The dispersion of wintering Purple Sandpipers *Calidris maritima* in relation to the tidal cycle and shore zonation

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The dispersion of Purple Sandpipers wintering on a 2-km length of rocky shore on the Kincardine coast was studied in relation to the tidal cycle and shore zonation. Birds stayed close to the water's edge at all stages of the tide, and occurred in smaller flocks when not roosting compared with roosting at high tide. They occurred at highest densities on shore sections where the seaweed Channel Wrack was least abundant. This seaweed grows high on the shore so large areas of it are indicative of shores which are initially very shallow sloping and have small amounts of the lower zones. This suggests that Purple Sandpipers prefer the lower inter-tidal zones.

INTRODUCTION

Many waders (Charadrii) inhabit inter-tidal muddy and sandy shores outside the breeding season, feeding in the inter-tidal zone at low tide and roosting above the high water mark at high tide (Hale 1980). Their dispersion is clumped at high tide roost sites but, whilst feeding at low tide, they adopt differing dispersion patterns depending on the distribution of their food, feeding behaviour and interactions with conspecifics (Goss-Custard 1970, Goss-Custard *et al.* 1977, Ferns 1992, Kalejta & Hockey 1994). In contrast to muddy and sandy shores, rocky shores have steeper profiles and the flora and invertebrate fauna are more highly zoned (Lewis 1964), providing distinct microhabitats in which the waders can feed.

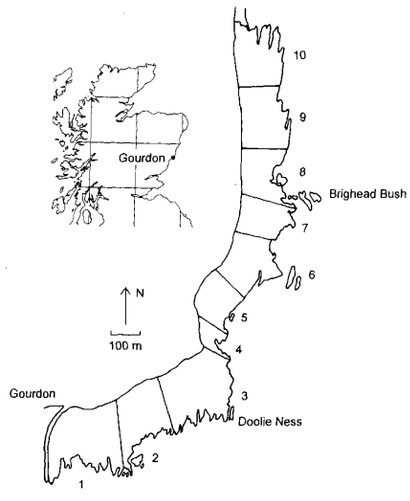


Fig. 1. The study area at Gourdon showing shore divisions. The location of Gourdon is inset.

The Purple Sandpiper *Calidris maritima* is one of the few waders that is virtually restricted to rocky shores outside the breeding season. Although it is known that Purple Sandpipers select broad shallow-sloping bedrock shores in preference to cliffs, steep bedrock and boulder shores (Summers *et al.* 1988, Summers *et al.* 2002), their habitat preference within a shore type has not been studied. In this study, we describe flock size, distance from the tide edge and attempt to account for the horizontal dispersion of Purple Sandpipers along a shallow-sloping rocky shore in winter.

STUDY AREA AND METHODS

The study was carried out on a 2-km length of shore (area 33.8 ha) between Gourdon and Inverbervie on the Kincardine coast, eastern Scotland (Fig. 1). The shore was split into ten sections and the divisions were marked with paint spots at 20 m intervals down the shore.

Purple Sandpipers start to arrive at Gourdon in July and depart in April and May. Peak numbers occur in winter (Summers *et al.* 2001). In order to describe the dispersion of the birds, monthly surveys were carried out during the winter months (November to March) from 1985–86 to 1987–88. The observer walked close to the tide edge (*c.*10–20 m) and the following variables were recorded: number of birds in a flock, distance from the centre of the flock to the water's edge, shore section, time and stage of tide. When birds were flushed ahead, a note was made of the section in which they landed and numbers adjusted to account for the flushed birds in such sections. Each survey took 3–4 hours. A flock was defined as those birds whose behaviour was likely to be influenced by its neighbours. Thus, if one bird took to flight when disturbed, the flock was defined as those that also flew. In order to measure the flock size in which the average bird occurred, flock sizes were ranked and multiplied by their frequency to obtain the total number of birds in each flock size. The midpoint of the sum of the totals gave the flock size for the average bird.

Profiles of the shore were drawn at section boundaries, surveying the levels at 5 m intervals down the shore. In order to describe the zonation of the main seaweeds and invertebrates, the presence of the following species or groups was recorded at 5 m intervals along transects down the section boundaries and down the centre of each section: Channel Wrack *Pelvetia canaliculata,* Flat Wrack *Fucus spiralis,* Bladder Wrack *F. vesiculosus,* Serrated Wrack *F. serratus, Mastocarpus stellata, Laurencia pinnatifida,* barnacles *Balanus* spp., limpets *Patella* spp., Blue Mussels *Mytilus edulis* and winkles *Littorina* spp. All descriptions extended to the edge of the kelp *Laminaria digitata* zone, which defined the bottom of the inter-tidal area. The percentages of each species or group within a section were determined by combining the scores from the transects down the section boundaries and the central transect. Areas of the sections were determined by cutting out each section from a 1:25,000 map, weighing the pieces of paper and relating them to the weight of paper representing 100 ha.

