Monitoring wader productivity during autumn passage in Iceland

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From mid July to early September 2005, age-proportions of 10,884 waders in 439 flocks were recorded in S and W Iceland. The aim was to provide current information about the timing of migration of age groups of high arctic and Icelandic breeding waders and to investigate the feasibility of using age proportions of waders in Iceland in autumn as a productivity monitoring tool. Juveniles of the high arctic species began to arrive in early to mid August whereas fledged juveniles of most resident species were already present in small numbers when the survey started. Potential sources of bias, like the effects of habitat, spatial and temporal scales and flock sizes on the proportion of juveniles recorded, are addressed. The differences between measuring juvenile proportions during passage and in winter are discussed.

INTRODUCTION

Recording of wader reproduction rates on wintering sites, mostly of birds caught for ringing, is becoming an ever more common practice and is proving to be a very useful tool for large-scale monitoring of wader breeding success (Minton 2003, Clark *et al.* 2004, Robinson *et al.* 2005). Monitoring of wader age-proportions during autumn passage has received much less attention. In most waders, juveniles migrate separately and later than their parents on their first autumn migration (Cramp & Simmons 1983). As a result, populations at autumn passage sites usually show a steady increase in the juvenile proportion (JP) and/or bimodal distributions of passage numbers when adults pass through and only juveniles remain (e.g. Gardarsson & Nielsen 1989, Gunnarsson 2001). The shape of these relationships and the timing of the age-shifts can give important information about age-specific migration patterns, productivity and annual variation in timing of breeding, given that there is relevant background data available for comparison. The biases associated with estimating JP in winter are well known (Minton 2003, Clark *et al.* 2004). During autumn migration the ever changing JP provides an additional challenge.

Iceland is a key stepping stone for several high arctic populations on the East Atlantic flyway into breeding quarters in arctic Greenland and Canada (Gudmundsson & Gardarsson 1993) and holds internationally important populations of breeding waders (Gunnarsson *et al.* 2006). Currently, no systematic monitoring is being conducted on the demography or migration patterns of waders in Iceland. A successful monitoring scheme should preferably incorporate surveys of age-proportions in autumn, both of high arctic species and of resident populations. These could allow annual comparisons to be made of when juveniles of high arctic waders reach Iceland, when Icelandic and high arctic adult waders leave Iceland and potentially the breeding success of both, providing there is adequate sampling effort and validation of methods and data. This could also be compared to age-proportions and numbers further south along the flyway.

In autumn 2005, an investigation into age-proportions of several wader species was carried out in S and W Iceland. The aims of the survey were to explore the feasibility of using age-proportions of waders in Iceland in autumn as a monitoring tool, to identify some associated biases and potential pitfalls and to recommend the best way of continuing such studies. The shape of the JP-curves were compared to available data from previous studies (Wilson 1981, Gardarsson & Nielsen 1989, Gunnarsson 2001) in an attempt to assess annual variation in the rate of change of the JP which will influence the feasibility of between-year comparison.

METHODS AND STUDY AREAS

The survey was carried out at important wader stopover sites in S and W Iceland from mid July to early September 2005. Previous studies have shown that August is the month in which the age-proportions of most species change most rapidly (Wilson 1981, Gardarsson & Nielsen 1989, Gunnarsson 2001). The sites were on the coast from Eyrarbakki in the south and to Grundarfjördur on the north side of the Snæfellsnes peninsula and incorporated several habitat types (Fig. 1). Wader flocks on inland hayfields were also surveyed when encountered, as well as in other habitats (e.g. tidal sandflats) opportunistically. In total, 439 flocks were studied. Surveying was carried out on 23 days; only part of the study area was covered each day. The number of flocks of the different species that could be surveyed varied, ranging from only six flocks of Sanderling to 84 flocks of Eurasian Golden Plovers (Table 1). Overall, sample sizes of birds aged ranged from 1 to 401; the main limitation being the relatively small size of wader flocks in Iceland in late summer. Birds were aged from a distance with a telescope (e.g. Rogers *et al.*

