# The decline of Purple Sandpipers *Calidris maritima* in the Moray Firth, Scotland – an effect of recruitment

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Numbers of Purple Sandpipers at roosts in the Moray Firth, NE Scotland, declined by 55% between winters 1986/87–1990/91 and 1996/97–2000/01. To investigate the decline, changes in recruitment (percentage of first-year birds) were examined at three major roosts that showed a slightly greater decline than the total population. The percentage of first-year birds varied between roosts and years, declining during the late 1980s and early 1990s, but increasing later. The percentages were also low compared to other studies. A model incorporating a varying percentage of first-year birds and constant mortality provided an explanation for the decline. Therefore, it is possible that the decline in numbers was due to poorer recruitment. The Moray Firth population is derived from at least two breeding populations, but we could not tell if one or both breeding populations were affected by the poor recruitment.

## INTRODUCTION

Unlike most other waders, the winter habitat of the Purple Sandpiper *Calidris maritima* outwith the breeding season is primarily rocky sea-shores. In Britain, the majority of wintering birds occur on the northern islands (Orkney, Shetland and the Outer Hebrides) and the northeast coast of Scotland (Nicoll *et al*. 1988). Rocky shores are poorly represented in the long-running Wetland Bird Survey (WeBS) (formerly the Birds of Estuaries Enquiry) and, in contrast to estuarine waders, there are no reliable annual indices of abundance for Purple Sandpipers (Prys-Jones *et al*. 1994, Musgrove *et al*. 2001, Austin *et al*. 2004).

The first nationwide census of birds inhabiting non-estuarine shores took place in winter 1984/85 during the Winter Shorebird Count, providing an estimate for the total number of Purple Sandpipers occurring in Britain (Moser & Summers 1987). In 1997/98, the Non-estuarine Coastal Waterfowl Survey (UK-NEWS) repeated this survey but it was not as comprehensive as the Winter Shorebird Count. The UK-NEWS estimated that the UK population of Purple Sandpipers was 17,220 and that it had declined by 21% since 1984/85 (Rehfisch *et al*. 2003b). Localised counts showed that some areas had greater declines than others. Counts along the Lothian coast (Fig. 1) indicated that numbers of Purple Sandpipers had declined by 88% between the 1970s/1980s and the 1990s (Dott 1997). The decline appears to have occurred during the late 1980s. At Hartlepool, Durham (Fig.1), the decline was not as severe. Numbers fell steadily from around 300 to 210 between winters 1986/87 and 1993/94 (Burton *et al*. 1996). In contrast, no decline was noted on the island of Sanday, Orkney (Fig. 1), between 1982/83 and 1991/92 (Corse & Summers 1999).

The Purple Sandpipers wintering in Britain vary in bill size, reflecting their different breeding origins. The birds in E Britain (Kincardineshire to Yorkshire, Fig. 1) are mainly short-billed and come from Norway (Rae *et al*. 1986), whilst those in N Scotland are mainly long-billed and thought to come largely from Canada (Nicoll *et al*. 1988). Therefore, it is possible that the decline seen in Lothian, but not in Orkney, was due to a decline in the Norwegian population or a tendency for more birds to remain in Scandinavia for the winter.

The Moray Firth (Fig. 1) lies between the centres for the Norwegian and presumed Canadian wintering birds, and flocks comprise birds from both populations (Nicoll *et al*. 1988). It is fortunate that the WeBS counts in the Moray Firth include sections of rocky shore allowing us to examine trends in numbers of Purple Sandpipers at the main roosts. Further, the Highland Ringing Group has been trapping Purple Sandpipers at some of the roosts, allowing us to see if there have been any long-term change in the composition of the flocks (age ratio and the ratio of short-billed to long-billed birds), which may help us interpret any change in numbers. Here, we examine the annual changes in the numbers of Purple Sandpipers and the percentages of first-year birds (a measure of recruitment). In addition, the population structure in terms of the percentages of birds in different bill size categories (reflecting sex and geographical origin) is examined.

