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No. 269

Isle of May seabird studies in 1997

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Comments: The Isle of May is one of JNCC's Seabird Monitoring Programme key sites, and JNCC continued to fund aspects of ITE's work there in 1997 (in particular monitoring of breeding success, adult survival and food of a range of species). SNH carried out monitoring of the numbers of some species; the results of this work will be reported upon separately.

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1 Summary

1. Shag numbers increased only slightly following the dramatic crash in 1994 and the small recovery in 1995 and 1996. The first egg was laid on 12 March, which was the earliest recorded, and laying continued until early July. Nesting success (0.92 young per incubating pair) was higher than the long-term average.

2. Most pairs of kittiwakes which were present built nests and clutch-size was larger than in recent years. Some chicks were neglected, but there was little evidence of serious food shortage. Most broods survived the severe easterly gales in late June which caused major losses further south in England. Breeding success was moderate (0.40 fledged per nest) and lower than in 1996 (0.56), but still an improvement over that of 1993 (0.07) and 1994 (0.16). One pair reared three young - the first such record since 1989. Few pairs appeared to be prospecting.

3. Guillemots and razorbills both had a good season, with outputs of 0.77 and 0.71 young fledged per pair respectively. Puffin breeding success (at 0.65 young fledged per egg laid) was the lowest ever recorded on the Isle of May. Heavy rain caused many burrows to flood. Fulmar breeding success (0.37 young fledged per incubating pair) was slightly below normal.

4. Shag survival rate was again extremely high (91.1%) and survival rates of kittiwake (78.7%) and puffin (90.7%) were normal. Survival rates of guillemots (91.8%) and razorbills (82.1%) returned to normal after the reduction over the 1995-96 winter.

5. An analysis of the resighting records of colour-ringed puffins indicated that there had been an abrupt decline in adult survival rates between 1980 and 1981. Survival rates before and after this change were 97.5% and 91.8%. Survival between 1990 and 1991 (80.2%) was unusually low. No obvious reason for this major change in survival rates has been detected.

6. Sandeels predominated in the diet of all species. Puffins and kittiwakes fed their young mainly on 0-group fish, whereas shags and guillemots concentrated on older and larger sandeels. Most non-sandeels eaten were sprat and herring. There was no evidence that the young of any species were short of food.

2 Background

The Joint Nature Conservation Committee (JNCC) has a responsibility to advise on certain aspects of the condition of the natural marine environment. Seabirds are one of the more important components of this environment, and Britain has internationally important populations of several species. JNCC has designed a programme that will allow the numbers and breeding success of selected species of seabirds to be monitored at a range of colonies throughout the UK. In addition, selected colonies have been targeted for more detailed monitoring of reproductive performance and annual survival rates. These selected colonies are geographically spread in order to give as full a coverage as possible of British waters. The Isle of May NNR is a very suitable site in eastern Britain.

The Institute of Terrestrial Ecology (ITE) has had a long-term interest in seabirds on the Isle of May. Since 1986, ITE has received NCC-CSD/JNCC support for a more formalised seabird monitoring programme. Long-term studies on numbers, breeding success, adult survival, and chick food are under way on up to eight species. Due to the long period of immaturity and high annual survival rates of seabirds, it is essential that continuity of these long-term studies is maintained. As part of its Seabird Monitoring Programme, JNCC has a contract with ITE to:

a) ensure that the breeding success of fulmars *Fulmarus glacialis*, shags *Phalacrocorax aristotelis*, kittiwakes *Rissa tridactyla*, guillemots *Uria aalge*, razorbills *Alca torda* and puffins *Fratercula arctica* is monitored;

b) monitor adult survival of kittiwakes, guillemots, razorbills and puffins. Monitoring of shag adult survival was also included up to March 1994, was then excluded for the 1994 season, but was reinstated in May 1995;

c) assess food of young shags, kittiwakes, guillemots, razorbills and puffins;

d) undertake special studies on species agreed between the nominated officer and the contractor.

The development of an extremely large and concentrated industrial fishery for sandeels on the Wee Bankie off the entrance to the Firth of Forth has caused much concern. The EC has funded a three-year study into the Effects of Large-scale Industrial Fisheries On Non-Target Species (ELIFONTS) centred on the Firth of Forth. ITE has the responsibility for seabirds in this integrated project and is carrying out fieldwork, based on the Isle of May, during 1997 and 1998. The objectives are:

- to quantify breeding parameters of three species of avian top predator in the Firth of Forth;
- to identify foraging areas of these species during the breeding season;
- to quantify diurnal and seasonal patterns of foraging activity for these species;
- to assess diurnal and seasonal variation in diet of these species.

This study (organised by Dr Sarah Wanless) links closely with, and complements, the JNCC-supported project reported here and various NERC-funded projects. Together these studies will make an important contribution to understanding the relationships between seabirds and their prey.

3 Methods

3.1 Breeding success

The standardised methods used involved minimal disturbance of birds and are described in detail in the *Seabird monitoring handbook for Britain and Ireland* (Walsh *et al.* 1995).