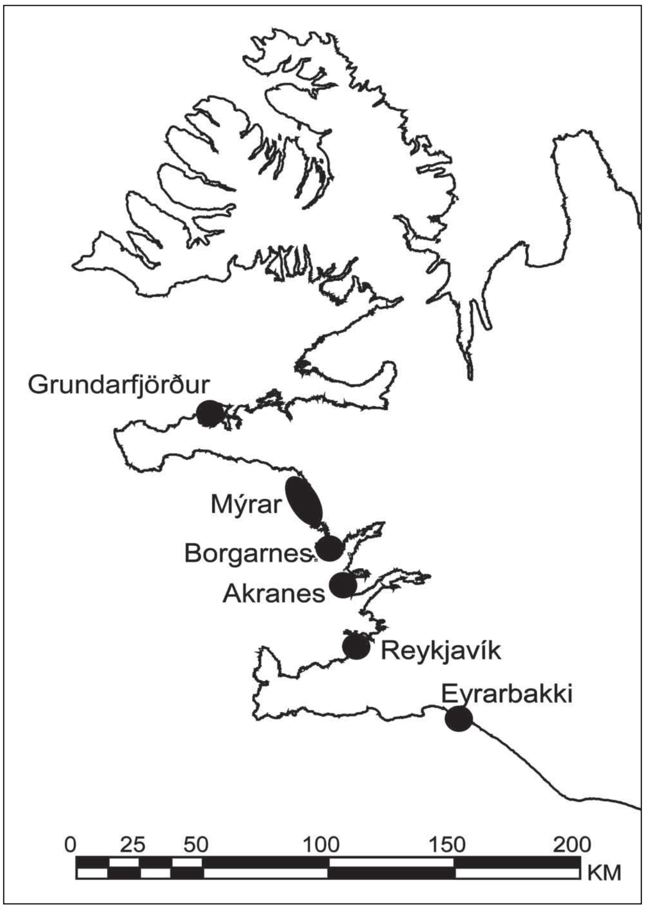

Fig. 1. Map of W Iceland showing the main coastal areas surveyed in S and W Iceland.

2005a). Where possible, all birds in a flock were aged but in some cases it was only possible to age a sample. In these, care was taken to distribute the sample as widely as possible across the flock in view of the fact that birds of different age may not be evenly distributed (Gunnarsson 2001, Minton 2003). Plumage characteristics and sometimes size (e.g. bill length in the larger waders) and colour of bare parts (e.g. bill colour of oystercatchers) were used to age birds (Prater *et al.* 1977, Cramp & Simmons 1983). The freshness of the plumages of juveniles and the paler edges of their wing coverts were particularly helpful in most species.

There was no means of distinguishing populations of species that breed in both Iceland and the High Arctic. These are Dunlin, Ringed Plover and probably also Purple Sandpiper (Wilson 1981, Gardarsson & Nielsen 1989).

Although the survey was neither randomised or stratified in terms of habitat type, all habitats in which birds were found were recorded and are described below. The potential effects of habitat type on JP were also explored statistically. Habitat types surveyed included sandy beaches, shingle beaches, mudflats, saltmarshes, tidal sandflats and hayfields. State of the tide, time of day and aspects of bird behaviour were also recorded but sample sizes were too small to investigate the effects of these factors statistically.

STATISTICAL ANALYSIS

Temporal shifts in age-proportions were first explored by including all data for each species, without considering potential spatial differences or data heterogeneity stemming from variation in flock-size. This was carried out by regressing JP (the number of birds aged as juvenile in a flock divided by the total birds aged (Minton *et al.* 2003a, b)) against date. This gives the overall pattern of the occurrence of adults and juveniles, particularly when the juveniles fledge (or arrive from the High Arctic), and when the adults and juveniles leave or pass through the study area. This was carried out using data for all flocks surveyed irrespective of flock-size giving each bird a sample status (Clark *et al.* 2004). For each day JPs were averaged to produce a single day-mean. Curves were fitted to the data, where appropriate, using the curve selection process in SPSS 12 for Windows.

To show temporal shifts in the age-proportions of the different species the analysis described above is useful. However, there are biases associated with the indiscriminate use of such data (see Clark *et al.* 2004) that need to be addressed. These particularly affect the relationship between flock-size and JP as juveniles often occur more frequently in smaller flocks (Boyd & Piersma 2001, Gunnarsson 2001, Minton 2003, Clark *et al.* 2004, Rogers *et al.* 2005b). To further explore potential sources of bias and differential distribution of the age-groups, general linear regression models (GLMs) were constructed for each species where sample sizes allowed. The JP was modelled as a function of flock size (i.e.

Table 1. Breakdown of the data analysed in this study of the proportion of juveniles in flocks of waders in S and W Iceland during July–September 2005.

Species	Number of flocks	Mean flock size (SE)	Number aged
Eurasian Oystercatcher *Haematopus ostralegus*	58	11 (2.0)	620
Eurasian Golden Plover *Pluvialis apricaria*	84	33 (4.3)	2,734
Ringed Plover *Charadrius hiaticula*	39	12 (1.9)	469
Dunlin *Calidris alpina*	56	50 (8.3)	2,815
Purple Sandpiper *Calidris maritima*	8	6 (2.5)	49
Red Knot *Calidris canutus*	19	43 (11.2)	819
Sanderling *Calidris alba*	6	15 (4.1)	88
Ruddy Turnstone *Arenaria interpres*	35	17 (3.9)	610
Redshank *Tringa totanus*	56	15 (2.9)	845
Black-tailed Godwit *Limosa limosa*	66	26 (3.6)	1,726
Whimbrel *Numenius phaeopus*	12	9 (2.6)	109
Total	**439**		**10,884**

number aged per sample), date and habitat type (categorical) as main effects and the interaction term date × flock-size (Clark *et al.* 2004). At first, all four variables were entered; then the least significant ones were removed one by one to produce the minimum adequate model. The LSD post hoc procedure in SPSS 12 was used to find differences in the effects of categorical variables. However, it should be noted that it assumes equal variances and computes all pair-wise comparisons with *t*-tests without adjusting the error rate stemming from multiple comparisons. The species specific details are set out in the results. Alpha level was 0.05 in all tests.

