chick (P. Hawkey pers. comm.). This movement must be considered exceptional, because the bird had apparently bred in the study area since at least 1971 and had been caught in 4 previous seasons; furthermore, it was back at its Isle of May site in March 1987. We do not know how many pairs actually bred in the area

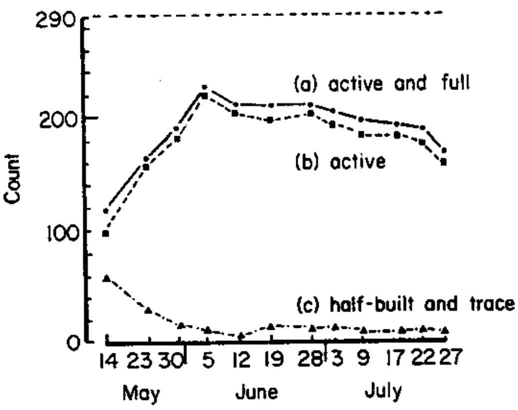

Figure 2. Counts of (a) active and full nests combined, (b) active nests and (c) half-built and trace nests in the study area in 1986. Data are from normal counts without using photographs. The decline in the number of active nests in June and July is significant ($r = -0.94$, $P < 0.001$) and its mean rate was 0.86 nests per day (regression analysis).

in 1986 but the maximum number of pairs occupying sites on any day was 240 on 5 June.

The first egg on the island was seen on 4 May and the first in the study area 2 days later. From then on, nests were both started and disappeared (with the material being stolen by neighbouring pairs) throughout the breeding period. The total number of active nests present increased to a peak of 224 (89% of the season's total) on 5 June and then declined slowly but significantly (Fig. 2). The number of half-built and trace nests showed a corresponding decline and remained at around 10. The peak count of total nests was 237 (82% of all those recorded) and this also occurred on 5 June.

DISCUSSION

On any one day some pairs will not have started breeding, while others will have failed and left. Thus maximum counts will underestimate the population. However, the total number of sites used during a season will overestimate the population, as some birds change sites during the season. On the Farne Islands, where Shags also nest on open ledges, Potts, Coulson & Deans (1980) considered that the most consistent and accurate index of population size was the maximum numbers of nests occupied at any time. They expressed this nest count as breeding pairs, noting that each pair (as defined above) occupied 1.15 sites per season. Despite over 80% of the adults being individually recognizable (G.R. Potts pers. comm.) some unsuccessful pairs probably moved from site to site without being identified, so this ratio will not allow for some sites being used by more than one pair within a season. On the Isle of May in 1986, 290 sites had a nest at least started and the maximum number of sites occupied at one time was 240 (based on checks using photographs)—a ratio of 1.21 sites occupied per pair if, and we have no evidence to back this up, we assume that all pairs were actually nesting at one time. In 1982, Aebischer (1985) used photographs to check the whole of the Isle of May colony several times and found that 1916 sites had had a pair and at least a trace of a nest at some time during the season. His maximum count was 1733, giving a ratio of 1:11. Ratios of this type will doubtless vary between colonies and G.R. Potts (pers. comm.) noted that they were higher in low-quality nesting areas, such as places where waves wash away nests.

A further source of inaccuracy in counts is the difficulty in actually seeing nests. This was not a problem in our area but elsewhere on the Isle of May some Shags nests are hidden in caves and fissures in the cliffs. Such nests are easily missed. Aebischer (1986) considered that 15% of all nests on the island would have been overlooked during a normal nest-count. Counts of peak nest numbers are likely to underestimate the population.

Census counts in Britain are usually made in early June, following the findings of Potts (1969) on the Farne Islands that numbers of occupied nests tended to be highest then. The timing of breeding of Shags is extremely variable and this might be expected to influence the best date to make counts. There are few data on median laying dates but the first egg dates on the Farne Islands for 15 seasons 1972–86 was 12 April (s.d. = 12 days) (Hawkey & Hickling 1972–86). Start of laying on the Isle of May showed a similar annual variation, with the first egg dates for 20 seasons during the period 1962–86 ranging from 23 March to 20 May (mean = 21 April, s.d. = 18 days) (Aebischer 1986; pers. obs.). Thus 1986, with the first egg on 4 May, was a late season. The optimum time for a single count of the nests, that is the time when the maximum number of sites was occupied, was the first third of June on the Isle of May in each year 1981, 1982 and 1986, even though the first egg dates in these years varied 28 March–4 May. However, in 1976 laying started on 20 May—one of the two latest dates on record (Aebischer 1986). On 2–4 June H. Galbraith (pers. comm.) counted 348 occupied nests on the Isle of May whereas on 27–30 July M.P.H. and others found 479. It would be interesting to have details of the nesting pattern in such a very late season. Our subjective impression is that laying is more synchronized in late seasons. Thus, care must be exercised in using June counts made in very late seasons, of which there have been 3 since our records began on the Isle of May in 1972. Laying patterns at other colonies should be checked before taking the first week of June as standard time throughout Britain. For, although the available evidence confirms the view of Potts *et al.* (1980)

that a single count of occupied nests at this time is normally a good index of the number of pairs breeding that year (even though its accuracy remains unknown), Shags breed much earlier in southwest Britain than they do in the northeast (Table 3 in Potts 1969). Counts should perhaps be made earlier in these regions.

Occasionally, as shown by Aebischer (1986), large numbers of Shags fail to nest. In such seasons any count of nests will give a misleading indication of population size. Therefore, any count of Shag nests should include an objective assessment of the timing and breeding and also a subjective assessment of whether there seemed fewer nests than would have been expected from the numbers of adults present. For instance, annual counts of the number of pairs of Shags nesting on Canna, Inner Hebrides showed a dramatic increase between 1974 (856 nests) and 1985 (1690 nests). The count for 1986 was only 436 nests but over 1000 adults were counted on rocks close to the colony; obviously many pairs had not bred (details from Swann & Ramsay 1986). Such details are important to later workers when they need to compare counts. Aebischer (1986) showed convincingly the importance of having sufficient ringed birds in populations that are counted regularly to determine whether low nest counts do or do not reflect population declines. Adult Shags are now being colour-ringed on the Isle of May and at other Scottish colonies for just such a purpose.

ACKNOWLEDGMENTS

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(MS received 20 November 1986; revised MS received 1 April 1987)

Appendix 5. A method for monitoring the breeding success of the fulmar

1. This is a straightforward procedure but both the suggested methods necessitate 4-5 visits to the colony.

2. Both methods necessitate selecting study plots.

2.1 As with all monitoring, the problem is to reduce the chances that the samples you choose are atypical of the colony as a whole.

2.2 If the colony is small, try and check all the visible nests. Even in a large colony, the higher proportion of the population checked the better.

2.3 If the colony is large, sample areas (called plots) must be chosen. Virtually all studies of colonial seabirds have shown that many aspects of biology vary within the colony, and often the laying or productivity of pairs are clumped, e.g. some groups of birds breed early/late, have high/low productivity, etc.

2.4 This causes problems in sampling but it is far better (on both statistical and practical grounds) to choose many relatively small plots scattered throughout the colony than one or two large plots. A plot containing 30-50 nest sites is considered a reasonable size.

2.5 Two methods for dispersing these plots have been used.

(a) Random position. This is <u>not</u> haphazard. Go along the colony and find all the groups of which 30-50 sites which can be checked accurately and safely. Include all the areas used by birds for nesting and try not to bias the plots to top/bottom, centre/edge of the colony. Plots can abutt each other. Draw rough diagrams of where these plots are. When you get to the end of your defined colony, give each plot a number, say 1-20. Then decide how many you can check (remembering the more the merrier!). Let's say 6. Then choose six of the 20 numbers by using a table of random numbers or writing numbers on cards and then pulling six of the 20 out of a hat. Record how many plots you choose from (i.e. 20).

(b) Divide the colony into say 4 or 5 approximately equal parts (either by cliff top lengths or number of sites) and pick (say) 2 plots in each area. Have the same number of plots in each area. Again, try not to bias the choice towards top or bottom areas. If the cliffs are not too high, the plots should span from the cliff-top to sea. This method is probably not as good as (a) but has been used where the number of possible plots is small.

2.6 Whatever method you use, document exactly how you made your choice.

2.7 If you are constrained absolutely just to check specific plots for any reason (safety, time, only places not to disturb birds or the public), say so.

2.8 It is not necessary to use the same plot each season as we are not comparing counts but breeding output.

3. Photograph the chosen plots, then either

(a) Method 1: tape on a transparent overlay and mark on and number nest-sites.
(b) Method 2: delimit the boundaries of the plot directly on to the print with waterproof ink.

4. Checking

4.1 Method 1

4.1.1 Visit the area three times 3-4 days apart in late May/early June by when the bulk of birds have laid. For each occupied nest site (that is where a bird appears to be sitting tight) record on a check sheet what you think the bird is doing. For instance, record 'egg seen', 'no egg present' 'incubating'. Do not flush birds or eggs will be lost.

4.1.2 The main problem with fulmars is to decide how many pairs are actually breeding. The best estimate is the number of eggs seen plus sites where a bird was 'incubating' on all three checks.

4.1.3 Check each numbered site again in early to mid August for the presence or absence of a chick. Assume that all large young fledge.

4.2 Method 2

4.2.1 Visit the area on several days in June and count the number of apparently occupied sites - one or two fulmars occupying a site capable of holding the fulmar's single egg. Calculate the average number of occupied sites.

4.2.1 Visit the area in early to mid August and count the number of chicks. Assume that all large young fledge.

5. Productivity

5.1 Express the results as the mean number of young fledging per bird incubating (method 1) or per occupied site (2).

5.2 Do not pool results from plots as if there are significant differences between plots the colony production will be the average of the plot means.

Appendix 6. A method for monitoring the breeding success of the puffin.

1. Puffins do not tolerate much disturbance when nesting so neither of the two methods which have been developed involve handling the adult.

2. Method 1. This is suitable for colonies where burrows are in soil and where there are no Manx shearwaters present. It involves feeling down a burrow with a short bamboo or stick.

   2.1 Check a series of burrows after the peak of laying (usually early May).

   2.2 Select a series of sticks 6-20" long. Take the longest, lie on the ground and push the stick and your arm down the burrow. Any incubating puffin will move off the egg which can usually be felt with the stick on the floor of the nest-chamber. If the stick is too long to go around a bend in the burrow, try again with a shorter one. Be careful not to break the egg. Any burrow where an egg is felt is then staked (but not necessarily numbered) bearing in mind that the vegetation may well grow quite tall and you will want to find the burrow again. These checks are best made when the ground and burrow floor are dry.

   2.3 Disperse the burrows checked through the colony. Try for a sample of 100^+ burrows.

   2.4 Recheck the burrows when birds have very large chicks (early July in northeast Britain, mid-July, elsewhere). It is usually easy to determine if the nest has been successful, either by feeling the chick, finding the chick's latrine at the first bend of the burrow or searching for moulted down among the nest lining a bit of which is easily pulled out.

   2.5 Success is expressed as the number of chicks present/the total number of burrows refound where presence or absence of a chick was determined.

3. Method 2. This is suitable where birds nest among rocks or where colony is shared with Manx shearwaters.

   3.1 Find a vantage point where burrows can be watched from a distance.

   3.2 Mark all visible burrows with large numbered stakes and early in the season record which burrows are being regularly used by puffins.

   3.3 When birds are feeding large chicks, make a few watches to determine which burrows have fish taken down them. This is best done in the early morning when feeding frequency is highest.

   3.4 Express success as the number of successful burrows/number occupied early in the season.

4. Method 1 is also suitable for Manx shearwater and some black guillemot colonies; Method 2 is suitable for black guillemots nesting among boulders.

Appendix 7. Food samples collected from adults feeding chicks in 1988

Data for Kittiwakes are presented in Section 5.3 and for other species on Fair Isle and at Hermaness in Section 7.3 and Appendix 8, respectively.

1. Fulmar

Fair Isle 1 July-10 August

38 Samples: 32 fish offal or discards, 3 small fish, 1 whelk operculum, 1 sandeel.

2. Shag (regurgitates)

Isle of May 15 June - 19 July

16 totalling 675 g; all sandeels except for one regurgitate from an adult which contained 1 sandeel, 1 dragonet/scorpion fish type and 1 butterfish. Sandeels mostly 10-16 cm long.

Inverhill, Caithness 6-23 July (S Mackay)

16 totalling 286 g; all sandeels (except one sample which also had 1 very small crustacea). Sandeels lengths estimated as
16 x 12-14 cm
42 x 5-8 cm.

Fair Isle, 3-30 July

11 totalling 408 g; sandeels 97% by number and 95% by weight. Only other prey was 1 sea scorpion. Sandeels 11-17 cm (mostly 12-13 cm).

Canna (R Swann)

May - load of 5 medium sandeels
July - load of 8 sandeels (52 g); lengths 10-12 cm, 125, 127 133 and 151 mm.

Sumburgh 30 June (D. Okill)

3 samples totalling 213 g:
100% sandeels; including 13 10-14 cm.

2. Puffin (loads)

Isle of May	No.	Wt of load (g) mean±SE	No.	Fish/load mean±SE
13 June-4 July	107	9.3±0.9	107	8.2±0.8

Skomer				
20 June-9 July	19	9.1±0.6	19	8.2±0.5
Fair Isle				
2-12 July	34	6.0±0.8	14	4.4±1.4

Measurements of fish (mm)

	Species	No	Mean±SE
Isle of May	sandeel (small)	664	65.8±0.5
	sandeel (large)	27	140.6±3.3
	herring	113	62.7±0.6
	saithe	3	72,60,42
	cod	2	55,52
	sprat	1	105
Skomer	sandeel	135	69.4±0.8
	clupeidae (probably sprat)	21	55.5±1.5
Fair Isle	whiting*	72	46.7±1.3
	sandeel	64	72.4±4.4
	clupeidae	8	38.5±1.3
	flatfish	1	22
	rockling	1	22

*includes a few Norway pout

Feeding frequency

Isle of May 26 June; 49 burrows
mean = 5.1±0.4 feeds/chick/day

4. Guillemot

Diet (observations)
Isle of May 30 May -21 July

Fish	Size class	No.	Calculated wt (g)
Sandeel	very large	6	?
	large	85	13
	medium	159	7.6
	small	67	4
	minute	20	?
Sprat	large	128	18
	medium	98	11
	small	25	?

Saithe	small/medium	3	5
Gadidae sp.	medium	1	?

Mean fish weight = 11.1 g

Marwick Head, Orkney (from Thomas 1988, NCC CSDR No. 872)

Sandeel	25
Gadoid	8
Other	9
Unidentified	4

Fair Isle (Riddiford & Silcocks 1988, NCC CSDR No. 879)

sandeels	76
unknown	5

Feeding frequency

Isle of May
13 June 3.14 feeds/chick/day (91 young)
16 June 3.30 feeds/chick/day (98 young)

Fish measurements
Probably include some dropped by displaying birds

Place	Species	No.	Length (mm)±SE	
Isle of May	sandeel	21	144.6±4.9	
	sprat	7	107.6±8.2	
	saithe	2	80, 103	
Fair Isle	sandeel	10	111±14	
	saithe	1	120	
Canna	sandeel	18	150.1±6.7	
	sprat	16	111.6±2.3	
	whiting	9]		
	Norway pout	4]	87.5±3.2	
	pollack/saithe	1]		Gadoid sp.
Sumburgh	sandeel	12	158.5±5.5	

5. Razorbill

Diet

Isle of May 4 June-21 July
Loads composed of:-

sandeels (large)	21
sandeels (medium)	60
sandeels (small)	50
sprat	1
small ?herring	7
minute	2
Unknown fish	1

Canna, July

Load - 3 sandeels (66, 70, 77 mm)
Load - 3 sandeels (15, 26, 31 mm)

Fair Isle, 3-30 July

4 loads - 3 x sandeels (55, 55, 159 mm)
- 1 sprat or herring (11 cm)

Feeding frequency
Isle of May

13 June	3.14 feeds/chick/day (13 young)
16 June	3.30 feeds/chick/day (14 young)

6. Black Guillemot

Fair Isle 11 July - 4 August

Collected fish

short-spined sea scorpion	5 (79, 70, 85, 85, 90 mm)
long-spined scorpion	52 (88, 90 mm)
Yarrell's blenny	1 (149 mm)
rockling	1 (20 cm)
butterfish	2 (149, 133)

Fish seen during feeding observations 11 July - 4 August

butterfish	17
Gadoid	6
flatfish	3
Yarrell's blenny	1
sea scorpion	2

Appendix 8

In press: Bird Study

THE DIET OF ATLANTIC PUFFIN *FRATERCULA ARCTICA* AND NORTHERN GANNET *SULA BASSANA* CHICKS AT A SHETLAND COLONY DURING A PERIOD OF CHANGING PREY AVAILABILITY

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Short title: **DIET OF PUFFIN & GANNET CHICKS**

SUMMARY

The food of young Puffins and Gannets was examined between 1973 and 1988 on Hermaness, Unst. No prey other than fish was found in any year; ten species were taken by Gannets and at least 13 by Puffins during the study period. Sandeel *Ammodytes marinus* was found to be the dominant prey species for Puffins in every sampling year except the last two, comprising over 90% of the diet by weight in many annual samples. Sandeel formed 90% of the diet of young Gannets in 1981 but declined steadily in importance thereafter, falling to 6% in 1988 by which time Herring *Clupea harengus* and Mackerel *Scomber scombrus* were the 2 most common prey species. In a successful breeding season, the Hermaness colonies of Puffins and Gannets consume about 3000 tonnes and 2500 tonnes respectively during their attendance at the colony. The mean weight of food loads delivered by Puffins to their young declined significantly after 1980, as did the size of Sandeels captured. Observation of the colonies reinforces the evidence from diet sampling that Sandeel has been less available to both seabird species in the latter years of the study. Gannets were able to switch to other prey with no loss of breeding success, but Puffins probably suffered a severe breeding failure between 1986 and 1988. Available data on Shetland Sandeel stocks provide evidence of a probable link between this species' abundance within the seabirds' foraging range and the quantity of Sandeels brought ashore to chicks by adult Puffins and Gannets.

INTRODUCTION

This paper reports on the food delivered by Puffins and Gannets to their chicks at Hermaness National Nature Reserve on the island of Unst, Shetland (60°50'N, 0°53'W) where they are among the most numerous breeding seabirds. The two species are confined to the N. Atlantic and breed on both east and west coasts of the British Isles. Colonies are normally associated with highly productive areas of cold temperate seas.

The diets of nestling seabirds have been found to vary between colonies and between years within the same colony, presumably reflecting changes in the relative abundance of fish species in nearby waters [1,2,3]. Such changes may occur naturally, as part of cyclic population fluctuations or in response to environmental perturbation, or may be partly due to human activity. The advent of oil production activities in Shetland waters in the 1970s and the development of a commercial fishery for Sandeel *Ammodytes marinus*, an important foodfish for seabirds in the area [1,4,5], were thus viewed by ornithologists with concern. The present study of Puffin diets on Hermaness began in 1973 and coincides with the first 15 years of this fishery. Samples of Gannet food were first examined in 1981, since when annual Sandeel landings from Shetland inshore waters increased to a peak of 52,000 tonnes in 1982 before declining to 33,000 tonnes in 1984 and 7,000 tonnes in 1987 [6].

THE STUDY AREA

Hermaness N.N.R. comprises a 5 km long peninsula and associated islands on the N.W. tip of Unst, Shetland. It is Britain's most northerly seabird colony, supporting 14 breeding species which have access to highly productive coastal shelf waters.

Puffins occupy burrows in rock scree and soil along most of the north and west coasts. The colony comprises about 50,000 breeding pairs and annual counts of occupied burrows in permanent transects indicate that the population size has remained fairly stable during the period of this study (Author's unpubl. data).

Gannets breed in two separate areas along the west coast of Hermaness and another on the outlying islands to the north. Nesting was first recorded in 1917 and some 7,700 pairs now breed [7], making this the largest colony in Shetland and one of the largest in Britain [8].

METHODS

Food-bearing adult Puffins were caught in June or July of 11 years between 1973 and 1988. They were mist-netted on approach to the colony, usually during the late afternoon or evening. Birds hitting the net invariably dropped the complete food load and this was collected during a careful search of the area under and around the net after each capture. Samples thought to be of incomplete or combined loads were discarded or noted as such. Each load was weighed to the nearest 0.1g, the length of each complete fish was measured from the tip of its snout to the tip of its tail and a count made of the remaining heads and tails. Individual fish not specifically identifiable on site were either photographed or preserved for later identification. In order to eliminate the effects of any possible variation in diet across the colony, all food samples were obtained from one mid-colony site of c.1000 burrows.

In a few cases, the contribution of a single fish species to the total weight of fish collected in any year could not be measured directly. In these circumstances, an approximate figure was derived by taking the product of the number of individuals and their mean weight, as determined either from my own data or by applying a weight / length function to their collective mean length (after Harris and Hislop [1]). This technique is not strictly accurate because the weight/length relationship is not linear but, since fish of any one species were usually of a similar size, any error will not be large and will be to underestimate the species' importance.

Samples of Gannet food were obtained in June and July in the form of boluses freely regurgitated by adults and chicks as we moved through the colony. Since all the samples were partially digested it was rarely possible to measure individual fish, but identification to species or species-group was normally possible by either visual inspection or examination of otoliths. In 1983 and 1984 some loads were weighed (to the nearest 5g). Food samples for this study were obtained from two mid-colony sites, each with c.150 nests.

The quantity of each prey species consumed by the colonies of the two seabirds during the breeding season was estimated by determining the energetic requirements of the birds, the calorific value of their prey and the ratio of the different prey species in the diet, by weight. The energy needs of a breeding adult were calculated using the equation for Basic Metabolic Rate (BMR) in Kendeigh *et al* [9] :

$$\text{daily BMR (kcals)} = 0.5224\ W^{0.7347} ,$$

where W = body weight of an adult of the species in g.

The total seasonal requirement of the colony can then be estimated as :

no. adults (breeders and non-breeders) x no. days in or near colony

x daily BMR x MF ,

where MF is an appropriate multiplication factor relating BMR to the energetic costs of breeding.

A value for MF of 5.0 was chosen as being a reasonable approximation based on a number of seabird studies which indicate a figure of between 2.6 and 7.7 BMR including the energetic costs of chick-rearing (summarised in Ellis [10]).

RESULTS

1. Puffins

A summary of the food-loads collected during the 11 sampling years is given in Table 1. Fish were the only prey in all 478 loads examined. By weight, Sandeel was the dominant prey in every year except 1987 and 1988, when the contribution of this species to the total sample dropped below 79% for the first time since the study began. All Sandeels from the 1973, '74 and '76 samples were *Ammodytes marinus* (see Harris and Hislop [1]) and it is thought that no other member of the family has subsequently occurred, at least to a significant extent. For simplicity, the term 'Sandeel' will be used below as though referring to a single species, but it is recognised that in fact two or more *Ammodytidae* may be represented in both Puffin and Gannet catches. At least twelve other species of fish were found during the study (Table 1) but only Rockling *Ciliata / Gaidropsarus* spp. and Haddock *Melanogrammus aeglefinus* formed 10% or more of the diet by weight in any year prior to 1987. In the 1987 sample of only four loads some unidentified Gadoids and a single Sprat *S. sprattus* assumed unusual importance. This sample is too small to be reliable and has been disregarded in some of the analyses presented below. In 1988 Rockling formed 42% of the diet and Gadoids, mostly Saithe *Pollachius virens*, comprised a further 21%.

