

Sex determination of juvenile Dunlins migrating through the Polish Baltic region

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Received 12 November 2004; accepted 11 March 2005

ABSTRACT. Fifty-six Dunlins (*Calidris alpina*) that died accidentally at banding sites in Buck Bay (southern Baltic Sea), Poland, between 1998–2001 were sexed by dissection and measured. Measurements and sexes of these 32 females and 24 males were used to derive a discriminate function to help predict sexes of the *C. a. alpina* race using phenotypic measurements (bill, tarsus, and wing). Another sample of 16 female and 19 male Dunlins was used to validate this function. The best discriminate function for predicting the sex of juvenile Dunlins in the Southern Baltic included bill, tarsus, and wing length. Among single measurements, wing length was the poorest predictor of sex. Bill length was the best indicator, correctly identifying 91% of juvenile Dunlins in the validation sample. Longer-billed females were more likely to be mis-classified than shorter-billed males. The bills of juvenile Dunlins migrating through the Southern Baltic region in the autumn are still growing, and it appears as if these long-billed juvenile female Dunlins take more time to reach their final bill size than males.

SINOPSIS. **Determinación del sexo an juveniles de *Calidris alpina* que migran a través de la región báltica de Poland**

Un total de 56 individuos de *Calidris alpina* que murieron accidentalmente durante un periodo de captura y anillaje en la Bahía Buck (parte sur del Báltico) en Polonia, fueron sexados utilizando como procedimiento, la disección, examen y medida de la gónada. El estudio se llevó a cabo de 1998–2001. Las medidas de las gónadas de 32 hembras y 24 machos fue utilizada para derivar una función de discriminación para predecir el sexo, utilizando medidas fenotípicas (ej. largo del pico, tarso y ala). Otra muestra de 16 hembras y 19 machos se utilizó para validar la función. La mejor medida de función discriminativa para poder predecir el sexo de los juveniles incluyó la longitud del pico, tarso y ala. Entre estas medidas, el tamaño del ala resultó ser la alternativa más pobre para predecir el sexo. Por su parte el largo del pico resultó ser el mejor indicador y permitió identificar el sexo del 71% de los juveniles de *Calidris*. Las hembras de pico largo fueron mas propensas a ser mal identificadas que los machos de pico corto. El pico de los juveniles, que migran durante el otoño por la región, se encuentra aún creciendo y parece ser que las hembras juveniles de pico largo toman más tiempo en desarrollar el tamaño final del pico que los machos.

Key words: autumn migration, biometrics, discriminant analysis, sexing, waders

Juvenile Dunlins (*Calidris alpina*), like other shorebirds, exhibit no plumage dimorphism between the sexes. Females are larger than males, but distributions of all measurements in both sexes overlap to some extent (Zajac 1980; Brennan et al. 1984; Engelmoer and Roselaar 1998). Discriminant analysis has been widely applied to sex live birds that are monomorphic in plumage (Brennan et al. 1984; Bosch 1996; Mawhinney and Diamond 1999; McCloskey and Thompson 2000; Torlaschi et al. 2000). In the case of the North American Dunlin, Brennan et al. (1984) employed discriminant analysis to sex the subspecies *C. a. pacifica* in winter plumage. They were able to correctly sex 91.5% birds. Although the Dunlin is one of the most

common shorebirds migrating through Europe, methods have not been developed to predict the sex of *C. a. alpina*. Birds sexed by discriminant analysis can be used to address questions about intersexual differences in habitat use, migration chronology, or foraging behavior (Hulscher et al. 1996; McCloskey and Thompson 2000; Both et al. 2003), or to verify hypotheses on the occurrence of sex bias in samples of birds caught (Durell and Goss-Custard 1996).

Recently sex determination using molecular methods has become popular (Baker et al. 1999; Jodice et al. 2000; Väli and Elts 2002), but sexing birds by discriminant analysis is cheaper and may be used for individuals measured in the past. Additionally, blood-sampling may have an influence on the birds' subsequent behavior, especially if their nutritional status is compromised (Piersma et al. 2000).