RESULTS

Overall, 10,884 waders of eleven species were aged in 439 flocks (Table 1). Data were collected on 23 days between mid July and early September.

Eurasian Oystercatcher

Fifty-eight flocks of oystercatchers were surveyed and they produced 12 day-means (Fig. 2). On average, the oystercatcher flocks contained about 25% juveniles from late July until surveys ended. Oystercatchers are different from most of the other species in this study in that the chicks and juveniles are fed by their parents, often until long after fledging (van de Kam *et al.* 2004). As a result, the age-classes are more likely to migrate together. Thus fledged juveniles are likely to appear in the company of adults and hence the increase in JP is likely to be asymptotic (Fig. 2). The data suggests that this is the case, but surveys were probably not carried out long enough for a clear pattern to emerge. Therefore a curve was not fitted to the data for oystercatcher. Thirty-two of the oystercatcher flocks were located on hayfields and 13 on each of mudflats and sandy beaches. The final GLM for oystercatcher contained only habitat type ($F_{2,54} = 4.8$, $R^2 = 0.16$, $P = 0.012$). The post hoc test showed that the mean JP was significantly lower on hayfields (0.15, SD±0.16) than on sandy beaches (0.36, SD±0.26) ($P = 0.003$). JP on mudflats was intermediate (0.24±0.15 SD) and was not significantly different from the others. This habitat difference might partly be due to progression in habitat use through time, as flocks on sandy beaches were found significantly later (mean = 2 August) than flocks in hayfields (mean = 26 July; dates expressed as days after 30 June: $t_{40} = 3.9$, $P = 0.001$). A higher proportion of adults may have left during this time explaining both the increase in JP through time and a higher JP on beaches.

Whimbrel

Whimbrels were aged in twelve flocks, producing seven day-means (Fig. 2). Flocks with only adults were encountered a few times from mid July to early August then no flocks were located until late August when two flocks of only juveniles were encountered on 26 August. Six of the Whimbrel flocks were located on heathland, three on hayfields and three on sandy beaches. Several flocks of unaged birds (though probably adults given the date, Fig. 2) were seen heading high out to sea on the south coast in the last days of July and the first days of August. The sample size for Whimbrel was too small to fit a GLM and no regression was fitted because of the distribution of the data.

Redshank

Fifty-six flocks of Redshanks were surveyed, giving eighteen day-means (Fig. 2). Redshank was the only species that showed a decline in the JP during the study period. The majority of birds in flocks were already juveniles when the survey started in the second half of July. There was a slight tendency for a decline in JP during the period of the study but 15 out of 18 day-means had greatly varying age-proportions ($Y = 366.48 - 0.0095X$, $R^2 = 0.27$, $P = 0.026$). Twenty-two of the Redshank flocks were on mudflats, 21 on sandy beaches, eight on hayfields and five on saltmarshes. The GLM for redshank returned no significant predictors of JP.

Black-tailed Godwit

Sixty-six flocks of Black-tailed Godwits were found, producing 16 day-means (Fig. 2). The first fledged juvenile in a flock was found on 19 July. JP increased sharply at the beginning of August and most adults had left by the end of the month ($Y = 598809 - 31.075X + 0.0004X^2$, $R^2 = 0.83$, $P < 0.001$). Forty-eight of the flocks were found in hayfields, 17 on mudflats and one on saltmarsh. Towards the end of the pre-migration period, godwits were exclusively found on mudflats and had stopped using hayfields. The overall GLM for Black-tailed Godwit was highly significant ($F_{1,62} = 63.9$, $R^2 = 0.51$, $P < 0.0001$) but contained only date as a significant predictor (Table 2).

Dunlin

Fifty-six Dunlin flocks were surveyed and produced 16 day-means (Fig. 2). Dunlins showed a very clear increase in JP from hardly any juveniles in flocks in mid July to about 50% by the end of the month ($Y = -330820 + 17.134X - 0.0002X^2$; $R^2 = 0.86$, $P < 0.001$). By the end of August, very few adults were left. Twenty-six of the Dunlin flocks were encountered on mudflats, 19 on sandy beaches, five on saltmarshes, and three on each of hayfields and shingle beaches. The overall GLM for Dunlin was highly significant ($F_{3,55} = 4.8$, $R^2 = 0.53$, $P < 0.0001$) and contained date, flock-size and the date × flock-size interaction (Table 2).

Red Knot

Nineteen flocks of knots were surveyed and they produced nine day-means (Fig. 2). The first knot flocks containing only adults were located at the end of July. JP changed sharply with the first juveniles being recorded in the first week of August and hardly any adults were left by the end of the month ($Y = -520573 + 26.956X - 0.0003X^2$; $R^2 = 0.86$, $P < 0.001$). Eleven of the flocks were located on mudflats, five on shingle beaches and three on saltmarshes. When running the GLM for knot, the sample sizes were small when split by habitat so the potential effects of habitat type were not explored. The overall GLM for knot was highly significant ($F_{2,17} = 40.6$, $R^2 = 0.84$, $P < 0.0001$) and contained date and the date × flock-size interaction (Table 2). The last adults seen in Iceland had mostly finished body moult.