RESULTS

Flock size

Flocks of roosting birds ranged from 1–40 birds. Roosts of a few birds often formed close to high tide or at neap high tides, and it was only on spring high tides that birds coalesced into flocks of tens of birds at the main roost sites. There were three main roosts, at Doolie Ness, Brighead Bush, and a rocky point between these (Fig. 1). Sometimes, all three roosts coalesced if there was disturbance on the shore.

The data for non-roosting birds were split into two-hourly periods before and after high tide (Table 1). The range of flock sizes for non-roosting birds was as great as for the flock sizes of roosting birds, though the frequency distributions and median values were different. The median flock size of non-roosting birds in the inter-tidal zone was 2, and 6 for roosting birds at high tide roosts. This difference was statistically significant (Mann-Whitney $U = 3434$, $p < 0.001$). However, median flock sizes give a misleading impression of the dispersion of the birds because there are more birds in the larger flocks. Thus, the average bird was in a flock of 4 when not roosting, and in a flock of 20 when roosting at high tide. When the flock sizes of non-roosting birds were compared for the two-hourly time-periods through the tidal cycle, there were no significant differences in size (Kruskal-Wallis test statistic = 8.12, $p = 0.15$), though there was an indication that flock size increased just prior to high tide (Table 1).

Distance from water's edge

During winter, Purple Sandpipers occurred mainly within a metre or two of the water's edge and rarely more than 10 m, regardless of the state of tide (Fig. 2). There was no significant difference in the pattern for non-roosting birds during two-hourly periods through the tidal cycle (Kruskal-Wallis test statistic = 7.241, $p = 0.203$). However, on one day the distribution was noticeably different. On 25 January 1988, a strong north-east wind and heavy surf resulted in large amounts of foam being blown in over the lower part of the shore in the northern sections (4–10) and caused the Purple Sandpipers to move up to 80 m away from the water's edge.

When roosting, the Purple Sandpipers were on average less than 1 m from the water's edge (range 1–3 m).

Shore shape and zonation of seaweeds and invertebrates

The shore profiling showed that there were differences in the shapes of the slopes down the shore at each section and consequently differences in the size of the different seaweed and invertebrate zones. Fig. 3 illustrates two contrasting profiles. The shore at transect 2 was shallow-sloping initially and had broad Channel and Flat Wrack zones, and a narrow barnacle zone where it fell more steeply. In contrast, transect 8 fell steeply so that the Channel Wrack and Flat Wrack zones were narrow and the barnacle zone was broad, occupying over half the shore. Thus, although the shore at transect 8 was shorter, it had a greater breadth of the lower zones compared with the shore at transect 2. It also had a Blue Mussels growing in the lower zones.

The average density of Purple Sandpipers found in each section in winter 1985–86 at low tide varied from 1.2 to 9.2 birds per hectare. The variation in bird density between sections was tested in relation to percentages of the section areas covered by different seaweeds and invertebrates. The best fitting model was a negative relationship with Channel Wrack (Fig. 4). Higher densities occurred where there was less Channel Wrack. Shore sections with little Channel Wrack tended to have greater percentages of lower zone seaweeds and invertebrates. There were significant negative correlations between Channel Wrack and *Mastocarpus stellata* ($r_s = -0.673$, $p < 0.05$), limpets ($r_s = -0.685$, $p < 0.05$) and barnacles ($r_s = -0.744$, $p < 0.02$).

Table 1. Group sizes of roosting and non-roosting Purple Sandpipers in winter (November to March) at Gourdon. The data for non-roosting birds have also been split into different parts of the tidal cycle.

	Sample size	Mean	Median	Range	Flock size for the average bird
Roosting birds	40	10.4	6	1–40	20
Non-roosting birds	359	3.0	2	1–50	4
0–2 hours after HT	35	2.2	2	1–9	2
2–4 hours after HT	42	3.0	2	1–15	4
4–6 hours after HT	58	3.5	2	1–30	8
4–6 hours before HT	111	2.2	1	1–22	3
2–4 hours before HT	76	3.5	2	1–31	6
0–2 hours before HT	37	4.6	1	1–50	20