In all years with an adequate sample the weight of individual Sandeels was considerably greater than that of any other species captured. In 1984, for example, the average weight of a Sandeel (0.52g) was nearly four times that of the average Rockling, the second most commonly captured species. In 1979, although only 23% of the fish sampled were Sandeels, the relatively high individual weight of this species resulted in Sandeels forming 90% of the diet by weight.

Overall, the mean weight of loads varied significantly between years ($F_{9,424}$ = 8.5, p<.001) (Fig. 1), as did the mean number of fish per load ($F_{10,425}$ = 17.1, p <.001). More importantly, the mean length, and thus the mean weight, of individual Sandeels captured declined significantly from 1981 onwards (r=-0.99, d.f.=3, p<.01) (Fig. 2), as did the mean weight of loads (r=-0.96, d.f. = 4, p<.001) (Fig. 1). The heaviest loads recorded during the study were of 21.5g, 20.0g and 18.1g. Generally, Puffins carrying exclusively Sandeels had much heavier loads than those birds whose catch comprised less than 50% Sandeels by number (e.g. 1984 sample : t_{36} = 26.3, p <.001).

Paradoxically, a significant negative correlation was found between the mean load weight and the mean number of fish per load in the eight years for which there are more than 10 sample loads (r=-0.85, d.f.= 7, p < .05). Within years the negative relationship between the weight and number of constituent fish in each load was strongest when substantial numbers of species other than Sandeels were taken. Indeed a significant positive relationship was found in 1981 and 1983 when more than 90% of the catch by weight was Sandeels. On balance, it would seem that the relationship between load weight and the number of fish in the load results entirely from the fact that non-Sandeels in the catch are, on average, individually smaller and lighter than Sandeels.

In 1978, the only year in which sampling was spread over a period of four weeks or more, no significant difference was found in mean load weight, mean number of fish per load or mean Sandeel length between early and late samples. Differences in these parameters between early and late samples in other years showed no consistent trend across years. The regression of mean Sandeel length on mid-date of sampling period for each year was not significant ($r=0.50$, d.f. = 7, $p>0.1$).

A large majority of Sandeels taken in most years were 0-group (first year) fish although individual sizes and weights varied from 24mm (0.05g) to 172mm (8.7g). If a length of 100mm is taken to be an approximate cut-off point between 0-group and 1-group fish in June and July (derived from data in Anon [6] and appendix to Harris & Hislop [1]), then between 0.2% (1988) and 68% (1979) of the Sandeels sampled in each year comprised 1-group or older fish (Table 2). July samples contained a higher proportion of older fish than those taken in June, but year-to-year variation in the size of Sandeels captured in July was high (Fig. 3).

Some fish in each year were still alive when collected from Puffins at the colony. This confirms the impression given by other observations that Hermaness birds, like those at other colonies [1,11], were often feeding within a few kilometres of the coast.

An energetic requirement of 4.3266×10^9 kcals was calculated for the Hermaness colony during the breeding season. This assumes (a) a seasonal length of 135 days (the beginning of April to mid-August) [12], (b) a colony size of 150,000 birds comprising 50,000 breeding pairs (Author's unpubl. data) and 50,000 immatures and nonbreeders (derived from breeding : non-breeding ratios in Harris [12]), (c) a mean body weight of 390.6g [13], and (d) that breeding was successful.

Using the above energy requirement, the calorific densities of the various fish species in the diet (taken from Barrett *et al.* [14], Harris and Hislop [1], Montevecchi *et al.* [15], Murray and Burt [16]) and the ratios of fish species by weight in the diet each year found by the current study, estimates can be derived for the total tonnage of each prey species taken (Table 1). These figures assume (a) that the sample is representative of the season as a whole, and (b) that adult Puffins eat the same mixture of prey species as is fed to chicks. The most obvious support for the first assumption is that the composition of the Puffin diet was found to be broadly similar in all sampling years prior to 1987, with Sandeel always dominant no matter when the samples were taken. The diet of adult Puffins around Hermaness is not known but it is likely to be at least broadly similar to that fed to chicks. Breeding success is thought to have been good until 1984, but the 1986, 1987 and 1988 seasons were probably poor (see discussion) so fewer fish were probably taken in these years. Given such uncertainty and the inevitable degree of error incorporated in the other parameters it would be unwise to consider the consumption estimates as precise, but a round figure of 3,000 tonnes is probably a reasonable approximation for the season as a whole. Almost all of this would normally comprise Sandeel and, with a mean fish weight of 0.25g - 3.5g (Table 2, Fig. 4), this represents about 750 - 3000 million individuals per season.

2. Gannets

Ten species of fish, and no other type of prey, were found in regurgitates from Gannets during the six seasons examined : Greater Argentine *Argentina silus*, Sandeel, Haddock, Whiting *Merlangius merlangus*, Blue Whiting *Micromesistius poutasou*, Cod *Gadus morhua*, Saithe, Mackerel, Herring and Red Gurnard *Aspitrigla cuculus*. Sandeel was the only species in 90%, 62%, 37%, 15%, 14% and 6% of the 1981, '83, '84, '86, '87 and '88 identifiable bolus samples respectively (Table 3). Mackerel was the only other species to be positively identified in each year of the study but, since 7% of the regurgitates could only be determined as 'non-Sandeel', it is probable that other species were also caught a little more frequently than the data suggest.

A combined total of 124 regurgitates were weighed in 1983 and 1984. The annual mean weights were not significantly different, so the data were pooled. The weight range of regurgitates was 40g to 365g. Heavier loads usually comprised one entire fish or a partially-digested bolus of Sandeels. The latter were almost never measurable but they appeared to be usually large 0-group or 1-group fish. The overall mean weight of regurgitates was 151g, and 64% weighed between 100g and 200g. Gannet chicks at the time of sampling were up to five weeks of age, with weights ranging from 60g to 2500g.

No significant difference was found between the weight of boluses comprising the different species of fish ($H=6.23$, d.f.=4, $p>0.1$, Kruskal-Wallis 1-way anova). Table 3 and Fig. 5 show the percentage of the total identifiable sample in each year contributed by each species.

Using an estimate of 22,500 Gannets in the colony (from Wanless *et al.* [17], assuming nests represent 2 birds and other occupied sites represent 1), an attendance period of 210 days (derived from Nelson [3]) and a mean body weight of 3015g [3], an energetic requirement of 4.4423×10^9 kcals was calculated for the Hermaness Gannetry during the breeding season. Using the techniques outlined above (see results : Puffins), the weight of fish of each prey species consumed by the colony was calculated and is shown in Table 3.

The uncertainties inherent in the calculations must be taken into account when examining the results. Nonetheless, a range of seasonal consumption of around

2000-3000 tonnes of fish is indicated, and the annual figure has probably fallen by 20% over a period of 7 years as more energy-rich species such as Mackerel and Herring have replaced Sandeel. By 1988 Herring, absent from the diet in 1981 and 40% more energy-dense than Sandeel, was being consumed at eight times the rate of the smaller species (Fig. 5).

DISCUSSION

Studies of a range of seabird species in Shetland have demonstrated that Sandeels normally form the major part of the communities' food requirements [1,4,5,18,19]. Apart from the major local whitefish species, at least one other important marine predator in these waters, the Grey Seal *Halichoerus grypus*, probably also feeds largely on Sandeels [20]. This fish is thus almost certainly the most vital link in vertebrate food chains in Shetland waters. Sandeel was the primary prey species for both Puffins and Gannets in the first years of this study, but a marked change occurred in the diet of both birds in the early 1980's. The changes may have been caused by the same circumstances, probably a reduction in the availability of Sandeel, but the nature of the change differed between the two species and the consequences in terms of reproductive output were markedly different.

Puffins

In every year up to 1987, Puffins relied almost exclusively on Sandeels to raise their young and during this period dietary change appeared quite subtle in that it was the number and size of fish being captured, rather than the species, which altered. In 1987 and 1988, for the first time in this study, Sandeel formed a minor proportion of the diet and simultaneously other characteristics of Puffin feeding changed, showing that the quantity of fish being captured had markedly decreased.

Our failure to collect adequate samples of food loads in 1986 and 1987 is, in itself, informative. The sampling technique and collecting effort was similar to all the earlier years, but very few adult Puffins were bringing food to the burrows. No detailed estimate of delivery rate was made in either year but my assessment, backed up by the number of loads collected per hour of effort, is that food-bearing adults were at 20% or less of the level normally seen at a similar stage of the season. Independent observers (T.Boulinier & M. Pennington, pers. comm.) noted no deliveries at all to the same section of the colony during several days of close observation in late July 1987 and very few during the same period in 1988 when the nestlings would normally be large and fed frequently.

A puffin chick normally requires about 40g of fish per day to fledge successfully [21]. The mean load weight delivered to burrows on Hermaness was 3.4, 4.4 and 3.3g in 1986, 1987 and 1988 respectively, so between 9 and 12 loads per day would have been required even if the calorific value of the fish being captured was as high as normal (in 1988, at least, it was much lower than usual). Such a large mean number of meals per day has not been recorded at any puffin colony to date [21] and is considerably greater that the figure of 3.3 per day determined for Hermaness birds at the same site in 1974 [13]. The conclusion which must be drawn from this and other evidence presented above is that few, if any, Puffin chicks were successfully fledged on Hermaness in the seasons of 1986, 1987 and 1988.

Breeding failures have been noted in other Puffin colonies, particularly in the Lofoten Islands, Norway [14,22] where almost no young were fledged in 7 years between 1975 and 1982. The failure was blamed on the overfishing by Man of Herring, the Puffins' main prey in the area. When the Herring stocks increased, in 1983, Puffins began breeding successfully once more [14] but have failed again between 1986 and 1988 (T. Anker-Nilssen, pers. comm). Even after many years of low recruitment, the relatively high survival rate of Puffins ensures that total population size declines slowly [22], allowing recovery if food stocks return to normal. Breeding failure on Hermaness for a few years would thus not pose a long-term threat to the colony if Sandeels become available once more.

Gannets

The change in the food of Gannets since the first sampling year of 1981 is very obvious but does not appear to have been accompanied by any reduction in breeding success. Nearly all nests contained an apparently healthy chick in every year of the study and the proportion of chicks and adults regurgitating food when disturbed remained constant throughout.

The major dietary change for Gannets was a steady decrease in the amount of Sandeel eaten, from 90% to 6% of the catch, and a parallel increase in the importance of other species, especially Herring. Sandeel would seem to be an unsuitable quarry for a plunge-diver like the Gannet, but it is possible that the technique used to take them is different from that used for larger species of fish. Gannets have been observed diving from the surface for food in the manner of Puffins [3] and can slant-dive at a very high rate. Both techniques could prove worthwhile in dense shoals of Sandeels. Alternatively, the Sandeels may be taken from fishing boats, particularly as the nets are hauled near to the vessel, in which case the dietary change may merely reflect the decline in the Sandeel fishery. Adult Gannets commonly take fish from around fishing boats in Shetland waters [23] and some of the food examined on Hermaness (e.g. Red Gurnard, a bottom-dwelling species) can only have come from this source. Nearly all the fish taken by Hermaness Gannets are the subject of a local fishery and it is not possible to determine what degree of reliance this seabird has on such easy meals.

The ability of Gannets to exploit any locally abundant source of fish is well known [3], and the diet of the Hermaness birds should thus be expected to vary as shoals of different prey species become accessible. Herring has certainly increased in abundance around Shetland during the 1980s [24] and as Sandeel has decreased over the same period it is not surprising that one has replaced the other in the Gannet diet.

Herring, Mackerel and, to a lesser extent, Sandeel have been recorded from Gannets at other British colonies; for example at Bass Rock [25] and Ailsa Craig [26]. Gannets were often seen fishing in dense groups within 5 km of Hermaness but columns of adults, presumably from this colony, regularly fly along the straits between Unst and Yell and are thus probably fishing at least 20 km from the nest. Even this minimum estimate of range would give a potential foraging area of 1100 km^2 of sea within which to find either fish shoals or fishing boats.

General

Observations of other seabird species on Hermaness provide useful additional pointers to what may be happening to stocks of prey fish. Arctic Terns, *Sterna paradisea*, abandoned their colony on the Reserve in the late 1970s and have not returned. This species is known to rely very heavily on surface-caught Sandeels and has recently experienced a series of disastrous breeding seasons in Shetland (P. Monaghan, pers. comm.). The diet of Guillemots *Uria aalge* was not intensively studied on Hermaness but a sample of prey items was examined during each visit to the Reserve and, until 1987, all were found to be Sandeel. In 1987 and 1988 few Sandeels were seen at the colony, but parent Guillemots were bringing small Norway Pout *Trisopterus esmarkii* in their place. In contrast, regurgitated pellets from the colonies of Shags *Phalacrocorax aristotelis* were, in 1987 and 1988 as usual, entirely composed of Sandeel otoliths and the production of chicks was no lower than normal.

This apparent variation in ability to catch sufficient food cannot be explained purely by the depth of water column available for foraging since, although Terns are restricted to surface feeding, Puffins can dive to depths of at least 60m if necessary [27]. A more likely explanation is suggested by Pearson [28], who demonstrated that the proportion of time spent foraging decreased with increasing body size in seabirds on the Farne Islands, N.E. England. Thus smaller birds such as Puffins and Terns would be less able to increase their foraging time than, for example, Shags and Gannets in time of need.

From the foregoing it may be inferred that the ability, and the need, to catch Sandeels differs between seabird species in Shetland. Sandeels are fairly energy-rich [1,16] and apparently preferred, by Puffins [12] at least. The inability to catch sufficient Sandeel during the breeding season is almost certainly the primary cause of the recent breeding failure in successive years of Arctic Terns in Shetland (P.Monaghan, pers comm.) and Puffins now seem to be suffering the same difficulties. At the same time, Gannets have exploited other prey species apparently without ill-effect and Shags are still finding sufficient Sandeels for their needs.

A full understanding of the reasons for dietary changes in seabirds requires, among other things, detailed information on the stock size, age frequency distribution and behaviour of the prey species in the foraging area used by the birds. Fortunately, information on Sandeel stocks in Shetland waters has been gathered from the industrial fishery since 1974, and was supplemented by some research vessel trawls (data kindly provided by the Department of Agriculture and Fisheries for Scotland), but it is subject to the normal limitations and biases inherent in fishery data and must therefore be used with caution. Since the annual fishery catch is determined by market forces as much as fish availability, gross catch figures cannot be relied on as an index of fish abundance. However estimates of abundance of the different age classes using virtual population analysis (V.P.A.) are not biased by fishery changes, and information on fish density in the locality of the Hermaness seabird colony can be gained by reference to research samples and the success of commercial catches in the area (I.C.E.S. square 50E9). V.P.A. estimates suggest that the classes of Sandeels most commonly taken by Puffins and Gannets (0-group and 1-group) reached a peak of abundance between 1981 and 1983 before declining, in 1985 and 1986, to levels similar to those found in 1974 and 1975 [6]. Meanwhile in 1986 and 1987 commercial and research trawls showed a dramatic drop in numbers of Sandeels on the main fishing grounds near the Hermaness seabird colony, the largest Sandeel ground in Shetland.

Thus, while other factors cannot be eliminated, it seems that the most striking feature of the dietary data for each of the two seabird species examined here could be explained by the changes in local Sandeel stocks. Firstly, a steady decline in the proportion of Sandeel in the diet of Gannets occurred during a period in which the abundance of Shetland Sandeels of the appropriate size dropped annually, and by more than 50% overall. Secondly, although Puffins appeared to withstand fluctuations in Sandeel stocks around Shetland as a whole for more than a decade, the virtual disappearance of fish from the vicinity of Hermaness was coincident with adult Puffins returning to their nests at this colony with small food loads comprising tiny fish, and this almost certainly led to breeding failure. In 1988, at least, such breeding failure was evident among many seabird species throughout Shetland, especially those which normally rely on Sandeels and are of smaller body mass [29]. The decline of this fish to below a critical level of availability is thus apparently widespread around the archipelago, but seabird breeding success was reported to be near-normal in the nearest island groups of Orkney and Faroe in 1988 [29].

With Sandeels in such short supply, direct competition between seabirds and the local commercial fishery for the same limited resource has probably increased, especially since both consume the smaller 0-group and 1-group fish predominantly [30]. The precise influence of the commercial fishery on the changing status of Shetland Sandeels is difficult to determine but clearly any future removal of fish from this depleted stock by Man will be detrimental to its recovery. Conversely, the current redirection of fishing effort towards whitefish, which also prey on Sandeels, may be expected to relieve the pressure on the smaller species and thus improve the prospects for Shetland's vulnerable seabirds.

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Table 1. Composition of the diet of Puffins on Hermaness, by fish species in each sampling year.

YEAR	NO. FISH EXAMINED	SPECIES > 10% BY WEIGHT IN SAMPLE	OTHER SPECIES		SEASONAL CONSUMPTION
1973	142	Sandeel 90% , 2649 tonnes	Norway Pout, Whiting, unid. Gadoids	294 tonnes	2943 tonnes
1974	109	Sandeel 79% , 2443 tonnes Haddock 14% , 431 tonnes	Gurnard, Rockling, Sprat, Mackerel, Whiting, Haddock, unid. Clupeid	217 tonnes	3091 tonnes
1976	434	Sandeel 81% , 2406 tonnes Rockling 16% , 474 tonnes	Sprat, Mackerel	89 tonnes	2969 tonnes
1978	335	Sandeel 87% , 2511 tonnes	Rockling, Sprat, Mackerel, unid. Gadoids	378 tonnes	2889 tonnes
1979	220	Sandeel 90% , 2637 tonnes	3 unid. species	289 tonnes	2926 tonnes
1981	495	Sandeel 99% , 2777 tonnes	Norway Pout	29 tonnes	2806 tonnes
1983	844	Sandeel 96% , 2737 tonnes	Haddock	114 tonnes	2851 tonnes
1984	1168	Sandeel 90% , 2626 tonnes	Haddock, Whiting, Rockling, Saithe/Lythe, Torsk, Blue Whiting	291 tonnes	2917 tonnes
1986	177	Sandeel 100% , 2791 tonnes		0 tonnes	2791 tonnes
1987	49	Rockling 31% * Sprat 26% * Gadoids 24% * Sandeel 19% *		*	*
1988	1329	Rockling 42% , 1655 tonnes Sandeel 36% , 1437 tonnes Saithe 21% , 820 tonnes	Torsk, Flatfish sp., Chrystal Gobie, 1 unidentified species	48 tonnes	3960 tonnes

The importance of the main prey species in each year is shown by the percentage of the weight of the total year's sample which comprised that species. Weights shown are the estimated total consumption of the fish species (in tonnes) by the Hermaness Puffin colony in the year assuming (a) a colony requirement of 4.3266 x 10^{9} kcals per season, (b) that the sample is representative of the season as a whole, and (c) that adult and young Puffins have the same diet (see text). An asterisk (*) indicates that the sample size was too small to allow a meaningful estimate of consumption.

Table 2. Characteristics of the Puffin diet on Hermaness, by year.

YEAR	LOAD WEIGHT (g) N	LOAD WEIGHT (g) $\bar{x} \pm 2$ S.E.	FISH PER LOAD N	FISH PER LOAD $\bar{x} \pm 2$ S.E.	NO SPECIES	DATES	% SANDEELS BY WEIGHT	% SANDEELS BY NUMBER $\pm$ 2 S.D.	SANDEEL LENGTH (mm) N	SANDEEL LENGTH (mm) $\bar{x}$	% SANDEEL > 100mm (at least 1 year old)
1973			18	7.9 ± 2.0	3	12/7-27/7	90	68 ± 8	94	77.3	8
1974	13	11.6 ± 3.1	31	3.3 ± 1.5	5	8/7-14/7	79	53 ± 10	58	97.4	57
1976	38	7.9 ± 1.3	43	10.1 ± 1.6	5	17/7-1/8	81	48 ± 5	206	80.9	12
1978	43	6.8 ± 1.1	43	7.8 ± 1.4	7	28/6-30/6 9/7-27/7	87	54 ± 7	176	79.8	3 12
1979	28	6.8 ± 1.8	29	7.6 ± 2.3	4	8/7-10/7	90	23 ± 6	53	105.4	68
1981	74	9.8 ± 0.8	75	6.6 ± 0.8	2	18/6-21/6	99	98 ± 1	471	76.7	4
1983	74	8.1 ± 0.8	74	11.4 ± 1.2	3	12/6-21/6	96	94 ± 2	601	64.3	3
1984	77	6.7 ± 1.0	78	15.1 ± 1.9	7	16/6-24/6	90	76 ± 2	607	56.9	2
1986	9	3.4 ± 1.0	9	13.2 ± 7.1	1	14/6	100	100	177	43.8	<1
1987	4	4.4 ± 2.9	4	12.3 ± 6.0	4	2/7	19	20 ± 12	10	<30	0
1988	74	3.3 ± 0.5	74	18.0 ± 1.9	6	24/6 - 1/7	36	49 ± 1	692	37.3	0.2

Table 3. Composition of the diet of Gannets on Hermaness, by fish species in each sampling year.

YEAR	NO. LOADS EXAMINED	SANDEEL		MACKEREL		GADOIDS		HERRING		OTHER		SEASONAL CONSUMPTION
		%	wt(t)	%	wt(t)	%	wt(t)	%	wt(t)	%	wt(t)	
1981	61	90	2570	5	143	5	143	0	0	0	0	2855 t
1983	76	66	1727	22	576	9	234	3	79	0	0	2616 t
1984	99	39	1019	31	810	21	549	8	209	0	0	2587 t
1986	125	15	351	24	563	13	306	41	963	7	164	2347 t
1987	85	14	316	25	563	13	293	47	1059	1	23	2254 t
1988	111	6	140	22	514	19	444	51	1192	2	47	2337 t

The importance of the main prey species in each year is shown by the percentage of the weight of the total year's sample which comprised that species. Weights shown are the estimated total consumption of each fish species by the Hermaness Gannet colony in the year assuming (a) a colony requirement of 4.4423×10^{9} kcals per season, (b) that the sample is representative of the season as a whole, and (c) that adult and nestling gannets have the same diet (see text). The category "Gadoids" includes Cod, Haddock, Saithe and Whiting. All weights are in tonnes.

