THE STATUS OF ARCTIC TERNS *STERNA PARADISAEA* AT SHETLAND AND ORKNEY IN 1994

DE AANTALLEN NOORDSE STERNS OP DE ORKNEY EN SHETLAND EILANDEN IN 1994

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A census of Arctic Terns was carried out in Orkney and Shetland in 1994. The results indicated that the population in the Northern Isles as a whole was 32 400 (95% CI = 26 600-39 000), a decline of 27% (95% CI = 12-40%) since 1989. A population model indicated that this decline could be explained by poor natal recruitment following breeding failures on Shetland between 1985 and 1990 (Table 1). Within the two archipelagos, numbers declined by 47.5% in Orkney to approximately 15 600 birds, while in Shetland the population remained stable at 16 800 birds (95% CI = 11 400-23 800 birds). This is contrary to the predictions of the population model, which suggested a large decline in Shetland and a slight decline on Orkney. The best explanation for this discrepancy is that between 9000 and 10 000 Arctic Terns migrated from Orkney to Shetland, probably to exploit the increase in sandeel abundance there. The tern populations on Shetland and Orkney can therefore be regarded as components of a larger metapopulation.

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INTRODUCTION

Arctic Terns *Sterna paradisaea* have a circumpolar breeding distribution, with Great Britain and Ireland hosting approximately 10% of the global and 45% of the European population (Avery 1991a). The majority of the British Arctic Tern

population breeds on Orkney and Shetland where a survey in 1980 estimated a total of approximately 83 200 birds (Bullock & Gomersall 1981). By 1989 the population had fallen to 44 500 birds (Avery *et al.* 1993).

Sandeels *Ammodytes* spp. are the only small, energy-dense and abundant fish that Arctic Terns can exploit around the Northern Isles (i.e. the Orkney and Shetland Islands), and their reproductive success is dependent on availability of 0-group and 1-group fish (Monaghan *et al.* 1989, 1992; Suddaby & Ratcliffe 1997). Low recruitment of sandeels into the Shetland stock during the late 1980s and 1990 led to complete breeding failures of Arctic Terns on Shetland (Monaghan *et al.* 1989, 1992, Suddaby & Ratcliffe 1997). However, poor productivity alone was not sufficient to explain the rate of decline in the Arctic Tern population on the Northern Isles between 1980 and 1989, suggesting that rates of either adult mortality, non-breeding or emigration increased as well over the same period (Avery *et al.* 1993).

The Arctic Tern is recognised as being of conservation importance by its inclusion in the 'amber' list of Birds of Conservation Concern in the UK (Gibbons *et al.* 1996) and is also listed in Annex 1 of the European Community 'Birds Directive'. In view of the population declines through the 1980s and the poor productivity during this period, regular monitoring of breeding numbers is essential to determine current population trends. This paper presents the results of a census in 1994 and a population model that tests whether the trends in the population can be explained by lack of productivity on Shetland during the late 1980s and 1990.

METHODS

In 1989, all known Arctic Tern colonies in Orkney and Shetland were visited once between 25 May and 12 July (Avery *et al.* 1993). The numbers of birds were expected to vary through the season, so each colony was randomly assigned to be counted in one of three time periods; period 1 (25 May-10 June), period 2 (11-28 June) and period 3 (29 June-12 July). This method ensured that the three groups were similar in all respects so that comparisons could be made between counts at different stages of the breeding season (Avery *et al.* 1993). Although the count methods were identical in the two island groups during 1994, the selection of colonies to be counted differed. In Orkney it was possible to census all colonies at some time during the season and sum the number of birds at them to arrive at a total population figure. However, towards the end of the season, counts are thought to become less reliable (Avery 1991b), so a second population estimate was made using trends at those colonies visited during periods 1 and 2 in both the 1989 and 1994 surveys (n = 140). In Shetland, 500 colonies were visited in 1989, 378 of which were visited in

periods 1 and 2. Of the latter, a sample of 172 colonies was randomly selected for counting during 1994.

Observers estimated the number of adults attending colonies using flush counts as in previous surveys (Bullock & Gomersall 1981, Avery *et al.* 1993). Three estimates were obtained within three minutes of flushing the birds and the mean of these was then taken as the number of birds present at the colony. All results refer to numbers of adult birds flushed and not pairs. The majority of counts were carried out between 08.00 and 18.00 h GMT, and this was comparable with the 1989 survey. At each colony we also recorded altitude, distance from the sea, habitat type and land use.