Purple Sandpiper

Purple Sandpipers were only encountered eight times during

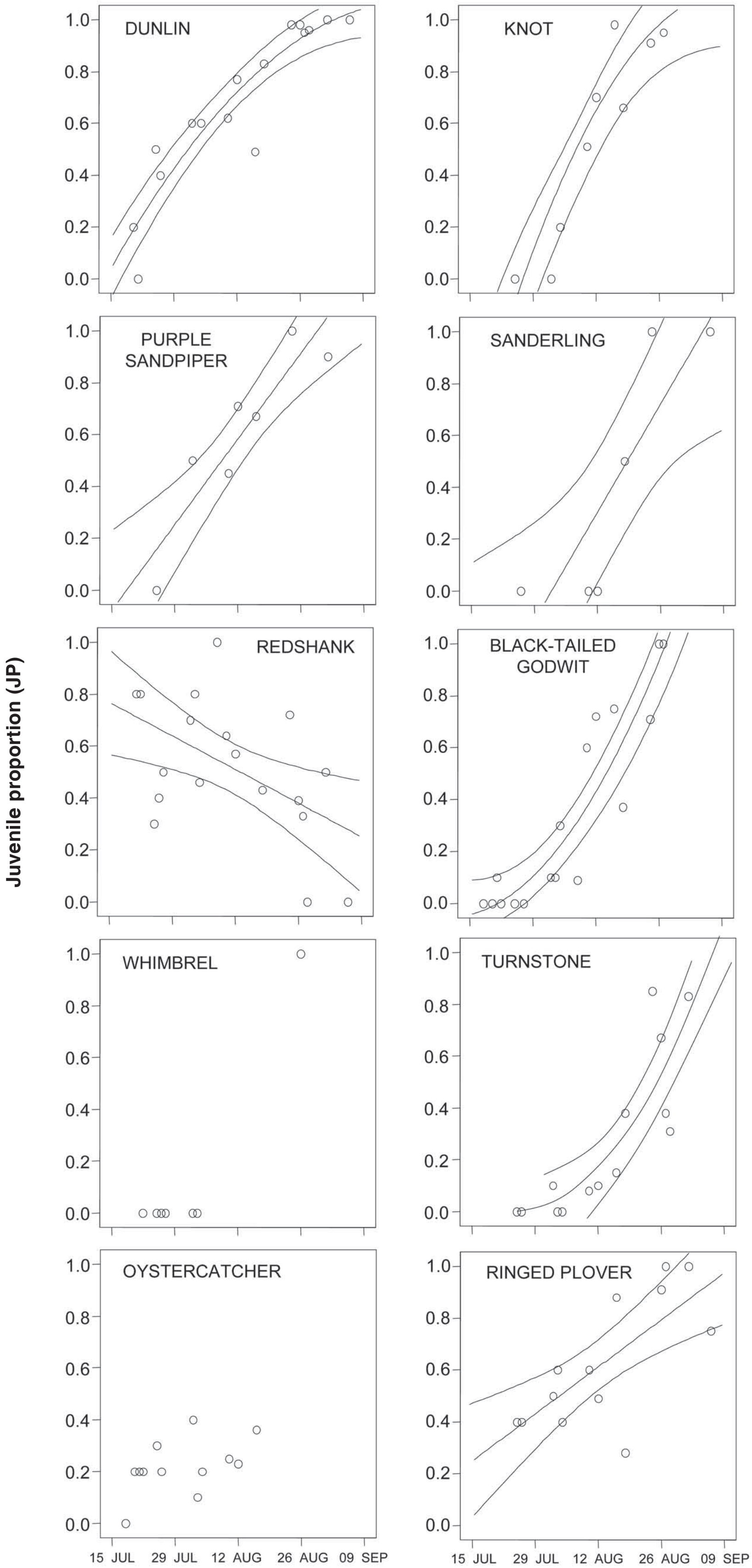

Fig. 2. Mean juvenile proportion per day during July–September 2005 for ten wader species in S and W Iceland plotted against date. Lines are linear or quadratic regressions (best fit according to curve fitting procedure in SPSS 12 for Windows) with 95% CIs. See text for details.

Table 2. Results of general linear models of juvenile proportion in wader flocks in W and S Iceland during July–September 2005 as a function of date, flock-size, habitat type and the date × flock-size interaction. Only species for which there were any significant predictors of juvenile proportion are included in the table. See Methods and Results for further details. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, NS $p > 0.05$.

	Date		Flocksize		Date × Flocksize		Habitat type	
	ß	T	ß	T	ß	T	ß	T
Eurasian Oystercatcher		NS		NS		NS	0.20	3.01**
Dunlin	0.011	4.10***	–0.005	–3.35**	0.000001	2.91**		NS
Red Knot	0.040	8.99***		NS	–0.000048	–2.32*		NS
Ruddy Turnstone	0.021	7.26***		NS		NS		NS
Black-tailed Godwit	0.023	7.99***		NS		NS		NS
Ringed Plover	0.009	2.47*		NS		NS	0.27	3.05**

the study period and 49 birds were aged producing seven day-means (Fig. 2). Although few, these flocks showed a marked increase in JP with mixed-age flocks occurring mainly in the first half of August ($Y = -907.64 + 0.0235X$, $R^2 = 0.83$, $P = 0.005$). The last flock was seen on 1 September with nine juveniles and one adult. All but two (which were on mudflats in W Iceland) of the Purple Sandpipers were found on sandy beaches in S and SW Iceland. The number of Purple Sandpiper flocks was too small to run a GLM.

