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# SEX DETERMINATION OF BLACK-CAPPED CHICKADEES WITH A DISCRIMINANT ANALYSIS

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Abstract.—Discriminant analysis of body size measures increased the efficiency of sex determination of Black-capped Chickadees (*Parus atricapillus*), relative to univariate methods. The function obtained from a population in central Alberta allowed correct classification of 92% of 52 females and 95% of 91 males. Wing length contributed most to the classification by sex, followed by body mass, and rectrix length. All three measures contributed significantly to sex discrimination, and should therefore be recorded when chickadees are captured. Tarsus length did not significantly improve separation of males and females.

**DETERMINACIÓN DEL SEXO EN INDIVIDUOS DE *PARUS ATRICAPILLUS* MEDIANTE UN ANÁLISIS DE DISCERNIMIENTO**

Sinopsis.—Un análisis de discernimiento de parámetros del cuerpo de individuos de *Parus atricapillus* incrementó la eficacia para poder determinar el sexo en esta especie. Los datos obtenidos de una población de aves en la parte central de Alberta, Canada, permitieron clasificar correctamente el 92% de las hembras ($n$ = 52) y el 95% de los machos ($n$ = 91). La longitud del ala fue el parámetro que más contribuyó a la clasificación de los sexos, seguido de el peso y la longitud de las rectrices. Todas la medidas contribuyeron significativamente para discriminar sobre el sexo de individuos, y por tanto deben registrarse cuando se capturan a estas aves. La longitud del tarso no mejoró significativamente el poder diferenciar entre machos y hembras.

As there are no marked differences in the plumage of female and male Black-capped Chickadees, early chickadee studies (e.g., Hamerstrom 1942, Odum 1941) used breeding behavior as the criterion to determine sex. Males sing and feed the female during incubation, whereas females utter distinctive "begging calls" and only females incubate. Outside the breeding season, however, one can assign the sex of past and future breeders only, which often represent a small proportion of nonbreeding populations (Desrochers et al. 1988, Smith 1984). Glase (1973) and others (Smith 1984, Clark Brittingham and Temple 1988) used a combination of wing length and breeding behavior to determine the sex of more birds. Mosher and Lane (1972) suggested a method to determine the sex of Black-capped Chickadees based on the shape and extent of the cap and the bib. However, Mosher and Lane's method has been questioned by Gochfeld (1977), who failed to find a relationship between head plumage and sex. Also, the latter method presumably requires much practice (I was not able to use this method after two years of observations and banding).

Despite the value of multivariate statistics in determining the sex in several species of birds (e.g., Green 1982, 1989; Maron and Myers 1984; Reese and Kadlec 1982), studies of parids have rarely involved a multi-

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variate approach to increase the number of birds classified by sex (but see Gustafsson 1988). In this paper, I show that discriminant analysis on body mass, wing length, and rectrix length can help to predict the sex of substantially more chickadees than univariate methods.

## METHODS

This study was carried out at the Meanook Biological Station (54°37′N, 113°20′W), near Athabasca, Alberta, Canada, from March 1985 to August 1987. Chickadees were captured with mist nets in winter or nest-box traps in the breeding season. Each individual was banded with a Fish and Wildlife Service band and three color bands.

*Measures.*—Two field workers and I measured body mass (nearest 0.1 g), flattened wing length (nearest 1.0 mm), and tarso-metatarsus (nearest 0.1 mm). The outermost right rectrix was plucked and we measured its length (nearest 1.0 mm) on a flat surface. Less than 10 birds had extensive tail wear; I removed them from the analysis.

Body mass was significantly related to the time of day in November–February (linear regression, $F_{1,1289} = 177$, $P < 0.001$), to a lesser extent in March–July ($F_{1,169} = 5.9$, $P = 0.02$), but not in August–October ($F_{1,349} = 0.6$, $P = 0.4$). Therefore, I used regression coefficients for each season to correct body masses for circadian variation, as Haftorn (1976) did with Great Tits (*P. major*). Hereafter, "body mass" will mean "corrected body mass."

I looked for effects of feather wear on measurements by comparing wing lengths of individuals captured one to six months apart (periods not including a molt). A linear regression analysis failed to show a significant decrease in wing length from September to June ($F_{1,163} = 0.01$, $P = 0.9$); therefore, I did not correct wing lengths for wear effects. Since rectrices were plucked for measuring, I was unable to show variation in their length due to wear. However, the wear of outer rectrices (which are shorter and less exposed than central rectrices) was not noticeable on individuals captured in spring. I therefore assumed that wear did not measurably influence rectrix length.