## METHODS

The study area comprised the shoreline between Brora in the north and Buckie in the east (Fig. 2), with the exception of a few small stretches that were difficult to access. Co-ordinated high tide counts of roosting waders were conducted

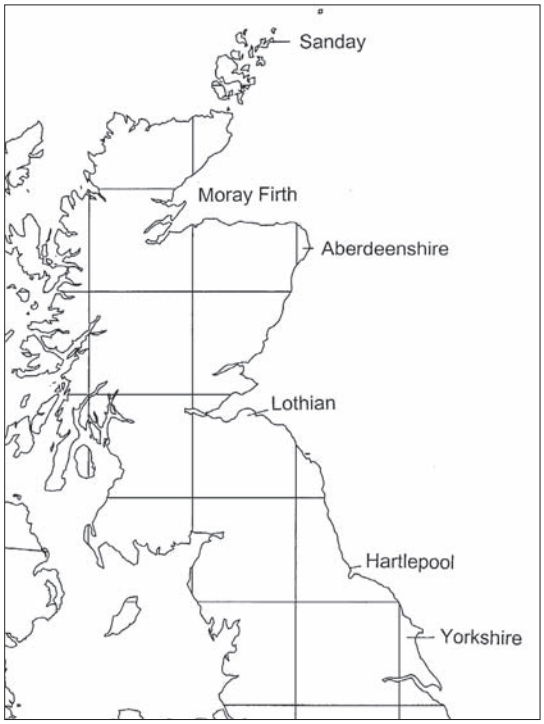


**Fig. 1.** The location of the Moray Firth and other places mentioned in the text.

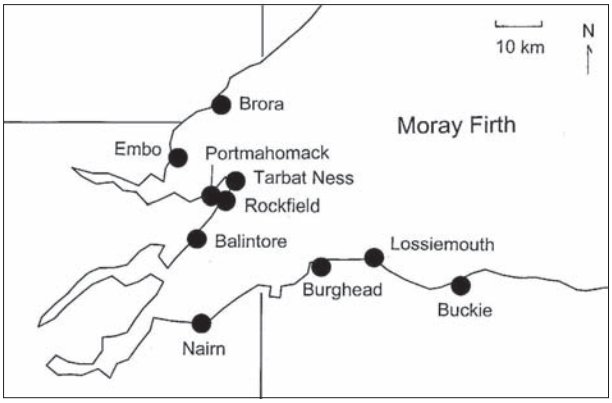


**Fig. 2.** The locations of the roost sites for Purple Sandpipers in the Moray Firth.

in December, January and February for winters 1986/87 to 2000/01. Each section of the study area was thoroughly searched for waders, usually by an observer who was familiar with the area and the location of the high tide roosts. High tide is not the best state of tide to carry out counts of waders on rocky shores because not all birds can be seen at rocky roost sites (da Prato & da Prato 1979). However, indices of abundance can nevertheless be obtained.

There were 10 roost sites in the Moray Firth used by Purple Sandpipers (Fig. 2). Numbers were totalled for each count and the three counts in a winter were averaged to provide a figure for the winter population. However, in the early years, not all sites were surveyed each month. Therefore, a Poisson regression analysis (log link function) was carried out on the existing data, incorporating the effects of site, month and year, and their interactions (Crawley 1993). The resulting model allowed interpolation of estimates for the times when sites were not surveyed (*sensu* Underhill & Prys-Jones 1994).

The count data for the roosts where birds were trapped (Balintore, Lossiemouth and Buckie/Buckpool) were analysed separately to describe their pattern (Fig. 2). Although these three sites held the majority of Purple Sandpipers that wintered in the Moray Firth, they were analysed separately in case there were any deviations from the overall pattern. Numbers were averaged for each winter in the same way as for the counts for all localities.

The roosting flocks at Balintore, Lossiemouth and Buckie/Buckpool were cannon-netted between winters 1987/88 and 1998/99. Only catches of over 30 birds were considered for analysis. Captured birds were aged as first-year or adult on the colour of the median coverts (Prater *et al.* 1977). Bill length was measured with dial callipers to an accuracy of 0.1 mm from bill tip to the start of the feathering at the base of the bill. Bill length allowed us to categorise birds according to sex and breeding origin because males have shorter bills than females and Norwegian birds have shorter bills than birds from Canada. Thus, Norwegian males have bills <27.5 mm and Canadian females have bills >32.1 mm. The intermediate birds can be either Norwegian females or Canadian males (Nicoll *et al.* 1988). Any change in the ratio of these three bill size groups would indicate a change in the composition of the flocks, either in terms of sex or breeding origin.

Retrap records of Purple Sandpipers were examined to determine how site-faithful the birds were to given roosts, and thereby gauge the extent to which changes in numbers could be due to immigration/emigration from other wintering areas between years.