Counts made in periods 1 and 2 in both years were used in matched comparisons between years (1989 and 1994). For both Orkney and Shetland, only 1994 counts falling within 14 days of those in 1989 were used in calculations in order to minimise seasonal variations in colony attendance. This gave a matched sample of 140 colonies in Orkney and 172 in Shetland. In some cases, there was more than one count in both years that would have been suitable for comparison, so those closest in date were used for analysis. The mean ratio (1994:1989) of birds at individual colonies and 95% confidence intervals were calculated by bootstrapping (Manly 1991). In order to calculate overall numbers in Shetland, the mean ratios and confidence intervals were applied to the total count in 1989. The final population estimates were rounded to the nearest 100 birds.

In Orkney, survey coverage of the islands was complete and so all new colonies established since 1989 were counted. However, in Shetland, the survey was based on counts of a sample of colonies known to have been in existence in 1980 or 1989, so we allowed for the possibility that new colonies could have been established in the intervening years. The area of land in Shetland that was potentially suitable for breeding terns was first estimated. The suitability of 1-km squares in Shetland was determined by assessing the altitude and distance from the sea of all colonies present during 1980 and 1989. Of the colonies present in Shetland in either 1989 or 1980, 86% (n = 500) were within 800 m of the sea and at an altitude of 50 m or less. Only 1-km squares containing land that fulfilled these criteria (n = 1278) were assumed to be potentially suitable for breeding terns in further analysis.

In 1994, a survey of Red-throated Divers *Gavia stellata* was undertaken in Shetland (Gibbons *et al.* 1997). As part of this survey work, all 5-km squares with standing freshwater were surveyed in late May or June, at the time of the optimum Arctic Tern survey period. During this survey, all previously unknown Arctic Tern colonies were counted using identical methods to the main survey. However, not all ground within the 5-km squares had been searched with equal effort so the survey data were broken down by 1-km square.

Only those squares that had received at least 50% coverage and contained land suitable for breeding terns were included in the analysis (n = 62). The bootstrapped mean number of Arctic Terns at new colonies per 1-km square was thus obtained and this figure was multiplied by the number of suitable squares on the whole of Shetland to obtain a total estimate of the number of birds at new colonies.

A simple deterministic population model was used to test whether the observed population trends can be explained by low Arctic Tern recruitment. The model used estimates of mortality and recruitment rates to predict the size of the breeding population in 1994. The annual adult survival rate of Arctic Terns on the Farne Islands was 88%, survival to recruitment 53% and modal age of first breeding four years (Coulson & Horobin 1976). These were used in conjunction with population and productivity estimates from Shetland and Orkney as parameters in the model. Population figures for the Northern Isles Arctic Tern surveys are based on counts of the number of birds, while the model requires knowledge of the number of pairs in order to estimate the number of chicks fledged. A correction factor of 1.5 birds to one pair was used to estimate the number of pairs (Bullock & Gomersall 1981).

In Shetland, productivity was zero from 1985 to 1990 (Monaghan *et al.* 1989, 1992; Walsh *et al.* 1990) and so no recruitment was expected to occur between 1989 and 1994 given the recruitment age of four years (Coulson & Horobin, 1976). Thus, population size was expected to decline by 12% per annum due to adult mortality. For Orkney, the prediction of the population in 1994 was more complicated and involved more assumptions. Productivity was higher in Orkney during the 1980s than on Shetland, but it was not accurately quantified. Calculating recruitment between 1989 to 1994 therefore demands estimation of the population size and productivity from 1985 to 1990. Population status figures in these years were estimated by calculating the annual rate of population decline between 1980 and 1989 and then using this rate to calculate the population size in each successive year. The average productivity recorded from 1990 to 1997 (0.31 chicks per pair) was used as the value for productivity during 1986-1989, after which observed values for each year were used. This technique assumes that the annual rate of decline between 1980 and 1989 was constant and that average productivity during 1985 to 1989 on Orkney was similar to that between 1990 and 1997. The parameters described above were substituted into the following equation (Croxall & Rothery 1991) to predict the population size in terms of the number of pairs:

$$N_{t+1} = S_A N_t + f S_i N_{(t+1-k)}$$

N_t = Number of females in year t, f = productivity (female chicks per pair), S_A = Adult survival rate, k = recruitment age, S_i = Immature survival rate. The number of pairs was converted back into the number of individual birds using the 1.5 birds to pairs correction factor and compared with the observed number of birds from the 1994 survey.

