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Different timing of autumn migration of two Ringed Plover *Charadrius hiaticula* subspecies through the southern Baltic revealed by biometric analysis

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Ringed Plovers were trapped in Puck Bay (southern Baltic) between 1983 and 2002 during autumn migration. In adults a clear decrease of mean wing and bill lengths occurred between the third decade (ten-day period) of July and the first decade of August. A similar pattern was observed in juvenile wing lengths, whereas a sharp decline in mean bill length occurred later, between the second and the third decade of August. These changes in biometrics suggested that the larger birds passing through the study area in July belonged to the *hiaticula* subspecies and late migrants (adults caught from the beginning of August and juveniles caught from the third decade of August) were of the *tundrae* subspecies. This was supported by comparison of mean measurements of these early and late migrants passing through Puck Bay with data from other areas where only either *hiaticula* or *tundrae* occur. These data were used to compare the biometrics of adults and juveniles of each subspecies.

Within Ringed Plovers *Charadrius hiaticula* two subspecies are recognised: *tundrae* breeds in northern Europe and northern Asia, while *hiaticula* occupies more southerly areas (Glutz von Blotzheim *et al* 1975, Cramp & Simmons 1983). The Ringed Plover is one of the classic examples of leap-frog migration in which birds from more southerly populations winter close to the breeding grounds and those from northernmost parts of the breeding range make longer flights to more distant wintering grounds (Salomonsen 1955). The subspecies *tundrae* migrates to Africa across inland Europe, whereas *hiaticula* moves towards west European and north African wintering grounds mainly along the coasts of the Baltic and North Sea (Glutz von Blotzheim *et al* 1975, Cramp & Simmons 1983, Siefke & Kastepold 1985). The majority of adult *hiaticula* start moulting primaries at the breeding grounds and continue during migration, whilst *tundrae* do not start moult until they have reached their African wintering grounds in November, and they finish replacement of primaries in February (Glutz von Blotzheim *et al* 1975).

Previous published studies on autumn migration of the Ringed Plover through the southern Baltic have considered migration dynamics only with respect to general descriptions of the migration periods of both subspecies (Glutz von Blotzheim *et al* 1975, Siefke & Kastepold 1985, Meissner & Huzarski 2006). Birds of the *hiaticula* subspecies depart from their breeding grounds in July and adults migrate together with juveniles (Siefke & Kastepold 1985). Northern populations belonging to subspecies *tundrae* start their breeding-season and southward migration later than birds from more southerly areas (Glutz von Blotzheim *et al* 1975, Siefke & Kastepold 1985). In this subspecies, the migration periods of adults and juveniles are more separated in time than in *hiaticula*. Adult *tundrae* pass Denmark between mid August and the beginning of September, whereas juveniles occur there in September (Meltofte 1993). The aim of this paper is to describe the migration timing of *hiaticula* and *tundrae* more precisely based on an analysis of biometric data.

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METHODS

Study site

Birds were caught between 1983 and 1999, mainly in walk-in traps (Meissner 1998) placed on the Puck Bay coast at three closely positioned sites: at Jastarnia, in the Reda river mouth and at Rewa (Meissner & Remisiewicz 1998) (Fig 1). Fieldwork started in mid July and finished at the end of September. This period covered almost the whole period of Ringed Plover migration in the study area, which began about mid July and finished usually in the first days of October (Meissner & Sikora 1995). In total, 421 juvenile and 242 adult birds were caught.

Biometrics and data analysis

Each bird was aged (Prater *et al* 1977) and the following measurements were taken: wing length, total head length,

Figure 1. Location of the ringing sites of the Waterbird Research Group 'KULING' in Puck Bay. RE – Rewa, RM – Reda mouth, JA – Jastarnia.

bill length and tarsus-plus-toe length (Meissner 2000). Data from all sites were combined. From some of the trapped Ringed Plovers not all measurements were taken: thus the sample sizes in analyses were always smaller than the total number of birds caught. Samples with fewer than 10 birds measured were not included in the statistical analyses. Every year the accuracy and the repeatability of measurements taken by different ringers were checked as described by Busse (2000). Biometric data were analysed with respect to birds caught in successive ten-day periods (referred to as decades) from the start of the fieldwork each year. All statistical tests were done in STATISTICA 6.0 (StatSoft Inc., Tulsa, USA).

