The Purple Sandpiper *Calidris maritima* breeds mainly in the Arctic, from Canada in the west to the Taimyr Peninsula in Russia in the east. However, the breeding range also extends south to islands in Hudson Bay (56°N), Iceland (64–66°N), the mountains of southern Norway (60°N) (Cramp & Simmons 1983) and to the central Highlands of Scotland (57°N), where a tiny group of birds exists. Breeding was first recorded in 1978 (Dennis 1983) and a small population has persisted since then. Apart from data collected on numbers, no information has been published about this isolated group. This paper describes aspects of the habitat use, breeding biology and survival of Scottish Purple Sandpipers.

It is likely that the Scottish population was derived from one of the groups of wintering birds in the UK. These have been attributed to two main breeding populations, characterised by differences in bill length (Atkinson et al. 1981; Nicoll et al. 1988). Short-billed birds originate from southern Norway (Rae et al. 1986), while long-billed individuals may originate from Canada. Given the geographical variation in body size among Purple Sandpiper populations (Engelmoer & Roselaar 1998), data on biometrics of Scottish breeders were used to identify their likely origin.

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Methods

The long-term data on numbers of breeding pairs were obtained primarily from the records of the Rare Breeding Birds Panel (Spencer et al. 1991; Ogilvie et al. 2002, 2003).

Observations of breeding Purple Sandpipers were made at three montane sites at an altitude of over 1,000 m in the central Scottish Highlands, between 1987 and 1993. Visits to the three sites varied from several times per week between May and mid August for area A (c. 4 km²) to only once or twice over the course of each season for areas B and C (c. 2 km² and 8 km²). Probably all breeding pairs in area A were seen, but pairs could have been missed in areas B and C, especially those which failed to produce chicks.

Purple Sandpipers generally occur at low breeding densities (Tomkovich 1985; Summers & Nicoll 2004) and are inconspicuous. Incubating adults are cryptic, sit for long spells (Swanberg 1945; Cresswell & Summers 1988) and crouch when approached, often allowing humans to within 1–2 m before flushing (Bengtson 1970). Consequently, little attempt was made to locate all nests. Instead, nests were searched for in locations where pairs had been seen frequently, or where nests or nest-scrapes had been found previously. However, all pairs that hatched chicks in area A are likely to have been located, because adults usually gave alarm calls when humans approached within c. 50 m of chicks.

After locating a nest, the length and breadth of eggs was measured with dial callipers to 0.1 mm, and egg volume determined from the equation used by Väisänen et al. (1972) for Dunlins C. alpina, a species with similarly shaped eggs. Eggs were also floated in water to give an indication of the stage of incubation (fresh eggs sink in water whereas well-incubated eggs float). Visits were then made every few days (without necessarily flushing the incubating adult), with increased frequency when hatching was expected. Some adults were trapped, either at the nest or when accompanied by a brood of chicks, and were given a unique combination of colour rings. Chicks were usually ringed when a few days old in area A, but some may have escaped detection in areas B and C. The following measurements were taken from adults: maximum wing length, bill length (exposed culmen), head length (nape to bill tip) and foot length (tarsus plus longest toe; Anderson 1975), all with a stopped rule to 0.5 mm or 1 mm; and mass with a Pesola balance to 1 g. The total head length of growing chicks of known age was used to derive a growth curve, and this was used to calculate the age of chicks whose nests had not been discovered. Adult males were distinguished from...
females by their shorter bill lengths (Cramp & Simmons 1983).

The vegetation community, as characterised by McVean & Ratcliffe (1962), and physical features were recorded within a 1-m radius of both full-grown birds (adults and fledged young) and broods throughout the breeding season. Only the dominant and up to two co-dominant habitat features were noted per sighting. At two nests, the percentage cover of habitat features within 1 m was estimated.

Results

Arrival on the breeding grounds

During the detailed study, one colour-ringed bird was seen at an altitude of 920 m on 9th May, some 130 m elevation below, and 1 km from, its breeding territory. Otherwise, the earliest birds were recorded between 13th and 31st May in each of the seven summers (mean = 19th May). In at least five years, birds were already paired when first seen.