Figure Legends

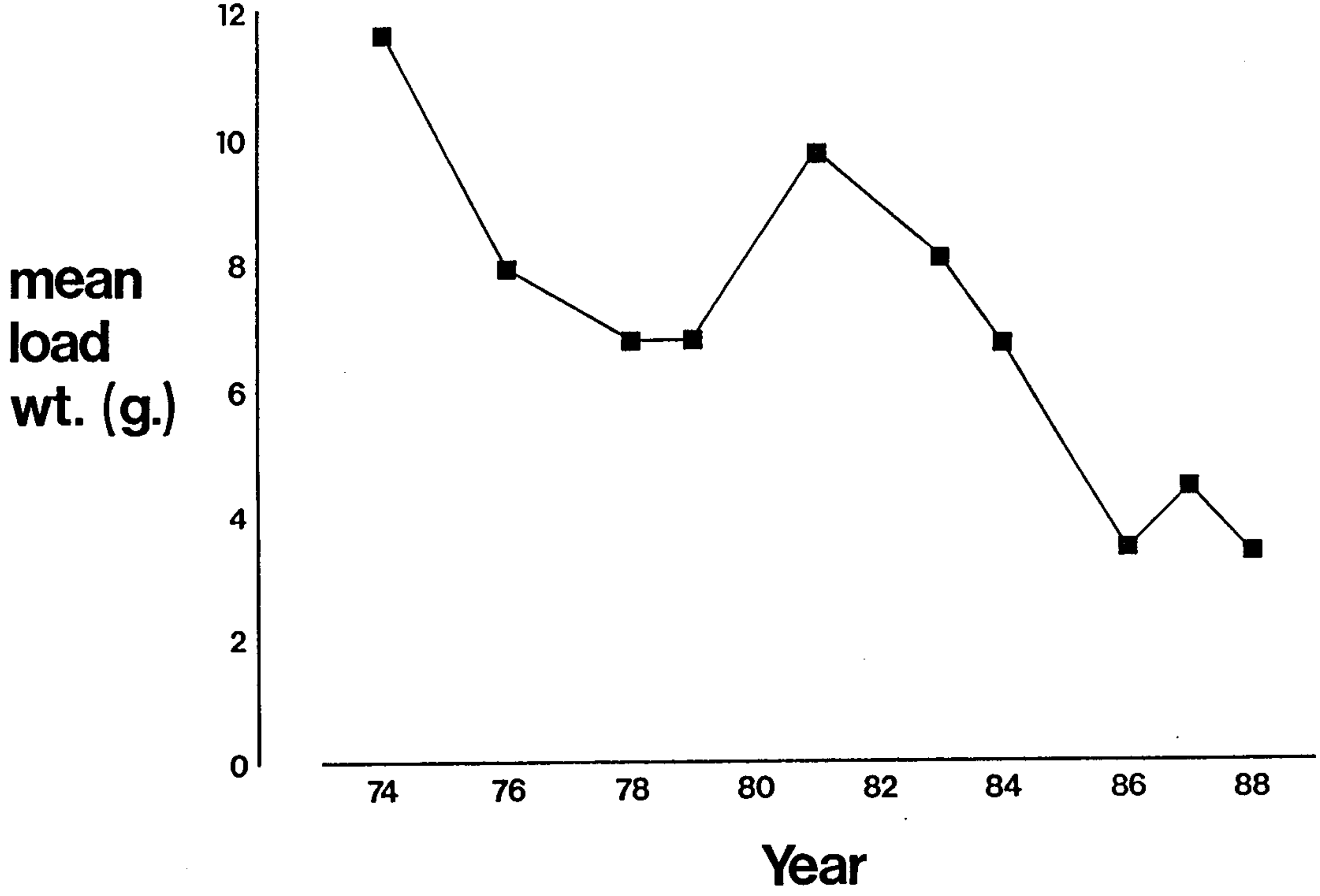
1. Mean weight of food loads delivered to Puffin chicks on Hermaness, by year.

2. Mean length of Sandeels delivered to Puffin chicks on Hermaness, by year.

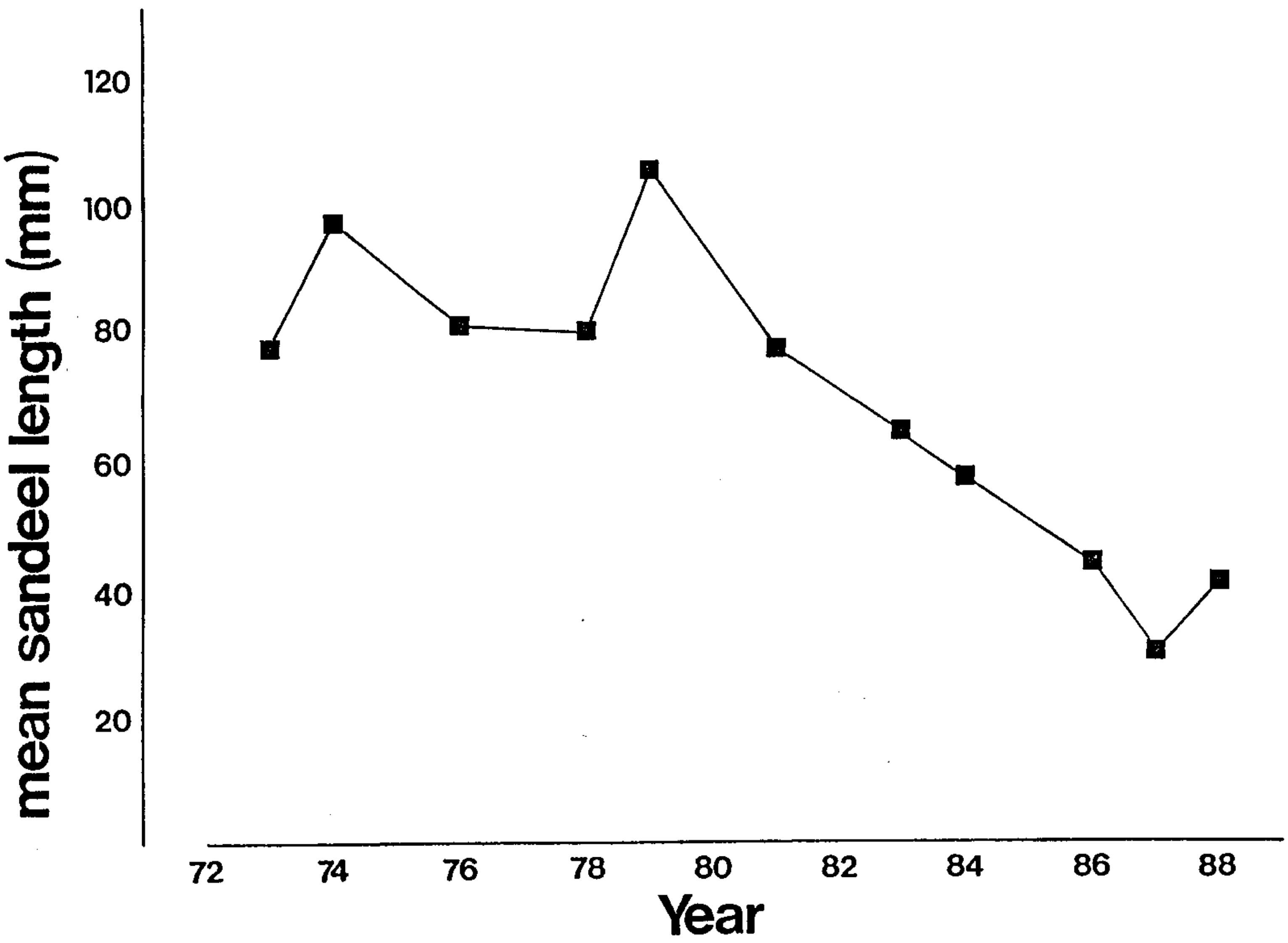
3. Percentage of Sandeels greater than 100mm in length (approximately corresponding to fish with an age of one year or more) within the diet of Puffins on Hermaness, by year. The annual figure is plotted against the mid-date of the sampling period. The two plots for 1978 represent two discontinuous sampling periods in the same season.

4. Mean weight of individual fish delivered to Puffin chicks on Hermaness, by year.

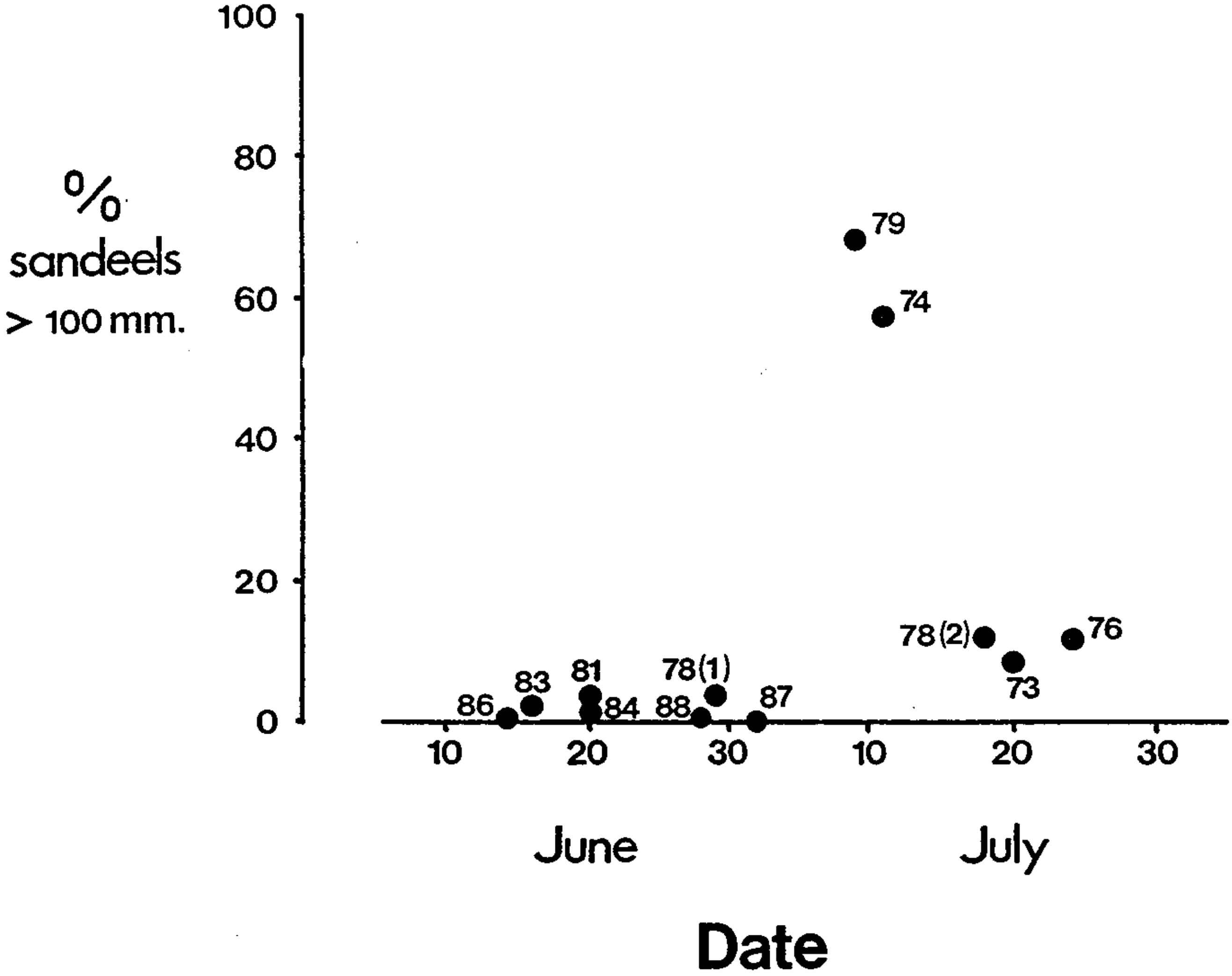
5. Species composition of the diet of Gannets on Hermaness, by weight in each sampling year.



MARTIN Fig. 1

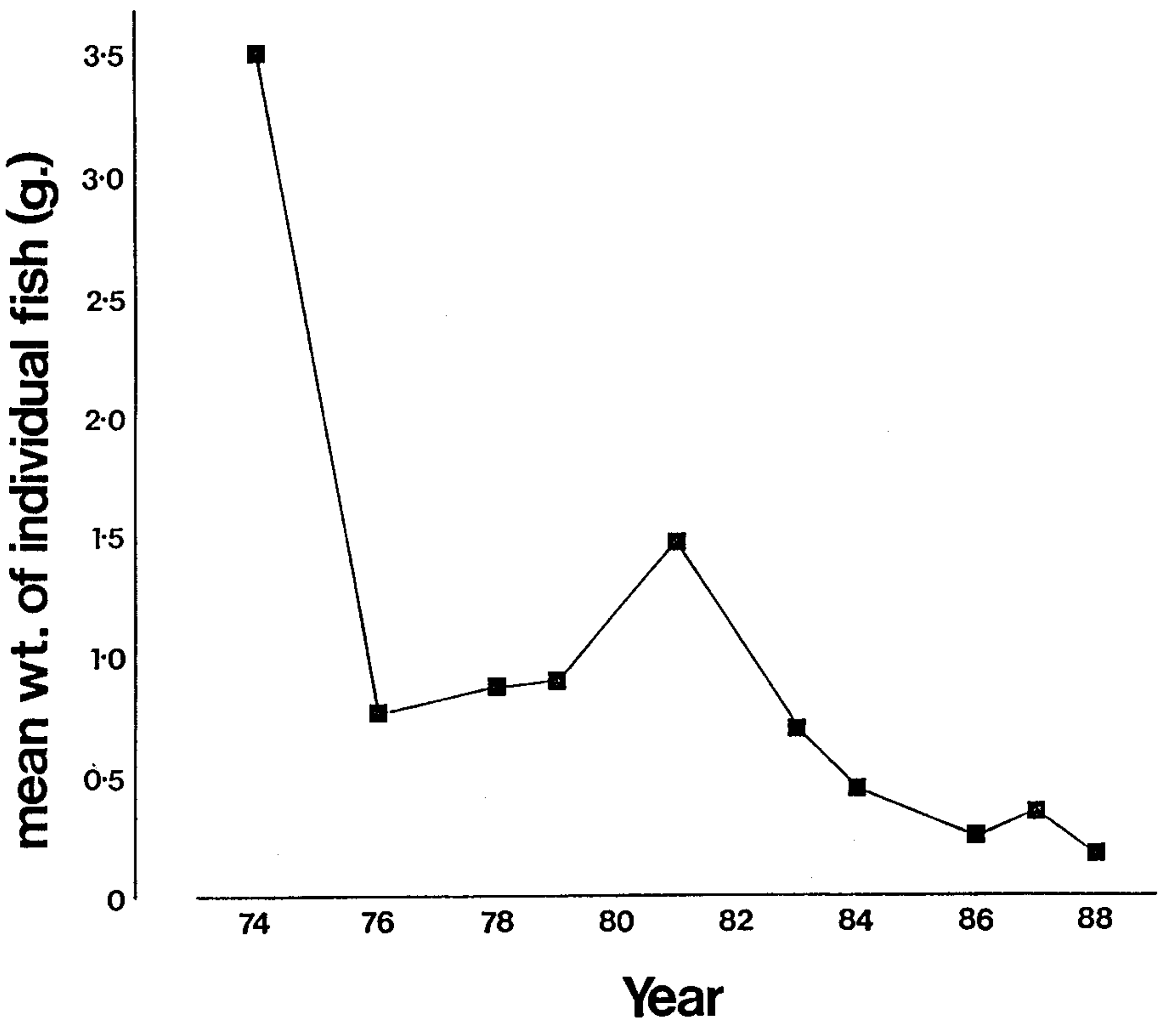

mean sandeel length (mm)
120
100
80
60
40
20
72
74
76
78
80
82
84
86
88
Year

MARTIN, Fig. 2

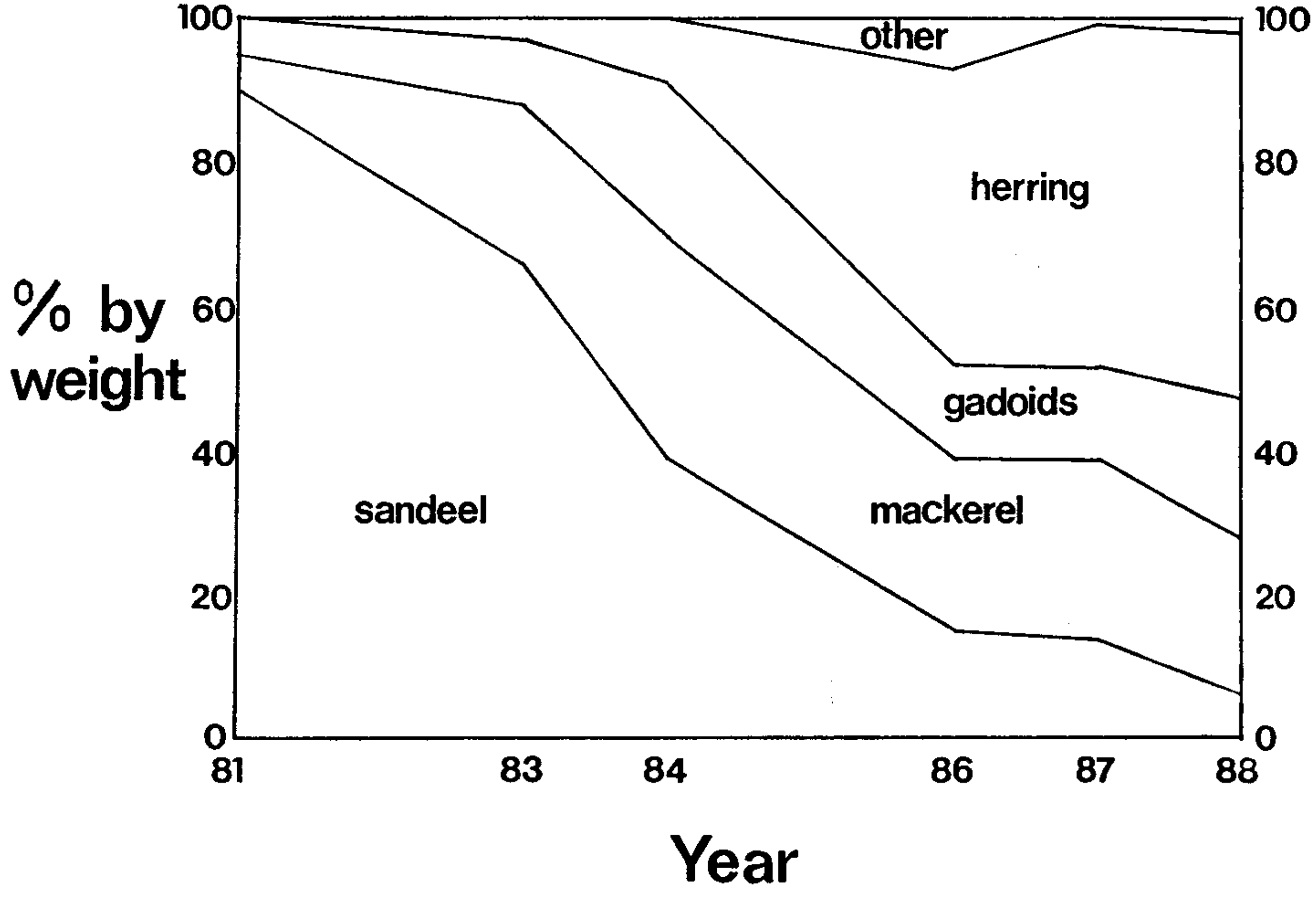


100
80
60
40
20
0
%
sandeels
> 100 mm.
79
74
78(2)
76
73
81
78(1)
83
86
84
88
87
10
20
30
10
20
30
June
July
Date

MARTIN Fig. 3


mean wt. of individual fish (g.)
3·5
3·0
2·5
2·0
1·5
1·0
0·5
0
74
76
78
80
82
84
86
88
Year

MARTIN Fig. 4


% by weight
100
80
60
40
20
0
81
83
84
86
87
88
Year
other
herring
gadoids
mackerel
sandeel

MARTIN Fig. 5

Appendix 9. (a) Calorific values of fish from seabirds 1987
Isle of May 29-9 July
Canna July
Shetland 27 June-3 July
P = Puffin G = Guillemot K = Kittiwake S = Shag

	length	kJ/g (wet)	kJ/g (dry)	Total Value of fish kJ	% wet wt Water	% wet wt Fat	% wet wt Protein	Bird Species
Sprat								
Isle of May	115	8.6	30.8	105	72	8	18	G
" "	81	6.8	23.6	29	71	?	16	P
" "	80	6.8	24.3	27	72	8	18	P
" "	92	7.2	24.8	45	71	6	18	P
" "	79	?	?	?	74	4	17	P
" "	78	?	?	?	77	4	16	P
" "	102	5.1	21.4	42	76	5	16	P
Canna	98	9.9	28.3	113	65	16	16	G
"	112	9.4	26.9	124	65	16	17	G
"	105	8.8	27.5	80	68	13	17	G
"	95	7.8	25.2	79	69	11	18	G
Sandeel								
Isle of May	102	6.2	22	23	72	9	17	P
" "	120	?	?	?	77	1	18	P
" "	104	?	?	?	71	7	17	P
Shetland	130	4.0	19.1	33	79	1	17	G
"	144	5.7	22.0	61	74	7	17	G
"	172	6.2	23.3	108	74	5	18	G
Isle of May	mush	4.8	20.9	?	77	2	18	S
" "	"	?	?	?	76	4	16	K
" "	"	5.7	19.7	?	71	?	19	K
" "	"	?	?	?	75	[3]	[15]	K
" "	"	?	?	?	71	6	18	K
" "	"	?	?	?	73	4	19	K
" "	"	5.6	22.2	?	75	3	19	K
Shetland	"	?	?	?	76	3	18	K

(b) Calorific values of fish from seabirds 1988
All Isle of May 19-30 June

Sprat	120	8.5	24.2	125	65	12	21	G
Herring	73	4.8	17.6	9	73	?	19	P
	69	4.8	17.7	8	73	?	22	P
	60	5.6	19.4	16	71	?	20	P
Sandeel	172	7.8	24.3	133	68	10	14	G
	59	4.8	17.6	14	73	1	21	P
	118	6.0	22.1	33	73	3	21	P
	65-85	5.9	21.1	?	72	2	22	P
	60-65	4.8	17.1	?	72	?	22	P
	114	6.7	21.1	49	68	5	23	P
	118	5.6	20.0	21	72	?	17	P
	120	5.8	19.4	37	70	6	15	P
	134	8.9	25.4	69	65	12	23	P
	155	6.1	22.0	57	72	5	15	P
	131	7.0	23.3	53	70	5	20	P
	142	6.8	21.8	62	69	6	20	P
	70-82	6.5	20.3	?	68	?	23	P
	mush	?	?	?	70	5	20	K
	mush	4.0	17.5	?	77	4	20	K
	mush	5.1	20.5	?	75	4	17	K
	mush	5.0	17.9	?	72	4	17	K
	mush	6.2	20.8	?	70	5	22	K
	mush	7.1	18.8	?	62	6	26	K
	mush	6.3	19.6	?	68	5	22	K
Saithe	72	4.1	17.7	13	17	?	17	P

APPENDIX 10. Weights of shag chicks in 1986-88.