RESULTS

In adults, the mean wing length and bill length of birds caught in successive ten-day periods differed significantly (ANOVA, $F_{6,213}=6.64$, $P < 0.001$ and $F_{4,156}=4.71$, $P < 0.002$, respectively). A clear decline of both measurements occurred between the third decade of July and the first decade of August (Fig 2). A similar pattern was observed in juveniles in the case of the wing length (ANOVA, $F_{7,404}=5.17$, $P < 0.001$) with a significant difference between birds trapped in July and those caught subsequently (post hoc Newman–Keuls test, $P < 0.05$) (Fig 3). A sharp decline of mean bill length in juveniles occurred between the second and the third

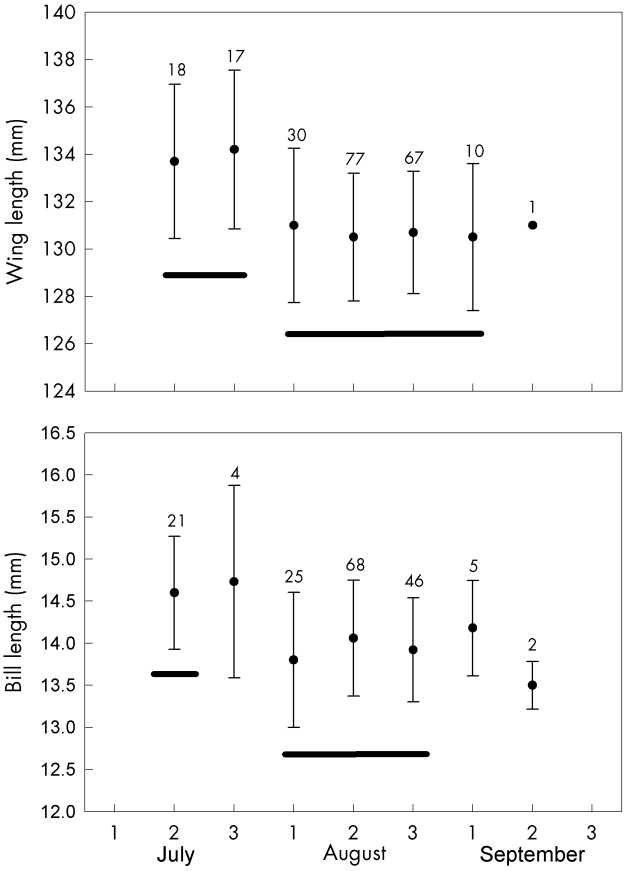

Figure 2. Changes in the mean wing and bill length of adult Ringed Plovers caught in Puck Bay in successive ten-day periods during autumn migration. Dot – mean, vertical line – standard deviation, numbers above denote sample size. Horizontal lines denote homogeneous groups of means which did not differ significantly (ANOVA and post hoc Newman–Keuls test $P > 0.05$). Means calculated from samples of fewer than 10 birds were omitted from statistical analysis.

week of August, which was later than the decline in wing length (Fig 3).

From published studies on the migration periods of *hiaticula* and *tundrae* through the southern Baltic, the marked differences in mean wing and bill length of birds passing through the Puck Bay area at different times during autumn migration suggest that adults caught in July belonged to *hiaticula* subspecies, whereas those caught in August and September were *tundrae*. Similarly, juveniles caught in July were likely to be *hiaticula* and those from the third decade of August *tundrae*. Comparison of the mean wing and bill lengths of these presumed *hiaticula* and *tundrae* birds from Puck Bay with data from other areas where only one or the other of these subspecies occurs supports this interpretation (Fig 4).

The Puck Bay data were then used to investigate age-related differences in biometrics within each subspecies. Juveniles caught in the first and the second decade of

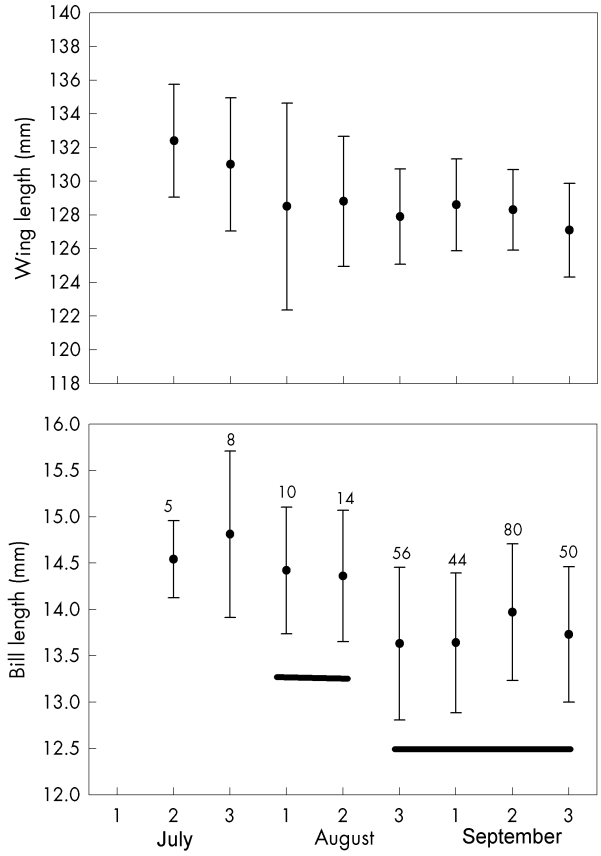

Figure 3. Changes of the mean wing and bill length of juvenile Ringed Plovers caught in Puck Bay in successive ten-day periods during autumn migration. Conventions and other details as in Fig 2.