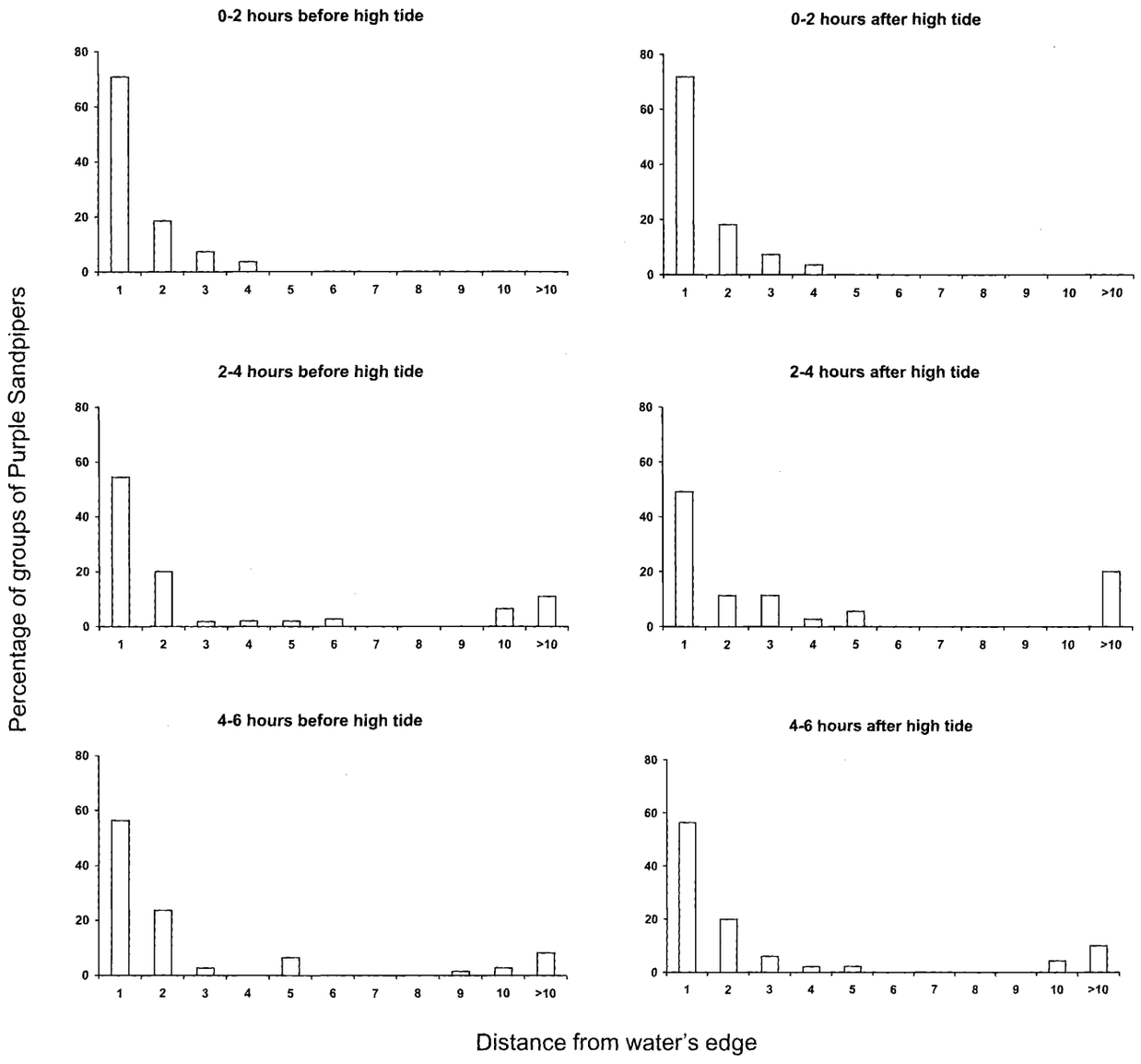


Fig. 2. The percentages of groups of non-roosting Purple Sandpipers at different distances from the water's edge at different stages of the tidal cycle. Distance 1 refers to 0–1 m. Sample sizes are shown in Table 1.