C_1–C_3	Isle of May 1986
C_4–C_6	Isle of May 1987
C_7–C_9	Isle of May 1988
C_{28}–C_9	Fair Isle 1987; b/1
C_{30}–C_{31}	Fair Isle 1987; b/2
C_{32}–C_{33}	Fair Isle 1987; b/3
C_{40}–C_{41}	Fair Isle 1988; b/1
C_{42}–C_{43}	Fair Isle 1988; b/2
C_{44}–C_{45}	Fair Isle 1988; b/3
C_{46}–C_{48}	Canna 1986
C_{49}–C_{51}	Canna 1987
C_{52}–C_{54}	Canna 1988

On Isle of May (C_1,C_4,C_7) and Canna (C_{46},C_{49},C_{52}),
1 = b/1, 2 = b/2 (smaller), 3 = b/2 (larger),
4 = b/3 (smaller), 5 = b/3 (middle), b = b/3 (larger)

Measurements are wing (mm) and weight (g)

ROW	C1	C2	C3	C4	C5	C6	C7	C8	C9
1	6	111	950	1	168	1640	1	145	1470
2	5	93	800	1	168	1750	1	164	1450
3	4	56	340	1	150	1370	1	164	1420
4	3	144	1250	1	84	840	1	89	970
5	2	122	1150	1	49	460	2	82	820
6	3	147	1150	1	147	1190	1	58	640
7	2	138	1250	1	205	1650	1	204	1480
8	5	114	960	1	183	1400	1	165	1620
9	6	121	950	1	160	1480	1	122	1170
10	4	95	850	1	157	1460	1	121	1190
11	3	106	850	1	62	570	1	101	880
12	2	90	750	1	178	1640	1	135	1140
13	6	111	890	1	162	1410	1	162	1440
14	5	94	940	1	185	1640	1	154	1480
15	4	55	500	1	172	1780	1	199	1880
16	4	115	1100	3	176	1650	1	173	1620
17	5	122	1150	3	60	560	1	126	1180
18	6	125	1100	3	71	760	1	101	1020
19	6	162	1300	3	147	1300	1	102	950
20	4	143	1150	3	177	1550	1	178	1550
21	5	154	1250	2	200	1480	1	195	1640
22	4	125	970	3	189	1550	1	75	800
23	6	140	1150	2	182	1550	1	108	1000
24	5	134	1100	2	181	1640	1	58	700
25	5	97	850	2	167	1390	1	142	1250
26	6	100	850	2	110	1170	1	78	740
27	4	77	600	3	182	1680	1	68	620
28	6	129	1050	2	123	1200	1	190	1850
29	4	116	850	3	158	1470	1	161	1500
30	5	120	750	3	172	1560	1	80	670
31	5	119	850	2	205	1520	1	72	680
32	4	118	800	2	183	1670	2	73	740
33	6	128	1050	2	126	1260	2	126	1150
34	6	126	1050	2	52	510	2	62	560
35	5	114	900	2	71	760	2	162	1500
36	4	94	650	2	132	1180	2	61	640
37	6	96	750	2	174	1460	2	140	1500
38	5	95	800	3	212	1810	2	59	790
39	4	72	500	2	172	1330	2	70	685
40	5	126	850	3	187	1550	2	128	1180
41	6	131	1050	3	195	1500	2	105	1010
42	4	104	800	3	186	1610	2	137	1170
43	4	81	600	3	110	1180	2	143	1270
44	5	86	550	2	180	1550	2	86	890
45	6	99	800	3	157	1500	2	46	480
46	5	115	1000	2	147	1300	2	128	1190
47	6	116	900	2	139	1340	2	180	1520
48	4	71	700	3	208	1920	2	92	960
49	6	111	950	3	192	1750	2	167	1480
50	4	92	850	5	168	1470	2	164	1420
51	5	111	1000	4	142	1360	2	133	1180
52	5	108	950	5	238	2070	2	148	1440
53	6	112	950	5	105	1070	2	114	1160

54	4	85	700	6	151	1390	2	171	1500
55	4	100	900	6	162	1360	2	224	1760
56	6	127	1100	4	201	1770	2	48	440
57	5	115	950	4	107	1110	2	116	1000
58	5	182	1600	6	170	1450	2	103	1290
59	4	170	1500	5	176	1540	2	157	1380
60	6	189	1550	4	145	1350	2	207	1740
61	6	87	700	5	172	1420	2	98	980
62	5	80	700	4	156	1390	2	70	730
63	4	58	500	5	147	1430	2	205	1900
64	10	173	1550	5	110	900	3	82	870
65	8	136	1150	4	128	1120	3	164	1570
66	9	143	1300	6	158	1380	3	79	760
67	7	125	1050	4	217	1890	3	175	1500
68	5	109	900	4	100	840	3	97	980
69	4	87	750	5	112	1020	3	154	1610
70	6	111	900	4	128	1190	3	62	650
71	6	167	1100	6	207	1510	3	78	805
72	4	153	1250	6	138	1240	3	138	1330
73	5	155	1200	4	148	1420	3	130	1370
74	6	172	1400	4	173	1560	3	138	1180
75	4	155	1350	6	166	1480	3	151	1340
76	5	160	1200	4	148	1360	3	95	1040
77	1	114	800	6	162	1250	3	60	550
78	3	132	1100	6	150	1350	3	200	1540
79	2	115	800	4	90	970	3	200	1540
80	6	141	1200	6	176	1450	3	94	1000
81	5	132	1100	5	151	1410	3	170	1400
82	4	115	950	6	243	2050	3	183	1520
83	4	138	1050	6	116	1070	3	143	1220
84	5	151	1200	5	158	1520	3	154	1470
85	6	152	1250	5	205	1860	3	118	1180
86	2	65	600	5	131	1160	3	181	1750
87	3	90	800	5	165	1520	3	250	1950
88	3	107	900	6	193	1510	3	68	690
89	2	79	750	5	145	1400	3	135	1410
90	1	149	1250	6	160	1640	3	126	1290
91	6	139	1150	5	160	1250	3	162	1400
92	4	119	1000	5	141	1250	3	221	2000
93	5	121	900	6	112	1050	3	115	1080
94	3	122	950	10	169	1490	3	112	1030
95	2	74	600	10	150	1590	3	212	2050
96	3	145	1150	8	135	1390	4	135	1180
97	2	136	1150	8	144	1580	4	147	1240
98	1	100	1000	9	142	1350	4	95	1010
99	2	103	800	9	149	1250	4	132	1280
100	3	128	1000	7	135	1230	4	202	1600
101	1	90	760	7	128	1230	4	196	1400
102	5	139	1000	*	*	*	4	48	480
103	1	151	1250	*	*	*	4	58	580
104	6	139	1100	*	*	*	4	188	1750
105	4	112	900	*	*	*	4	119	1250
106	2	115	850	*	*	*	4	176	1600
107	3	136	1000	*	*	*	4	188	1750
108	4	150	1300	*	*	*	4	67	720
109	6	181	1550	*	*	*	4	162	1480
110	5	157	1250	*	*	*	4	72	800
111	2	132	1150	*	*	*	4	147	1450
112	3	157	1300	*	*	*	4	86	895
113	1	177	1450	*	*	*	4	111	1150
114	2	116	1000	*	*	*	4	160	1600
115	3	136	1050	*	*	*	4	48	500
116	1	121	1050	*	*	*	4	39	360
117	3	154	1300	*	*	*	4	41	420

118	2	144	1050	*	*	*	4	192	1380
119	3	107	800	*	*	*	4	177	1550
120	2	94	750	*	*	*	4	48	500
121	6	124	1050	*	*	*	5	162	1400
122	4	113	800	*	*	*	5	147	1500
123	5	115	900	*	*	*	5	101	910
124	6	171	1400	*	*	*	5	172	1530
125	5	169	1300	*	*	*	5	203	1420
126	4	164	1250	*	*	*	5	206	1540
127	3	158	1350	*	*	*	5	85	890
128	2	155	1400	*	*	*	5	88	990
129	3	142	1100	*	*	*	5	193	1760
130	2	116	900	*	*	*	5	159	1650
131	1	142	1300	*	*	*	5	188	1900
132	3	164	1400	*	*	*	5	194	1640
133	2	152	1300	*	*	*	5	131	1340
134	2	161	1250	*	*	*	5	172	1600
135	3	163	1300	*	*	*	5	55	580
136	1	84	650	*	*	*	5	68	710
137	6	165	1500	*	*	*	5	102	1000
138	5	163	1500	*	*	*	5	162	1650
139	1	84	650	*	*	*	5	123	1200
140	1	144	1100	*	*	*	5	169	1500
141	3	164	1600	*	*	*	5	167	1450
142	1	65	550	*	*	*	5	85	800
143	2	154	1400	*	*	*	5	55	550
144	2	119	950	*	*	*	5	62	620
145	3	130	1100	*	*	*	5	207	1480
146	2	124	950	*	*	*	5	186	1580
147	1	148	1100	*	*	*	5	85	800
148	1	144	1100	*	*	*	5	103	955
149	3	141	1200	*	*	*	6	180	1650
150	2	97	950	*	*	*	6	174	1640
151	3	176	1400	*	*	*	6	107	980
152	2	172	1300	*	*	*	6	183	1650
153	1	164	1350	*	*	*	6	209	1720
154	1	187	1400	*	*	*	6	212	1510
155	1	174	1500	*	*	*	6	93	910
156	1	151	1100	*	*	*	6	102	970
157	2	211	1350	*	*	*	6	208	1700
158	3	222	1550	*	*	*	6	171	1650
159	2	169	1500	*	*	*	6	196	1900
160	3	171	1700	*	*	*	6	196	1850
161	1	138	1150	*	*	*	6	140	1220
162	1	157	1400	*	*	*	6	174	1620
163	1	184	1500	*	*	*	6	68	700
164	1	136	1000	*	*	*	6	82	785
165	2	146	1300	*	*	*	6	103	1120
166	3	161	1500	*	*	*	6	163	1550
167	6	188	1800	*	*	*	6	137	1160
168	5	181	1800	*	*	*	6	190	1850
169	4	164	1500	*	*	*	6	219	1950
170	3	175	1500	*	*	*	6	88	860
171	2	175	1400	*	*	*	6	58	500
172	2	142	1250	*	*	*	6	62	620
173	3	159	1400	*	*	*	6	208	1750
174	1	167	1250	*	*	*	6	197	1740
175	1	134	1100	*	*	*	6	88	860
176	3	157	1350	*	*	*	6	118	1180
177	2	155	1100	*	*	*	*	*	*
178	2	190	1500	*	*	*	*	*	*
179	3	195	1700	*	*	*	*	*	*
180	1	164	1400	*	*	*	*	*	*
181	1	97	850	*	*	*	*	*	*
182	1	168	1500	*	*	*	*	*	*
183	1	165	1450	*	*	*	*	*	*
184	1	209	1500	*	*	*	*	*	*
185	3	244	1750	*	*	*	*	*	*
186	2	238	1850	*	*	*	*	*	*
187	1	200	1800	*	*	*	*	*	*
188	1	128	1100	*	*	*	*	*	*

ROW	C28	C29	C30	C31	C32	C33
1	69	650	73	805	81	810
2	84	870	91	925	99	990
3	69	840	123	1125	90	990
4	142	1500	122	1200	94	910
5	*	*	90	830	49	480
6	*	*	72	690	92	1000
7	*	*	85	820	72	660
8	*	*	79	770	76	650
9	*	*	63	590	67	730
10	*	*	69	630	113	1190
11	*	*	87	850	131	1260
12	*	*	98	940	128	1300
13	*	*	81	720	146	1240
14	*	*	86	840	169	1500
15	*	*	117	1160	163	1560
16	*	*	135	1170	104	960
17	*	*	126	1100	93	890
18	*	*	119	1000	110	1110
19	*	*	155	1490	82	830
20	*	*	158	1510	91	950
21	*	*	100	850	65	660
22	*	*	91	810	103	1120
23	*	*	65	590	106	1300
24	*	*	69	620	94	920
25	*	*	69	640	73	720
26	*	*	61	530	70	640
27	*	*	50	410	75	640
28	*	*	69	590	82	810
29	*	*	64	630	80	770
30	*	*	69	670	59	600
31	*	*	93	890	46	410
32	*	*	96	940	47	500
33	*	*	113	1090	53	510
34	*	*	121	1160	63	610
35	*	*	73	720	68	730
36	*	*	77	780	70	700
37	*	*	84	770	131	1210
38	*	*	89	860	126	1220
39	*	*	62	590	130	1110
40	*	*	61	620	89	840
41	*	*	138	1200	73	740
42	*	*	162	1510	90	900
43	*	*	151	1390	58	510
44	*	*	143	1390	59	530
45	*	*	109	1020	49	470
46	*	*	119	1100	124	1160
47	*	*	143	1410	108	970
48	*	*	149	1320	113	1110
49	*	*	*	*	138	1300
50	*	*	*	*	130	1190
51	*	*	*	*	127	1210
52	*	*	*	*	73	710
53	*	*	*	*	78	720
54	*	*	*	*	52	460

ROW	C40	C41	C42	C43	C44	C45
1	154	920	93	900	135	1280
2	124	1240	88	865	152	1435
3	*	*	142	1420	148	1300
4	*	*	139	1490	136	1390
5	*	*	125	1260	110	1170
6	*	*	122	1070	94	1103
7	*	*	139	1275	85	885
8	*	*	133	1275	97	910
9	*	*	123	1220	129	1190
10	*	*	124	1240	110	1120
11	*	*	106	980	128	1410
12	*	*	110	940	127	1150
13	*	*	147	1430	128	1250
14	*	*	147	1430	114	1170
15	*	*	152	1450	121	990
16	*	*	149	1630	107	1135
17	*	*	190	1720	112	1160
18	*	*	185	1800	78	630
19	*	*	70	740	100	1000
20	*	*	124	1155	105	1080
21	*	*	110	1025	115	1060
22	*	*	102	1030	*	*
23	*	*	176	1630	*	*
24	*	*	172	1630	*	*

ROW	C46	C47	C48	C49	C50	C51	C52	C53	C54
1	1	251	1810	6	220	1780	4	182	1430
2	1	195	1930	5	216	1670	5	179	1440
3	1	197	1790	6	209	2080	5	178	1700
4	1	192	1940	4	251	1410	4	153	1230
5	1	186	1720	6	221	1810	5	230	1750
6	1	231	1690	6	222	1780	4	192	1350
7	2	175	1620	6	212	1640	4	183	1600
8	2	201	1680	5	210	1930	6	226	1850
9	2	162	1700	5	234	1900	5	190	1650
10	3	222	1950	4	228	1800	5	195	1400
11	3	227	1700	5	195	1620	5	160	1650
12	3	227	1620	5	225	1600	4	175	1500
13	2	183	1820	5	243	2000	6	164	1650
14	3	163	1520	5	228	1460	5	165	1450
15	3	235	1820	5	225	1930	4	175	1450
16	3	206	1800	4	220	1420	4	125	1000
17	3	163	1440	5	245	1530	6	190	1650
18	3	197	1520	5	219	1580	6	202	1750
19	2	204	1820	5	207	1600	4	190	1650
20	2	211	1670	4	185	1570	5	188	1650
21	2	216	1840	4	211	1580	5	220	1750
22	3	183	1540	4	207	1780	6	180	1450
23	2	133	1160	5	208	1670	5	230	1950
24	2	213	1820	5	251	1520	5	189	1490
25	2	181	1430	4	204	1800	6	179	1530
26	2	159	1530	5	215	1810	4	175	1620
27	2	191	1620	5	206	1880	5	165	1450
28	6	190	1660	4	207	1950	6	219	1900
29	6	200	1620	4	220	1690	6	199	1800
30	6	231	1840	5	235	1640	6	235	1500
31	6	211	1780	6	203	1500	4	221	2000
32	5	180	1740	4	221	1820	4	166	1450
33	5	199	1740	4	242	1870	4	179	1650
34	5	190	1420	4	222	1450	6	165	1500
35	5	224	1920	4	221	1720	5	195	1600
36	5	209	1810	5	236	1840	5	160	1300
37	4	110	1050	6	247	1520	6	180	1700
38	4	162	1730	4	204	1690	5	188	1500
39	4	152	1230	4	193	1700	5	135	1050
40	4	197	1600	6	212	1570	4	165	1400
41	4	186	1870	5	218	1600	5	195	1700
42	6	192	1600	6	224	1870	6	215	1550
43				4	185	1600	6	190	1600
44				6	251	1670	4	215	1750
45				5	206	1650	5	153	1450
46				4	212	1800	6	238	1950
47				4	202	1490	6	196	1630
48				6	211	1640	4	163	1270
49				6	237	1990	6	187	1780
50				6	240	1980	6	174	1450
51				4	180	1430	4	195	1650
52				6	217	1750	5	195	1450
53				6	244	1510	5	197	1750

54	6	235	1870	5	223	1900
55	6	228	1620	6	203	1750
56	6	243	1770	6	197	1530
57	4	235	1570	4	130	1250
58	6	222	1800	6	225	1850
59	6	212	1400	4	142	1150
60	5	206	1740	4	120	1550
61	3	180	1570	6	198	1750
62	3	236	1500	6	153	1300
63	3	227	1680	5	176	1800
64	2	199	1420	4	165	1500
65	3	260	1900	5	198	1800
66	2	206	1610	4	165	1650
67	3	212	1600	6	235	1750
68	3	231	1900	4	125	1300
69	3	255	1920	4	213	1850
70	3	212	1500	3	180	1500
71	2	206	1570	3	217	1850
72	3	243	1950	2	236	1600
73	3	215	1710	3	205	2000
74	3	187	1480	3	210	1700
75	3	225	2010	2	145	1350
76	2	200	1910	2	175	1450
77	2	211	1620	2	237	1750
78	3	250	1560	2	221	1450
79	2	240	1370	2	190	1750
80	2	190	1530	2	175	1300
81	2	179	1800	3	125	850
82	2	224	1720	3	225	1900
83	2	210	1840	2	208	1600
84	3	217	1930	2	195	1600
85	2	222	1600	2	150	1400
86	3	214	1820	3	173	1500
87	2	185	1240	2	188	1600
88	2	222	1760	3	190	1650
89	2	244	1510	3	195	1800
90	2	197	1390	2	177	1450
91	3	217	1600	2	216	1500
92	2	233	1970	3	235	1900
93	2	183	1550	2	202	1800
94	2	182	1660	2	200	1650
95	2	222	1900	3	160	1450
96	3	206	1750	3	167	1350
97	3	238	1610	3	260	1950
98	2	245	1700	3	225	1750
99	3	243	1510	3	208	1750
100	3	191	1870	3	190	1450
101				2	118	850
102				2	215	1900
103				3	215	1900
104				3	218	1700
105				3	180	1600
106				2	165	1450
107				3	195	1650
108				2	173	1530
109				2	190	1800
110				1	193	1730

Appendix 11. Weights of kittiwake chicks 1986-88.

C_1-C_3	Isle of May	1986	
C_4-C_6	Isle of May	1987	
C_7-C_9	Isle of May	1988	
C_{10}-C_{12}	Canna	1987	(R Swann)
C_{13}-C_{15}	Canna	1988	(R Swann)
C_{16}-C_{18}	Fair Isle	1986	(FIBOT)
C_{19}-C_{21}	Fair Isle	1987	(FIBOT)
C_{22}-C_{24}	Fair Isle	1988	(FIBOT)
C_{25}-C_{27}	Shetland	1987	(D Okill)
C_{28}-C_{30}	Shetland	1988	(D Okill)
C_{31}-C_{33}	Caithness	1987	(S Mackay)
C_{34}-C_{36}	Caithness	1988	(S Mackay)

In each trio of columns First = brood size with

1 = b/1

2,3 = b/2

4,5,6 = b/3

Second = wing (mm)

Third = weight (g)

@@@@@@@@@@@@@@@@@@@@@@@@@@@@@R@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@@

ROW	C1	C2	C3	C4	C5	C6	C7	C8	C9
1	1	158	311	2	90	220	2	48	137
2	3	125	281	3	97	252	3	68	201
3	2	111	251	1	37	136	2	28	55
4	1	100	262	2	39	91	3	38	77
5	3	167	319	3	48	168	3	75	219
6	2	155	320	3	89	230	2	64	156
7	1	170	332	2	75	202	3	107	240
8	1	106	298	3	129	296	2	58	156
9	3	133	283	2	117	242	3	154	326
10	2	112	266	1	107	270	2	120	257
11	2	86	192	2	45	144	1	168	329
12	3	92	215	3	64	195	3	112	273
13	2	141	267	1	129	268	2	99	205
14	3	161	324	1	191	368	1	85	263
15	1	126	309	3	177	373	3	88	234
16	4	48	123	2	158	302	2	74	193
17	5	78	222	1	130	288	3	42	124
18	6	81	217	1	136	258	2	40	104
19	4	149	305	2	176	298	2	42	119
20	6	188	340	3	179	313	3	63	172
21	5	175	342	2	168	263	3	46	139
22	3	69	155	3	175	312	2	34	96
23	2	50	129	2	179	302	2	92	239
24	1	96	257	3	182	328	3	94	226
25	2	84	205	1	201	458	1	63	205
26	3	96	230	2	190	278	3	58	170
27	3	67	175	3	200	293	2	42	108
28	2	59	180	2	156	263	2	81	182
29	2	73	205	3	162	328	3	85	189
30	3	82	234	3	195	372	3	95	259
31	2	81	210	2	194	312	2	73	148
32	3	99	226	2	115	243	1	103	206
33	3	37	122	3	132	298	3	82	182
34	2	37	116	2	184	268	2	54	144
35	1	65	174	3	206	408	3	120	201
36	2	119	281	2	31	78	2	87	155
37	3	127	310	3	41	128	1	107	183
38	3	36	109	2	211	393	1	88	170
39	2	32	99	3	215	363	1	116	258
40	1	42	142	3	125	258	1	107	246
41	2	60	176	2	118	273	1	118	290
42	3	63	152	1	224	413	3	159	364
43	2	54	162	3	153	333	1	120	219
44	3	56	170	2	125	253	2	52	135
45	2	81	216	1	145	308	3	65	200
46	3	86	260	1	207	396	2	69	150
47	6	92	229	2	121	273	3	104	231
48	4	67	164	3	146	241	1	133	296