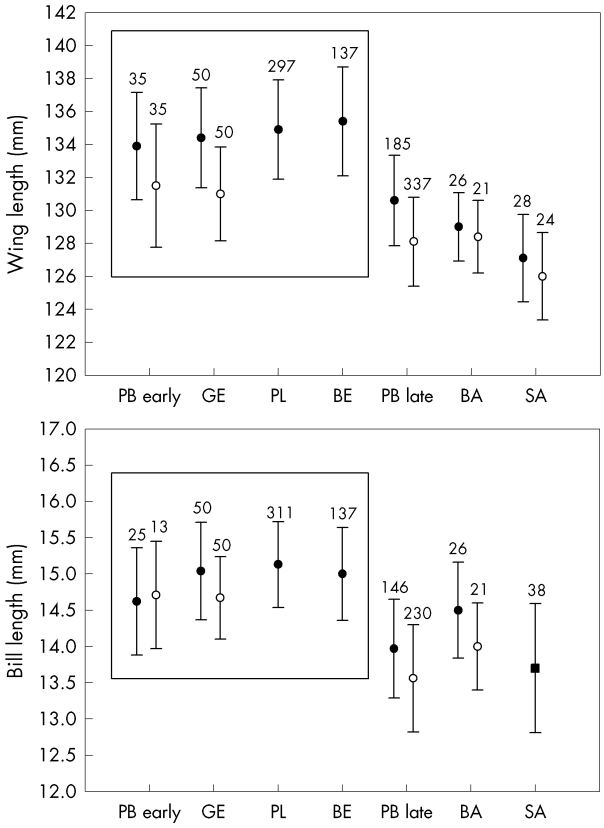

Figure 4. Comparison of the mean wing and bill length of Ringed Plovers caught in Puck Bay with those measured alive elsewhere within the ranges of *hiaticula* (inside the box) and *tundrae*. Filled dots – adults, open dots – juveniles, square dots – both age classes combined. Dot – mean, vertical lines – standard deviation, numbers above denote sample size. PB – Puck Bay (early and late migrants), GE – German Baltic coast (Holtz 1987), PL – Polish breeding population (Chylarecki 2000 and unpubl. data), BE – Belarussian breeding population (Pinchuk in litt.), BA – migrating in autumn through Bahrain (Hirschfeld *et al* 1996), SA – wintering in South Africa (Tree 1977).

August were excluded from this part of the analysis because their mean bill length in these periods had intermediate values (Fig 3). In both subspecies, the mean wing length of adults was ≈2.5 mm longer than in juveniles (t-test, $P \leq 0.006$; Table 1). In *hiaticula*, mean total head length and bill length of adults and juveniles were similar (t-test, $P > 0.7$) but, in the *tundrae* subspecies, adults had greater mean total head length and bill length (t-test, $P < 0.0001$). Juvenile *tundrae* had a slightly smaller (0.8 mm) mean tarsus-plus-toe length than adults (Table 1); analysis of this biometric in *hiaticula* was not possible due to very small sample sizes. The wing length data of adult *tundrae* showed evidence for slight bimodality, while bill length of both age classes was unimodal in distribution (Fig 5).

DISCUSSION

The differences in wing and bill measurements over the course of the autumn migration strongly suggest that smaller Ringed Plovers of the *tundrae* subspecies migrate through the southern Baltic later than larger *hiaticula* individuals. In the case of juveniles, the proportion of these two subspecies changed more gradually over the autumn migration, but the difference in migration timing was distinct nevertheless. A rapid decrease in mean bill and wing lengths for the adults caught between the end of July and the beginning of August suggests that the *tundrae* subspecies quickly replaced *hiaticula* in this stopover site. This assumption was supported by the fact that adults moulting primaries were recorded in Puck Bay exclusively in July (Meissner & Huzarski 2006), and only *hiaticula* is thought to moult on migration (Glutz von Blotzheim *et al* 1975).