Sanderling

Sanderling was the species that was encountered in flocks on the fewest occasions, just six times on 6 days (Fig. 2). Three adult-only flocks were encountered between late July and mid-August, one mixed flock on 18 August and juvenile-only flocks on 24 August and 6 September ($Y = -1154.764 + 0.0299X$, $R^2 = 0.74$, $P = 0.027$). All the Sanderlings were located on sandy beaches in S Iceland. The number of Sanderling flocks was too few to run a GLM.

Ruddy Turnstone

Turnstones were found in 35 flocks which produced 14 day-means (Fig. 2). The first adult turnstones were encountered at the end of July and the first juvenile was seen on 2 August. JP increased slowly until mid-August when it took off, very few adults were left at the end of August and beginning of September ($Y = 772857 - 40.088X + 0.0005X^2$, $R^2 = 0.73$, $P < 0.001$). Seventeen of the turnstone flocks were found on sandy beaches, 11 on mudflats, five on shingle beaches and two on saltmarshes. The overall GLM for turnstone was highly significant ($F_{1,33} = 52.7$, $R^2 = 0.62$, $P < 0.0001$) but contained only date as a significant predictor (Table 2).

Ringed Plover

Thirty-nine flocks of Ringed Plovers were located, producing 13 day-means (Fig. 2). When the first flocks were surveyed on 24 July, JP was already as high as 0.2. Then there was a steady increase and most birds surveyed were juveniles by the end of August ($Y = -484.43 + 0.0126X$, $R^2 = 0.50$, $P = 0.005$). Twenty of the Ringed Plover flocks were on sandy beaches, 16 on mudflats and three on saltmarshes. The overall GLM for Ringed Plovers was highly significant ($F_{2,35} = 8.2$, $R^2 = 0.33$, $P = 0.001$) and contained date and habitat as significant predictors (Table 2). The mean JP was significantly higher on sandy beaches (0.63, SD±0.31) than on mudflats (0.35, SD±0.25) ($t_{34} = 2.94$, $P = 0.006$), but there was no temporal trend in which habitats flocks were recorded in (with date expressed as days after 30 June: mean date for mudflat records = 40.4 (SD±10.5), and mean date for sandy beach records = 41.5 (SD±13.4; $t_{34} = 0.25$, $P = 0.81$) suggesting that there might be a difference in habitat selection between age groups (i.e. unlike oystercatcher which showed a temporal trend in the relationship between JP and habitat use).

Eurasian Golden Plover

Eighty-four flocks of golden plovers were surveyed producing 19 day-means. The JP ranged from 0 to 0.3 and showed no trend during the study period. Confident ageing became very difficult in the latter part of August as most adults had then moulted into winter plumage and the plumage of the (older?) juveniles had suffered some wear. Sixty of the golden plover flocks were found in hayfields, 13 on mudflats, nine on grazing pastures and two on sandy beaches. The GLM for golden plovers returned no significant predictors of JP.

DISCUSSION

Eurasian Oystercatcher

Juvenile oystercatchers are usually fed by their parents after fledging and it takes them months to become independent (van de Kam *et al.* 2004). Due to this life-history strategy, different from most of the other waders, JP will not progress in the same way but will probably be more stable, and affected more by productivity in a given year than age related differences in the timing of migration. Apart from one data point with a JP of 0 (Fig. 2), JP did indeed remain rather constant for oystercatcher at around 0.25. However, the temporal change in JP with habitat might suggest that there is a proportionately faster departure of adult than juvenile oystercatchers from Iceland in autumn, possibly through non-breeders and non-successful breeders migrating earlier than adults accompanied by young. It is also possible that some of the difference is due to higher mortality of juveniles than adults. Although most Icelandic oystercatchers migrate south in winter, a few thousand remain (Gardarsson 1975), largely in the areas surveyed. This could also affect the result if there is an age-related difference in tendency to migrate.

Whimbrel

Whimbrel flocks are encountered irregularly in late summer, when they feed in loose aggregations, usually on heathland.