3.1.1 Fulmar: The positions of apparently incubating birds in ten areas were marked on photographs on 1, 4 and 7 June. At sites where birds appeared to be incubating on all three visits, or where an egg was seen, breeding was assumed to have occurred. These sites were checked again on 12 July (to determine eggs which had hatched) and on 20 August (by J. Wilson), when those with a large chick were assumed to have been successful.

3.1.2 Shag: The positions of nests in fourteen areas were marked on photographs and the state and contents of these nests were checked weekly from 26 March until 10 August by F. Daunt. Nests with small chicks on 10 August were assumed to have failed, those with older chicks to have been successful.

3.1.3 Kittiwake: The position of nests in fourteen areas were marked on photographs and the presence or absence of an incubating bird, or the number of young present at each, were checked on 1 and 10 June and on 16 July - a day after the first young on the island had fledged. Checks were repeated on 23 July when few small chicks remained. These were assumed to fledge.

3.1.4 Guillemot and razorbill: Daily checks of the state of breeding of numbered nest-sites in five study plots were made from permanent hides.

3.1.5 Puffin: In each of four areas, samples of 50 burrows where an egg could be felt on 3-4 May (when most pairs had laid) were staked. The staked burrows were re-checked between 30 June and 2 July (when chicks were near fledging). All large young present were assumed to have fledged, as were young from empty burrows where there were many droppings, moulted down and feather sheaths.

3.2 Adult survival rates

For all species, adult survival rates were based on sightings of individually colour-ringed birds. The areas in which birds were originally marked were checked regularly throughout the season and adjacent areas were searched from time to time in an attempt to pick up birds which had moved. Searches were also made of the whole island for birds which had moved out of the study areas. These latter searches are very time consuming, and superficially unrewarding, but are essential if accurate estimates of survival are to be obtained. Observations on the survival of adult puffins are concentrated at Little Hole (where most burrows are individually numbered).

3.3 Food of chicks

Food regurgitated by adult shags feeding young and by young shags and young kittiwakes, and loads of fish dropped by adult puffins caught in mist-nets were collected. These samples were weighed and the fish identified and, where possible, measured (total length to tip of tail). Where necessary, fish otoliths were extracted and examined and the lengths of the fish from which they came were calculated using regressions derived from the otoliths of fish of known length collected from birds on the island in 1997. Records were kept of fish brought to young guillemots and razorbills during four all-day watches and opportunistically at other times, and uneaten fish were collected from breeding ledges to assess sizes and confirm identifications.

4 Results

4.1 Breeding success

Species accounts are given in Tables 1-4 and a comparison with recent years' results is shown in Table 5.

4.1.1 Fulmar: The first egg was seen on 14 May. Breeding success was 0.37 young per incubating pair, which was the lowest since the notably poor 1990 season, when it was 0.24. In other years it has varied between 0.42 and 0.54. The methodology used is not designed to determine when breeding attempts fail, but it appeared that more eggs than chicks were lost.

4.1.2 Shag: The first egg was laid on 12 March, which is the earliest ever recorded on the Isle of May. The median laying date was 11 April, again the earliest (by a week) ever recorded.

A total of 109 pairs laid (or were apparently incubating) in the study plot. This was marginally up from 105 in 1996; fifteen other nests were started but there was no evidence that eggs were laid. These 109 nests fledged a total of 100 young - an average of 0.92 per pair. Overall, success was slightly higher than the mean of 0.74 for the previous seasons. Success remained low (fifteen pairs reared a total of six young) at the North Horn plot, despite the public being again denied access during the summer.

4.1.3 Kittiwake: Timing of breeding was normal (Table 13) with the first egg being seen on 10 May, the first young on 6 June and the first fledged young on 15 July. Chicks were frequently neglected (14% of broods of one and 42% of broods of two - Table 11), but there was no evidence that adults were having difficulty in feeding chicks. One pair at Cornerstone reared three young, which was the first time that this has happened on the Isle of May since 1989.

Pairs in 1997 reared slightly fewer chicks (0.40 per nest) than they did in 1996 (0.56), but 1997 was a much better breeding season than those of 1993, 1994 and 1995 (Tables 3 and 5).

During the period 1986-96, the breeding success of kittiwakes on the Isle of May, declined by an average of 0.09 chicks per pair per year. This, and the high proportion of adults failing to breed in 1994, suggests that, as in Shetland in the late 1980s, adults were having difficulty in finding sufficient food to breed successfully. This was not a purely local phenomenon, as monitoring at other colonies by JNCC showed that breeding success of kittiwakes over a 250-300 km stretch of coast in south-east Scotland and north-east England was depressed (Harris & Wanless 1997). Breeding success on the Isle of May was again depressed in 1997, although not to the low levels recorded at Bempton and the Farne Islands where a storm in late June caused the deaths of *c.* 100 000 young (RSPB press release, J. Walton pers. comm.). Winds during this storm were from the north and east. The resulting waves battered the east side of the Isle of May, but the main seabird cliffs, on the west side, were generally well-protected.