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Table 1. Mean measurements [mm] of male and female juvenile Dunlins captured at Puck Bay (Polish Baltic coast) between 1993 and 2001. Means, \pm SD, sample sizes (N), and ranges are given.

| Measurement | Males | Females | <i>t</i> -test |
|-------------------|-------------------------------------|-------------------------------------|---------------------------|
| Bill length | 31.25 \pm 1.12 (42), 27.8–33.4 | 35.26 \pm 1.80 (49), 31.3–39.0 | $t = 12.59$; $p < 0.001$ |
| Total head length | 54.82 \pm 1.24 (43), 51.2–56.5 | 59.11 \pm 2.00 (48), 55.4–63.8 | $t = 12.03$; $p < 0.001$ |
| Tarsus length | 24.65 \pm 0.66 (34), 23.2–25.8 | 26.06 \pm 0.79 (36), 24.7–27.5 | $t = 8.05$; $p < 0.001$ |
| Wing length | 118.9 \pm 2.50 (43), 112–123 | 122.6 \pm 2.50 (49), 117–128 | $t = 7.14$; $p < 0.001$ |

Here I present a method to sex juvenile Dunlins using discriminant function analysis, and I test its effectiveness on a sample of known-sex birds.

METHODS

Between 1998 and 2001, 56 juvenile Dunlins accidentally died at banding sites of the Waterbird Research Group KULING, located in the Puck Bay region of Poland. Each bird was sexed by dissection and aged according to plumage (Prater et al. 1977). This sample, consisting of 32 females and 24 males, was used to derive a discriminant function. Another sample of 35 juvenile Dunlins (16 females and 19 males) that died in the years 1993–1997 was used to evaluate this function. The following measurements were taken to the nearest 0.1 mm using calipers: total head length (Green 1980), bill length (Prater et al. 1977), and tarsus length (Svensson 1992). Wing length (maximum chord) was measured by a stopped ruler to the nearest 1 mm (Evans 1986). Each year the accuracy and repeatability of measurements taken by different banders were checked; about 75% of the birds were measured by W. M. Some carcasses were partly damaged and not all measurements were taken from each specimen, and thus the sample sizes for measurements are not equal. All data met the assumptions of normality (Shapiro-Wilk test, $P > 0.05$) and homogeneity of variances (F -test, $P > 0.05$) except that for bill length. Variances of bill length in males and females differed (F -test, $P = 0.01$). However, data were not transformed, because discriminant analysis is robust with respect to the latter assumption, especially when deviations are mi-

nor (StatSoft 2001). Statistical analyses were done using STATISTICA 6.0 (StatSoft 2001).

RESULTS

Females were significantly larger than males in all body dimensions (Table 1); however, distributions of all measurements overlapped. Among single measurements, bill length was the best indicator of sex, correctly identifying 91% of juvenile Dunlins in the validation sample (95% of males and 88% of females). For total head length, all males were correctly sexed, but the percentage of erroneously sexed females was higher (75%). Wing length was the poorest predictor of sex in juvenile Dunlins, with only 63% of males and 66% of females sexed correctly using this measurement. More females than males were mis-classified according to bill length and total head length. Total head length was excluded from the discriminant analysis, because this measurement was highly correlated with the bill length ($r = 0.98$). In all cases values of $D > 0$ identified females and values of $D < 0$ identified males. The best discriminant function included bill length, tarsus length, and wing length. The resulting function was:

$$D_1 = 0.48*BL + 0.60*TL + 0.13*WL - 47.09 \text{ (Wilks' } \lambda = 0.252). \quad (1)$$

This function correctly identified the sex of 100% of males and 81% of females. However, after removing wing length, the resulting formula (D_2) correctly classified the same number of males and females in the validation sample, despite slightly lower discriminatory power (higher Wilks' lambda coefficient):

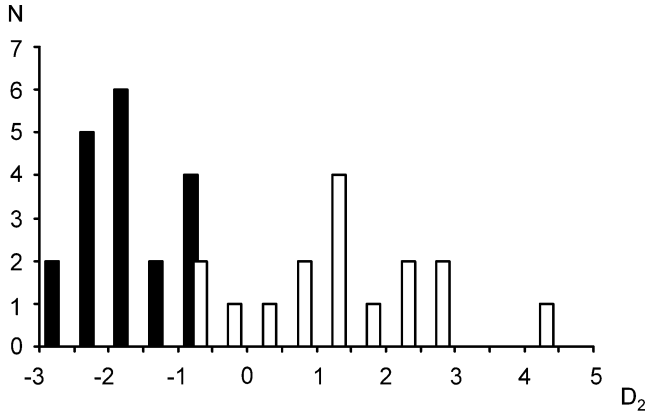


Fig. 1. Predictive classification success based on a discriminant function analysis of bill and tarsus length in Dunlins. Black bars are males, white bars are females. Only data from the validation sample were used.