Numbers

The maximum number of breeding pairs per season fluctuated between one and four between 1978, when breeding was first recorded, and 2001, as reported to the Rare Breeding Birds Panel (fig. 1). During the intensive study (1987–93), between one and five pairs were discovered each year. In some years, more were reported to the RBBP than were recorded in the intensive study. Between one and three pairs were present in the main study area (A) of c. 4 km² (table 1). In addition, single unpaired adult males were identified in two summers and they displayed over large areas. Known (colour-ringed) pairs remained together prior to laying, and ranged over areas of between 100 and 150 ha.

Table 1. Number of breeding pairs and breeding success of Purple Sandpipers Calidris maritima on the Scottish breeding areas from 1987 to 1993. All counts, especially in study areas B and C, and of broods, are minima. Values in parentheses indicate that no young were seen but were assumed to be present by the behaviour of the attendant male. Broods more than 20 days old had fledged. * denotes colour-ringed chicks.

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<tr>
<td>Number of pairs</td>
<td>3</td>
<td>2–3</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
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<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>12</td>
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<td>Broods &gt;10 days old</td>
<td>2</td>
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<td>1</td>
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<td>0</td>
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<td>9</td>
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<td>Broods &gt;20 days old</td>
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<td>1</td>
<td>1</td>
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<td>0</td>
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<td>6–7</td>
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<td>0</td>
<td>3</td>
<td>1</td>
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<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Broods &gt;10 days old</td>
<td>0</td>
<td>(1)</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4–5</td>
</tr>
<tr>
<td>Broods &gt;20 days old</td>
<td>0</td>
<td>(1)</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>4–5</td>
</tr>
<tr>
<td>Number of chicks ringed</td>
<td>1</td>
<td>2*</td>
<td>7</td>
<td>4</td>
<td>4*</td>
<td>4</td>
<td>1</td>
<td>23</td>
</tr>
</tbody>
</table>
Laying and incubation

One nest was found before laying commenced. The clutch of four eggs was laid between 25th and 30th May and hatched on 22nd June (incubation period of 23 days). In the following summer, the same female laid her fourth (last) egg on 1st June and the clutch hatched 22 days later. In total, five nests were located, all of which hatched young (no failures in a total of 102 days of observation). A sixth nest with at least two broken eggs was located post-failure near a well-used footpath. The pair concerned re-nested on 26th or 27th June and the male was subsequently located with a brood late in the season. There were four eggs in all five extant clutches. The mean egg dimensions were 34.57 mm (sd = 0.94, range = 32.9–36.5 mm) x 25.94 mm (sd = 0.62, range = 25.0–27.3 mm; n = 20) and mean volume was 10.61 cm³.

The percentage cover of plants and boulders within 1 m of two nests was as follows: nest 1, 70% Three-leaved Rush Juncus trifidus, 20% boulders, 10% Dwarf Willow Salix herbacea; nest 2, 50% Mat-grass Nardus stricta, 30% Dwarf Willow, 10% moss and 10% Stiff Sedge Carex bigelovii.

Hatching dates and chick survival

The first nests hatched on 18th June, and the peak of hatching occurred soon afterwards (median date = 27th June, fig. 2). Two late nests hatched on approximately 20th and 28th July and may have been relays after previous failures. Pairs incubated through snowfalls of 10–15 cm that caused many neighbouring Dotterels Charadrius morinellus and Snow Buntings Plectrophenax nivalis to fail (Smith & Marquiss 1994). The five monitored clutches (20 eggs) produced 18 hatched chicks (90% hatching success), giving a mean brood size at hatching of 3.6. Although no systematic observations of brood survival were made, the alarm calls of adults attending broods signalled when chicks were still alive. However, some adults were less demonstrative and broods moved over large distances (observations up to 2 km apart), so the estimate of brood survival was conservative. In area A, 12 of 14 pairs were seen with hatched chicks. Of ten broods that were first seen when less than five days old, at least eight survived to ten days old and at least five reached 20 days old. One chick could fly when 19 days old, so young fledged successfully from at least five broods. Including all study areas, 19–21 pairs produced fledged young from at least 10–11 broods (table 1). The average brood size decreased from 2.3 chicks (n = 14 broods) in the first week after hatching, to 1.5 (n = 8 broods) in the second week, and 1.7 (n = 6 broods) in the third week. These values for brood sizes are probably underestimates because the chicks became widely dispersed and difficult to count. Therefore, a conservative estimate for productivity was 0.81–0.98 fledged young per pair.