49	5	88	210	2	145	256	1	82	219
50	2	75	223	3	148	294	3	141	288
51	3	109	273	2	132	269	2	131	240
52	1	70	203	3	174	353	1	154	314
53	1	109	272	3	150	330	1	159	291
54	1	108	243	2	139	322	3	132	293
55	1	42	142	1	140	303	2	101	193
56	3	90	255	2	72	165	1	127	290
57	2	64	180	3	96	230	1	133	341
58	2	35	110	3	145	340	3	96	178
59	3	40	131	2	130	331	2	89	187
60	6	116	301	2	177	371	1	71	185
61	4	80	221	3	182	338	2	45	178
62	5	111	281	1	205	394	3	65	178
63	2	49	161	2	141	305	3	99	232
64	3	70	189	3	164	332	2	69	186
65	2	74	204	3	167	375	2	131	289
66	3	79	120	2	129	271	3	150	326
67	2	61	175	1	195	368	1	129	300
68	2	80	215	2	194	340	1	146	302
69	1	109	253	3	195	329	3	174	392
70	2	46	130	3	105	237	2	150	384
71	3	102	255	2	102	212	1	187	387
72	3	125	319	3	219	378	1	160	338
73	2	116	257	2	212	420	1	106	263
74	2	93	250	2	199	386	1	71	197
75	3	101	238	3	201	370	1	75	209
76	3	147	320	2	180	374	1	71	191
77	2	125	287	3	182	393	1	46	127
78	1	98	247	1	178	333	1	43	132
79	3	121	289	3	210	356	1	70	185
80	2	109	283	3	192	328	1	69	193
81	4	41	106	2	176	223	3	103	245
82	5	64	150	1	78	173	2	62	163
83	6	71	177	1	45	103	1	119	270
84	1	87	227	1	80	183	1	33	92
85	1	95	258	1	125	228	1	105	264
86	1	39	115	3	170	208	3	67	184
87	3	93	251	2	160	268	2	125	274
88	2	74	203	2	186	318	2	77	201
89	3	46	129	3	200	393	3	100	231
90	2	31	80	3	220	333	1	87	272
91	1	30	93	2	220	288	1	89	259
92	6	103	227	3	175	358	2	107	251
93	5	96	225	2	160	323	3	134	299
94	4	70	185	1	155	367	1	105	214
95	5	100	250	1	166	340	2	75	172
96	4	71	185	1	60	184	2	87	181
97	6	106	281	1	70	219	3	99	224
98	1	66	186	3	150	361	1	57	163
99	1	118	309	2	165	340	1	203	378
100	1	83	226	2	57	158	1	190	349
101	1	32	92	3	70	209	1	190	349
102	1	112	264	5	68	212	2	119	254
103	1	94	239	6	80	196	3	143	276
104	1	105	270	4	51	140	2	111	215
105	3	136	312	*	*	*	3	141	284
106	2	121	240	*	*	*	3	169	327
107	3	119	262	*	*	*	2	144	300
108	2	100	218	*	*	*	1	118	284
109	3	192	381	*	*	*	1	157	340
110	2	185	358	*	*	*	1	145	314
111	1	134	282	*	*	*	3	168	316
112	2	78	183	*	*	*	2	167	314
113	3	106	232	*	*	*	1	159	327
114	3	139	317	*	*	*	2	168	324
115	2	122	261	*	*	*	*	*	*
116	3	151	297	*	*	*	*	*	*
117	2	128	250	*	*	*	*	*	*

118	3	162	318	*
119	2	160	333	*
120	3	168	327	*
121	2	152	333	*
122	1	101	243	*
123	1	79	203	*
124	1	170	369	*
125	6	151	295	*
126	4	118	212	*
127	5	144	262	*
128	2	186	366	*
129	3	188	388	*
130	2	110	273	*
131	3	123	265	*
132	3	142	325	*
133	2	129	271	*
134	2	116	256	*
135	3	125	264	*
136	1	133	291	*
137	2	118	230	*
138	3	133	265	*
139	3	138	284	*
140	2	135	278	*
141	3	141	314	*
142	2	117	268	*
143	3	105	227	*
144	2	90	225	*
145	3	101	243	*
146	2	98	267	*
147	3	154	344	*
148	2	131	300	*
149	2	101	249	*
150	3	110	265	*
151	4	63	187	*
152	5	86	247	*
153	6	101	276	*
154	4	64	185	*
155	5	104	264	*
156	6	109	267	*
157	1	121	298	*
158	6	94	254	*
159	5	93	246	*
160	4	81	244	*
161	1	30	77	*
162	1	51	155	*
163	1	49	130	*
164	2	146	290	*
165	3	155	287	*
166	3	175	340	*
167	2	170	356	*
168	3	179	304	*
169	2	170	335	*
170	3	104	222	*
171	2	94	210	*
172	1	75	191	*
173	1	102	268	*
174	1	111	281	*
175	1	124	271	*
176	2	83	239	*
177	3	105	264	*
178	2	61	207	*
179	3	62	181	*
180	2	33	91	*
181	3	38	120	*
182	3	45	130	*

ROW	C10	C11	C12	C13	C14	C15
1	1	150	344	1	66	171
2	1	109	246	1	45	115
3	1	97	260	1	63	215
4	1	127	308	1	91	209
5	1	114	290	1	120	248
6	1	95	228	1	93	228
7	1	159	332	1	116	253
8	1	33	56	1	65	152
9	1	101	255	1	80	188
10	1	152	344	2	75	185
11	1	136	300	2	70	141
12	1	141	345	3	64	150
13	1	140	305	2	63	167
14	3	164	340	2	65	138
15	3	97	233	2	65	146
16	3	114	290	3	82	179
17	3	124	322	2	32	108
18	2	83	195	2	49	122
19	2	82	236	3	59	158
20	2	85	210	3	76	217
21	3	102	245	2	52	126
22	2	78	182	3	61	149
23	3	88	250	3	83	215
24	3	146	342	2	84	178
25	3	170	360	3	94	210
26	2	147	320	2	79	191
27	3	114	280	3	117	254
28	2	161	375	3	80	190
29	2	69	198	3	80	168
30	2	107	290	2	48	111
31	2	103	290	3	75	210
32	3	111	276	3	74	201
33	3	94	262	3	83	178
34	3	100	254	2	79	186
35	2	96	225	3	39	98
36	3	96	245	3	67	188
37	2	64	180	2	51	124
38	2	131	300	2	60	121
39	2	147	335	3	82	195
40	3	153	310	2	59	180
41	2	112	295	2	71	180
42	3	126	312	3	113	235
43	3	143	338	2	70	190
44	3	143	300	3	90	205
45	2	67	185	2	115	210
46	3	157	374	3	75	171
47	2	72	180	2	68	168
48	2	26	70	2	86	180
49	2	105	280	3	83	155
50	2	103	243	2	66	160
51	2	141	295	3	84	202
52	3	89	234	2	53	148
53	2	140	345	3	110	224
54	3	100	240	2	93	208
55	3	33	90	3	90	245
56	4	83	220	*	*	*
57	5	98	275	*	*	*
58	6	111	305	*	*	*

183	2	38	110	*	*	*	*	*	*
184	1	38	112	*	*	*	*	*	*
185	3	64	111	*	*	*	*	*	*
186	2	60	197	*	*	*	*	*	*
187	1	70	191	*	*	*	*	*	*
188	3	88	218	*	*	*	*	*	*
189	2	63	185	*	*	*	*	*	*
190	1	35	107	*	*	*	*	*	*

ROW	C16	C17	C18	C19	C20	C21	C22	C23	C24
1	1	102	250	1	62	189	1	197	240
2	1	102	271	2	81	200	1	133	165
3	1	118	290	3	89	219	1	187	220
4	1	148	281	1	93	307	1	220	270
5	1	120	271	2	133	369	1	223	290
6	1	174	384	3	175	408	1	193	230
7	1	191	394	1	175	450	1	192	297
8	1	147	334	1	139	347	1	205	220
9	1	172	384	3	142	354	1	152	210
10	1	150	371	2	117	281	1	175	220
11	1	154	269	3	193	462	1	175	235
12	1	150	325	2	154	337	1	143	220
13	1	134	264	2	188	403	1	126.	180
14	1	121	294	3	201	404	1	200	190
15	1	189	396	3	212	428	1	117	215
16	1	138	304	2	205	333	1	120	156
17	1	161	311	2	141	312	1	194	285
18	1	50	148	3	163	362	1	199	300
19	1	69	191	2	69	196	1	171	265
20	1	54	159	3	73	209	1	161	265
21	2	113	284	1	102	269	1	126	210
22	3	118	293	2	131	299	1	210	225
23	2	180	384	3	139	306	1	168	305
24	3	172	378	1	190	391	1	187	225
25	2	121	290	2	79	214	1	179	245
26	3	129	290	3	84	229	1	195	290
27	3	163	364	2	134	321	1	205	275
28	2	144	325	3	159	346	1	215	295
29	3	100	240	1	78	202	1	180	235
30	2	92	228	2	49	162	1	175	285
31	3	141	326	3	63	191	1	120	250
32	2	150	331	1	121	302	1	202	250
33	2	130	310	2	89	230	1	213	310
34	3	142	318	3	108	252	*	*	*

35	2	126	289	2	149	331	*	*	*
36	3	132	320	3	176	374	*	*	*
37	3	129	298	1	200	426	*	*	*
38	2	109	263	1	210	447	*	*	*
39	3	168	371	1	215	432	*	*	*
40	2	140	316	2	163	341	*	*	*
41	3	162	360	3	179	374	*	*	*
42	2	154	346	1	179	381	*	*	*
43	2	124	278	1	113	261	*	*	*
44	3	136	291	1	129	290	*	*	*
45	3	165	361	1	80	213	*	*	*
46	2	151	355	2	63	181	*	*	*
47	2	78	175	3	80	211	*	*	*
48	3	130	252	1	80	215	*	*	*
49	2	127	311	1	41	131	*	*	*
50	3	146	318	2	75	193	*	*	*
51	3	162	374	3	115	283	*	*	*
52	2	141	343	3	119	286	*	*	*
53	2	159	341	2	96	252	*	*	*
54	3	166	352	1	140	293	*	*	*
55	2	43	142	2	91	234	*	*	*
56	3	65	201	3	91	225	*	*	*
57	*	*	*	1	102	249	*	*	*
58	*	*	*	3	156	305	*	*	*
59	*	*	*	2	150	310	*	*	*
60	*	*	*	1	152	312	*	*	*
61	*	*	*	1	136	296	*	*	*
62	*	*	*	2	46	147	*	*	*
63	*	*	*	3	51	160	*	*	*
64	*	*	*	2	83	199	*	*	*
65	*	*	*	3	94	228	*	*	*
66	*	*	*	2	97	214	*	*	*
67	*	*	*	3	102	236	*	*	*
68	*	*	*	1	43	157	*	*	*
69	*	*	*	2	53	149	*	*	*
70	*	*	*	3	62	162	*	*	*
71	*	*	*	2	109	261	*	*	*
72	*	*	*	3	121	240	*	*	*
73	*	*	*	1	129	271	*	*	*
74	*	*	*	1	74	204	*	*	*
75	*	*	*	1	83	200	*	*	*
76	*	*	*	3	96	214	*	*	*
77	*	*	*	2	79	190	*	*	*
78	*	*	*	2	132	271	*	*	*
79	*	*	*	3	147	300	*	*	*
80	*	*	*	3	150	302	*	*	*
81	*	*	*	2	148	182	*	*	*
82	*	*	*	2	120	249	*	*	*
83	*	*	*	3	128	273	*	*	*
84	*	*	*	2	73	200	*	*	*
85	*	*	*	3	76	211	*	*	*
86	*	*	*	1	99	241	*	*	*
87	*	*	*	1	144	289	*	*	*
88	*	*	*	1	68	199	*	*	*
89	*	*	*	1	43	149	*	*	*
90	*	*	*	1	82	201	*	*	*
91	*	*	*	3	119	275	*	*	*
92	*	*	*	2	107	231	*	*	*

ROW	C25	C26	C27	C28	C29	C30
1	1	46	145	1	64	190
2	3	49	135	1	13	25
3	2	25	34	1	106	240
4	2	32	82	1	117	230
5	1	42	112	1	82	195
6	1	59	174	1	47	130
7	1	43	122	*	*	*
8	5	33	84	*	*	*
9	6	46	113	*	*	*
10	4	26	54	*	*	*
11	2	94	250	*	*	*
12	3	97	240	*	*	*
13	2	91	205	*	*	*
14	3	101	250	*	*	*
15	2	54	170	*	*	*
16	3	71	210	*	*	*
17	3	138	251	*	*	*
18	2	135	269	*	*	*
19	6	148	321	*	*	*
20	4	90	174	*	*	*
21	5	101	160	*	*	*
22	3	144	314	*	*	*
23	2	123	268	*	*	*
24	1	150	367	*	*	*
25	3	81	186	*	*	*
26	2	63	138	*	*	*
27	3	112	275	*	*	*
28	2	96	234	*	*	*
29	2	109	257	*	*	*
30	3	134	316	*	*	*
31	3	73	207	*	*	*
32	2	61	166	*	*	*

ROW	C31	C32	C33	C34	C35	C36
1	3	48	130	3	146	250
2	2	28	75	2	134	270
3	3	111	290	3	157	315
4	3	181	370	2	152	285
5	2	172	325	3	159	310
6	2	87	175	2	143	315
7	3	193	380	2	175	340
8	2	178	325	3	185	360
9	1	198	345	3	170	315
10	3	99	255	2	153	285
11	2	84	210	2	147	300
12	6	30	75	3	156	345
13	5	26	40	2	143	295
14	1	30	110	3	151	330
15	3	184	365	2	101	145
16	2	176	320	3	163	340
17	3	48	125	2	179	335
18	2	38	105	3	189	340
19	3	28	75	2	176	300
20	2	21	40	3	190	330
21	1	163	345	3	126	270
22	3	92	220	2	99	215
23	3	146	305	2	191	355
24	2	124	285	3	201	310
25	1	167	365	2	127	260
26	3	162	335	3	165	285
27	2	159	330	3	169	300
28	2	198	305	2	167	335
29	3	204	335	1	49	145
30	2	211	395	3	173	320
31	1	152	295	2	138	230
32	2	145	300	2	97	205
33	2	138	315	3	90	220
34	3	100	230	3	185	300
35	2	88	195	2	162	305
36	2	195	295	2	151	275
37	3	212	440	3	171	285
38	3	183	250	2	161	220
39	2	172	295	3	137	290
40	3	123	255	2	120	245
41	2	122	275	3	169	335
42	2	68	185	2	150	265
43	3	74	190	1	133	295
44	1	34	95	2	156	290
45	2	160	300	3	167	340
46	3	164	295	3	139	325
47	2	90	240	2	125	305

48	*	*	*	3	176	330
49	*	*	*	2	107	160
50	*	*	*	1	153	265
51	*	*	*	3	168	325
52	*	*	*	2	134	215
53	*	*	*	3	131	295
54	*	*	*	2	100	200
55	*	*	*	3	168	305
56	*	*	*	2	156	295
57	*	*	*	3	180	340
58	*	*	*	2	127	225
59	*	*	*	3	146	325
60	*	*	*	2	109	230
61	*	*	*	3	115	245
62	*	*	*	2	100	195
63	*	*	*	3	175	340
64	*	*	*	2	147	255
65	*	*	*	2	139	315
66	*	*	*	3	140	310
67	*	*	*	3	145	255
68	*	*	*	2	128	240
69	*	*	*	3	105	230
70	*	*	*	2	115	260
71	*	*	*	1	176	352
72	*	*	*	2	169	335
73	*	*	*	3	197	400
74	*	*	*	3	170	340
75	*	*	*	2	152	305
76	*	*	*	1	140	305
77	*	*	*	1	102	250
78	*	*	*	2	74	185
79	*	*	*	3	91	225
80	*	*	*	2	20	40
81	*	*	*	3	26	70
82	*	*	*	1	169	340
83	*	*	*	3	191	295
84	*	*	*	2	183	325
85	*	*	*	3	179	240
86	*	*	*	2	172	360
87	*	*	*	2	180	350
88	*	*	*	3	189	360

Appendix 12. Weights of guillemot chicks (a) on Isle of May 1982-88 and (b) at eight colonies in 1987.

(a) C_1, C_2 = 1982 wing (mm), wt (g)
C_3, C_4 = 1983
C_5, C_6 = 1984
C_7, C_8 = 1985
C_9, C_{10} = 1986
C_{11}, C_{12} = 1987
C_{13}, C_{14} = 1988

(b) weights of chicks with wings 60 or more mm long at Fair Isle, Sule Skerry, North Sutor, Canna, Flannan Is., Isle of May, Caithness and Compass Head (Shetland).

(a)

ROW	C1	C2	C3	C4	C5	C6	C7	C8
1	42	220	41	253	35	215	43	228
2	42	177	40	200	30	127	38	215
3	42	223	40	226	40	211	45	195
4	33	136	45	223	43	224	45	241
5	42	226	44	210	37	181	45	206
6	34	158	44	208	35	186	35	124
7	40	186	39	230	42	201	41	230
8	36	214	41	181	42	206	30	178
9	40	216	38	204	36	185	43	202
10	45	216	37	193	45	238	38	201
11	32	124	40	241	45	245	38	216
12	31	155	45	229	44	181	42	209
13	36	177	38	191	33	193	38	196
14	29	120	38	180	36	249	40	232
15	32	165	38	216	44	235	41	212
16	31	159	35	187	40	215	38	220
17	34	168	35	200	41	201	42	242
18	35	176	44	210	44	221	32	154
19	40	200	33	175	43	256	25	140
20	43	229	35	212	41	197	36	176
21	42	215	33	194	43	244	38	196
22	28	131	35	184	33	185	43	203
23	36	201	38	193	35	200	42	198
24	*	*	36	191	45	210	40	216
25	*	*	42	207	45	215	35	170
26	*	*	45	209	45	234	38	185
27	*	*	38	209	40	275	40	214
28	*	*	44	181	45	230	38	200
29	*	*	32	135	39	208	38	181
30	*	*	28	144	45	233	42	223
31	*	*	33	158	39	184	37	200
32	*	*	42	237	39	219	37	212
33	*	*	43	224	34	168	42	198
34	*	*	35	172	43	218	36	198
35	*	*	*	*	40	225	38	207
36	*	*	*	*	44	242	42	233
37	*	*	*	*	30	192	38	223
38	*	*	*	*	35	197	38	187
39	*	*	*	*	43	220	31	134
40	*	*	*	*	40	231	40	168
41	*	*	*	*	32	162	42	232
42	*	*	*	*	40	260	42	251
43	*	*	*	*	40	240	42	200
44	*	*	*	*	38	201	42	214
45	*	*	*	*	40	221	41	182
46	*	*	*	*	45	250	41	214
47	*	*	*	*	44	216	38	208
48	*	*	*	*	39	195	42	197
49	*	*	*	*	38	199	42	199
50	*	*	*	*	39	204	42	189
51	*	*	*	*	37	217	35	200
52	*	*	*	*	37	183	35	198
53	*	*	*	*	35	150	30	196
54	*	*	*	*	44	220	43	238
55	*	*	*	*	42	235	34	192
56	*	*	*	*	37	200	34	204
57	*	*	*	*	37	205	40	235
58	*	*	*	*	45	230	34	190
59	*	*	*	*	37	176	34	182
60	*	*	*	*	42	214	35	174
61	*	*	*	*	39	213	32	176
62	*	*	*	*	28	175	42	246

63	*	*	*	*	38	220	36	215
64	*	*	*	*	28	211	38	197
65	*	*	*	*	41	204	36	215
66	*	*	*	*	35	189	42	236
67	*	*	*	*	43	220	43	244
68	*	*	*	*	45	262	*	*
69	*	*	*	*	35	214	*	*
70	*	*	*	*	37	210	*	*
71	*	*	*	*	33	171	*	*
72	*	*	*	*	34	160	*	*
73	*	*	*	*	28	100	*	*
74	*	*	*	*	32	160	*	*
75	*	*	*	*	35	179	*	*
76	*	*	*	*	31	154	*	*
77	*	*	*	*	25	90	*	*
78	*	*	*	*	34	180	*	*
79	*	*	*	*	32	158	*	*
80	*	*	*	*	40	207	*	*
81	*	*	*	*	45	207	*	*
82	*	*	*	*	30	128	*	*
83	*	*	*	*	34	160	*	*
84	*	*	*	*	42	241	*	*
85	*	*	*	*	34	190	*	*
86	*	*	*	*	42	212	*	*
87	*	*	*	*	35	162	*	*
88	*	*	*	*	34	156	*	*
89	*	*	*	*	37	190	*	*
90	*	*	*	*	35	174	*	*
91	*	*	*	*	44	234	*	*
92	*	*	*	*	38	187	*	*
93	*	*	*	*	37	207	*	*
94	*	*	*	*	32	128	*	*
95	*	*	*	*	42	199	*	*
96	*	*	*	*	39	205	*	*
97	*	*	*	*	43	214	*	*
98	*	*	*	*	34	187	*	*
99	*	*	*	*	29	144	*	*
100	*	*	*	*	42	207	*	*
101	*	*	*	*	38	232	*	*
102	*	*	*	*	45	231	*	*
103	*	*	*	*	44	225	*	*
104	*	*	*	*	35	165	*	*
105	*	*	*	*	38	204	*	*
106	*	*	*	*	38	198	*	*
107	*	*	*	*	40	219	*	*
108	*	*	*	*	32	158	*	*
109	*	*	*	*	30	158	*	*
110	*	*	*	*	31	108	*	*
111	*	*	*	*	43	195	*	*
112	*	*	*	*	34	183	*	*

ROW	C9	C10	C11	C12	C13	C14
1	45	240	42	210	32	138
2	34	213	35	186	38	151
3	44	227	37	210	42	217
4	36	190	38	172	42	248
5	35	166	45	242	36	183
6	37	190	34	132	40	205
7	30	156	45	207	38	179
8	37	190	38	174	34	179
9	41	248	37	167	32	161
10	34	177	45	252	35	159
11	39	216	40	196	37	217
12	35	186	40	201	39	182
13	42	214	42	213	36	179
14	41	216	42	208	45	237