Studies of breeding Whimbrels in S Iceland have shown that most adults leave their breeding territories between mid July and mid August (Gunnarsson 2000), which is consistent with the results of the present study. The lack of sightings during most of August could be by chance or because juveniles do not start flocking until late August, leaving a gap of two to three weeks between the departure of the last adults and the start of the migration of the juveniles. Given the intensity of this study and the absence of any sightings of migrating Whimbrels after early August, it appears that the migration periods of adult and juvenile Whimbrels from Iceland are completely separated (at least they were in 2005). Gardarsson and Nielsen (1989) saw the last small flocks of migrating Whimbrels in SW Iceland on 30 August and 3 September in 1981. Given the results from this study, these are likely to have been juveniles. If it is true that adult and juvenile Whimbrel have completely separate migration periods, the use of age-proportions in autumn for monitoring productivity is likely to be problematic. Moreover their habit of foraging in loose aggregations on heathland prior to migration makes it difficult to obtain sufficient sample sizes. This study also suggests that adults and juveniles may not occur in mixed flocks. At dusk during late August and early September, juvenile Whimbrels use traditional roost sites (TGG unpubl. info.). Counting them in such places may be the best option for large-scale monitoring of Whimbrel productivity in late summer.

Redshank

JP for redshank was already high when the survey started and Redshank was the only species in which JP showed a declining trend. However, this pattern is greatly influenced by two late data points with a JP of zero so this should be interpreted with caution. There is a wintering population of 500–1000 birds in SW Iceland (Petersen 1998) that uses areas that were surveyed in this study. If those are more likely to be adults this might affect the JP towards the end of the study-period in the observed direction. In 2000, Gunnarsson (2001) recorded Redshank passage on a S Iceland estuary from the beginning of July to September. Maximum numbers occurred at the end of August with a steep drop at the beginning of September. Age-proportions were assessed twice during that study: on 17 August when only adults were present and on 5 September when only juveniles were found. In 1980, Gardarsson and Nielsen (1989) found that peak passage occurred on SW Iceland mudflats in July but migration continued only tailing off in Oct. They found the first fledged juvenile on 19 July.

Black-tailed Godwit

There were very few juveniles in Black-tailed Godwits flocks in July, but there was a sharp increase in JP in early August, continuing until the end of the month when almost all adults had left. In autumn 1980, Gardarsson and Nielsen (1989) found very few godwits on mudflats in SW Iceland in contrast to this study in which most of the godwits were found on mudflats. In 2000, Gunnarsson (2001) recorded a flock of pre-migratory juveniles on a S Iceland estuary between 13 August and 5 September. No other data on the autumn migration of Black-tailed Godwits in Iceland are available.

Dunlin

Dunlins showed a clear increase in JP throughout the study period. They were the only species in which JP was affected by flock-size. JP of Dunlins was also affected by the date × flock-size interaction term. Previous studies on pre-migrating Dunlin in Iceland have shown a relationship between JP and flock size (Gunnarsson 2001). Plausible reasons for this are either that the age-groups differ in small-scale habitat selection and/or that the adults move faster than the juveniles when foraging. This study shows that there is also a temporal component to this pattern as juveniles become less likely to occur in smaller flocks during the few weeks they stay in Iceland after fledging. It is likely that the short period between fledging and when they migrate is important in the development of flocking skills and risk-averse behaviour. However, to some degree this may be confounded with the departure of the adults and the arrival of more juveniles leading to an increase in flock-size and a higher JP. When monitoring age-specific migration or large-scale productivity of Dunlin this must be taken into account both in the field and statistically.

High arctic Dunlins *C. a. arctica* probably pass through Iceland in spring and autumn in unknown numbers. No attempt was made to separate these from the local breeding *schinzii* so it is not known to what extent this affects the results. Wilson (1981) found no *arctica* dunlins in catches totalling 511 on the west coast of Iceland in autumn 1972. Wilson (1986) and Whitfield & Magnusson (1989) also speculate that the autumn passage of *arctica* in Iceland may be negligible. Notes on the age distribution on pre-migrating dunlins in NE Iceland in 1986 showed that JP in flocks in late July was *c.*0.5 (Whitfield & Magnusson 1987), which is very similar to this study. Age-proportions on a study site in S Iceland in 2000 changed much more rapidly than reported here and JP had already reached *c.*0.9 at the beginning of August (Gunnarsson 2001), three weeks earlier than in this study. A similar pattern was found on mudflats in SW Iceland in 1980 (Gardarsson & Nielsen 1989). Wilson (1981) stated that the major departure of juvenile Dunlins from Iceland is in late August. This is supported by other studies (Gardarsson & Nielsen 1989, Gunnarsson 2001) which all show a sharp drop in Dunlin numbers at various sites in mid- to late August. The last adults to be seen in Iceland had largely completed their body moult which was not previously known.

Red Knot

Like Dunlins, Red Knots showed a clear increase in JP but at a faster rate. The first knots found were a flock of adults (30) in W Iceland on 25 July. The first juveniles were two birds in a flock of 167 on 2 August. On 10 August, JP was already up to 0.5 and by the end of the month the vast majority of adults had passed through. Wilson (1981) found the first adult knots in mid July and a peak of adult passage at the end of July. He found juvenile passage took place between mid-August and mid-September with a peak in the last week of August. Wilson (1986) found a similar pattern in NE Iceland with most flocks being seen in the latter half of July and early August and the first juveniles on 1 August. Gardarsson & Nielsen (1989) recorded knots from 10 July on mudflats in SW Iceland and only a few individuals after 3 August. They found the first juvenile on 29 July. All these first arrival dates of juvenile knots from the Arctic are very similar, grouped around the end of July and beginning of August. Knots showed a changing JP with the date and flock-size interaction term which suggests that the flocking behaviour of juveniles may change between their arrival and departure from Iceland. However, as with Dunlin, this may be confounded by the changing JP itself and the fact that most adults leave earlier than juveniles, leaving larger flocks consisting mostly of juveniles. More data are needed to tease apart the effects of these factors on JP.

