Estuarine, Coastal and Shelf Science 102-103 (2012) 126–132

Contents lists available at SciVerse ScienceDirect

Estuarine, Coastal and Shelf Science

journal homepage: www.elsevier.com/locate/ecss

Local and global influences on population declines of coastal waders: Purple Sandpiper *Calidris maritima* numbers in the Moray Firth, Scotland

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ARTICLE INFO

Article history:
Received 21 December 2010
Accepted 16 March 2012
Available online 23 March 2012

Keywords:
survival
recruitment
waders

ABSTRACT

Declines in numbers by several wader species in Britain have been linked to climate change, but the mechanism for the declines has rarely been explored. Britain lies at the northern end of the East Atlantic Flyway, and supports 1.3 million out of the Flyway's 8.5 million coastal waders (Charadrii) in winter and the Purple Sandpiper is one of the species whose numbers have declined. Here, we examine the dynamics of the decline as observed in the Moray Firth, northeast Scotland, investigating whether the decline was due to poorer apparent survival (return rate) or poorer recruitment of young birds. The maximum number in the Moray Firth declined from 860 in 1987/88 to 236 in 2006/07, with some increase during winters 2007/08 and 2008/09. At the three main high-tide roosts (Balintore, Lossiemouth and Buckie) the maximum combined number declined from 574 to 90. Changes in survival and recruitment (percentage of first-year birds) were examined at these roosts from captured samples, which were ringed and recaptured. There were no significant changes between winters in survival rates, nor were there differences between the survival rates of age groups (first-year and adult) or bill size groups, which represented birds of different sex and breeding origin. Annual survival estimates for the three roosts ranged from 72 to 77%. The percentage of first-year birds varied among roosts and years; the lowest values were during the late 1980s/early 1990s and early 2000s. A free-running population model incorporating varying percentages of first-year birds and constant mortality for each roost provided a plausible explanation for the decline. Although modelled numbers followed the observed pattern, a discrepancy in one year was carried forward in subsequent years, so that the fit with the observed numbers was parallel rather than similar. However, it seems that the decline in numbers was largely due to poorer recruitment. We discuss whether breeding success had declined, whether the population had responded to changes in the local sewage treatment systems, which could affect invertebrate food for Purple Sandpipers, or whether fewer birds chose to winter in Scotland. The Moray Firth population is derived from Norway and possibly Canada, and there is evidence that the Norwegian population was disproportionately affected. The reason for poor recruitment requires further study, and other wader species require examination to test if poor recruitment is a common feature of decline in numbers.
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1. Introduction

Approximately 8.5 million waders (Charadrii) spend the boreal winter on the coasts of the East Atlantic Flyway (Piersma et al., 1987). At the northern end, Britain supports about 1.3 million (Moser, 1987). Regular monitoring of numbers on estuaries by the Wetland Bird Survey (Prŷs-Jones et al., 1994) has shown declines in several species during the last decade (Ringed Plover *Charadrius hiaticula*, Grey Plover *Pluvialis squatarola*, Dunlin *Calidris alpina*, Bar-tailed Godwit *Limosa lapponica* and Curlew *Numenius arquata*; Calbrade et al., 2010) and shifts in the centres of their distributions within Britain (Austin and Rehfisch, 2005), and more generally within western Europe (MacLean et al., 2008). Climate change has been invoked as an explanation for these changes (Rehfisch et al., 2004; Austin and Rehfisch, 2005; MacLean et al., 2008). Thus, there is now a greater tendency for waders to occupy the food-rich east coast estuaries of Britain rather than the poorer west coast ones because the winters are now less severe on the colder east

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doi:10.1016/j.ecss.2012.03.026

coast (Austin and Rehfisch, 2005). In addition, the reduction in winter numbers in Britain has been mirrored by an increase in the Wadden Sea by several species (Hustings et al., 2009). The Wadden Sea is usually colder than estuaries in Britain, and therefore less attractive, but increasing temperatures now allow more waders to overwinter there. However, shellfish-dredging has reduced Edible Cockle *Cerastoderma edule* and Blue Mussel *Mytilus edulis* stocks, and changed the sediment structure of mudflats in the Wadden Sea, making it less suitable for some species, such as Red Knots *Calidris canutus* and Oystercatchers *Haematopus ostralegus* (van Gils et al., 2006; Kraan et al., 2009). Nevertheless, these shifts in distribution to the Wadden Sea allow some other waders to winter closer to their breeding quarters, and this is believed to be desirable, by shortening the migration distance or allowing early return to the breeding grounds (Ketterson and Nolan, 1976; Myers, 1981).

Although declines and shifts in distribution have been described for waders in Britain, the mechanism behind the changes has rarely been explored (Boyd & Piersma 2001). Possibilities include a lower return rate by adult birds. This could be due to poorer survival or a switch in wintering areas (*i.e.* a direct response to the weather; Austin and Rehfisch, 2005). Alternatively, there could be lower recruitment by young birds. This could be due to poorer breeding success or reduced use of more distant wintering areas.