$$D_2 = 0.55 \cdot BL + 0.66 \cdot TL - 35.51 \quad (\text{Wilks' } \lambda = 0.273). \quad (2)$$

$$D_3 = 0.49 \cdot BL + 0.19 \cdot WL - 39.64 \quad (\text{Wilks' } \lambda = 0.327), \quad (3)$$

In this case in the validation sample, only three females were mis-classified, and the highest values of the discriminant scores for males were far from the zero point (Fig. 1).

whereas a function with tarsus length and wing length (D₄) had the lowest discriminant power and allowed us to sex correctly only 79% of males and 75% of females:

A discriminant function with bill length and wing length (D₃) correctly sexed 89% of males and 81% of females:

$$D_4 = 0.98 \cdot TL + 0.25 \cdot WL - 55.08 \quad (\text{Wilks' } \lambda = 0.392). \quad (4)$$

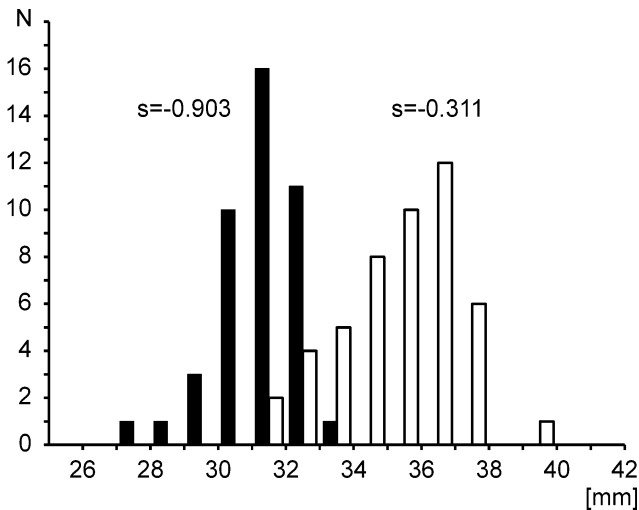


Fig. 2. Distribution of bill lengths of juvenile male (black bars) and female (white bars) Dunlins caught at Puck Bay, Polish Baltic coast, between 1993 and 2001. Skewness values (s) are given.

DISCUSSION

As was found by Brennan et al. (1984) for *C. a. pacifica*, bill length had the greatest discriminant power in sexing *C. a. alpina*. Bill length is also the best predictor of overall size in this subspecies (Goede and Nieboer 1983; Piersma and Brederode 1990) and is used as an index of body size (Engelmoer and Roselaar 1998; Shepherd et al. 2001). Discriminant functions with bill length and tarsus length increased the likelihood of correctly sexing birds with missing variables. Wing length is difficult to measure accurately, especially since the longer primaries may be damaged and worn. Thus, the best way to sex juvenile Dunlins is to use a model with bill and tarsus lengths, which has only a slightly lower Wilk's lambda coefficient than the model with three variables.

Like other shorebirds, during their first autumn, the bills of Dunlins are still developing (Meissner 1997; Meissner and Ściborski 2002). In females, reaching final bill size probably takes more time than in males since females typically have longer bills, and bill growth rate is about the same during postembryonic development in other bird species (Nitecki and Zamajska 1979; Caccamise 1980; Bancroft 1984; McLennan et al. 2004). A slightly left skewed distribution of bill lengths of females and an almost symmetrical distribution in males supports this hypothesis (Fig. 2). This is the likely explanation for why more females than males were mis-classified in the validation sample whenever bill length and total head length were used.

ACKNOWLEDGMENTS

I thank all the colleagues who helped with the field work. Nils Warnock and Leonard Brennan provided comments that improved this paper. This is Waterbird Research Group KULING Contribution No. 113.

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