15	35	176	42	211	37	185
16	40	204	37	209	38	190
17	31	161	42	214	34	201
18	39	204	35	203	35	199
19	31	142	35	167	39	217
20	45	224	42	242	38	185
21	44	218	38	199	38	215
22	39	214	35	171	42	199
23	35	162	42	251	42	222
24	37	179	35	217	35	152
25	44	192	42	241	40	169
26	38	197	42	206	36	177
27	43	205	34	210	40	217
28	41	218	45	210	40	210
29	38	194	44	229	40	188
30	35	197	40	195	38	183
31	40	248	42	203	42	238
32	42	215	42	·202	40	185
33	44	232	37	189	38	189
34	44	251	42	224	35	146
35	35	184	39	205	40	188
36	41	214	34	201	42	261
37	44	237	38	211	38	218
38	34	183	38	206	39	196
39	38	207	39	224	34	172
40	37	194	34	194	38	172
41	42	233	38	198	42	226
42	36	161	43	185	42	213
43	39	210	43	225	35	188
44	43	171	42	245	42	214
45	44	259	37	209	40	222
46	37	187	42	248	43	220
47	35	247	35	178	45	212
48	40	221	35	192	42	194
49	43	227	33	155	42	200
50	44	244	38	193	40	172
51	37	183	40	211	38	206
52	34	188	37	173	39	192
53	42	240	32	129	37	174
54	45	232	31	122	38	183
55	41	228	42	232	35	152
56	34	195	41	199	35	184
57	45	226	34	184	38	180
58	40	196	42	244	38	164
59	33	160	30	136	30	131
60	42	235	38	181	44	208
61	42	205	36	157	39	202
62	43	238	44	213	43	198
63	34	182	38	175	40	176
64	41	223	*	*	40	213
65	37	162	*	*	44	201
66	44	215	*	*	42	222
67	37	187	*	*	40	234
68	42	215	*	*	33	174
69	35	193	*	*	37	171
70	36	212	*	*	38	214
71	39	211	*	*	33	186
72	36	178	*	*	28	118
73	40	205	*	*	42	212
74	37	193	*	*	34	133
75	36	188	*	*	42	211
76	29	119	*	*	36	195
77	41	234	*	*	32	177
78	45	242	*	*	42	223
79	34	162	*	*	36	194
80	38	186	*	*	34	170
81	33	162	*	*	36	187
82	40	220	*	*	42	220
83	41	231	*	*	37	171

84	38	214	*	*	39	224
85	35	200	*	*	44	230
86	36	191	*	*	38	207
87	35	191	*	*	42	220
88	40	208	*	*	39	182
89	31	177	*	*	37	165
90	38	199	*	*	42	206
91	39	178	*	*	32	166
92	32	140	*	*	34	160
93	45	214	*	*	45	205
94	30	126	*	*	30	125
95	32	142	*	*	36	177
96	40	214	*	*	43	184
97	40	225	*	*	42	232
98	33	173	*	*	36	170
99	*	*	*	*	39	205
100	*	*	*	*	39	196
101	*	*	*	*	43	198
102	*	*	*	*	37	171
103	*	*	*	*	40	201
104	*	*	*	*	36	160
105	*	*	*	*	42	211
106	*	*	*	*	45	220
107	*	*	*	*	42	230
108	*	*	*	*	38	170
109	*	*	*	*	37	196
110	*	*	*	*	42	203
111	*	*	*	*	32	151
112	*	*	*	*	25	148
113	*	*	*	*	35	151
114	*	*	*	*	37	164
115	*	*	*	*	40	197
116	*	*	*	*	38	196
117	*	*	*	*	42	206
118	*	*	*	*	41	207
119	*	*	*	*	36	166
120	*	*	*	*	43	217
121	*	*	*	*	39	172
122	*	*	*	*	37	177
123	*	*	*	*	42	198
124	*	*	*	*	38	201
125	*	*	*	*	41	228
126	*	*	*	*	40	191
127	*	*	*	*	39	190
128	*	*	*	*	38	221
129	*	*	*	*	38	187
130	*	*	*	*	34	156
131	*	*	*	*	39	171
132	*	*	*	*	37	180
133	*	*	*	*	27	133
134	*	*	*	*	40	173
135	*	*	*	*	31	162
136	*	*	*	*	42	195
137	*	*	*	*	36	161
138	*	*	*	*	42	227
139	*	*	*	*	38	186
140	*	*	*	*	36	161
141	*	*	*	*	39	175
142	*	*	*	*	36	151
143	*	*	*	*	44	255
144	*	*	*	*	42	192

(b)

ROW	FAIR	SSKERR	SUTOR	CANNA	FLAN	MAY	CAITH	SHET
1	241	325	260	265	305	272	280	256
2	210	293	310	285	310	220	270	255
3	220	265	275	290	320	218	255	287
4	300	310	278	285	315	255	280	308
5	250	312	268	263	325	320	270	291
6	190	295	264	270	308	273	230	276
7	210	210	262	304	307	246	300	285
8	260	260	268	257	335	248	270	246
9	240	270	300	252	295	220	275	284
10	230	230	240	270	298	208	250	248
11	230	220	214	315		260	275	266
12	230	245	243	290		265	295	242
13		245	252	274		242	260	294
14		218	230	308		256	260	279
15		240	244	258		293	250	304
16		270	280	322		251	265	299
17		240	247	316		272	255	277
18		215	256	282		264	275	235
19		270	214	250		280	235	263
20		270	248	255		273	215	290
21		260	243	280		272	280	270
22		285		312		240	245	240
23		315		300		287	225	254
24		280		305		263	330	255
25		235		275		233	255	241
26		285		236		287	240	264
27		280		225		275	270	233
28		290		265		259	240	287
29		296		225		214	235	270
30		225		241		259	270	244
31		237		235		226	240	301
32		230		255		265	295	232
33		210		218		263	245	274
34		260		230		278	235	260
35		285		260		271	260	294
36		325		310		254	230	272
37		245		220		263	280	281
38		260		255		188	250	264
39		255		280		241	270	272
40		280		235		283	245	
41		240		265		260	285	
42		235		285		256	275	
43		248		220		220	275	
44		245		245		231	310	
45		265		275		273	290	
46		250		265		267	250	
47				238		239	230	
48				295		251	230	
49				248		248	260	
50				276		255	260	
51				250		311	290	
52				292		249	310	
53				310		235	260	
54				270		267	280	
55				275		263	320	
56				312		210	310	
57				240		213	310	
58				271		242	280	
59				326		272	325	
60				265		235	260	
61				232		303	320	

62	275	210	240
63		273	250
64		220	270
65		208	250
66		250	260
67		254	280
68		233	280
69		274	290
70		268	330
71		224	280
72		248	225
73		248	260
74		252	250
75		245	250
76		247	290
77		219	255
78		261	260
79		246	270
80		261	320
81		229	300
82		259	250
83		206	250
84		198	250
85			305
86			280
87			290
88			300
89			315
90			280
91			300
92			265
93			270
94			275
95			300
96			280
97			285
98			235
99			260
100			280
101			300
102			275
103			270
104			230
105			270
106			265
107			300
108			270
109			270
110			295
111			275
112			290
113			290
114			270
115			225
116			310
117			245
118			310
119			280
120			275
121			300
122			255
123			250
124			265
125			250
126			265
127			270
128			280

CANNA REPORT
No. 13

INTRODUCTION

This, our 13th Canna Report, covering the years 1987 and 1988, our 19th and 20th successive years on Canna, concentrates on our long-term seabird studies. Throughout the 1970's and into the early 80's the populations of most of the seabird species on Canna were rapidly increasing. These increases have stopped and the populations of most species are now either stable or declining so we can compare how various parameters have changed between times of growth and times of stability or decline. An attempt to do this with some of the data gathered so far is found elsewhere in this report.

During the two years our main aims were as follows:
1) To continue long-term seabird counts on the island.
2) To monitor the breeding success of selected seabird species.
3) To continue our ringing programme to establish dispersal patterns from the island, rates and causes of mortality and to establish the age of return to the island and age of first breeding.
4) To collect biometric data from young Guillemots, Kittiwakes and Shags.
5) To collect and measure food brought to young auks, Kittiwakes and Shags.
6) To continue our Corncrake study.
7) To collect data on other birds, particularly ducks, birds of prey, and waders.
8) During 1988 we also did survey work in four tetrads for the BTO Breeding Bird Atlas.

Eight visits were made over the two years:

1987			1988		
4 April	-	6 April	13 April	-	15 April
30 May	-	3 June	23 May	-	28 May
2 July	-	11 July	25 June	-	4 July
1 August	-	8 August	30 July	-	6 August

RESULTS

SEABIRD CENSUS AND BREEDING SUCCESS

Details of past counts can be found in *Swann and Ramsay 1984 (Long term seabird monitoring on the Isle of Canna - Scottish Birds:13,2)*. This report deals with counts from 1987 and 1988 and compares them with past data where appropriate. This report up-dates previous reports.
After a colder than average winter, April and May 1987 were warm and dry, allowing the birds to start breeding earlier than usual. However, over the summer months conditions tended to be cooler and wetter than normal. The 1987/88 winter was fairly wet and mild and was followed by an exceptionally warm and dry spring and early summer (April-June) which again allowed a very early breeding season. July and August, however, were exceptionally wet.

MANX SHEARWATER. In 1987 41 (66%) out of 62 study burrows had eggs, whilst in 1988 the figures were 31 (65%) out of 48. These are similar occupancy rates to those recorded in 1985 and 1986 (66%) but below the 1976-84 average of 75% (n=511). In 1987 breeding success was above average with 0.68 chicks fledged per egg laid. In 1988, however, breeding success was below average with only 0.42 chicks per egg. (1976-86 average = 0.58).

FULMAR. 551 occupied sites were located in 1987 and 593 in 1988, a slight but continuing increase since 1983, but still below the peak of 670 sites in the late 1970's. Breeding success showed much variation. On the Sanday study plot 16 large young were produced from the 35 sites occupied in 1987 (0.46 chicks per site) and 17 young were produced from 35 sites in 1988 (0.49 chicks per site), both similar to the 0.48 produced in 1986. At the Nunnery site, 10 young were produced from 13 birds that laid in 1987, but only 2 from the 15 eggs laid in 1988. The 0.77 chicks per egg in 1987 was much higher than the 0.20 recorded in 1986 and the 0.13 in 1988.

SHAG. The number of nests in 1987 had dropped by 9% from the 1984 peak count of 1753 nests to 1592 nests. 1988 saw a further 9% decrease to 1447 nests. Breeding success in both years was above average. In 1987 50 of the 57 study sites were laid in; mean clutch size was 2.8 and an average of 2.02 chicks were fledged per nest. In 1988 46 of 59 study nests were laid in; mean clutch size was 2.95 and an average of 2.04 chicks were fledged per nest. The 1976-84 mean was 1.8.

GREAT BLACK-BACKED GULL. Following years of stability (c.65 pairs 1969 - 1983) this species appears to be undergoing an increase in numbers with 71 territorial pairs in 1987 and 88 in 1988, our highest ever count.

LESSER BLACK-BACKED GULL. Up to 1978 55-60 pairs bred on Canna. Since then 36-46 pairs has been the norm. In 1987 38 pairs were located and in 1988 47 pairs.

HERRING GULL. Since 1969 total numbers have remained fairly stable at around 1000 pairs. But the population increased to 1373 pairs in 1987 and 1525 pairs in 1988. These increases were reflected in nest counts in our study areas:

	1984	1985	1986	1987	1988
no.nests	618	627	513	714	807

Breeding success in 1987 was average with 77% of 763 nests checked appearing to have had large young. 1988 was even better with 90% of the 798 nests checked producing chicks, but in mid-July many of these chicks died, prior to fledging. At the Rhu-langanais colony up to 30% may have died and at Lamasgor 10% (based on the number of dead ringed chicks found).

COMMON GULL. 12 pairs in 1987 and 14 pairs in 1988 were about average.

KITTIWAKE. A peak count of 991 nests occurred in 1982. Since then an erratic decline has taken place. The 917 nests in 1987 was similar to the 914 in 1984 and 889 in 1985, but 1988 saw a large drop to 839 nests, due mainly to a large decrease in the cliff colony on Sanday.

	North Cliff Colonies:			Sanday Colonies:		
	cave	sec.5	Buidhe Sgor	Ledge	Cliff	Dun Mor
1987	143	153	293	25	273	41
1988	137	154	281	28	191	48

This 30% decline at the Sanday colony in 1988 was partly a result of very low breeding success and a loss of nests that had failed. We photograph 4 sub colonies on Sanday in May to check on subsequent breeding success. In May 1988 180 nests were located on the cliff colony study plots, only 136 (76%) survived to July. In 1987 224 nests were located in the same area in May suggesting a 20% decrease between the two years.

Breeding success continues to be low at the Sanday colonies averaging 0.57 per nest in 1986, 0.56 in 1987 and 0.03 in 1988. There was also large variations between the study plots in the number of chicks fledged per nest with the Dun Mor sub-colony tending to do better than the rest:

	K1	K2	K3	K4 (Dun Mor)
1986	0.54	0.58	0.42	0.86
1987	0.32	0.17	0.95	0.96

In 1988 there was an almost complete failure at the Sanday colony with only 5 large/fledged young and four medium sized young (which may not all have survived to fledging) coming from 231 nests. The colonies on the north side of the island were fairing slightly better than those on Sanday. At the cave 137 nests produced 49 large young (0.36 per nest). This was still below the 1986 and 1987 Sanday figures and very low on a national scale. This suggests that Kittiwakes may be suffering from food shortages. The failure on Sanday was probably made worse by heavy predation by a pair of Great Black-backed Gulls.

COMMON TERN. In 1987 three pairs were present on Sanday of which two pairs bred, fledging at least one chick. In 1988 up to 20 birds were regularly present on the island and two pairs bred again at the 1987 site on Sanday fledging two chicks. This is the first recorded breeding on Canna.

RAZORBILL. Due to the very early breeding season in both years (first chicks hatched on 30 May 1987) no full count was possible as so many chicks had already left by the time of our late June/July visits. However late May counts in a few small sample areas suggest that numbers remained stable as suggested by the table below:

A comparison of late May counts at the Nunnery and Garrisdale with full counts (when available).

	1984	1985	1986	1987	1988
Nunnery & Garrisdale	58	74	73	67	73
All study sites	454	520	509	na	na

GUILLEMOT. Following years of continual increase which reached a peak in 1983 numbers now appear to have stabilised as shown by nest counts in our study plots:

1983	1984	1985	1986	1987	1988
1191	1093	1152	957	1043	1005 nests

A small colony established at Garrisdale in 1980, reached a maximum of 9 nests in 1984. In 1985 only 1 egg was laid and it failed. Since then this colony has been abandoned. Two of the breeding adults from this colony moved to the nearby sub-colony at the Nunnery about one mile to the east.

BLACK GUILLEMOT. Counts in 1987 and 1988 were 100 and 101 - the normal level since 1980.

PUFFIN. No counts are available in either 1987 or 1988 but numbers appear to be fairly stable.

OTHER SPECIES

Notes are kept on the status of other species recorded on the island and a brief summary of some of the more interesting observations is given here.

Ducks. EIDERS 49 broods were located in 1987 and 50 in 1988. This is about normal. 3 pairs of SHELDUCK raised 2 broods in 1987 but the four pairs in 1988 failed. RED BREASTED MERGANSERS produced one brood in 1988 and MALLARDS one brood in 1987.

Birds of Prey. GOLDEN EAGLES bred successfully on the island in 1987 and fledged the first chick since 1969. The birds fed mainly on Rabbits. A pair was present in 1988 but did not nest. BUZZARDS: at least 12 young fledged from 7 pairs in 1987 and in 1988 7 pairs produced 13 young. PEREGRINE: The Compass Hill pair failed in 1987, but in 1988 two pairs were present and both succesfully reared young.

Waders. Counts of breeding pairs were:

	1987	1988
Oystercatcher	57	61
Common Sandpiper	11	12
Ringed Plover	3	2

Others. HERON: In 1987 3 pairs nested (including one pair on the cliff at Rhu Carr-innis) and in 1988 two pairs. CORNCRAKES: Two calling birds 1987 (Coroghon and Caslum). The latter site reared a brood. In 1988 one calling bird was located in the Change House Park, however due to the drought and the retarded growth of the hay crop it moved on and no chicks were reared.

THE RINGING PROGRAMME.

Details are given below of the numbers of birds ringed on Canna in 1987 and 1988 along with the grand total of birds ringed since 1969.

	1987			1988			GRAND
	Adults	pullus	Total	Adult	pullus	Total	TOTAL
Manx Shearwater*	17	29	46	86	10	96	6033
Storm Petrel	–	–	–	–	–	–	13
Fulmar	24	29	53	8	20	28	332
Shag	149	539	688	215	562	777	8923
Heron	–	2	2	–	3	3	15
Pink-footed Goose	–	–	–	–	–	–	1
Eider	1	–	1	1	10	11	73
Mallard	–	1	1	2	–	2	14
Shelduck	–	–	–	–	–	–	1
Buzzard	–	1	1	–	3	3	23
Sparrow Hawk	–	–	–	–	–	–	9
Corncrake	–	1	1	–	–	–	191
Oystercatcher	–	4	4	–	7	7	80
Lapwing	–	2	2	–	5	5	15
Ringed Plover	–	–	–	–	–	–	13
Common Sandpiper	–	–	–	–	–	–	12
Snipe	–	–	–	–	–	–	8
GBB Gull	–	43	43	–	65	65	531
LBB Gull	–	14	14	–	14	14	255
Herring Gull	–	482	482	1	487	488	7028
Common Gull	–	2	2	–	2	2	70
Kittiwake	42	94	136	29	83	112	564
Arctic Tern**	–	–	–	–	–	–	45
Common Tern	–	1	1	–	5	5	6
Razorbill	50	106	156	64	170	234	4038
Guillemot	316	1067	1383	540	2422	2962	23634
Puffin	1	–	1	1	–	1	62
Black Guillemot	–	–	–	–	–	–	3
Hooded Crow	–	–	–	–	–	–	8
Skylark	–	–	–	–	–	–	7
Swallow	–	–	–	–	–	–	18
Collared Dove	–	–	–	–	–	–	9
Wood Pigeon	–	–	–	1	–	1	1

Wren	–	–	–	–	–	–	27
Blue Tit	–	–	–	–	–	–	1
Mistle Thrush	–	–	–	–	–	–	1
Song Thrush	–	–	–	2	–	2	42
Redwing	–	–	–	–	–	–	10
Blackbird	–	–	–	1	–	1	44
Wheatear	–	18	18	1	46	47	505
Whinchat	–	–	–	–	–	–	28
Stonechat	–	–	–	–	–	–	12
Robin	–	–	–	1	–	1	83
Sedge Warbler	–	–	–	–	–	–	30
Whitethroat	–	–	–	–	–	–	2
Willow Warbler	–	–	–	–	–	–	50
Chiffchaff	–	–	–	–	–	–	2
Tree Creeper	–	–	–	–	–	–	1
Goldcrest	–	–	–	4	–	4	24
Dunnock	–	–	–	2	–	2	40
Spotted Flycatcher	–	–	–	–	–	–	1
Starling	–	–	–	–	3	3	29
Pied Wagtail	–	–	–	1	–	1	99
Meadow Pipit	–	–	–	–	4	4	73
Rock Pipit	3	–	3	–	–	–	26
Greenfinch	–	–	–	1	–	1	45
Linnet	–	–	–	–	–	–	2
Twite	–	–	–	–	–	–	50
Chaffinch	–	–	–	6	–	6	170
Reed Bunting	–	–	–	–	–	–	15
House Sparrow	–	–	–	–	–	–	29
Tree Sparrow	–	–	–	–	–	–	51
TOTALS	603	2435	3038	967	3921	4888	53528

* 2440 ringed on Rum ** 45 ringed on Heisgeir

RINGING RECOVERIES SECTION

The following pages give full recovery details of the 147 birds ringed on Canna and notified to us since our last report. In addition details are given of the 6 birds ringed elsewhere and recorded on Canna during the same period.

For all recoveries of Canna ringed birds details are given regarding age of bird and date of ringing plus method, date and place of recovery along with distance and direction from Canna.

Recovery method is noted as follows:

x	found dead (cause of death given, if known)
x LD	found long dead
xx	ring only found
v	caught and released
vv	ring number read in field
vvC	colour ringed bird seen in colony
pull	ringed as a chick
Ad	ringed as an adult

The recoveries are listed in species then ring order.

ISLE OF CANNA RINGING RECOVERIES

FULMAR 1 recovery

FC29114	pull	3.8.87	x	2.10.87	Arisaig	47km.109'

SHAG 10 recoveries

1141972	pull	4.7.79	x	5.10.86	Northton,Harris,Western Isles	87km.340'
1188501	Ad	2.7.84	x	12.11.87	Canna	local
1237514	pull	9.7.87	x shot	10.12.87	Ard Chattan,Loch Etive,Argyll	102km.130'
1237722	pull	4.7.87	x	13.7.88	Tiree,Strathclyde	60km.188'
1237793	pull	29.7.85	x net	14.10.85	Dunstaffnage,Oban	96km.132'
1237953	pull	4.7.87	x net	7.5.88	Isle of Gigha,Strathclyde	160km.161'
1237983	pull	4.7.87	x	29.7.87	Loch Eishort, Skye	42km. 75'
1241915	pull	6.7.87	x net	Jan 88	Shesbader Bay,Lewis,Western Isles	136km. 11'
1251233	pull	8.7.87	x	6.2.88	East coast Benbecula	59km.319'
1251260	pull	9.7.87	x	(10.3.88)	Eriskay	44km.275'