The winter habitat of the Purple Sandpiper *Calidris maritima* outside the breeding season is primarily rocky sea-shores (Cramp and Simmons, 1983). Within Britain, the majority of the wintering birds occur on the northern islands (Orkney, Shetland and the Outer Hebrides) and northeast coast of Scotland (Nicoll et al., 1988). There are no reliable national annual indices of abundance for Purple Sandpipers, as for waders that inhabit estuaries (Prŷs-Jones et al., 1994; Musgrove et al., 2001), because counts of waders on rocky shores are poorly represented in the Wetland Bird Survey. However, a national count of waders inhabiting non-estuarine shores in Britain (the Winter Shorebird Count) took place during winter 1984/5, providing the first estimate for the total number of Purple Sandpipers in Britain (Moser and Summers, 1987). In 1997/8, the Non Estuarine Wader Survey (NEWS) repeated this survey, but because it was not as comprehensive as the Winter Shorebird Count, some counts were interpolated. The results indicated that Purple Sandpipers had declined by 21% nationally (Rehfisch et al., 2003).

Localised counts confirmed the decline, gave an indication of its timing and showed that some areas had greater declines than others. Counts along the Lothian (SE Scotland) coast indicated a decline of 88% between the 1970s/1980s (651 birds) and the 1990s (76 birds) (Dott, 1997). At Filey Brigg, Yorkshire, the mean number declined by 86% between 1977–1981 (290 birds) and 2003–2007 (40 birds), with the greatest fall during the late 1980s (Summers, 2009a). At Hartlepool, Durham, the decline was from around 330 to 230 (30% decline), but was gradual between winters 1986/7 and 1993/4 (Burton et al., 1996). In Orkney, the percentage decline (26%) was smaller, from 5603 in winters 1982/83 and 1983/84 to 4154 in 2006/07 (Corse and Summers, 2009).

The Purple Sandpipers that winter in Scotland originate from three different breeding populations, in which the birds vary in wing and bill length (Nicoll et al., 1991; Engelmoer and Roselaar, 1998). The birds in eastern Britain (Aberdeenshire to Yorkshire) are mainly short-billed, short-winged birds that come from southern Norway (Rae et al., 1986), whilst those in northern Scotland are mainly long-billed, long-winged birds that migrate through Iceland (Hallgrímsson et al., 2005; Summers et al., 2009) and are thought to originate largely from Canada (Nicoll et al., 1988). There are also some birds from Svalbard but these are believed to comprise a relatively small proportion of the wintering numbers (Summers et al., 2010). Therefore, it is possible that the large decline seen in Lothian and Yorkshire, but lesser one in Orkney, was due largely to a decline in the Norwegian breeding population.

The Moray Firth (Fig. 1) lies between the centres for the Norwegian and presumed Canadian populations of wintering birds, although the flocks comprise more 'Canadian' birds (10% Norwegian and 90% 'Canadian' at Brora, Sutherland, and 15% Norwegian and 85% 'Canadian' at Fraserburgh, Aberdeenshire; Nicoll et al., 1988). The Wetland Bird Survey of the Moray Firth includes sections of rocky shore, providing annual changes in numbers of Purple Sandpipers. Furthermore, trapping and re-trapping ringed Purple Sandpipers at some high-tide roosts, provides estimates of annual survival and descriptions of the composition of the flocks (age ratio and the ratio of bill size groups), which helps to interpret any change in numbers. Here we examine the annual changes in the numbers of Purple Sandpipers and model the changes based on estimates of survival and the percentage of first-year birds (a measure of recruitment), to determine which variable best accounted for the decline. In addition, the population structure in terms of numbers of birds in different bill size categories (reflecting sex and geographical origin) was examined to test the hypothesis that the decline was disproportionate for the two populations.

2. Methods

High tide counts of roosting Purple Sandpipers were conducted each winter (December, January and February) at ten roosts in the Moray Firth (58°N, 4°W) from 1986/87 to 2008/09 (Fig. 1). The maximum counts at each site, whether in December, January or February, were combined for all sites to give the population size in the Moray Firth each winter. Counts for the three main high-tide roosts (Balintore, Lossiemouth and Buckie) were also analysed separately. There is little movement between roosts (Atkinson et al., 1981; Burton and Evans, 1997; Dierschke, 1998), so counts are unlikely to be influenced by local movements.

In the winters 1986/87 to 1989/90, two roosts were not surveyed. Therefore, a Poisson regression analysis (log link function) was carried out on the existing data, incorporating the effects of roost, month and year, and their interactions (Crawley, 1993). The resulting model allowed interpolation of estimates for the times when the two roosts were not surveyed (*sensu* Underhill and Prŷs-Jones, 1994; Summers et al., 2005). The maximum interpolated

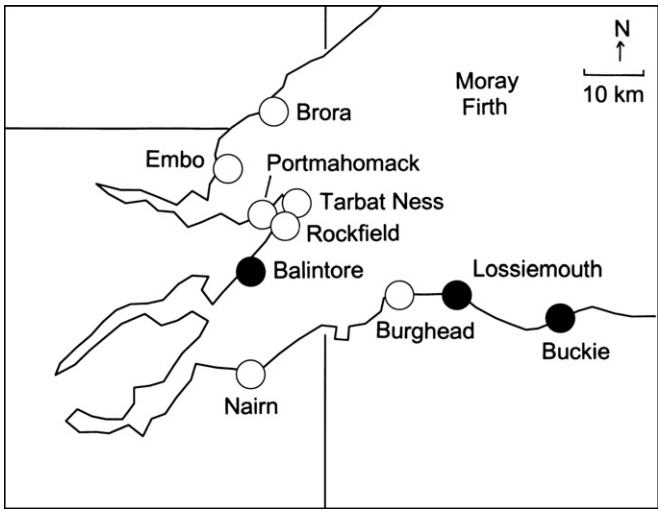

Fig. 1. The locations of the high-tide roosts for Purple Sandpipers in the Moray Firth. The main sites are the filled circles.

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