## RESULTS

### Numbers

During the first four winters (1986/87 to 1989/90), there were 9, 4, 4 and 6 missing counts from the 30 carried out each winter (3 counts each at the 10 roosts). Thereafter, the surveys were complete. The Poisson regression model of the counts incorporating the effects of year, month, site and their interactions provided an excellent fit to the data, such that the correlation between actual numbers and fitted values had a coefficient of 0.931 ($p < 0.001$). In addition, the regression line for the relationship between actual counts and fitted values had a slope that was close to one (0.994, SE = 0.019), showing that the interpolated counts were likely to be realistic. These comprised 33%, 5%, 3% and 0.4% of the total numbers in the first four winters respectively. Therefore, only the first winter was heavily dependent on the interpolated numbers.

The numbers of Purple Sandpipers in the whole study area totalled around 400–600 during the mid-late 1980s, but declined during the early 1990s (Fig. 3). Numbers then stabilised at around 200–300 during the mid-late 1990s. The downward trend was statistically significant ($r_s = -0.850$, $p < 0.001$), and the counts fell by 55% between the first five winters of counts and the last five winters.

A similar decline was noted at the main roosts at Balintore, Lossiemouth and Buckie (Fig. 4). This decline was also statistically significant ($r_s = -0.907$, $p < 0.001$), and the

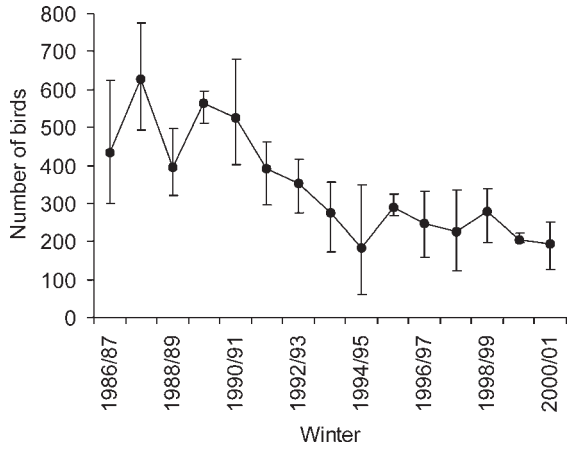


**Fig. 3.** Annual changes in the average number of wintering Purple Sandpipers in the Moray Firth based on roost counts. Vertical lines show the range of the counts (usually three) each winter.

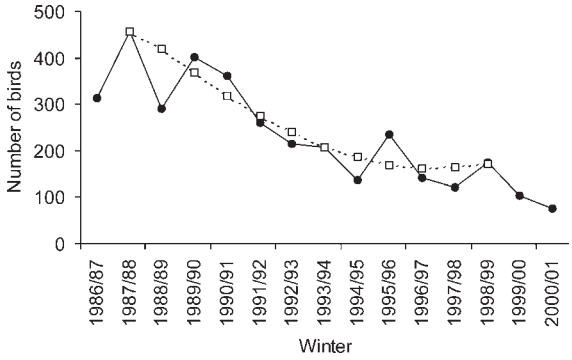


**Fig. 4.** Observed (•) and modelled (□) numbers of Purple Sandpipers at the three main roosts (Balintore, Lossiemouth and Buckie) in the Moray Firth.

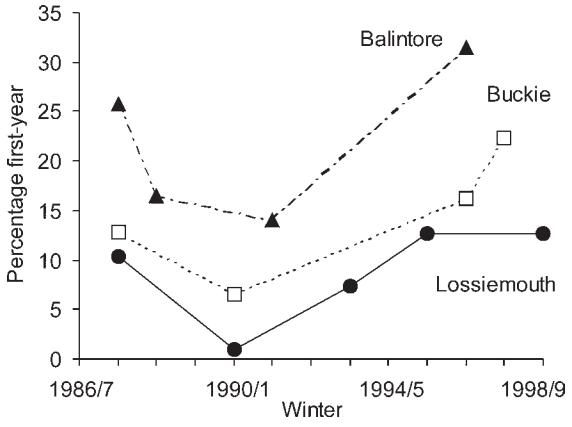


**Fig. 5.** Variations in the percentages of first-year Purple Sandpipers at three roost sites in the Moray Firth. Regression analysis showed an effect of site and a quadratic effect with year.

| Source | df | MS | F | *P* |
|---|---|---|---|---|
| Site | 2 | 235.7 | 12.1 | 0.004 |
| Year | 1 | 90.5 | 4.6 | 0.063 |
| Year$^2$ | 1 | 135.3 | 6.9 | 0.030 |
| Error | 8 | 19.5 | | |

counts fell by 66% between the first five winters and the last five winters. Thus, there was a greater decline at the main roosts.