4.1.4 Guillemot: Laying was fairly early, with the first egg being laid on 18 April. The median laying dates in the earliest and latest areas followed were 30 April and 10 May, ten and seven days earlier than in 1996. The first young left on the night of 15/16 June. Breeding success (0.77 young leaving per pair laying) was normal (Tables 4 and 5).

4.1.5 Razorbill: Breeding was earlier than in recent years, with the first egg being laid on 25 April. Breeding success (0.71 young leaving per pair laying) was normal. As usual, most losses occurred at the egg-stage and survival to fledging of chicks which hatched remained high (98%).

4.1.6 Puffin: Breeding was early. The first fish were seen brought ashore on 22 May, but some young must have hatched at least a week earlier as the first chick fledged on the 23 June. The overall success rate (0.65 chicks fledged per egg laid) was the lowest since records began (Tables 4 and 5). This was due, at least in part, to many burrows becoming flooded in late June and July.

In 1995 and 1996 spring and summer were both extremely dry and this resulted in extremely poor vegetation growth in many colonies and severe soil erosion. Despite the extremely high rainfall in 1997, the vegetation in the puffin colonies recovered only slightly. Great care is needed to prevent severe damage to burrows.

4.2 Adult survival

4.2.1 1997 results

Not every adult alive is seen each year and thus the survival rates between 1996 and 1997 of 78.7% for kittiwake, 91.8% for guillemot, 82.1% for razorbill, 90.7% for puffin and 91.1% for shag must be treated as minimum estimates. Sample sizes are given in Table 6.

In 1996, the resighting rates of adult guillemots and razorbills known to be alive in 1995 were unusually low, at 89% and 57% respectively. Three (of 45) missing guillemots were seen in 1997, which increases estimated survival over the 1995-6 winter to 90%. However, none of the 23 missing razorbills returned. Thus it appears that there was indeed a large mortality of adult guillemots and razorbills during the 1995-6 winter.

During 1997, 24 shags, fifteen kittiwakes, fourteen puffins and seven guillemots were colour-ringed.

4.2.2 Long-term trends in survival of Isle of May puffins

Adult survival

Although its numbers have declined substantially over the last 100-150 years, the puffin is still one of the most abundant seabirds in the northeast Atlantic. The study of the population on the Isle of May, which started in 1972, is both the longest and most detailed of this species yet undertaken. A modelling analysis (using SURGE) of survival data, collected partly under the JNCC contract to ITE, has recently been undertaken by M. P. Harris and S. Wanless (ITE), S. N. Freeman and B. J. T. Morgan (University of Kent) and C. V. Wernham (BTO). The main aim of this analysis was to document temporal variation in survival rates and attempt to relate this to changes in prey stocks or environmental conditions. A secondary aim was to look for evidence of sex- or age-related effects on survival. Full details will be found in a paper soon to be published in Journal of Avian Biology.

A total of 734 individuals were used in the analysis. The number of marked birds in the population increased during the study, from 79 in 1973 to 289 being seen in 1993.

We fitted a model with both survival and resighting probabilities varying between years. Both survival and resighting varied significantly over time (Table 14). We attribute the increased probability of resighting during the first seven years of the study to the increasing effort that we put into searching for marked birds. Estimated annual survival was always above 0.89, except in 1990 when it was 0.805 (± S.E. 0.027). There was also evidence of a temporal change, with survival being consistently lower after about 1980. We examined this feature further by constructing models with different survival rates at the beginning and end of the study, and with different years for the possible point of discontinuity. Full annual variation in resighting probability was maintained, as was a separate survival rate for 1990, and thus these models had 24 parameters (21 for resighting, three for survival). The best model estimated survival rates of 0.975 (S.E. 0.004) for the period 1973-80, 0.918 (S.E. 0.006) for 1981-94 and 0.802 (S.E. 0.026) for 1990. This model was preferred over both a reduced model, in which 1990 was given the same survival rate as the adjacent years, and the full model of Table 14. Finally, we considered a model with a gradual decline in survival, by fitting survival, again using SURGE, as a logistic function of time. Again the stepped model was preferred.

Sex effects

To investigate sex-related differences in survival, we initially used a model containing fully time-dependent survival and resighting probabilities of the same form as Table 14. Fitting this model to each sex separately did not significantly improve the fit, while models where either survival or resighting rate was constant significantly worsened the fit. As with the full data set, the reduced model, with different survival rates at the beginning and end of the study and a separate value for 1990, proved acceptable in comparison with full time-dependent survival and the point of discontinuity was again identified as 1980-81.

We then carried out more powerful tests for sex-related differences by including in this stepped model a single additive sex effect, on a logit scale, for resighting or survival probabilities. This approach allowed parameters to vary between the sexes but constrained them to do so in parallel over time. *A priori*, this assumption seems realistic as environmental and/or feeding conditions are likely to affect both sexes similarly. There was, however, still no evidence that resighting or survival rates differed between the sexes.

Age effects

In 48 cases (6% of the total), the age of a bird at ringing was known. Both the mean and median age of this sample was ten years (range 4-19 years) and we therefore assumed that where the age at ringing was unknown the individual was ten years old. Data were pooled by sex and location, and the analyses were repeated with both age- and time-dependence in survival, and time-dependence in the probability of resighting.