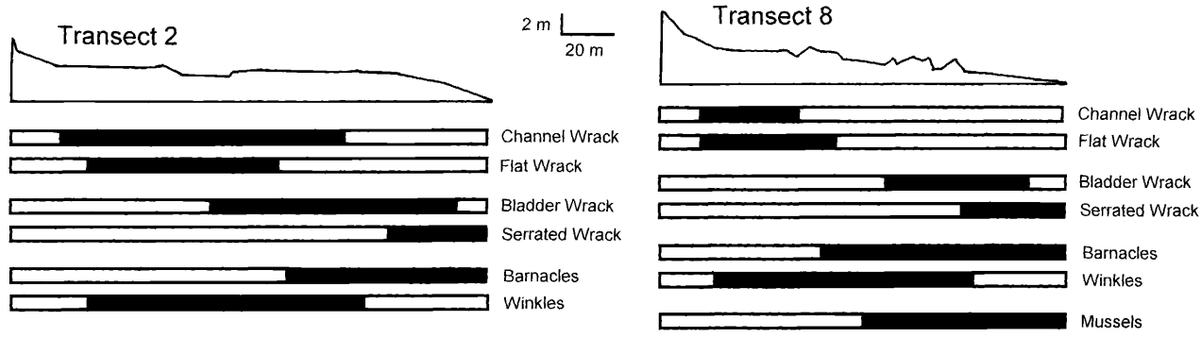
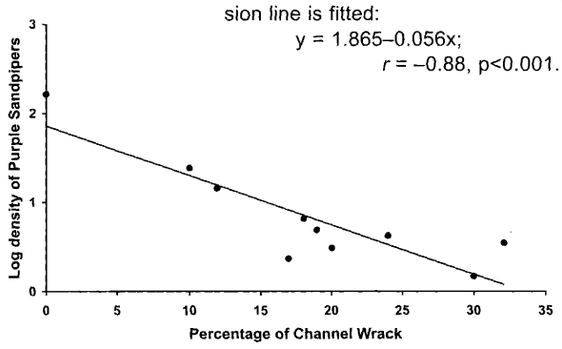


Fig. 3. Shore profiles down transects 2 and 8, and the ranges (in black) of the main seaweeds and invertebrates.

Fig. 4. The relationship between the log density of Purple Sandpipers in winter and the percentage of Channel Wrack on different shore sections at Gourdon. The regression line is fitted:
$y = 1.865–0.056x$;
$r = –0.88$, $p<0.001$.



DISCUSSION

The median flock size for Purple Sandpipers was only 2 when not roosting, and the average bird was in a flock of 4. These flock numbers are small compared to some species (e.g. Knot *Calidris canutus* and Dunlin *C. alpina*) (Goss-Custard 1970), and perhaps reflect differences in food abundance, foraging substrate and foraging methods. On rocky shores, the prey is generally visible on the surface, so, in contrast to tactile foragers on mudflats, the Purple Sandpiper will be able to forage visually and have a wider search path whilst foraging, like plovers. This technique would lead to greater interference between neighbours unless the birds were well spaced out (Young 1989). However, Purple Sandpipers probably also find food by taste and touch (Gerritsen *et al.* 1983) so when probing into clumps of seaweed, close neighbours could be tolerated.

A consequence of spacing and being in small flocks is that more time needs to be devoted to scanning for predators. Metcalfe (1984) showed that Purple Sandpipers devoted more time to being vigilant as the number of neighbours they could see decreased, and they also made use of Turnstones *Arenaria interpres* to alert them about predators.

The highest density of Purple Sandpipers occurred where there was no Channel Wrack on the shore (Fig. 4). Channel Wrack is the highest fucoid on the shore so a high percentage of this seaweed is indicative of a shore shape that has a shallow slope initially, before dropping more steeply. In contrast, shores with little Channel Wrack fall steeply close to the high water mark so that a large area of the lower zones is exposed once the tide falls to the level of the barnacle zone. In this area, the birds feed on winkles and Blue Mussels (Summers *et al.* 1990), taking them from crevices between barnacles and rocks. Here, they also probe into clumps of *Mastocarpus stellata*. Thus, the negative association with Channel Wrack is equivalent to a preference for the lower zones.

The fact that Purple Sandpipers stay close to the water's edge when the entire inter-tidal zone is exposed (Fig. 2) also suggests that they prefer the lower zones on the shore. There are several possible explanations for this dispersion. The lower shore is perhaps safer from land based aerial predators such as Sparrowhawks *Accipiter nisus*. For example, Redshanks *Tringa totanus* are less at risk from Sparrowhawk predation as distance from cover increases (Whitfield 2003). Alternatively, it is perhaps more profitable to feed low on the shore (Dierschke 1994). Feare (1966) showed that the diet of Purple Sandpipers changed at different stages of the tide, utilising predominately winkles in the mid shore and Dog whelks *Thais lapillus* and Blue Mussels in the lower zones. These changes may be associated with changes in prey quality. Another possibility for preferring the zone close to the water's edge is that winkles and Dog whelks recently exposed by the falling tide, or splashed by the rising tide, are more likely to be active, allowing Purple Sandpipers to distinguish live prey from empty shells. More observations are required to establish how live prey is detected and how prey biomass and intake rates of Purple Sandpipers vary according to different stages of the tide.

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