## Composition of flocks

The percentage of first-year birds at Lossiemouth and Buckie varied significantly among winters, and almost did so at Balintore (Table 1). The lowest percentages of first-year birds occurred during the late 1980s/early 1990s. Regression analysis showed that there was both a site effect and a winter effect, which was quadratic (Fig. 5). Thus, the percentages at all three roosts declined to minima about 1990, and then increased. There was no interaction between site and winter.

The percentage of birds in the three bill-size groups is shown in Table 1. There were significant changes among years in these percentages only at Balintore. However, there was no clear evidence of a trend, either in the short- or long-billed birds.

## Site fidelity

Two hundred and thirty birds, ringed between December and February, were retrapped in subsequent winters. Some were retrapped more than once, leading to 274 retrap records. Most of the retraps (98.9 %) were at the site where they were ringed (Table 2). Only three birds were retrapped at a different roost in a subsequent winter. Therefore, there was a high degree of site fidelity, and changes with wintering sites outside the Moray Firth are likely to be rare.

## Population dynamics

Given the high degree of site fidelity, it is possible to model the changes in the total numbers at the three main roost sites testing the effect of recruitment and survival, without considering annual variations in immigration and emigration. Note that this does not refer to the migrations between breeding and wintering grounds. The percentage of first-year birds was not determined annually, but by using the quadratic regression equation (Fig. 5), values were obtained for each site in each year. Thus, estimates of the percentage of first-year birds were made in three years in which no samples were caught. An overall estimate of the annual percentage of first-year birds for the three roosts was then derived by weighting the percentages at each site according to the numbers at each site.

A model was constructed using the number counted in 1987/88 as the starting population (the first winter that the percentage of first-year birds was assessed), an annually varying percentage of first-year birds recruiting into the population, and a fixed annual survival rate of 79.5% (Summers *et al*. 2001). The modelled trend followed the pattern of counts (Fig. 4). The correlation coefficient between actual and modelled numbers was 0.83 ($p < 0.01$), and the regression line for the relationship between actual and modelled numbers had a slope close to one (0.846, SE = 0.188). The modelled population was not extended beyond the last winter that the percentage of first-year birds was assessed. However, the model would have predicted an increase after 1998/99, when in fact the actual numbers continued to decline in the following two winters (Fig. 4).

**Table 1.** The composition of catches of Purple Sandpipers at roosts in the Moray Firth in terms of age and bill length.

| Date | Sample size | % first-year | Bill length | | |
|---|---|---|---|---|---|
| | | | % small (<27.5 mm) | % medium (27.5–32.1 mm) | % large (>32.1 mm) |
| **Balintore** | | | | | |
| 5 Jan 88 | 31 | 25.8 | 9.7 | 67.7 | 22.6 |
| 24 Dec 88 | 103 | 16.5 | 5.1 | 77.8 | 17.2 |
| 22 Dec 91 | 143 | 14.0 | 16.3 | 55.2 | 28.4 |
| 22 Feb 97 | 35 | 31.4 | 11.4 | 68.6 | 20.0 |
| **Lossiemouth** | | | | | |
| 24 Dec 87 | 182 | 10.4 | 16.1 | 55.6 | 28.3 |
| 16 Feb 91 | 105 | 1.0 | 7.6 | 60.0 | 32.4 |
| 12 Feb 94 | 96 | 7.3 | 12.5 | 65.6 | 21.9 |
| 23 Dec 95 | 134 | 12.7 | 15.1 | 60.3 | 24.6 |
| 2 Jan 99 | 110 | 12.7 | 20.4 | 58.3 | 21.3 |
| **Buckie/Buckpool** | | | | | |
| 17 Apr 88 | 141 | 12.8 | 11.5 | 56.8 | 31.7 |
| 3 Jan 91 | 77 | 6.5 | 13.0 | 66.2 | 20.8 |
| 28 Mar 97 | 37 | 16.2 | 27.0 | 46.0 | 27.0 |
| 1 Feb 98 | 107 | 22.4 | 11.4 | 64.8 | 23.8 |

**Statistical analysis**

Testing for differences in age composition between catches:

Balintore $\chi^2 = 7.3$, df = 3, p = 0.063
Lossiemouth $\chi^2 = 12.8$, df = 4, p = 0.012
Buckie $\chi^2 = 9.8$, df = 3, p = 0.021

Testing for differences in bill size groupings between catches:

Balintore $\chi^2 = 14.5$, df = 6, p = 0.025
Lossiemouth $\chi^2 = 11.3$, df = 8, p = 0.184
Buckie $\chi^2 = 10.8$, df = 6, p = 0.095

## DISCUSSION

The counts at the roosts in the Moray Firth showed that there has been a decline in numbers of Purple Sandpipers, as has been shown elsewhere in the country, though not as great as in Lothian (Dott 1997). The decline of around 55%, however, does represent a substantial drop in numbers in the Moray Firth.