The oldest fledgling known to have a parent in attendance was 26 days old, and the last date on which an adult was seen with a brood was 2nd August. Solitary chicks younger than 25 days old were not observed, though such chicks would have been difficult to detect if the adult had deserted them. Fledged chicks were also inconspicuous and were rarely seen more than once after fledging. Independent chicks from six broods were seen when between 27 and 37 days old, and apparently vacated the breeding grounds in late July or early August.

Brood-rearing was undertaken mostly by males (10 of 11 broods). However, one female was seen attending chicks and this unusual behaviour requires a full description. In May and June 1989, a previously colour-ringed male Purple Sandpiper was seen with an unringed female on the same territory that he had occupied the pre-

![Fig. 2. Hatching dates of Purple Sandpiper Calidris maritima clutches on the Scottish breeding areas between 1987 and 1993.](image-url)
vious summer. The unringed female was located with a two-day-old brood in the same area on 24th June and she was trapped and colour-ringed. Subsequently, she was seen with her brood on four occasions until they were 19 days old, at which time they could probably fly. Her mate was never seen with the brood, although he was seen in the territory when the young were five days old. The male was originally colour-ringed in 1987, and in both this year and 1988 he was seen alone attending broods on six occasions when the chicks were between five and 15 days old. Furthermore, in the summer following the female’s unusual behaviour (1990), the same pair nested together again, and on this occasion, only the male attended the chicks (on three occasions when they were between two and ten days old). In 1991, the female, but not the male, returned to breed. Only her new mate (ringed on the nest) was seen with the brood, on three occasions when they were 10–18 days old.

**Adult return rates**
Seven adults (five males and two females) were colour-ringed (all but one in area A) and five returned in the following summer(s). The overall return rate between summers was 64.7% (se = 11.6%, n = 17 possible returns). All 12 returns of ringed birds (including one reported in 1996) were to the same territory where the bird was ringed. The oldest bird was ringed as an adult in 1991 and was still breeding on the same territory in 1996. Individuals that failed to return in one summer were not seen subsequently, indicating permanent emigration or death. One female was found long dead on the study area two summers after it was ringed. On another occasion, freshly plucked breast feathers were found, suggesting raptor predation.

Only one ringed chick out of 22 ringed up to the penultimate year of the study is known to have returned to breed. It was ringed in 1987, and recorded as a male with a fledged brood in area B in 1990 (c. 3 km from its natal nest). It bred in the same area in 1991.

**Habitat use**
Full-grown Purple Sandpipers were most frequently associated with *Juncus trifidus* heaths (table 2). They were also found on dry ridges dominated by *Carex bigelowii*, *Rhacomitrium lanuginosum* heaths, or in wet, mossy flushes and by streams or pools. Adults with broods had similar habitat associations (table 2). The only significant difference between the two groups of birds was in their frequencies of occurrence with *Rhacomitrium* ($\chi^2 = 4.6, P = 0.03$). Almost all birds (94% of 63 observations) were on flat or gently sloping ground.
Adult biometrics and origin
Females were larger than males, especially for bill length (by 16.1% and 3.3–10.9% for other linear measurements; table 3). Most birds retained some winter feathers on the head and mantle. No moult of flight feathers was recorded in the six adults trapped with young chicks.

A comparison of the bill lengths of different breeding populations clearly shows that the mean length for Scottish birds closely matches that of birds from southern Norway (fig. 3). This is also the origin of one of the main wintering groups in the UK (Summers 2002). Egg size also varies among Purple Sandpiper populations, and the Scottish eggs had similar proportions to Norwegian eggs (mean length 36.16 mm, breadth 25.78 mm and volume 10.93 cm³; Innes 1979, Summers & Nicoll 2004). Therefore, it is most likely that the Scottish breeding population originated from Norway.