We initially fitted a model with separate survival rates for each year of age, while to account for the temporal variation we used two such values for each age class, the first applying in years before 1981 and the second to the period thereafter (a separate survival rate was retained for 1990). The inclusion of age-dependent survival significantly improved the model. The age-time interaction was not significant and was dropped. This left the difference between the two time-periods, represented by a single additive effect on a logit scale. Removal of either the main time or age effect significantly worsened the fit. The significance of the time effect in the presence of age-variation confirms that the temporal decline is not an artefact due to the presence of more older birds late in the study.

Survival rates estimated by capture-recapture models are a measure of both true survival and the probability that an individual returns to the colony and is thus potentially available to be resighted or recaptured. The decline in apparent survival could theoretically occur if older birds were less likely to visit the colony and hence the apparent age-dependence in survival could be due to reproductive senescence. To examine this possibility in puffins, we fitted a model without age-dependence in survival in either time period, but with birds aged at least 25 years having their own resighting probabilities in the last six years of the study. The results indicate that resighting probabilities are indeed significantly diminished among the oldest birds. While estimated survival is little affected by permitting this change in the model, the results in isolation suggest that the oldest birds might exhibit senescence in both survival and reproduction.

Environmental effects

There was a strong positive correlation between annual estimates of overwinter survival and stocks of sprat in the North Sea over the period 1973-84 ($r = 0.71$, $n = 11$, $P<0.001$). A model for the resighting data, with survival for these years functionally dependent upon sprat stocks, compared well with that of Table 14. However, the sprat stock collapsed in the early 1980s and no VPA stock assessments have been made since 1984. Estimates of abundance derived from catch-per-unit-effort figures suggest that the biomass of sprat has increased since 1985. Given the earlier relationship, survival rates of puffins would have been expected to increase. Such a response has clearly not occurred, but uncertainty over the reliability of the catch-per-unit effort method for estimating sprat abundance makes it difficult to interpret this result.

Stocks of other fish species and wind and sea temperature variables also showed considerable annual variation over the study period, with coefficients of variation (standard deviation/mean) varying from 35% (pout) to 881% (sea temperature anomalies). However, none of the data sets (either in total or on a month by month basis) showed a stepped change in the early 1980s, and neither was there anything exceptional about the conditions during the 1990-91 winter. Thus none of the correlations between puffin survival rates and estimates of other fish stocks or weather conditions were statistically significant.

Discussion

The use of stochastic models, such as those used in this analysis, substantially improve the accuracy of survival estimates compared with those derived from information on the proportion of adults seen at the start of one season and known to be alive the previous year. Thus, in this study, annual survival rates estimated with SURGE were, on average, 2.9% per annum (0.8) higher than the basic resighting estimates, even when the comparison was restricted to cases where there were at least seven years available for resightings.

Survival rates estimated for puffins during the first half of our study are amongst the highest recorded for any species of seabird, and even after the decline in 1980 values were still relatively high. Results from the Isle of May were broadly similar to estimates from elsewhere; for example, the 0.955 (0.01) resulting from an analysis of ringed puffins from the Farne Islands (86 km south of the Isle of May) found dead in a wreck in 1969, and 0.884 (0.01) for birds on Skomer Island in Wales over the period 1972-93 (C.M. Perrins & R.H. McCleery unpublished data).

In common with several other long-term studies, we found evidence of age-specific survival rates, with values being lower in the oldest age groups. We also found some evidence of a decline in resighting probability with age, which indicates that survival senescence may be compounded by reproductive senescence. Although more data are needed to confirm this, a similar result was reported on Skomer Island where Davidson (1984) found a lower resighting rate among birds that were at least ten years old. The demonstration of age-specific survival rates in the puffin means that temporal trends in survival estimates for a population could, in theory, be due to long-term shifts in colony age structure.

A major aim of the population studies on the Isle of May is to assess the scale of long-term demographic variation in seabird species. Two temporal changes in survival rates of adult puffins were apparent during the twenty years of the study. One was a catastrophic event in 1990, in which the mortality rate increased by 140%, and the other was a marked discontinuity, with survival rates being consistently lower after 1980. The extremely low survival rate recorded on the Isle of May between 1990 and 1991 coincided with a large winter mortality of seabirds in the northern North Sea, in which fifteen times the normal number of puffins were found dead on beaches in Shetland. Ringing recoveries confirmed that many of these birds came from the Isle of May, and thus it seemed reasonable to attribute the low survival rate we recorded at the colony to losses incurred during the wreck. Such concordance between beached bird survey data and colony based population studies, is not always apparent. For example, many ringed adults from the Isle of May were found in a large wreck in the southern North Sea during February 1983. The proportion of birds seen at the colony the following breeding season was lower than normal and this was initially interpreted as evidence of large scale mortality in the wreck. The present analysis, where survival rates and resighting rates were estimated separately, indicates clearly that mortality had not increased. Instead the resighting rate decreased in 1983, which suggests that attendance patterns at the colony were disrupted. Such discrepancies highlight the difficulties of using beached bird survey data to assess the magnitude and impact of wrecks on specific seabird populations.