Purple Sandpiper

Purple Sandpiper flocks were scarce in the study sites throughout the survey. However, the flocks that occurred did show an increasing JP. Purple Sandpiper is one of the species in which local breeding populations are likely to mix with high arctic passage migrants. As well as Icelandic breeders of the subspecies *littoralis*, Purple Sandpipers of the *maritima* race also occur in Iceland in autumn (G.T. Hallgrimsson, pers. comm.). No other Icelandic studies of JP in Purple Sandpipers in autumn are available for comparison. Purple Sandpipers are mainly birds of rocky shores of which none were included in this survey. Future studies should be extended to this habitat to obtain better data on this species (Summers *et al.* 2002).

Sanderling

Sanderling is not nearly as common in Iceland as several of the other species studied and only six flocks were encountered. The first adult Sanderlings were found on 26 July; the first juveniles on 18 August and only juveniles thereafter. In 2000, Gunnarsson (2001) found the first Sanderlings on 1 August on a S Iceland estuary and the last birds on 5 September. Wilson (1981) reports that the main migration of adults is from just before mid July to the first week of August and that juveniles pass through from mid-August to mid-September. Whitfield and Magnusson (1987) reported a few Sanderlings on passage through NE Iceland in July 1986 but none in August. Wilson (1986) found several Sanderlings in NE Iceland in July during visits in the 1970s and a small flock on 19 August in E Iceland. None of these studies allow data on JP to be extracted for comparison.

Ruddy Turnstone

Ruddy Turnstone showed an increasing JP, slowly until mid-August but then more quickly and by the end of August most were juveniles. The first juveniles were found on 2 August. Wilson (1981) concluded that adult passage begins at the end of July and continues through August and that juveniles pass from mid-August through most of September. Whitfield and Magnusson (1987) found turnstone passage from the latter part of July throughout August in NE Iceland in 1986 with the first juveniles appearing in the first week of August. Wilson (1986) found turnstones at several sites in NE Iceland in late July and early August in the 1970s. Therefore all studies show quite similar patterns, adult passage peaking in late July and the first juveniles arriving in the first week of August.

Ringed Plover

When Ringed Plovers started to collect in flocks in the last week of July, JP was already up to *c*.0.4. By the end of August, most of the adults had passed through. On a S Iceland estuary in 2000, Ringed Plover passage was from 3 July to 5 September, but peak passage was around mid-August. On 15 and 18 July, only adults were recorded but on 13 and 19 August JP was 0.38 and 0.40 respectively (Gunnarsson 2001). On mudflats in SW Iceland in 1980, Ringed Plover passage reached a peak at the end of July, but continued throughout August (Gardarsson & Nielsen 1989). Wilson (1981) states that the departure of adult Ringed Plovers is mainly in the latter half of July through August and that juveniles are present until the 3rd week of September. Wilson (1986) found that two flocks (each of *c*.100 birds) on mudflats in SE Iceland on 22 and 23 August 1971 both contained *c*.50% juveniles. It is probable that some high arctic Ringed Plovers pass through Iceland and a later peak in a bimodal distribution of spring passage has been attributed to these birds coming through in late May, a month later than resident breeders (Gardarsson & Nielsen 1989). However, the magnitude of the passage of high arctic Ringed Plovers through Iceland in autumn is unknown. In this study, Ringed Plovers showed a habitat related difference in JP which did not seem to be temporally structured. Many studies have shown habitat segregation of adult and juvenile waders (e.g. Ruiz *et al.* 1989, Durrell *et al.* 1996, Minton 2003) which is likely to be related to experience, but perhaps also preferences stemming from differences in morphology and/or requirements. When monitoring JP in Ringed Plovers habitat differences need to be incorporated.

Eurasian Golden Plover

Golden plovers showed no trend over the study period and ageing them with certainty became very difficult towards the end of August. The mean JP was around 0.1 overall but only comparison with data from other years will show whether that is an index of productivity in 2005. In 1980 on mudflats in SW Iceland, Gardarsson and Nielsen (1989) recorded the beginning of autumn passage in late July, peak in late September to early October and the last birds were seen in early November. They found the first juveniles on 3 August and an evenly increasing JP to *c*.0.60 towards the end of August.

FUTURE STUDIES

The main aims of this preliminary study were to provide current large-scale information about age-specific migration and to identify some of the factors that influence JP in each species so that it can be used as an index of productivity in the future. Spatial variation (except the variation that operates through habitat-type) was lumped to provide overall patterns of changing JP for each species. Future monitoring should aim for temporally more extensive data from key sites as this is likely to provide a better comparison between years. Even though correcting for sampling time is likely to be useful it might be more useful in some species (those where most juveniles remain after most adults have left) to count juveniles alone at selected sites (e.g. Robinson *et al.* 2005).