Discussion
Occupancy and habitat use
One observation indicated that birds arrive on lower ground before occupying breeding territories. Few of such arrivals would have been detected, however, because the lower slopes were not searched systematically. In most summers, large tracts of snow-free ground (including previous nest-sites) were available long before the birds returned, indicating that spring arrival was probably not dictated by snow conditions. Any snowfall in late May could have delayed breeding temporarily, but once the birds were nesting, moderate falls of snow did not prevent incubation.

Although the number of territories counted in area A was probably accurate, 1–2 pairs per year may have gone undetected in areas B and C, especially if these failed to hatch chicks. Therefore, only the breeding density in area A (0.25–0.75 pairs per km²) is regarded as accurate. This density is less than that reported for southern Norway (2–3 pairs per km²; Cane 1979), but not as low as in some parts of the Arctic (Tomkovich 1985; Summers & Nicoll 2004).

Colour-ringed birds were not known to move to other parts of the study area, and both sexes returned to their original territory, even if a partner did not return. There were two recorded instances of unmated birds (both males). This is perhaps not surprising in such a small

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Table 2. Habitat characteristics associated with Purple Sandpipers Calidris maritima breeding in Scotland, both full-grown birds (pairs, single adults and fledged young) and broods. Totals exceed 100% because more than one habitat characteristic may occur at a site.

<table>
<thead>
<tr>
<th>Habitat feature</th>
<th>Full-grown birds (n = 48)</th>
<th>Broods (n = 26)</th>
<th>All birds</th>
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</thead>
<tbody>
<tr>
<td>Juncus trifidus</td>
<td>56.3%</td>
<td>53.8%</td>
<td>55.4%</td>
</tr>
<tr>
<td>Carex bigelowii</td>
<td>27.1%</td>
<td>7.7%</td>
<td>20.3%</td>
</tr>
<tr>
<td>Rhacomitrium lanuginosum</td>
<td>20.8%</td>
<td>0.0</td>
<td>13.5%</td>
</tr>
<tr>
<td>Nardus stricta</td>
<td>4.2%</td>
<td>7.7%</td>
<td>5.4%</td>
</tr>
<tr>
<td>Empturum sp.</td>
<td>2.1%</td>
<td>0.0</td>
<td>1.4%</td>
</tr>
<tr>
<td>Deschampsia flexuosa</td>
<td>2.1%</td>
<td>0.0</td>
<td>1.4%</td>
</tr>
<tr>
<td>Snow-bed community</td>
<td>4.2%</td>
<td>7.7%</td>
<td>5.4%</td>
</tr>
<tr>
<td>Boulders</td>
<td>2.1%</td>
<td>0.0</td>
<td>1.4%</td>
</tr>
<tr>
<td>Pool</td>
<td>8.3%</td>
<td>11.5%</td>
<td>9.5%</td>
</tr>
<tr>
<td>Stream</td>
<td>4.2%</td>
<td>7.7%</td>
<td>2.7%</td>
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<td></td>
<td></td>
<td>15.4%</td>
<td>8.1%</td>
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Fig. 3. Mean bill lengths of male (circles) and female (squares) Purple Sandpipers Calidris maritima from different breeding populations, arranged from west to east. Vertical lines show 95% confidence limits. The data are from Summers et al. (1988), Nicoll et al. (1991) and Engelmoer & Roselaar (1998).
The only Scottish chick known to return and breed was not seen in its first and second summers. It is likely to have bred for the first time as a one-year-old bird (Summers & Nicoll 2004), however, and escaped detection in two summers.

Adults and broods were both found predominantly in Arctic/alpine habitats (*Juncus trifidus* and *Carex bigelowii* heaths), which are restricted in Britain to northern montane areas (McVean & Ratcliffe 1962). Here, the vegetated areas form a mosaic with areas of bare ground or boulders. Boulder areas are common to other breeding areas in the Arctic and perhaps provide some shelter for the chicks. The birds were also found by water or in flushes.