GUILLEMOT 78. recoveries

GP45240	Ad	18.6.74	x	25.12.77	nr.Brixham,Devon	760km.160'
GP22745	Ad	1.7.75	x	29.11.87	Aird Ardvasar,Skye	41km. 85'
GK23829	pull	2.7.76	x oil	3.2.87	Sennan Cove,Cornwall	790km.176'
GK19615	pull	4.7.77	x	14.4.83	L'Aber,Wrach,Finistere,FRANCE	948km.172'
GK71264	pull	5.7.78	x	28.5.87	Loch Bharcasaig,nr.Dunvegan,Skye	71km. 59'
GJ05243	pull	6.7.80	x oil	24.2.88	Salcombe Harbour,Devon	778km.165'
GJ33595	pull	5.7.82	x net	Feb 86	Youghal,Cork,Eire	572km.188'
GJ50537	pull	6.7.82	x net	16.5.87	5 mls.off W.coast Galway,Eire	457km.201'
GJ50927	pull	4.7.83	x shot	23.11.86	Barbatre,Vendee,FRANCE	1161km.165'
GJ55695	pull	9.7.84	x LD	17.8.87	Scurdie Ness,Montrose,Tayside	255km. 99'
GJ70560	pull	6.7.83	x shot	?	ICELAND	1087km.324'
GJ70754	Ad	27.5.84	x oil	Dec.86	nr.Carnsore Pt.,Wexford,Eire	543km.179'
GJ70760	pull	3.7.84	x	5.7.87	Canna	local
GJ75595	pull	6.7.82	x net	11.3.87	Ile d Croix,Morbihan,FRANCE	1067km.169'
GH01207	pull	4.7.84	x	(12.7.88)	El Ferrol,Coruna,SPAIN	1512km.185'
GH16005	pull	4.7.84	x	8.1.87	Whitby,Yorks	468km.127'
T02960	pull	3.7.84	x	30.4.87	Plouncur-Bodou,Cotes-du-Nord,FRANCE	943km.167'
T03306	pull	30.6.84	x	20.12.87	Ballycotton Bay,Cork,EIRE	535km.187'
T03499	pull	1.7.84	x	(25.6.87)	Fanadhead Beach,Donegal,EIRE	205km,198'
T05279	pull	4.7.84	x	22.3.87	Canna	local
T06447	pull	4.7.84	x net	13.12.86	Knockadoon Head,Cork,Eire	578km.183'
T05726	pull	4.7.84	x oil	19.2.86	Asturias,Oviedo,SPAIN	1508km.177'
T11321	Ad	4.7.84	x oil	11.2.88	Rocquaine,Guernsey,Channel Is.	893km.163'
T16197	pull	30.6.85	x shot	17.5.86	Hornafirdi,A.-Skaft,ICELAND	921km.330'
T16265	pull	30.6.85	x oil	4.12.86	Gyleen,Cork,Eire	592km.190'
T16295	pull	30.6.85	x shot	1.1.86	5 miles S.of Bordoy,FAEROES	565km.360'
T16344	pull	30.6.85	x	9.11.85	nr.Busum,Schleswig-Holstein,WEST GERMANY	1022km.108'
T30007	pull	7.7.85	x oil	13.2.87	Ameland,NETHERLANDS	877km.117'
T30048	pull	7.7.85	x	Feb 87	Les Sables D Olonne,Vendee,FRANCE	1217km.164'
T30139	pull	7.7.85	x net	Feb 86	Youghal,Cork,Eire	572km.189'
T30269	pull	3.7.86	x oil	20.3.88	Hondsbossche Zeewering,Noord Holland,NETHERLANDS	861km.124'
T30532	pull	4.7.86	x	16.5.88	Monifieth,Tayside	237km.105'
T30631	pull	3.7.86	x net	18.3.87	Oporto,Douro Litoral,PORTUGAL	1760km.184'
T30679	pull	4.7.86	x	12.8.88	Kilbirnie,nr.Oban,Strathclyde	109km.138'
T30789	Ad	5.7.86	x	7.1.88	Barnstable,Devon	683km.166'
T31711	Ad	28.6.86	x oil	27.3.88	btwn.Beer & Branscombe,Devon	713km.162'
T31716	pull	28.6.86	x oil	11.3.88	Den Helder,Noord Holland,NETHERLANDS	851km.122'
T31754	pull	3.7.86	x net	1.1.88	Youghal,Cork,Eire	572km.188
T31965	pull	4.7.86	x	4.3.88	Bude,Cornwall	795km.169'
T32653	pull	5.7.86	x	8.7.87	Newburgh,Grampian	277km. 84'
T32700	pull	5.7.86	x net	17.6.88	5mls. N of Horn Head,Donegal,Eire	217km.204'
T32785	Ad	5.7.86	x net	22.2.88	nr.Browns Town,Waterford,Eire	549km.184'

T32893	pull	5.7.86	x	28.1.87	Ball,castle,Antrim,Northern Ireland	207km.171°
T32972	pull	5.7.86	x	5.4.87	Dalmeny,Lothian	231km.121
T32968	pull	5.7.86	x net	19.1.88	Lindesnes,Groeningen,Vest-Agder,NORWAY	827km. 83°
T33011	pull	5.7.86	x net	15.11.87	nr.Billiers,Morbihan,FRANCE	1086km.159
T33117	pull	5.7.86	x	22.3.88	Polnoe Pt.,Kilmore Quay,Wexford,Eire	513km.189°
T33298	pull	2.7.87	x shot	20.10.87	Nolsoy,FAEROES	531km.350
T33358	pull	2.7.87	x	5.11.87	32 miles N.of Thyboron,Jylland,DENMARK	900km. 92°
T33393	pull	2.7.87	x shot	31.10.87	Tangafjordur,FAEROES	533km.359°
T33501	pull	6.7.87	x net	21.1.88	Dokeafjord,Rogaland,NORWAY	752km. 72°
T33587	pull	7.7.87	x net	20.12.87	Dales Voe,Delting,Shetland	485km. 40°
T33623	pull	7.7.87	x	12.12.87	Spurn Pt.,Humberside	571km.132°
T33680	pull	7.7.87	x	27.9.87	Camus Malag,L.Slappin,Skye	43km. 67
T33705	pull	7.7.87	X	8.11.87	Burray,Orkney	294km. 47°
T33806	pull	7.7.87	x net	26.9.87	Loch Carnoy,Skye	32km. 24°
T33824	pull	7.7.87	x	13.2.88	Zuidpier Beach,Ijmuiden,Noord-Holland,NETHERLANDS	878km.126
T33911	pull	7.7.87	x net	3.4.88	NE Sjaellands Rev,Sjaelland,DENMARK	1097km. 96
T41017	pull	7.7.87	x net	8.12.87	Farsund,Vest Agder,NORWAY	807km. 82°
T41033	pull	7.7.87	x	1.2.88	East Kyle,Bute,Strathclyde	155km.145°
T41034	pull	7.7.87	x	15.12.87	Anglesey,Wales	457km.162°
T41533	pull	5.7.86	x	29.2.88	Barmouth Est.,Bontddu,Gwynedd,Wales	508km.161°
T42095	pull	5.7.86	x	21.2.88	Oosterende,Terschelling,NETHERLANDS	856km.118°
T45207	Ad	5.7.86	x oil	21.11.86	Canna	local
T45396	pull	5.7.86	x oil	14.3.87	Golspie,Sutherland	183km. 56
T45571	pull	6.7.87	x	21.10.87	Dacondale,S.Mainland,Shetland	438km. 41
T45578	pull	6.7.87	x net	21.9.87	Sigersvold,Farsund,Vest-Agder,NORWAY	807km. 82
T45666	pull	2.7.87	x net	29.11.87	Farsund,Vest-Agder,NORWAY	807km. 82
T45707	pull	2.7.87	x net	11.1.88	Stroestad,Goteborg-och-Bohus,SWEDEN	1067km. 79°
T45712	pull	2.7.87	x net	6.2.88	Hakefjorden,Goteborg-och-Bohus,SWEDEN	1095km. 85°
T45782	pull	7.7.87	x	31.10.87	Balmedie,Grampian	274km. 85
T45809	Ad	7.7.87	x oil	11.2.88	Herqueville,Manche,FRANCE	875km.159
T45835	pull	7.7.87	x net	1.1.88	Knockadoon Head,Cork,EIRE	578km.189°
T45925	pull	2.7.87	x net	10.12.87	nr.Skagen,Jylland,DENMARK	1047km. 85
T58024	pull	4.7.87	x net	27.1.88	10km.SE Gedser,Lolland,DENMARK	1216km.109
T58058	pull	2.7.87	x net	29.1.88	Indroy I Solund,Sogn Og Fjorden,NORWAY	772km. 55
T58064	pull	4.7.87	x shot	17.11.87	Tangafjordur,FAEROES	576km.352°
T58071	pull	4.7.87	x shot	27.11.87	Tangafjordur,FAEROES	578km.358°

A colour ringed bird seen at Fenella Bay, Peel, Isle of Man on 24.10.87 was almost certainly ringed as a chick on Canna in 1987.

RAZORBILL 11 recoveries

M16736	Ad	4.7.76	x	28.2.79	Tyrella Beach,Down,Northern Ireland	313km.171°
M23897	pull	6.7.78	vv	21.6.87	Great Saltee,Wexford	550km.180
M24651	pull	1.7.79	x	31.12.86	Kiloran Bay,Colonsay,Strathclyde	109km.167°
M26958	Ad	4.7.81	x oil	6.4.88	nr.Bierum,Friesland,NETHERLANDS	897km.117°
M26767	pull	8.7.87	x oil	5.2.88	Plouguerneau,Finistere,FRANCE	949km.172°
M32927	pull	5.7.80	x	1.9.87	Uh Gauscavaig,Skye	38km. 76°
M38163	pull	29.6.86	v net	(9.7.87)	Gortahork,Donegal,EIRE	237km.204
M40603	pull	29.6.85	x net	July 87	btwn.Stags Head Rock & Old Head of Kinsale,Cork,Eire	621km.193
M40749	pull	28.6.86	x	21.2.88	Machir Bay,Islay,Strathclyde	143km.178°
M40776	pull	28.6.86	v net	10.6.88	Killala Bay,off Lenadoon Pt.,Mayo,Eire	344km.207°
M42903	pull	28.6.86	x net	15.3.88	El Grove,Pontevedra,SPAIN	1625km.185°

HERRING GULL 13 recoveries

GF32656	pull	29.6.71	x	17.7.87	Canna	local
GP73165	pull	21.6.73	x	30.7.88	Canna	local
GK17867	pull	2.7.75	x	5.7.87	Canna	local
GL18327	pull	28.6.75	xx	11.1.88	Edinburgh,Lothian	240km.121°
GL21279	pull	30.6.75	x	15.5.88	Canna	local
GK32355	pull	29.6.76	x	22.8.87	Canna	local
GK48643	pull	6.7.77	x	30.7.88	Canna	local

GL62221	pull	5.7.81	x	Sep 87	Bretignolles,Vendee,FRANCE	1207km.164'
GL79805	pull	2.7.78	x	17.1.88	Harris,Rum	28km.157'
GL79961	pull	4.7.80	x	22.9.87	Canna	local
GL79983	pull	4.7.80	x	6.9.87	Airds Bay,Gatehouse of Fleet, Dumfries & Galloway	285km.147'
GJ73701	pull	3.7.82	x	6.7.87	Belfast,Antrim,Northern Ireland	272km.171'
GJ73922	pull	3.7.82	x	11.10.87	Carrickfergus,Antrim,Northern Ireland	265km.168'
GJ73911	pull	3.7.82	x	26.5.87	Camus Ban,nr.Portree,Skye	41km. 31'
GJ91535	pull	8.7.87	vv	7.9.87	Lossiemouth,Grampian	211km. 67'
GJ91551	pull	8.7.83	x	5.3.87	Gairloch,Highland	95km. 29'
GJ91940	pull	6.7.83	x	20.9.87	Isle of Eigg	31km.119'
GG04094	pull	11.7.81	x	6.7.87	Canna	local
GG05206	pull	9.7.82	x shot	19.7.88	Meigle Bay,nr.Skelmorlie,Strathclyde	169km.142'
GG15315	pull	5.7.83	x	29.5.88	Canna	local
GG15402	pull	6.7.83	x	(9.9.97)	Glendale,Dunvegan,Skye	43km.360'
GG15447	pull	8.7.83	vv	26.10.87	Ainsdale,Merseyside	442km.150'
GG15487	pull	10.7.83	x	(27.9.86)	Lough Foyle,Greencastle,Donegal,Eire	207km.187'
GG27199	pull	5.7.91	x	10.3.87	Padgin Is.,Lough Neagh,Armagh,NorthernIreland	292km.177'
GG27246	pull	3.7.84	x	6.11.87	Canna	local
GG27437	pull	29.6.85	x LD	6.7.87	Millport,Cumbrae,Strathclyde	175km.144'
GG33096	pull	3.7.85	x	10.3.87	Lochgilphead,Argyll	132km.148'
GG33114	pull	3.7.85	vv	9.10.86	Ainsdale,Southport,Merseyside	442km.150'
GH16075	pull	1.7.86	vv	15.7.88	Agadir,Morocco	2755km.
GH16209	pull	2.7.86	vv	24.12.87	Ainsdale,Merseyside	442km.150'
GH16379	pull	5.7.85	vv	23.1.87	Southport,Merseyside	410km.149'
GH16437	pull	12.7.85	v	28.12.85	Bridge of Dee,Aberdeen,Grampian	271km. 88'
GH29577	pull	8.7.87	x	27.8.87	Kinloch,Rum	19km.102'
GH29780	pull	1.7.86	x LD	8.9.87	Lochmelm,nr.Ullapool,Highland	127km. 44
GH50055	pull	8.7.87	x net	(2.11.87)	L.Craignish,Strathclyde	119km.148'
GH50279	pull	6.7.87	x	21.6.88	Limekilns,Fife	222km.121'
GH50309	pull	6.7.87	x	21.12.87	Brodick,Arran	185km.152'
GH50317	pull	6.7.87	vv	23.2.88	Southport,Merseyside	410km.149'
GH50378	pull	9.7.87	vv	31.3.88	Lossiemouth,Grampian	211km. 69'
GH50426	pull	9.7.87	v	14.11.87	Dublin,Eire	373km.176'
GH50467	pull	6.7.87	x	18.6.88	Hollywood,Down,N.Ireland	271km.170'
GH50469	pull	6.7.87	x	5.3.88	Southend,Argyll	200km.163'
GH50497	pull	6.7.87	x	1.11.87	Greenock,Strathclyde	165km.137'

GREAT BLACK-BACKED GULL 4 recoveries

HW71957	pull	7.7.84	x	10.7.86	Peninerine,South Uist	57km.297'
HW89442	pull	11.7,82	vv	25.9.87	Southport,Merseyside	410km.149'
HT03905	pull	4.7.85	x LD	19.6.87	Crovie,Gardenstown,Banff	264km. 75'
HT13720	pull	8.7.87	x	4.10.87	Loch Mealt,Skye	67km. 20'

OYSTER CATCHER 2 recoveries

FV35473	pull	9.7.82	x	1.7.87	Canna	local
FV82318	8	24.5.81	x	July 88	Canna	local

RINGED BIRDS FOUND ON CANNA

HERRING GULL							
GG14331	8	10.3.83	Helensburgh,Strathclyde	x	1.9.87	Canna	161km.315'
YY3048	7	31.1.79	Bishopbriggs,Glasgow	x	30.7.88	Canna	153km.312'
GREAT BLACK-BACKED GULL							
HW94920	pull	5.7.84	Slignech Mor,Loch Sunart,Argyll	x	2.7.88	Canna	56km.319'
GUILLEMOT							
GF65781	pull	8.7.72	Great Saltee,Wexford,Eire	v	30.6.85	Canna	518km.360'
RAZORBILL							
EC00131	pull	30.6.61	Faraid Head,Highland	v8	31.5.87	Canna	205km.212'
BLACK-TAILED GODWIT							
GE16120	Ad	4.11.86	Triaize,Vendee,FRANCE	x	1.5.87	Canna	

SPECIES ACCOUNTS

Since the production of our last report all the recoveries of birds ringed on Canna have been put into a computer data base to assist analysis. This resulted in the discovery of several mistakes and ommissions in previous reports. The data in this reort therefore updates and supercedes any data in prior reports.

SHAG

This species has been ringed on Canna since 1961 and this report summarises the results for all ringed birds recovered up to 1st August 1988. Four periods of ringing are used in these analyses: 1961-65, 1969-75, 1976-80 and 1981-87. Birds from cohorts in 1969-75 would have been entering the population in a period of great fluctuations in numbers, those from 1976-80 in period of growth and those since 1980 in a period of decline.

Table 1.AGE OF RECOVERY OF CANNA SHAGS 1969-83.

	Number (and %) recovered in:				
No.ringed	1st year	2nd year	3rd year	4th year	5th year
5250	150 (2.9%)	21 (0.4%)	14 (0.2%)	11 (0.2%)	6 (0.1%)

Most shags are recovered in their first year of life (table 1). The percentage so recovered varies from year to year but has shown a continual and significant decline as the study has progressed (table 2).

Table 2. RECOVERY RATE OF FIRST YEAR SHAGS 1961-1987.

	no.ringed	no.recovered	% recovered
1961-65	350	31	8.9
1969-75	1483	70	4.7
1976-80	2342	57	2.4
1981-87	3031	52	1.7

The recovery patterns of first year shags have been examined to detect any changes in timing, place and method of recovery. There was no significant difference in place of recovery with 124 (57%) from the Western Isles, 45 (21%) from Highland Region, 39 (19%) from Strathclyde and 2 (1%) from Northern Ireland. Significant changes have taken place in the timimg of recoveries however (table 3, χ^2_6 = 21.04,p<0.001) with significantly more being recovered in summer (May-July) and fewer in autumn (Aug-Oct) since 1975 (χ^2_1 = 17.55,p<0.001). Recovery method has also altered significantly (table 4,χ^2_6=13.81,p<0.05) with significantly fewer reported as shot since 1980 (χ^2_1=9.59,p<0.01).

Table 3.TIMING OF RECOVERIES

MONTHS	1961-1965		1969-1975		1976-1980		1981-1987	
August-October	12	39%	24	34%	17	30%	8	15%
November-February	14	45%	37	53%	18	32%	23	44%
March-July	5	16%	9	13%	22	39%	21	40%

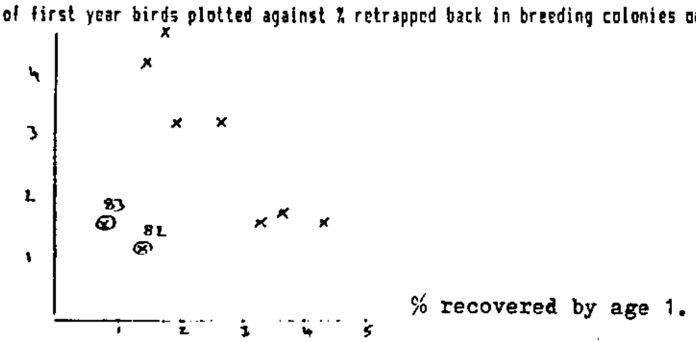
Table 4. METHOD OF RECOVERY.

	1961-1965		1969-1975		1976-1980		1981-1987	
Found dead	14	45%	46	66%	34	60%	40	77%
Killed/Shot	11	36%	15	21%	15	26%	3	6%
Caught/Net	6	19%	9	13%	7	12%	7	13%

Note: Single birds were also recovered as oiled in 1978,82 and 84.

Our last report gave details of the return rate of pullus to the colonies as measured through retrapping breeding adults. There was a good correlation between the number of chicks recovered in their first year from the 1975 to 1981 cohorts and the number subsequently controlled back in the colonies by age five (r=0.89). The higher the recovery rate, the fewer returned (fig.1). The 1982 and 1983 cohorts differed in having low recovery rates but also low recruitment rates.

Percentage recovery rate of first year birds plotted against % retrapped back in breeding colonies on Canna by age five.



GUILLEMOT

We have now ringed 23634 Guillemots on Canna and these have resulted in 551 recoveries of which 77 are detailed in this report. Table 1 gives recovery rates of first year birds during the period covered by this report. Comparison with table 6 shows that although the recovery rate of the 1987 cohort was typical, significantly fewer 1986 birds were recovered in their first year than would be expected (X^2 = 35.36,p<0.001)

Table 1. FIRST YEAR RECOVERY RATES OF CHICKS RINGED IN 1986 AND 1987.

	no.ringed	no.recovered	% recovered
1986	1912	5	0.3%
1987	1067	26	2.4%

Table 2 gives details of the numbers and age of young birds caught/sighted on Canna in 1987 and 1988 for the first time after fledging.

Table 2. AGE OF RETURN AND AGE OF FIRST KNOWN BREEDING OF GUILLEMOT CHICKS.

	1987			1988		
AGE	RETRAPPED BIRDS:		Colour ring	RETRAPPED BIRDS:		Colour ring
	no.returning	no.breeding	sightings	no.returning	no.breeding	sightings
2	0	0	0	1	0	0
3	4	1	2	1	0	0
4	9	4	6	4	0	1
5	23	1	6	15	3	3
6	8	4	1	33	4	4
7	15	1	*	19	2	0
>7	25	5	1	63	13	1

* no birds were colour ringed in 1980.

Following years of continued increase, Guillemot numbers peaked on Canna in 1983 and then remained fairly stable. There is due either to increased adult mortality rates or reduced recruitment of young birds into the population.
To see if there has been any change in adult mortality between the times of rapid growth (1974-83) and of stability (1984-88) the number of adults recovered in each period were examined (table 3). Only those adults recovered within three years of ringing were used to avoid biases due to increased likelihood of recovery with time and the effects of ring wear and loss. Those ringed between 1974 and 1980 were used to calculate recovery rates in the period of growth as all recoveries would have occured prior to the 1983 summer. Those ringed between 1983 and 1985 would be recovered in the period of stability. No significant differences were noted.

Table 3.RECOVERY RATES OF ADULT GUILLEMOTS RINGED ON CANNA AND RECOVERED WITHIN THREE YEARS OF RINGING.

	No.Ringed	No.Recovered	% Recovered
1974-80	1529	9	0.6%
1983-85	1748	12	0.7%

Data on recruitment comes from the number of chicks retrapped on Canna in subseqent years. No bird ringed as a chick was caught in its 1st or 2nd year of life but subsequent records up to summer 1988 were 3rd year (10), 4th year (31), 5th year (47), 6th year (75) and 7th year (99). Thus very few birds returned into the colonies before their 4th year. Of the 1305 colour ringed ringed chicks, only one was sighted at a colony in its second year, 5 in their third year but 20 in their fourth year. Thereafter the number of sightings declined, possibly because the colour rings started to fall off.
Are young birds now finding it more difficult to become established in the colonies, resulting in birds returning at a later age, or are fewer young birds returning to be recruited into the breeding population? We looked at the number of young birds aged 4-7 years from the 1974-79 cohorts that had returned to the island by 1983 (ie. during the years of high growth) with the numbers of those returning of similar age since and found that significantly fewer were caught in the latter period (table 5).

Table 4. NUMBER AND PERCENTAGE OF CHICKS RETURNING BY AGE 4 TO AGE 7 ON CANNA DURING PERIODS OF GROWTH AND STABILITY.

	Up to 1983			Since 1983			Difference btwn. two time periods
by age:	no.ringed	no.back	% back	no.ringed	no.back	% back	
4	2936	35	1.2%	7282	42	0.6%	**
5	2688	68	2.5%	5761	84	1.5%	**
6	1905	83	4.4%	5554	171	3.1%	**
7	1196	76	6.4%	4064	186	4.6%	*

Note: Difference between two time periods statistically significant (**=p<0.01, *=p<0.05).

The lack of chicks could be due to birds returning to other colonies or else due to higher mortality rates. We have no records of Canna chicks turning up at other seabird colonies, but this could be due to lack of ringing effort at other colonies. However we do have information on the number of chicks that on their return to Canna establish themseves in their natal sub-colony or move to a new one. Perhaps if more are moving to new sub-colonies on the island, more are likely to be moving to colonies outwith the island. Up to summer 1988 there was no significant difference between the number of chicks caught outwith their natal sub-colony in the two time periods (35 of 145 moved out in the period up to 1983 and 98 of 421 moved out in the period since).

Most chicks were recovered in their first year of life and the recovery rate of these birds has increased since 1980 (table 5). The first year recovery rate of the 1980-85 cohorts was significantly higher (table 6) than that of the 1974-79 cohorts (χ^2=25.2,p<0.001). Since most chicks return in their fourth and subsequent years, the bulk of the 1974-79 cohorts would have returned to the island prior to 1983 during the period of maximum growth. The 1980 chicks, characterised by a high first year recovery rate, should have returned in numbers from 1984 onwards. This coincides with the cessation of growth in these colonies, suggesting poor recruitment. The recovery rate of immature birds in their 2nd and 3rd years has, like that of adults, not increased significantly in recent years (table 6).

Table 5.GUILLEMOT RECOVERY RATE IN FIRST YEAR OF LIFE.