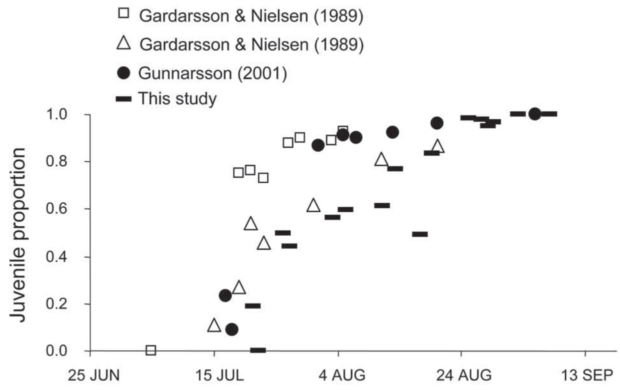

Fig. 3. Juvenile proportion in Dunlin plotted against date using four different datasets: (1) & (2) Gardarsson and Nielsen (1989) for two nearby mudflats in SW Iceland in 1980; (3) Gunnarsson (2001) for an estuary in S Iceland in 2000; and (3) this study.

For each species, this study highlights the appropriate period when sampling of age ratios should take place. Information on productivity will either be obtained simply by counting juveniles using the same sites in different years (and, for example, comparing maximum numbers) or by recording JP in relation to date. How variable JPs are on specific dates in different years will only become clear after more years of sampling.

Dunlin is the species for which the most JP data are available from this and other studies. When these are plotted together, it appears that there is considerable variation in the progression of JP, even between nearby mudflats in the same year (Fig. 3). However, the difference between the curves is almost all between mid-July and mid-August. Most of the Dunlin studies also showed that nearly all adult Dunlins have left by the end of August. Therefore, for this species, counts on staging sites from late August onwards are likely to produce useful indices of annual productivity. Similar thresholds are likely to exist for the other species and more data should clarify this.

Another issue that needs to be resolved is that for some of the species, two or more sub-populations (High Arctic and Icelandic) or even sub-species may occur together in Iceland in autumn (Wilson 1981). The most straightforward way of tackling this is to run a catching and marking programme parallel with counts and observations on staging sites. The use of stable isotopes in feathers might also help to distinguish birds that hatched on the young Icelandic geological substrate (basalt) from high arctic ones that are likely to come primarily from old (granite) substrates (Rubenstein & Hobson 2004).

IS RECORDING OF JUVENILE PROPORTIONS DURING AUTUMN PASSAGE USEFUL OR A WASTE OF TIME?

It has been suggested that data on JP during southward migration may be "... at best only qualitative" for estimating productivity (Minton 2003). Indeed, monitoring JP in passage populations (which is ever changing) does mean that additional factors have to be taken into account compared with monitoring in winter. However passage sampling could prove to be a very useful approach and in some cases the only possible approach, as it is in Iceland where most species leave for the winter. The accuracy of measured JP in autumn will depend on productivity in a given year, the relative timing of migration of the age-groups and possibly annual variation in proportions of different age-groups passing through study areas. Only multiple years of data will allow these factors to be separated but modelling JP within a GLM framework to separate confounding factors is likely to be a useful tool (e.g. Clark *et al.* 2004).

Correcting for sampling time will be particularly important in autumn but hopefully future studies will be carried out throughout the migration period to allow full comparison of the shapes of the JP curves between years. Data on JP collected in autumn as opposed to winter is subject to exactly the same caveats, i.e. it is difficult to know how accurate the information it gives is until datasets have been built up and can be compared with each other and with other indices of recruitment. For example, multiple years of data made it possible to link age-proportions of waders wintering in S Africa to arctic lemming-cycles (Summers & Underhill 1987) and showed that age-proportions of Ruddy Turnstones and Sanderlings wintering in Australia are highly correlated (Minton 2003). Analysis of long-term datasets is the only way to determine the usefulness of autumn monitoring. Early autumn sampling also has some major advantages over data collected by catching birds in the winter. The main one being that sampling is not restricted to sites and times as it is with most catching techniques. As a result, recording JPs in autumn is more flexible and can be successfully carried out anywhere, anytime during daylight hours, as long as juveniles are easily distinguishable from adults in the field. During the first weeks of the fledging period, as in the situation described here, it is very easy to separate adults from juveniles with a telescope. Another major benefit is that recording of JPs in the field can be done effectively by a single person, whereas successful catching (especially cannon-netting) is labour intensive and requires whole teams of people. In this study, for example, nearly 11,000 waders were aged in 439 samples with an input of only 23 person-days. In contrast, a day of cannon-netting will often exceed this in terms of fieldworker time (sometimes even without any success!). Moreover there are other types of valuable data that can be collected while measuring JPs in the field, particularly on timing of migration and numbers using different sites.

For most types of demographic data and their interpretation, long term studies are extremely valuable (Dunnet 1991) and in long-lived birds like waders, long-term datasets are essential for successful monitoring and conservation (Minton 2003, Robinson *et al.* 2005). Recording JPs on passage is cost-efficient and effective and should be encouraged where situations allow.

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