RESULTS

Orkney The total number of Arctic Terns at all colonies on Orkney during 1994 was 15,600 birds (Table 1). This compares with a total of 29,700 birds in 1989, representing an overall decline of 47.5%. The analysis of trends at individual colonies for the 140 colonies covered in either period 1 or 2 in both 1989 and 1994 showed that numbers fell by 47.8% between 1989 and 1994, which was similar to the percentage change derived from the analysis of all counts combined.

Shetland The rate of change between 1989 and 1994 at the sample of colonies censused in periods 1 and 2 at Shetland did not differ significantly (Period 1: mean 1.588, 95% Confidence Interval, CI = 0.992 - 2.563; Period 2: mean 0.867, 95% CI = 0.498 - 1.422) and therefore all ratios were pooled. The overall ratio between 1994 and 1989 was 1.102 (95% CI = 0.772-1.505) indicating that the population size had not changed significantly on Shetland. Multiplying these ratios by the population estimate from the complete count in 1989 gives a population estimate for Shetland of 16 200 (95% CI = 11 400-22 200) without allowing for the formation of new colonies between the two count periods.

In the 62 suitable 1-km squares that were searched for new colonies, two new colonies holding a total of 27 birds were found, a mean of 0.44 birds per square (95% range 0-1.24). The total number of birds at new colonies in Shetland was estimated to be 562 birds (95% CI = 0-1585 birds), which is very small compared with the confidence intervals around the estimate from established colonies. This was added to the sample census estimate to give a total Shetland population estimate of 16 800 birds (95% CI = 11 400-23 800) which is not significantly different from the estimate for 1989 (Table 1).

Northern Isles total The number of Arctic Terns on the Northern Isles as a whole in 1994 can be estimated by summing the Shetland and Orkney estimates, giving a total of 32 400 (95% CI = 26 600-39 000, Table 1). This represents a population decline of 27% (CI = 12-40%) from 1989 to 1994.

Modelling population size The total number of Arctic terns predicted to occur in the Northern Isles by the population model was 33 100 and is well within the sampling error of the observed population estimate (Table 1). This suggests that

Table 1. Total numbers of breeding Arctic Terns counted in Orkney and Shetland between 1980 and 1994 and predicted values from the population model.
Tabel 1. Aantallen broedende Noordse Sterns op Orkney en Shetland tussen 1980 en 1994 en de voorspelde aantallen op grond van een populatie-model.

	Shetland	Orkney	Total
1980	40 800	42 400	83 200
1989	14 700	29 700	44 400
1994 (Observed)	*16 800	15 600	32 400
1994 (Predicted)	7800	25 300	33 100

*95% Confidence Interval of count: 11 400-23 800 birds

the low recruitment due to breeding failures on Shetland from 1985 to 1990 might explain the observed population decline on the Northern Isles. However, the number of birds observed on Shetland was far higher than predicted, while the numbers on Orkney were much lower than predicted. This finding is best explained by 9000-10 000 Arctic Terns emigrating from Orkney to Shetland between 1989 and 1994, although there are insufficient data from ringing studies to confirm this.

DISCUSSION

The Arctic Tern population in the Northern Isles halved between 1980 and 1989 (Bullock & Gomersall 1981, Avery *et al.* 1993). The results of the 1994 census show a further decline of approximately 27% since 1989. The population trends of Arctic Terns on the Northern Isles are closely mirrored by long-term trends of the sandeel stocks in Shetland waters. This would be expected since sandeels are the only suitable prey species for terns around Shetland and Orkney and productivity is strongly related to their availability (Monaghan *et al.* 1989, 1992; Suddaby & Ratcliffe 1997). The recruitment and spawning stock of sandeels in Shetland waters increased dramatically through the late 1970s and peaked in the early 1980s before declining due to low recruitment rates between the mid 1980s and 1990 (Wright & Bailey 1993).