Stepped changes in survival appear to be rather rare events in population studies of marine birds. The only other instances that we are aware of are the wandering albatross in the Indian Ocean and the puffin on Skomer Island. In the former, mean survival increased from 0.909 between 1966 and 1977 to 0.968 between 1978 and 1982, while in the latter an abrupt decline in survival occurred in 1977-78 (Davidson 1984, Weimerskirch, Clobert & Jouventin 1987). A possible explanation for both types of temporal change in survival recorded on the Isle of May is that they were associated with perturbations in environmental conditions. However, none of the estimates of prey abundance or indices of weather conditions that we collated showed either a particularly extreme value during the winter of 1990-91 or a marked discontinuity centred on 1980-81. Moreover, whatever caused the changes appeared to be very specific to puffins, since similar patterns were not apparent in long-term studies of other seabirds breeding in eastern Britain (e.g. kittiwake, guillemot and shag).

The abrupt change in survival rates of wandering albatross in the Indian Ocean was attributed to accidental deaths in fishing tackle compounded by deliberate trapping and shooting by fishermen (Weimerskirch, Clobert & Jouventin 1987). Anthropogenic effects could, in theory, also be responsible for the marked decline in the survival of adult puffins on the Isle of May, since the North Sea is increasingly subject to pressures from fisheries, oil and gas production, pollution etc. There is, however, no independent evidence to support this, since there are no reports of increased numbers of dead puffins, e.g. being found oiled or entangled in nets. In conclusion, although it is clear that there were marked differences in survival rates of adult puffins on the Isle of May over a twenty year period, we have not been able to identify the factor(s) underlying these changes. In part this failure may reflect general inadequacies in our knowledge of what constitutes pertinent information on the nature and significance of environmental variables for seabird species. Hopefully improvements in our understanding of the ecology and behaviour of puffins while they are at sea and in our ability to measure key variables such as food availability will ultimately allow us to identify the factors that influence survival of this species.

4.3 Food of young

The 54 samples from shags were composed entirely of sandeels *Ammodytes marinus* and 84% (of 152 fish measured) were 12-14 cm long (Table 7). No otoliths from other species were present in the samples. Of the 105 sandeel otoliths examined, 100 (95%) came from fish one year or more old.

Sandeels were the commonest food (99% by number of 1111 otoliths) of young kittiwakes (Table 7). Approximately 95% of the sandeels in regurgitates were 0-group fish 7-8 cm long (n = 1111 otoliths examined). Sandeels contributed 94% by weight of the kittiwake regurgitates. Seven regurgitates had sprat *Sprattus sprattus* 7-10 cm long. Four whiting *Merlangius merlangus* and one *Nephrops* were presumably trawler discards.

Of 1682 fish delivered to young guillemots, 1451 (86%) were sandeels - mostly 10-14 cm long - and the remainder (14%) were Clupeidae of similar lengths (Table 8). Of five clupeids examined, three were sprats (10-13 cm) and two were herring (13-15 cm). The average weight of a fish (calculated from lengths) was 6.1 g.

Razorbill loads brought to chicks were almost entirely made up of several small or many tiny sandeels (Table 8).

By number, sandeels made up 90% of the diet of young puffins (Table 10) and the proportion in biomass terms was only slightly reduced, to 86%. Many of the small Clupeidae were small and difficult to identify, but the bulk appeared to be sprat. For the second year no young rockling were brought ashore.

5 The future

5.1 During the 1970s and for most of the 1980s, conditions were very favourable for seabirds in the North Sea, since populations of most species, excluding terns, increased greatly. Since the late 1980s, monitoring has shown drops in numbers, and to a lesser extent, breeding success, of several species. The reasons for these changes are not clear but, at least for guillemots, change started in the north and gradually moved south. Population declines started significantly earlier and were fastest in northern colonies. Numbers of auks are now increasing again. A run of unproductive years by kittiwakes, and the apparent dearth of prospecting birds in the colony, causes concern for the future breeding population.

5.2 Long-term studies, partly funded under JNCC's integrated Seabird Monitoring Programme, in the Firth of Forth have shown a much reduced survival of adult puffins in the 1980s and early 1990s (documented in this report) and adult shags in 1994; low recruitment of some cohorts of young guillemots; poor breeding and non breeding of kittiwakes; delayed (and irregular) breeding of shags; reduction in the intake of young guillemots and sporadic food shortage in several species. Again, neither the ultimate or the proximate factor causing these changes have been determined.

5.3 In 1991, several Danish fishing vessels trawled for sandeels over the Wee Bankie to the north-east of the Isle of May. Many more were reported to be fishing there in 1992, and in 1993 the reported catch was 115,000 tonnes (ICES Working Group report CM 1995/ Assess:5). An additional 72,000 tonnes came from the fishery area 1A immediately south of the Isle of May. Fewer boats fished the area in 1994, apparently because sandeels were available closer to Denmark. In 1995, Danish vessels fished in the entrance to the Firth of Forth early in the season but then moved elsewhere. Some Scottish vessels have been reported fishing for sandeels off eastern Scotland and landing their catches in Denmark. The Danish fleet returned to the Wee Bankie in 1996 and that summer saw a high profile protest by the Greenpeace ship Sirius, which spent much time around the Wee Bankie and the Isle of May. The "Save the Wee Bankie" campaign attracted much TV and other media attention, and the Isle of May is now well known to a much wider public. Despite initial rumours that the fishery was to be closed, the Danish fleet (with a few Scottish boats) again fished over the Wee Bankie in 1997.