Year	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
No.ringed	222	356	618	709	783	248	1109	1215	1490	1699	1769	2236
No.recovered	2	0	10	10	9	1	32	29	28	50	46	81
% recovered	0.9%	-	1.6%	1.4%	1.1%	0.4%	2.9%	2.4%	1.9%	2.9%	2.6%	3.6%

Table 6.GUILLEMOT RECOVERIES ACCORDING TO AGE AND YEARS OF RINGING.

		in first year:		in second year:		in third year:	
years	no.ringed	no.rec.	% rec.	no.rec.	% rec.	no.rec.	% rec.
1974-1979	2936	32	1.1%	16	0.5%	14	0.5%
1980-1985	9518	266	2.8%	52	0.5%	29	0.3%

The increased mortality rates of first year birds since 1979 does not seem to have been due to a lack of food during the breeding season as the weights of chicks approaching fledging were amongst the highest recorded at any European colony suggesting that the chicks were in good condition when leaving the island.

Changes have taken place in the timing and causes of mortality of first year birds away from the island as shown by the recoveries of ringed birds. Fewer are recovered in summer between May and August and more in mid-winter between December and February (table 7). Also fewer are now reported as being shot (table 8).

Table 7.TIMING OF FIRST YEAR MORTALITY BETWEEN 1974-79 COHORTS AND 1980-85 COHORTS.

	1974-1979 cohorts		1980-1985 cohorts	
Sep-Nov	7	22%	59	22%
Dec-Feb	9	28%	123	46%
Mar-Apr	2	6%	38	14%
May-Aug	14	44%	45	17%

Table 8.METHOD OF RECOVERY OF FIRST YEAR GUILLEMOTS.

	1974-1979 cohorts		1980-1985 cohorts	
oiled	4	12.5%	33	12%
netted	9	28%	79	30%
found dead	12	37.5%	140	53%
shot	7	22%	13	5%

The largest concentration of recoveries of first year birds in mid-winter is in the North Sea (51 out of 147 mid-winter recoveries being reported from the North Sea). This is significantly higher than the 14 North Sea recoveries out of the total of 73 mid-winter recoveries of older birds (=9.42,p<0.01).

DISCUSSION

Up to 1983 Guillemot numbers on Canna were increasing rapidly but since then this growth has ceased. This could be due to increased adult mortality or lower chick recruitment or both.

Adult mortality rates appear not to have increased over the study period, but chick recruitment rates have declined. This could be due to fewer young Guillemots returning to breed on Canna, they may be moving to other colonies instead. There was no change in the number of young birds establishing themselves in other sub-colonies on the island, so it is perhaps unlikely that more moved outwith the island. Furthermore the reduction in population growth has occurred at several other colonies in Scotland since about 1983. Mortality rates of chicks have increased significantly from 1980-85. As most chicks do not return to the colonies prior to their fourth year this would result in fewer potential breeders post 1983, hence leading to the cessation of growth in the colony.

Harris and Wanless studying Guillemots on the Isle of May in the Firth of Forth also noted that growth in numbers ceased around 1983. Adult survival rates there were exceptionally high whereas few colour ringed chicks returned to the island, which led them to suggest that lower chick recruitment rates probably accounted for the lack of growth. Our results support this theory.

A series of major wrecks, mostly of young birds, have occurred since 1980, mainly in the North Sea. These wrecks have usually been associated with food shortage (G.P.Mudge pers.comm.), the concentration of young Canna birds in the North sea combined with a major decline in Sprat abundance may be resulting in winter food shortages and therefore increased mortality. Mortality rates of older birds have not decreased, presumably because they winter outwith the North Sea, possibly in areas where fish stocks are healthier or because they are more efficient feeders.

HERRING GULL

Most birds are reported as dead within their first year of life. Of the 4706 birds ringed between 1969 and 1983 61 (1.3%) were recovered in their first year, 15 (0.3%) in second, 13 (0.3%) in third, 14 (0.3%) in fourth and 17 (0.4) in fifth year. Recovery rates of birds reported as dead since ringing began in 1969 are shown in table 1. The 1980-83 cohorts have tended to have a lower first year recovery rate than the 1969-79 cohorts and a higher recovery rate of 2-5 year olds. The differences, however, were not significant.

Table 1. Recovery rates of dead Herring Gulls ringed on Canna.

	1969	1971	1973	1974	1975	1976	1977	1978	1979
no.ringed	493	118	131	160	510	454	409	379	124
no.recovered 1st year	10	2	0	7	6	7	5	4	0
% recovered 1st year	2.0	1.7		4.4	1.2	1.5	1.2	1.1	
no.recovered by 5th year	16	2	3	7	10	8	12	6	1
% recovered by 5th year	3.3	1.7	2.3	4.4	2.0	1.8	2.9	1.6	0.8

	1980	1981	1982	1983	1984	1985	1986	1987
no.ringed	495	519	464	450	469	446,	355	482
no.recovered 1st year	3	4	7	6	5	6	0	7
% recovered 1st year	0.6	0.8	1.5	1.3	1.1	1.4		1.5
no.recovered by 5th year	11	15	12	17				
% recovered by 5th year	2.2	2.9	2.6	3.8				

Two of the birds detailed in this report were recovered unusually far south in France and Morocco. Whilst this could represent an expansion in range it could also be that the birds were infact Lesser Black-backed Gulls.

GREAT BLACK-BACKED GULL

All previous recoveries of this species from Canna have been in west coast waters and mainly in the Irish Sea. The bird recovered at Banff is therefore our first from the North Sea.

RAZORBILL

The four summer recoveries of young birds and immatures in west coast waters off Ireland back up the few previous summer recoveries. The adult bird sighted at Great Saltee is our first recorded incident of a Canna bred bird presumably breeding at another colony.

SEABIRD FEEDING STUDIES

Fish samples were collected from three species in both years. These consisted of regurgitations from both adult and young Shags and young Kittiwakes. Shag pellets were also collected in 1988. Guillemot samples were obtained from adults which dropped whole fish as they were caught for ringing.

GUILLEMOT

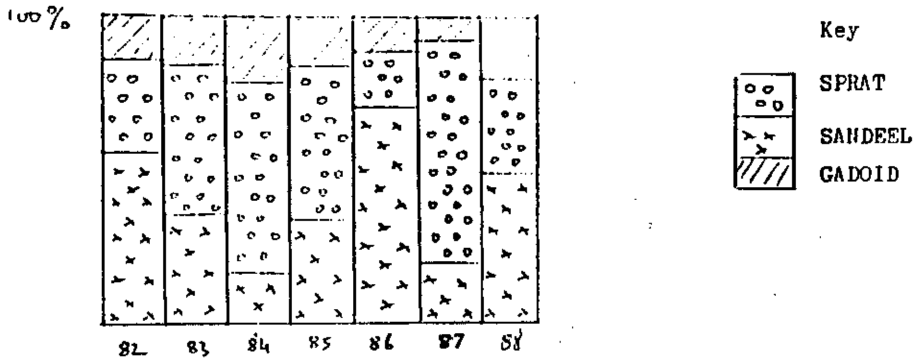
22 fish were collected in 1987 and 65 in 1988. Details are given in table 1.

Table 1 GUILLEMOT FISH SAMPLES

	1987				1988			
	n	%	mean length	weight	n	%	mean length	weight
Sandeel	4	18%	146 (4)	7.9 (4)	31	48%	150 (18)	11.6 (18)
Spratt	16	73%	106 (16)	10.3 (16)	18	28%	112 (16)	11.0 (16)
Herring					1			
Gadoids	2	9%			15	23%	88 (15)	5.1 (15)

Figures in parenthesis refer to sample sizes of fish weighed (g.) and measured (mm).
Gadoids included 2 whiting in 1987 and 9 Whiting, 4 Norway Pout, 1 Pollack or Saithe in 1988.

Figure 1. Fish samples from Canna Guillemots 1982 - 1988.



Between 1981 and 1986 185 fish were collected from Guillemots of which 87 (47%) were Sandeels, 65 (35%) Spratts and 31 (17%) Gadoids. The 1988 samples did not vary significantly from this pattern, but the 1987 sample had significantly more spratts than expected (x^2= 11.4,p<0.01). Figure 1 shows how the fish collected have varied between 1982 and 1988.

The mean size of fish caught 1981-88 were: Sandeel 147.3mm (n=54, excluding the 1986 sample which were unusually small) and Spratt 109.8mm (n=95). As table 1 shows the Sand eels caught in 1987 and 1988 did not differ much from the mean, but the Spratts caught in 1987 were much smaller than usual.
Since 1981 we have been weighing and measuring a sample of chicks each year (bar 1982). Birds with wing-lengths over 60mm show no significant change in weight with increasing wing-length. There weights can therefore be be taken as an indirect measure of fledging weight. Table 2 shows that this has varied between 257g and 280g on Canna.

Table 2. Weights of chicks (g.) with wing-length >60mm.

	1981	1983	1984	1985	1986	1987	1988
mean	261	280	272	273	280	271	257
n	9	17	12	20	10	65	42

There was no relationship on Canna between annual mean weight of chicks and type or size of fish caught.
KITTIWAKE
In 1987 regurgitations from seven chicks were examined. These were composed of 1 load of Sandeels and 6 loads of assorted gadoids (mostly Trisopterus sp. Norway Pout, Bib and Poor Cod). In 1988 five regurgitations were also composed of Trisopterus sp.
SHAG
All fish collected in 1987 and 1988 were sandeels. Since 1981 we have collected 21 'loads' of fish (ie regurgitations). 19 of these (90%) were entirely composed of sandeels, one of gadoids and one contained two gadoids and one Spratt.
The sandeels have varied in size from 40-170mm. Most (91%) have been classified as medium in size (c.120mm). The mean of the 14 measured was 117.6mm. The number of sandeels in each load has varied from 2-30 (mean 8.7,n=14).

ACKNOWLEDGEMENTS

We would like once again to thank the National Trust for Scotland for giving us permission to continue our studies on Canna and Dr. and Mrs. J.L.Campbell for their continued help and encouragement.

Many people assisted with the fieldwork carried out over the two years. In particular we would like to thank David Aiton, Dave Broadhead, Philip Brown, John Carruthers, Ronnie,Sheenac,Kenny and Alan Graham, and John MacDonnel all of whom put in a great deal of effort to help gather the data that is presented in this report. The pupils of Glenurquart High School Bird Club are also thanked for their efforts in the May trips. These school trips have provided us with a continual supply of good comparative data since 1975. Special thanks go to David Aiton (again), Robbie Paterson and Donald (Vikker) Fraser for helping, but most importantly to our head chef Hugh Maclean, who also assists with the August trips. Mike Thomson and Ian Mackay assisted with the April 88 trip and Ian also provided us with metereological data from Tiree. M.P.Harris of the ITE at Banchory, as usual, helped with the identification of fish samples and provided Darvik for the Guillemot colour rings.

As ever we are indebted to the locals on the island, who help make our visits so enjoyable. In particular to Winnie for arranging bookings and accommodation and for organising Dora's birthday party! Pakky once again assisted with the Corncrake study. We are also very grateful to him for taking us by boat to the north side of the island to count the more inaccessible areas and for landing us at the cave and also at Ha'aslum. Iain, Dan and Robin all assisted with transport and evening entertainment and Nora put up with our visits to the Change House! To all we are very grateful.

Financial assistance was provided in both years by the Nature Conservancy Council through a grant via Mike Harris. This greatly assists our many visits to the island and helps pay for rings and equipment. In return we are happy to act as a seabird monitoring station providing the NCC with data. Scottish Brewers (Inverness) also provided us with a crate of beer in 1988 to help us overcome the very dry summer on the island!

R.L.Swann. 28 Druimlon,Drumnadrochit,Inverness-shire.
A.D.K.Ramsay,Hardanger,Coulnagour,By Culbockie,Ross-shire.

December 1988.

Appendix 14

Ornithological Fieldwork on Hermaness NNR, Shetland conducted by the Cambridge Group, June/July 1988

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INTRODUCTION

A visit to Hermaness NNR, Unst, Shetland, was made by three ornithologists during the period 21 June - 3 July 1988. The visit was the twelth of a series which started with a group from the University of East Anglia in 1973. Reference to earlier reports (Albon *et al.*, 1976; Martin, 1976, 1978, 1981, 1982, 1984, 1988) should be made for information on previous expeditions and their work.

The major tasks for the 1988 group were as follows:

1. Monitoring of puffin burrows in the permanent transects at Sothers.
2. Collection and identification of food samples from puffins, gannets and any other seabird species where opportunity permitted.
3. Ringing of seabirds of selected species.
4. Observation of colour-ringed adult gannets and shags.
5. Assessment of shag breeding success in 4 study beaches.
6. Estimation of the total number of breeding pairs of puffins on the Reserve.

RESULTS

1. Puffin Breeding Pairs within the Permanent Transects at Sothers

The Sothers transects, covering 369m² of grassy slope, were examined on 22 June.

Year	Total burrows in transects (369m²)	Total No. occupied burrows	% Occupancy	Density of occupied burrows (nests/m²)	% Change in no. occupied burrows since '73
1973	197	172	87	0.47	0
1974	195	186	95	0.50	+8
1978	237	177	75	0.48	+3
1980	230	203	88	0.55	+17
1981	258	208	81	0.56	+20
1983		180		0.49	+4
1984	220	178	81	0.48	+3
1986	216	159	74	0.43	-8
1987	263	188	71	0.51	+9
1988	260	203	78	0.55	+17

Table 1. Details of the 1988 burrow count compared with those of earlier years

Ironically, in view of the difficulties currently facing puffins in Shetland, the number of occupied burrows was apparently higher in 1988 than in any year since 1981. This is thought to reflect good numbers of breeding attempts of which, according to our evidence, many or all were subject to failure early in chick-rearing. A weakness of the counting method is that, while unused burrows can be determined as such, it is rarely possible to discriminate between those currently in use and those which had recently failed. If puffins were having difficulty finding sufficient quantities of food to rear their chicks (see Appendix 8), failure would probably occur in the first week or two after hatching. Judging by the size of chicks being ejected from burrows this is the stage reached when our count was being made, so a rapid change in numbers of surviving chicks may have been occurring, undetected, immediately before the count was made.

2. Diet of Various Seabird Species

1. Gannets.
2. Puffins.

Details of diet sampling for these species in 1988 are contained in the paper attached as Appendix 1.

3. Guillemots.
4. Razorbills.

No detailed assessment was made for either species, but both were bringing sandeels and gadoids back to the colony. Guillemots captured approximately 4 large sandeels for every 1 pout *Trisopterus esmarkii*, while razorbills took medium-large sandeels and an unidentified gadoid in the ratio of about 7:1.

5. Shags.

As in 1987, the evidence indicated an exclusive diet of sandeels for this species. Approximately 50 regurgitates from 4 beaches were carefully examined in 1988.

3. Ringing

Ringing totals were as follows (Table 2):

	Adult	Pullus	Re-ring	Retrap & Control	Total
Gannet	22	262	2	2	286
Shag	5	89	0	1	94
Greater BB Gull	0	1	0	0	1
Great Skua	1	27	0	1	28
Herring Gull	0	2	0	0	2
Guillemot	3	17	0	0	20
Razorbill	25	159	0	3	184
Fulmar	20	0	1	10	21
Puffin	81	1	0	8	82
Arctic Skua	1	0	0	0	1
Kittiwake	0	0	0	1	0
Snipe	0	1	0	0	1
TOTALS:	158	559	3	26	720

The only notable aspect of the '88 figures was the low number of pullus shags ringed; this was partly because relatively few eggs had hatched before our departure and partly because fewer nests than normal were active in our study beaches. The reason for the lateness of hatching in this species is not known, but it could be brought about if there was a poor food supply prior to egglaying. For a discussion of nest density see section 5.

4. Colour-Ringing Study

No further colour-rings were put on either of the previous target species (shags and gannets) in 1988. The totals reached in '86 and '87 combined, of 144 shags and 100 gannets, was considered sufficient at least to determine if the method could be used to calculate adult survival rates. Observations in '87 and '88 lead to these conclusions:-

a. Shags.

Colour rings were effective and robust; no bird was seen to have lost more than one of its three rings and most had all three intact. Differentiating brown from red or orange was sometimes a problem in poor light and this had to be taken into account both in checking field records and when ascribing sightings to particular birds. All other colours used (white, yellow, green) were fine in this respect.

The assumption that adults ringed at a particular nest return to breed at the same nest or same immediate area in subsequent years appears to be correct for most birds, but not all. In 1988 one bird moved 15km to a new site in s.w. Unst and another 700m to another colony on Hermaness. No other movement of >150m was noted in either 1987 or 1988, despite careful searches of most of the other colonies on the Reserve.

The turnover of adults in all 4 worked beaches was apparently high, as judged by the rapidly diminishing proportion of loafing adults seen with colour-rings in successive years. An initial calculation of adult survival, corrected for birds missed in '87 but known to be alive in '88, is s=0.56. This is based on a total of 121 birds 'at risk' of being seen in 2 consecutive years after ringing and 23 'at risk' of being seen 1 year after ringing.

b. Gannets

In contrast to the work on shags, colour-ringing of gannets has not proved to be a success, for 2 main reasons. Firstly, the loss rate of rings is relatively high,such that about half the birds have lost at least one ring within a year. Secondly, the behaviour of gannets is such that an observer is unlikely to see all 3 rings on a bird before it flies from the nest, and there are no loafing areas on which they stand when 'off duty'.

Equal care was taken when attaching rings to this species, but their strong beaks are probably able to wrench them off more easily than is the case for shags. Observations will continue in the hope that something may be learned from having a number of known individuals in a colony, but there seems little prospect of being able to derive reliable survival data from this study.

5. Shag Nesting Success

Careful counts of shag nests were made during several visits to the Reserve from 1974 onwards. Table 3 presents the 1988 counts in comparison with those of earlier years.

	Humla	Clingra	Urda	Clett	Σ	% of 1974 figures
1974	23	73	44	59	199	100
1984	15	66	34	NE	126 (3 beaches)	-
1986	7	56	38	50	151	76
1987	5	31	24	33	93	47
1988	2	23	13	35	73	37

Table 3. Counts of shag nests occupied in late June in 4 boulder beaches on Hermaness.

The trend is clear, and there is little sign of a slowing of the rate of change, with the 1988 total only 48% of that in 1986. These figures refer to nests occupied at the time of the count and don't include those abandoned earlier in the season, but all counts were carried out at about the same time of year, so should be comparable.

In order to avoid double-counting, nest cavities were marked with paint. This permitted the comparison of cavity occupancy across years and it soon became clear that although some sites were in continual use during the 1970s and early 1980s a high turnover rate increasingly occurred in the later years of the study. Only 42 out of 143 (29%) nest sites marked in 1986 were still occupied in 1988.

The evidence from this aspect of our work on shags, when considered with the data from the colour-ringing study, indicates a recent problem for this species on Hermaness. The number of young shags fledging from the Reserve is currently very low, due to a high level of nest failure and probably fewer nesting attempts. The adult survival rate appears to be low, and if our estimate is biased by birds moving sites between years, then they are moving considerable distances.

Continuance of the colour-ringing work, and observations of study beaches, should show if the situation changes and if a proportion of the missing birds return after perhaps a nesting failure early in the season or even skipping breeding for one or more years.

6. Counts of Puffins

As in 1987, attempts were made to estimate the number of breeding pairs of puffins on the Reserve, using ratios of loafing birds : known nests in a sample area to allow extrapolation from counts of loafers elsewhere in the colony. Counts were made on several days when loafing birds were relatively numerous around the Reserve, but abnormal puffin behaviour indicated that all was not well with the colony. The evidence of food sampling and the increasing numbers of dead puffin chicks found in burrows suggested that nests were failing rapidly and that the counting technique would probably be rendered invalid in such circumstances. With the benefit of hindsight, the 1987 estimate of around 25,000 breeding pairs on the Reserve as a whole can be assumed to an underestimate, given that we now know that many nests had already failed at the time of the count.

GENERAL COMMENTS AND OBSERVATIONS

1. Birds

1988 was the year in which evidence of a crisis for many of Shetland's seabirds became overwhelming and irrefutable, and gained widespread publicity. Of the species monitored regularly by our group on Hermaness, the puffin has probably suffered to the greatest extent (see Appendix 1) and may have produced very few fledglings in recent years, but the species' high annual rate of adult survival has apparently so far prevented any drop in the number of breeding pairs on the Reserve. Breeding failures can be expected to start having an effect on recruitment 4 years later, as has been seen in Norway recently and, on our evidence, we expect that effect to commence in either 1989 or 1990 on Hermaness.

In Shetland as a whole shags have apparently withstood the reduction in sandeel stocks rather better than some of the smaller species. In 1987 we attributed the noticeable drop in nests in our study beaches on Hermaness to raven predation. This report presents evidence that the shag colonies on Hermaness have in fact been in decline for many years and are currently at little more than a third of their level at the start of our series of visits in 1974. There is some indication that a lor adult survival rate may be implicated in this situation, but it may also be the case that shags have either moved elsewhere, that their breeding attempts are failing early, or that they don't even attempt to breed. Whichever possibility is correct, there does seem to be a problem which results in few young shags being reared. Since this species is solely reliant on sandeel in the breeding season the proven diminution of this food source must be suspected as a possible root cause of the loss of reproductive output.

2. Reserve Management.

In many of our reports we have raised the topic of management, in particular the almost total lack of guidance to visitors. Every year we encounter people indirectly causing the loss of eggs and young of uncommon and sensitive species by unknowingly blundering into their territories and allowing bonxies to take advantage of the disturbance. We believe this to be one of the main factors behind the drastic decline in Arctic skuas and eiders on the reserve, and it has certainly reduced red throated diver breeding success.

For the benefit of both the visitors, who often don't find the finest areas of the Reserve, and the birds, we again strongly urge the NCC to take the necessary steps to improve this situation. Such steps would be neither costly nor intrusive and the logistical requirements could easily be accomplished by the Warden who is already employed but under-used. One final plea is for the hut to receive some maintenance, again a task easily accomplished by the Warden and requiring little outlay. Apart from the undoubted value to visitors, the provision of hut accommodation by the NCC has facilitated the continuance of the seabird monitoring carried out by ourselves since 1973 and which has provided some of the most valuable information on the current seabird/sandeel crisis. We acknowledge with gratitude the great help provided over the years by the NCC and kindly request that our ageing bodies continue to be protected from the worst rigours of a Shetland summer.

ACKNOWLEDGEMENTS

We thank the Nature Conservancy Council for permission to work on the Reserve and the Senior NCC Northern Isles Officer, Dr Mike Richardson, and his staff, for help and support in many ways. The NCC and the Shetland Oil Terminal Environmental Advisory Group (SOTEAG) once again provided the funding which has made our work possible.

We are grateful to Dr Mike Harris of ITE Banchory for support and sage advice, and Mike Pennington for help on the Reserve.

BUDGET

EXPENDITURE	£
Ferries, Aberdeen-Lerwick and return + inter-island	312.80
Fuel, oil, insurance, etc.	173.00
Rings and equipment	175.00
Food	165.00
Total Expenditure:	825.80

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