**Breeding and population dynamics**

Given a laying period of five days, an incubation period of 22–23 days (similar to values given by Cramp & Simmons 1983 and Pierce 1997), and a median hatching date of 27th June, most clutches would have been initiated in late May/early June, approximately 1–2 weeks after the birds were first seen on the breeding grounds. Therefore, breeding commenced at a similar time to that in southern Norway (Innes 1979).

Hatching success was high and about half the pairs reared broods, with a mean size of 1.7 chicks, giving an overall productivity of around 0.9 fledged young per pair. Comparable data from Svalbard showed that a mean clutch size of 3.84 gave rise to 3.77 hatched chicks per successful nest. Nest survival was 49% so that the number of chicks hatched per pair was 1.85. Further losses of 33–50% before fledging brought the productivity to 0.93–1.24 fledged young per pair (Payne & Pierce 2002). Thus, productivity in Scotland was not dissimilar to that on Svalbard, and was better than that for other calidrid sandpipers: 0.7 fledged young per adult for Temminck’s Stints *C. temminckii*, where the male and female have a clutch each (Hildén 1978); 0.52 fledged young per pair for Dunlins (Soikkeli 1967); and 0.26–0.30 fledged young per pair for a declining population of Dunlins (Jönsson 1988).

The return rate (probably close to annual survival) of the Scottish breeding Purple Sandpipers was 64.7% (se = 11.6%). This return rate is similar to that for Purple Sandpipers in Svalbard (54% of females and 60% of males; Payne & Pierce 2002) and lies in the middle of values for other small monogamous calidrid sandpipers: 50% and 47% for male and female Semipalmated Sandpipers *C. pusilla*; 58% and 49% for Western Sandpipers *C. mauri*; 65% and 38% for Least Sandpipers *C. minutilla*; 77 and 71% for Dunlins; and 74% for Rock Sandpipers *C. ptilocnemis* (Oring & Lank 1984; Gill et al. 2002). It was, however, smaller than that recorded during a study of wintering Purple Sandpipers in Scotland, including Norwegian birds (79.5%, Summers et al. 2001).

Other studies of wintering Purple Sandpipers estimated annual survival at 75% and 57% in two years (Burton & Evans 1997), and 36% and 80% for first-years and adults respectively (Dierschke 1998). There was a very low return rate of birds marked as chicks. Only one chick (4.5%) was found out of 22 marked up to 1992, although the small number colour-ringed made detection difficult. Natal philopatry is typically low in sandpipers, however (3.1% for Semipalmated Sandpiper, 3.7% for Western Sandpiper, 8.1% for Temminck’s Stint and 3.6–11.2% for Dunlin; Oring & Lank 1984). Therefore, although based on small sample sizes, the different components of the demography of Scottish Purple Sandpipers are not dissimilar to those of other small sandpipers, and may be adequate to maintain the small population. The counts derived from Rare Breeding Birds Panel data (fig. 1) suggest repeated fluctuations between one and four pairs. This instability could have been due to differences in 

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**Table 3. Biometrics of breeding Purple Sandpipers *Calidris maritima* in Scotland.** Values in parentheses represent measurements of the same male in two different summers.

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<tr>
<td>Bill length (mm)</td>
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<td>47, 49, 48.5, 49.5, 54</td>
<td>49.6</td>
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<tr>
<td>Foot length (mm)</td>
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<td>47.9</td>
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<tr>
<td>Mass (g)</td>
<td>50, 58, 60, 64, (48, 66)</td>
<td>57.8</td>
</tr>
<tr>
<td>Wing length (mm)</td>
<td>130, 137</td>
<td>133.5</td>
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<tr>
<td>Bill length (mm)</td>
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<td>28.8</td>
</tr>
<tr>
<td>Head length (mm)</td>
<td>54, 56</td>
<td>55.0</td>
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<td>Foot length (mm)</td>
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<tr>
<td>Mass (g)</td>
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survey effort between years, though even in our study area A, which was consistently well-surveyed, there were losses of up to two pairs. Despite these erratic changes, the population has persisted, but not expanded, in the main area. Purple Sandpipers have been recorded on other Scottish mountains, so it is possible that the Scottish breeding population is larger than the number recorded for the main area. Nevertheless, the area of Arctic-alpine habitat is small in Scotland and it is unlikely that the population of Purple Sandpipers will ever be large.