In Ringed Plovers, males are larger than females (Glutz von Blotzheim *et al* 1975, Cramp & Simmons 1983). The expected bimodality due to sex differences in mean measurements occurred only in the case of the wing length in adult *tundrae* and it was small. The difference between the mean bill length of adult males and females in this

Table 1. Comparison of mean measurements (mm) of juvenile and adult Ringed Plovers caught at Puck Bay, presumed to be of the *hiaticula* and *tundrae* subspecies on the basis of differential timing of autumn migration (see text for details).

hiaticula								
Measurement	Adults			Juveniles			t-test	
	Mean	SD	N	Mean	SD	N	t	*P*
Total head length	41.45	0.92	29	41.34	0.768	14	0.37	0.713
Bill length	14.62	0.74	25	14.71	0.740	13	0.348	0.730
Wing length	133.9	3.26	35	131.5	3.729	35	2.866	0.006
tundrae								
Measurement	Adults			Juveniles			t-test	
	Mean	SD	N	Mean	SD	N	t	*P*
Total head length	40.34	0.82	156	39.91	0.88	276	5.00	<0.0001
Bill length	13.97	0.68	146	13.56	0.74	230	5.40	<0.0001
Tarsus+toe length	46.1	1.50	34	46.9	1.66	28	2.08	0.042
Wing length	130.6	2.75	185	128.1	2.69	337	10.46	<0.0001

species is about 0.4–0.5 mm, whereas for wing length it is about 1–4 mm (Dementiev & Gladkov 1966, Holtz 1987). In the present study, the difference between the two peaks in adult wing length (Fig 5) was only around 2 mm.

Although adults had worn primaries, the average wing length of juveniles, which migrated in a fresh plumage, was significantly shorter than adults. Similar results were obtained in African wintering grounds (Tree 1977, Wymenga *et al* 1990) and in Bahrain (Hirschfeld *et al* 1996). Thus, it seems that the relatively short wing may be a general rule in juvenile Ringed Plovers on migration. Shorter wings in juveniles than in adults were found in autumn also in the Turnstone *Arenaria interpres*, Knot *Calidris canutus* and Grey Plover *Pluvialis squatarola* (Meissner & Koziróg 2001, Krupa & Krupa 2002, Meissner & Kamont 2005). Shorter bills than adults in juvenile waders caught during autumn migration might result from the fact that growth had not been finished before departure from the breeding grounds (Meissner 1997, Meissner & Ściborski 2002). A similar difference at this stage of autumn migration was described also in the Bar-tailed Godwit *Limosa lapponica*, Common Sandpiper *Actitis hypoleucos* and Knot (Meissner 1997, Meissner & Ściborski 2002, Meissner & Kamont 2005). Therefore, the shorter mean bill and total head lengths of juvenile *tundrae* suggests that they leave the breeding grounds at a slightly earlier developmental stage than juvenile *hiaticula*. The longer tarsus-plus-toe in juvenile *tundrae* compared to adults is probably related to the ossification process of the leg, which consists of progressive shortening of long bones caused by the decrease of cartilage content in joints (Cymborski & Szulc-Olechowa 1967). This temporary 'overgrowth' of the leg length in juveniles was found also in the Common Sandpiper (Meissner 1997).

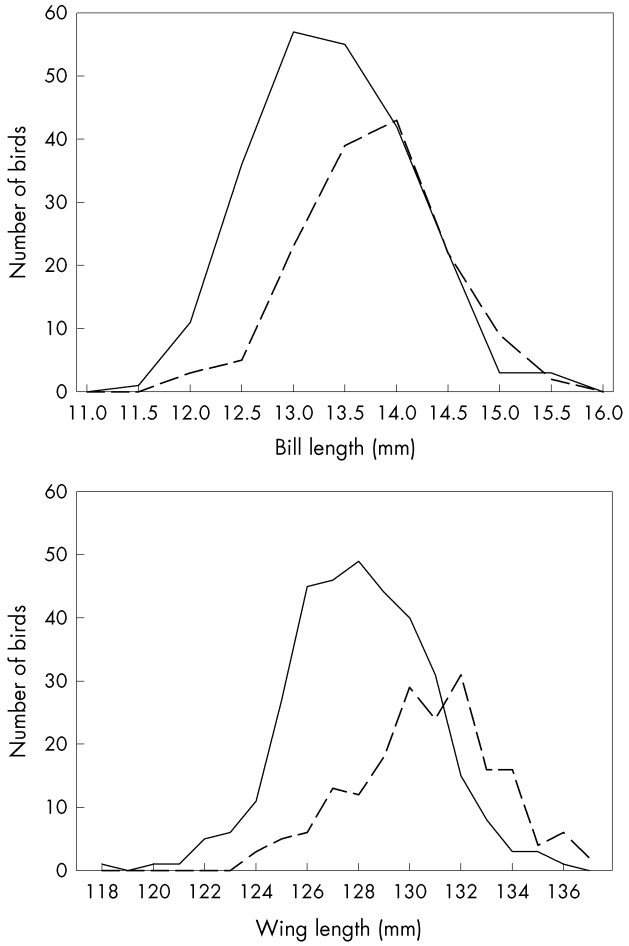

Figure 5. Distributions of the bill and wing lengths of Ringed Plovers caught in Puck Bay and presumed to be of the *tundrae* subspecies on the basis of later migration (see text for details). Dashed line – adults, solid line – juveniles.

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