5.4 The summer of 1997 saw the start of the two field season multi-institute project ELIFONTS (Effects of Large-scale Industrial Fisheries On Non-Target Species). This is part-funded by the EC Directorate General XIV (Fisheries). The objectives relevant to seabirds are:

5.4.1. to determine the availability of lesser sandeels to top predators (grey seals, kittiwakes, guillemots, and shags) in the Moray Firth and Firth of Forth;

5.4.2. to investigate the effects of between and within year variations in sandeel availability on the foraging behaviour, foraging efficiency, diet and reproductive output of top predators and on the diet of predatory fish;

5.4.3. to evaluate the potential impact of a large scale fishery on top predators in the Firth of Forth and to examine the generality of the results.

The JNCC-funded contract complements this study.

5.5 There is, as yet, no direct evidence that such industrial fishing has an adverse effect on the availability of food for seabirds. Whether or not such a fishery continues to develop, it is imperative that the monitoring of seabird breeding success, numbers (carried out by SNH), recruitment, and diet on the Isle of May continues, so that we can determine the factors controlling the numbers of seabirds in the North Sea and so assess the importance of the many anthropogenic influences on the seabird populations.

6 Acknowledgements

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Table 1 Fledging success of fulmars on the Isle of May in 1997

Area	Incubating birds	No. probably hatched	Young fledged
1. Cleaver	10	8	7
2. Pilgrim's Haven	1	1	1
3. Cornerstone	11	7	5
4. Loch (S)	44	24	20
5. Greengates	30	16	7
6. Horse Hole	5	1	1
7. Rona	1	0	0
8. Tarbet	23	14	8
9. Low Light	7	7	1
10. Colm's Hole	4	2	1
Totals	136	76	51
		Overall mean	**0.37 fledged/pair**

Notes:

Incubating birds were those sitting tight on three checks or where an egg was seen. Chicks present on 20 August were assumed to have fledged. The final check was made by J Wilson.

Table 2 Fledging success of shags on the Isle of May in 1997

Area	Total incubated	Young fledged 1	2	3	Other nests	Total young fledged	Mean young fledged per incubated nest
3 Maidens	11	3	3	1	1	12	1.09
5 Chatterstanes	5	1	0	0	1	1	0.20
16 Pilgrims Haven (S)	11	1	2	4	1	17	1.55
6 Colony A	1	0	0	0	0	0	0
7 South Face	1	1	0	0	0	1	1.0
8 Mill Door (N)	7	1	3	1	0	10	1.43
9 Mill Door (S)	11	2	2	2	0	12	1.09
10 Bishop Cove	1	0	1	0	0	2	2.00
8 Horse Hole	19	6	1	3	2	17	0.89
15 North Horn	15	0	3	0	2	6	0.40
12 Tarbet	10	1	2	1	2	8	0.80
13 Low Light	9	1	3	1	1	10	1.11
14 Colm's Hole (N)	10	1	2	2	2	11	1.10
Totals	**111**	**18**	**22**	**15**	**12**	**107**	**0.96**

Notes:

Plot 1 had no nests.
Plots 2 and 4 had one 'other nest' each.
Nests were checked until late September.
The average success given by the mean of the 13 areas where eggs were laid was 0.97±0.15.

Table 3 Fledging success of kittiwakes on the Isle of May in 1997

Area	Completed nests	Trace nests	Fledged young per completed nest			Total young produced[2]	Fledging success	
			0	1	2		per completed nest	all pairs (incl. trace)
1. Cleaver	35	2	18	12	5	22	0.63	0.59
2. Pilgrim's Haven	23	0	12	11	0	11	0.48	0.48
3. South Face	30	0	15	12	3	18	0.60	0.60
4. Colony 4	60	1	41	19	0	19	0.32	0.31
5. Cornerstone	88	0	42	30	16[1]	63	0.72	0.72
6. Loch (S)	77	1	76	1	0	1	0.01	0.01
7. Loch (N)	105	0	86	15	4	23	0.22	0.22
8. Greengates	69	1	50	15	4	23	0.33	0.33
9. Bishop's Cove	59	0	35	17	7	31	0.53	0.53
10. Horse Hole	6	0	5	1	0	1	0.17	0.17
11. Iron Bridge	63	0	42	16	5	26	0.41	0.41
12. Rona	37	0	25	11	1	13	0.35	0.35
13. Tarbet	116	3	69	41	6	53	0.46	0.45
14. Low Light	29	0	14	14	1	16	0.55	0.55
15. Colm's Hole	25	0	18	7	0	7	0.28	0.28
						Mean	**0.40**	**0.40**
						SE	**0.05**	**0.05**

Notes:

1) Includes one brood of three.
2) Four broods of single small chicks present at the second check were assumed to have failed.