Parental care
In most monogamous single-clutch waders, the parents share incubation. However, males often assume a greater role towards hatching and play a greater part in brood care (reviewed by Miller 1985). In some species, both parents remain with the brood for a week or more after hatching, before one parent, usually the female, leaves the brood in the care of the male until the chicks fledge (e.g. Dunlin, Soikkeli 1967; Semipalmated Sandpiper, Gratto-Trevor 1991). In the closely related Rock Sandpiper, the male usually attends the chicks (68–81% of observations) and on some occasions both parents attend, at least until the chicks are 8–9 days old (Gill et al. 2002). Initially, it was thought that only male Purple Sandpipers cared for the chicks (Swanberg 1945), but later observations showed that some females occasionally did so (5–10% of broods; Pierce 1997; Summers & Nicoll 2004). A possible explanation for the early departure of the female is that, by the end of incubation, she is in a poorer condition than the male, having laid the clutch and participated in incubation, which restricts feeding (Ashkenazie & Safriel 1979; Holt et al. 2002). Until this study, there was no information about the behaviour of the male when the female did attend the brood. In the case of the one brood in our study attended by the female, the male was still present in the territory. Moreover, he was known to have reared broods alone in both of the previous and following summers. The retention of brood-rearing behaviour in female Purple Sandpipers would presumably be advantageous if they lost their mate during incubation or at hatching, but in this case, the male was available and apparently capable of attending the brood. Therefore, it is unknown why the female took on brood-rearing duties in this case. In the Rock Sandpiper, a female was seen persistently chasing her mate after the chicks hatched, and she alone attended the chicks (P. Tomkovich in litt.).

Females were rarely seen after the brood hatched, and males left quickly after the chicks reached independence. None of the trapped adults had begun wing moult (birds trapped with chicks up to nine days old). Fledged young departed within two to three weeks of fledging, having lost the majority of their chick down.
These birds may have departed immediately for the wintering areas, as found for Purple Sandpipers that breed in the mountains of Norway (Atkinson et al. 1981; Cresswell & Summers 1988).

Population origins
Comparisons of biometrics of adults and eggs indicated that the most likely origin of the Scottish population is Norway. In Britain during winter, Norwegian birds occur mainly on the east coast, between Kincardineshire and Yorkshire, with smaller numbers elsewhere (Nicoll et al. 1988). It is conceivable that the colonisation of the Highlands may not have been from the main wintering areas on the east coast, but from the relatively few wintering birds on the west coast, as they flew across Scotland on spring migration.

Threats
The small size of the breeding population means that it could easily die out through chance events or suffer inbreeding. Nonetheless, the population has persisted for 25 years, so several generations of birds have been involved. Purple Sandpipers are tolerant of people passing by, so hill-walkers should not disturb them unduly. Unfortunately, the breeding area is known to egg-collectors, who pose a greater threat. In addition, corvids Corvus spp. and gulls Larus spp. are common predators of nests in the Scottish mountains. Purple Sandpiper nests are difficult to find, however, because the sitting bird does not flush easily, so few clutches appear to be lost to collectors or natural predators. During this study, nest predation was not recorded. One nest with broken eggs was found, although it is not known why this nest failed. It appears that adults are occasionally lost to predators.

Climate change is regarded as a threat to montane birds in Scotland and it is likely that their numbers will decline as the climate becomes warmer (Hall et al. 1999). This process is likely to affect Scotland's small population of breeding Purple Sandpipers.

Acknowledgments
Fieldwork for this study was carried out while RDS received support from Scottish Natural Heritage's Mountain Plateau Ecology Project. The drafts were kindly commented upon by Keith Duncan, Mark Hancock, Pavel Tomkovich and Jeremy Wilson.

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Scottish Purple Sandpipers

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