The decline in sandeel availability was associated with poor reproductive success of Arctic Terns on Shetland during 1983 and 1984 (Ewins 1985) and complete breeding failures between 1985 and 1991 (Walsh *et al.* 1990). However, at the same time, Arctic Terns on Orkney were provisioning their chicks with sandeels and no widespread breeding failures were evident (Monaghan *et al.* 1992), suggesting that stocks around the two archipelagos may fluctuate independently. The rate of decline in the Arctic Tern population between 1980 and 1989 could only partially be explained by poor productivity,

and so it appears likely that adult mortality, emigration or non-breeding rates must also have increased during this period (Avery *et al.* 1993).

Sandeel abundance in Shetland waters increased dramatically during 1991 due to larval advection from Orkney, and this was associated with increased Arctic Tern productivity. However, the results of the 1994 Arctic Tern survey indicate that the population in the Northern Isles has undergone further declines since 1989 at a rate of 6% per annum. However, since the modal age of first breeding is 4 years old (Coulson & Horobin 1976), the chicks fledged on Shetland during 1991 would not have recruited by 1994. Modelling of expected population trends suggested that the results of the census in the Northern Isles could be adequately explained by natal recruitment being insufficient to balance losses due to adult mortality.

Population trends within Orkney and Shetland between 1989 and 1994 were very different from one another. The Orcadian population declined by 48% between 1989 and 1994 while that on Shetland did not change significantly. This is contrary to the trends predicted from the model, which suggested that the population on Shetland should have almost halved due to a lack of recruitment, while that on Orkney should have declined only slightly. The best explanation for this discrepancy is that between 9000 and 10 000 Arctic Terns emigrated from Orkney to Shetland between 1989 and 1994, probably to exploit the massive increase in sandeel abundance around Shetland following the high recruitment during 1991 (Wright & Bailey 1993). The Arctic Tern populations on Orkney and Shetland therefore appear to form components of a metapopulation, with birds moving among the archipelagos in response to changes in food availability.

Between 1990 and 1998, Arctic Tern productivity on Orkney and Shetland has fluctuated considerably (Ratcliffe *et al.* 1996; Thompson *et al.* 1997, 1998). The level of productivity required to maintain a stable population is 0.49 chicks per pair, but the 9 yr means on Shetland and Orkney were 0.32 and 0.30 respectively. It is therefore likely that further declines of Arctic Terns will occur and it is important that monitoring continues to examine whether this prediction is accurate. A complete census of Arctic Terns during the year 2000 should be a high priority. We would also advocate complete censuses of the Northern Isles in the future to ensure that precise population trends are obtained. The 1994 census on Shetland demonstrated that sample counts offer poor precision, as the low site fidelity of Arctic Terns results in high variance in the trends at individual colonies.

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SAMENVATTING

Op de Orkney en Shetland Eilanden werd in 1994 het aantal broedende Noordse Sterns Sterna paradisaea *geteld. In totaal werden 32 400 (95% CI = 26 600-39 000) paren geteld, hetgeen een afnamen van 27% (95% CI = 12-40%) sinds 1989 betekende. Een populatiemodel liet zien dat de afname veroorzaakt zou kunnen zijn door een geringe rekrutering in de populatie van jonge vogels na de teleurstellende broedresultaten tussen 1985 en 1990, als gevolg van voedselgebrek nadat de populatie zandspiering in dit gebied was ingestort (Tabel 1). Op de Orkney Eilanden nam de populatie af met 47.5%tot ongeveer 15 600 vogels, terwijl de stand op Shetland min of meer gelijk bleef op 16 800 (95% CI = 11 400-23 800. Dit resultaat is in precies het tegendeel van wat het populatiemodel zou hebben voorspeld: een grote afname in Shetland en een gering verschil op Orkney. De aangedragen verklaring is, dat tussen 9000 en 10 000 Noordse Sterns van Orkney naar Shetland zijn verhuisd, misschien als reactie op de snel herstellende voorraad zandspiering in die omgeving. Als dat juist is, dan zouden de sterns op Orkney en Shetland tot één en dezelfde metapopulatie gerekend kunnen worden.*

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Arctic Tern *Noordse Stern* (C.J. Camphuysen)