Table 4 Breeding success of auks on the Isle of May in 1997

Species	Area	Pairs laying	Young hatched	Young 'fledged'	Young leaving/pair
Guillemot	Dense	278	235	219	0.79
	Hide/White	89	77	66	0.74
	Colony 4	228	195	179	0.79
	South	50	41	38	0.76
	Cornerstone	197	172	154	0.78
	Mean ± S.E.				**0.77±0.01**
Razorbill	Hide/White	21	18	16	0.76
	Colony 4	39	28	28	0.72
	South	15	10	9	0.60
	Cornerstone	57	43	42	0.74
	Mean ± S.E.				**0.71±0.04**
Puffin	Lady's Bed	45	?	30	0.67
	Kirkhaven	43	?	32	0.74
	Burrian	37	?	21	0.57
	Rona	41	?	25	0.61
	Mean ± S.E				**0.65±0.04**

Table 5 Breeding success (young reared per pair breeding) of some seabirds on the Isle of May, 1989-97

Species	**1989**	**1990**	**1991**	**1992**
Fulmar	0.54 (93)	0.24 (66)	0.42 (100)	0.47 (129)
Shag	1.09 (234)	0.30 (154)	1.06 (187)	0.87 (181)
Kittiwake	1.11 (1327)	0.17 (1095)	0.27 (1172)	0.61 (1062)
Guillemot	0.85 (757)	0.78 (748)	0.81 (754)	0.85 (745)
Razorbill	0.74 (97)	0.76 (100)	0.72 (104)	0.86 (105)
Puffin	0.88 (164)	0.66 (176)	0.78 (153)	0.87 (184)

	1993	**1994**	**1995**	**1996**	**1997**
Fulmar	0.44 (121)	0.47 (122)	0.48 (126)	0.44 (135)	0.37 (136)
Shag	0.21 (80)	0.68 (74)	0.84 (131)	1.05 (105)	0.92 (109)
Kittiwake	0.07 (1034)	0.16 (861)	0.40 (874)	0.56 (825)	0.40 (822)
Guillemot	0.76 (797)	0.79 (775)	0.81 (805)	0.82 (786)	0.77 (842)
Razorbill	0.72 (119)	0.69 (134)	0.62 (143)	0.63 (140)	0.71 (132)
Puffin	0.69 (182)	0.85 (189)	0.84 (180)	0.78 (173)	0.65 (166)

Notes:

The number of pairs followed is given in brackets. Details of methods, etc. can be found in this and previous reports to JNCC.

Table 6 Annual survival of adult seabirds on the Isle of May 1987-97

Species	No. seen in 1996	No. alive in 1997	% Survival 1996-97	1995-96	1994-95	1993-94	1992-93
Kittiwake	136	107	78.7	75.8	72.7	79.5	80.8
Guillemot	389	357	91.8	88.9	95.6	95.0	95.0
Razorbill	28	23	82.1	56.6	92.6	84.5	91.5
Puffin	225	204	90.7	90.1	93.0	93.1	84.0
Shag	147	134	91.1	93.6	?	?	79.6

Species	% Survival 1991-92	1990-91	1989-90	1988-89	1987-88
Kittiwake	80.7	84.2	78.7	90.9	86.0
Guillemot	93.3	91.0	94.9	92.4	91.5
Razorbill	89.8	79.6	75.0	90.5	88.1
Puffin	86.8	71.4	63.3	85.2	76.1
Shag	79.9	82.8	78.7	90.9	86.0

Notes:

Only birds which had definitely bred in 1996 or earlier are included.
Directly comparable figures for adult survival in earlier seasons are given. These have not been corrected for missing birds seen in later years, and so are serious under-estimates of actual survival rates.
These figures should not be used for population dynamics calculations without consultation with M.P. Harris.
Details of earlier estimates are given in previous reports to NCC-CSD/JNCC.

Table 7 Food fed to young kittiwakes and shags on the Isle of May in 1997

	Kittiwake	**Shag**
No. of regurgitations	89	54
Range of dates	11 June-16 July	8 May-16 July
Total weight (g)	1211	1557
% regurgitations with sandeels	99	100
with Gadidae	4.5	0
with Clupeidae	7.8	0
% (by weight) of sandeels in sample	93.7	100
% (by numbers) of sandeels in sample	99	100
Lengths of majority of sandeels (cm)	7-8	12-14 cm
Non-sandeel remains identified	Whiting (3) Polychaete (1) *Nephrops*(1) small pelagic crustaceans	None

Notes:

Samples collected from chicks (kittiwake) or chicks and adults with chicks (shag)
Counts and lengths of fish in kittiwake samples were based on otoliths retrieved from the regurgitations.

Table 8 Food of young guillemots on the Isle of May in 1997

		Number of sandeels			Number of Clupeidae			Number of Gadidae
	minute/ larval	small	medium	large	small	medium	large	
Mean length (cm)	?	8.5	13	16	10	12	14	
All-day watches								
15 June	0	81	242	9	11	15	3	0
22 June	2	17	43	2	3	2	2	0
27 June	0	26	35	4	1	1	1	0
29 June	0	6	20	9	8	14	2	0
29 May-6 July	5	302	586	62	103	54	11	0
Total	7	432	926	86	126	86	19	0

Note:

Lengths were based on visual estimates against the bird's bill checked by samples of dropped fish collected from the breeding ledges.