As shown for other studies (Atkinson *et al*. 1981, Burton & Evans 1997, Dierschke 1998, Rehfisch *et al*. 2003c), the Purple Sandpipers in the Moray Firth showed a high degree of site fidelity within and between winters. Therefore, it is unlikely that changes in numbers at given sites were greatly influenced by movements between roosts, or emigration from the Moray Firth.

Comparisons with other studies show that the percentages of first-year birds in the Moray Firth were smaller than elsewhere: 24% in E Scotland during the 1970s (Atkinson *et al*. 1981), 18–20% at sites in Orkney during the 1980s and early 1990s (Corse & Summers 1999), and 21% in northern Norway (Summers *et al*. 1990). Most of the catches in the Moray Firth comprised <20% first-year birds (Table 1). An age composition including 20% first-year birds can be regarded as sufficient to offset annual loses, given that the survival rate of Purple Sandpipers in E Scotland has been estimated at 79.5% (Summers *et al*. 2001). Thus, it seems likely that the recruitment has been too low to maintain the numbers. The similarity between counts at the three main roosts and the modelled numbers (Fig. 4) suggests that the changes in recruitment can account for the decline.

**Table 2.** Numbers of ringed Purple Sandpipers retrapped at the site of ringing, and at other sites in subsequent winters. The data were restricted to birds ringed and retrapped between December and February.

| Ringing site | Retrap site | | |
|---|---|---|---|
| | Balintore | Lossiemouth | Buckie |
| Balintore | 78 | 2 | 0 |
| Lossiemouth | 0 | 177 | 1 |
| Buckie | 0 | 0 | 16 |

Poor recruitment into the wintering population could be due to poor breeding success (e.g. caused by poor weather or high predation), due to smaller numbers of first-year birds migrating to Britain, or fewer first-year birds choosing the Moray Firth as a wintering area. Unfortunately, we have no data with which to test any of these possibilities for Purple Sandpipers.

It is possible that the wintering conditions are changing in the Moray Firth due to improvements in sewage treatment and the relocation of outfalls into deeper water (see review by Burton *et al.* 2002). It is known that invertebrate numbers are high close to sewage outfalls because of the enhanced levels of nutrients (Pearson & Rosenberg 1978). Although rocky shores with high wave action are unlikely to be enriched by

sewage in the way that estuaries are, there may have been declines in invertebrates in rocky bays close to towns and villages where sewage treatment has changed. In at study at Hartlepool, however, Eaton (2000) found no significant change in numbers, survival or diet of Purple Sandpipers and Ruddy Turnstones *Arenaria interpres* one year after cessation of the discharge of untreated sewage that could not be attributed to broader scale factors. Therefore, there is no evidence at present to support the idea that food supplies are declining in the Moray Firth due to changes to sewage systems.

Climate change is another recent factor that may be determining the distributions of waders, causing numbers to decline in the Moray Firth. Rehfisch *et al*. (2004) found a change in the distribution of Purple Sandpipers between the two surveys of the non-estuarine coasts of Britain (the Winter Shorebird Count in 1984/85 and the UK Non-estuarine Coastal Waterfowl Survey in 1997/98). The proportion of Purple Sandpiper numbers increased in the northwest and this was correlated with temperature and wind chill. Unfortunately, the UK-NEWS survey was not as extensive as the WSC (only 38% of Britain's non-estuarine coast was surveyed compared with 78% in the first survey). More importantly, only about 12% of the Outer Hebrides was surveyed (Rehfisch *et al*. 2003a), yet this major area for Purple Sandpipers (Buxton *et al*. 1985) lies at the northwest of the British range. Therefore, the apparent shift in distribution requires confirmation.

Although there was some indication of changes in the composition of flocks in terms of the ratio of short-billed to long-billed birds, the differences were not part of a trend suggesting a reduction in numbers of a particular population. Therefore, we cannot tell whether the decline in numbers affected one breeding population more than the other.

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