Table 9 Food of young razorbills on the Isle of May in 1997. Figures are numbers of loads of various types of food

	Single sandeel			Several sandeels				Clupeidae
	large	medium	small	large	medium	small	tiny	
All-day watches								
15 June	2	2	2	0	6	12	7	7*
22 June	0	0	0	0	2	2	1	0
27 June	0	0	0	1	3	1	1	0
29 June	0	0	0	0	0	1	1	0
3-25 June	2	0	5	0	27	50	48	5
Total	**4**	**2**	**7**	**1**	**38**	**66**	**58**	**12**

Notes:

* Includes six single large and one with two medium fish.
No fish were collected for measuring.
Data collected by S. Finney.

Table 10 Food of young puffins on the Isle of May 16 June to 8 July 1997

	Sample size	Mean	S.E.
a) Load weight (g)	88	9.7	0.47
b) Fish/load	88	7.7	0.46
c) Numbers and lengths of fish (mm)			
Sandeels *Ammodytes* sp.	664	74.6	0.66
Sprat *Sprattus sprattus*	23	70.9	1.79
Herring *Clupea harengus*	5	74.8	4.3
Clupeidae	36	58.2	1.8
Cod *Gadus morhua*	3	36.0	-
Whiting *Merlangius merlangus*	3	48.7	6.0
Saithe *Pollarchius virens*	1	38.0	-

Table 11 Percentage of kittiwake broods of one and two chicks which had no adults present during daily checks in the middle of the day

Year	One young	Two young
1986	1	7
1988	31	66
1989	13	32
1990	21	45
1991	2	13
1992	13	28
1993	12	31
1994	1	19
1995	3	14
1996	7	27
1997	14	42

Note:

Figures are based on 50-200 broods in the same areas each year. These are means of daily checks made between the dates the first neglected chick was noted and the start of fledging in the areas. In 1997, the counts were made in the period 30 June-15 July. (Details of methods are given in Wanless & Harris, *Scottish Birds* 15 (1989): 156-161.)

Table 12 Percentage of sandeels (by weight) in the diet of young seabirds on the Isle of May, 1987-97

	1987	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**
Shag	100	98	100	95	100	97	99	86	85	99	100
Kittiwake	95	94	95	86	50	61	63	81	86	81	94
Guillemot	81	41	74	24	74	53	17	19	78	44	79
Puffin	77	85	89	96	87	86	46	57	50	88	86

Notes:

Dates and sample sizes can be found in the contract report for respective years.
Sandeels also made up the bulk of the food of young razorbills in most years, but it is extremely difficult to assess the proportions in terms of biomass.

Table 13 Kittiwake first-egg dates and clutch-sizes on the Isle of May, 1986-97

Year	**First date egg seen**	**Mean clutch-size (eggs)**
1986	9 May	no data
1987	4 May	no data
1988	6 May	no data
1989	27 April	2.04
1990	2 May	1.82
1991	6 May	1.86
1992	30 April	1.83
1993	4 May	1.78
1994	17 May	0.86
1995	16 May	1.61
1996	24 May	1.13
1997	10 May	2.03

Note:

1997 data collected by B. Clarke

Table 14 Probability of resighting and survival of adult puffins on the Isle of May 1973-93, assuming both probabilities are year-dependent. Maximum likelihood estimates are given with standard errors in parentheses.

	Number of marked birds seen	Probability of: Resighting		Survival	
1973	79	-	-	0.989	(0.020)
1974	123	0.410	(0.056)	0.988	(0.016)
1975	140	0.556	(0.039)	0.986	(0.016)
1976	130	0.616	(0.034)	0.965	(0.017)
1977	234	0.785	(0.029)	0.983	(0.009)
1978	276	0.866	(0.021)	0.983	(0.009)
1979	263	0.904	(0.017)	0.954	(0.013)
1980	248	0.929	(0.016)	0.963	(0.013)
1981	262	0.915	(0.018)	0.921	(0.018)
1982	212	0.872	(0.022)	0.918	(0.022)
1983	167	0.781	(0.029)	0.913	(0.023)
1984	188	0.962	(0.016)	0.899	(0.024)
1985	164	0.850	(0.028)	0.930	(0.022)
1986	171	0.883	(0.025)	0.936	(0.022)
1987	154	0.813	(0.031)	0.914	(0.026)
1988	141	0.747	(0.035)	0.959	(0.026)
1989	170	0.775	(0.035)	0.892	(0.033)
1990	227	0.652	(0.038)	0.805	(0.027)
1991	289	0.871	(0.023)	0.936	(0.016)
1992	295	0.894	(0.019)	0.891	(0.019)
1993	289	0.921	(0.017)	-	-

Note:

Under this model the survival rate for 1993 and the resighting rate in 1994 are not separately identifiable.