The measured wing length of individual birds did not differ between banders 1, 2, and 3 (paired *t*-tests, df $> 17$, $P > 0.17$ in all three comparisons). Therefore, I pooled wing lengths from all banders. However, tarsus lengths of particular birds differed significantly between banders 1 and 3 (df $= 9$, $P = 0.001$) and banders 2 and 3 (df $= 61$, $P < 0.001$); tarsus lengths were thus corrected for the effect of banders on mean lengths. Masses and rectrix lengths were easily determined and I assumed that they were not influenced by the measurers.

Lastly, I examined possible age effects on body size by selecting individuals that were measured both as yearlings and later, as adults ($>1$ year old). None of the measures increased (Table 1). I therefore combined birds of different ages in the analysis.

*Discriminant analysis.*—This multivariate method produces a linear function that combines the predictor variables (in this case, mass, wing,

TABLE 1. Variation of chickadee body size within individuals, between age classes.

| Variable | $n$ | Yearling | | Older | | Paired $t$-test |
|---|---|---|---|---|---|---|
| | | Mean | SE | Mean | SE | $P$ |
| Mass (g)[a] | 22 | 12.24 | 0.21 | 12.23 | 0.19 | 0.9 |
| Wing (mm) | 23 | 67.25 | 0.44 | 67.13 | 0.55 | 0.6 |
| Tarsus (mm)[b] | 23 | 16.86 | 0.11 | 16.70 | 0.11 | 0.1 |
| Rectrix (mm) | 22 | 62.90 | 0.51 | 63.64 | 0.48 | 0.1 |

[a] Mass corrected for time of capture.
[b] Values corrected for differences between banders.

tarsus and rectrix) in a way that best separates the groups to be distinguished (in this case, sexes). I used reference samples of 143 females and 171 males (known from their reproductive behavior but captured in the same period as other birds) to compute the discriminant function using SPSS programs (Norusis 1986). I did not use reference samples that generated the discriminant function to estimate the percentage of cases correctly classified because this method tends to overestimate the true performance of the function in the population (Lachenbruch 1975). Instead, I used measurements from another sample of 52 known females and 91 known males to estimate the percentage of cases classified correctly. None of the variables departed from the assumption of normality, and covariance matrices for males and females were not significantly different (Box's $M = 10.1$, $P = 0.13$).

## RESULTS

Males were larger than females with respect to all four morphometric measures (Table 2). In an SPSS stepwise discriminant analysis (Norusis 1986), wing length contributed most to the discrimination, followed by body mass, and rectrix length, respectively. All three variables significantly contributed to the discrimination by sex. After wing length, mass and rectrix length were considered, tarsus length did not improve discrimination significantly. Table 3 shows the increase in classification rate as more variables were added to the analysis. The linear function best discriminating males and females was as follows:

$$D = -44.07 + 0.55(\text{mass}) + 0.47(\text{wing}) + 0.095(\text{rectrix})$$

where D is the discriminant score. Mean discriminant scores for males and females were 1.072 and −1.282, respectively. The discriminant function provided little size overlap between sexes (Fig. 1) and classified correctly 92% of 52 females and 95% of 91 males.

## DISCUSSION

Several studies of parids demonstrated that there are marked intersexual differences in behavior outside the breeding season (e.g., Desrochers 1989, Glase 1973, Gosler 1987). Unlike the breeding behavior method, a mor-

TABLE 2. Variation of body size between males and females.

| Variable | Males Mean | Males SE | Males *n* | Females Mean | Females SE | Females *n* | *t*-test *P* |
|---|---|---|---|---|---|---|---|
| Mass (g)[a] | 12.53 | 0.04 | 192 | 11.52 | 0.05 | 154 | <0.001 |
| Wing (mm) | 68.14 | 0.11 | 192 | 64.71 | 0.11 | 154 | <0.001 |
| Tarsus (mm)[b] | 16.87 | 0.05 | 183 | 16.29 | 0.06 | 143 | <0.001 |
| Rectrix (mm) | 64.65 | 0.13 | 185 | 62.12 | 0.16 | 151 | <0.001 |

[a] Mass corrected for time of capture.
[b] Values corrected for differences between banders.

phometric approach allows sex determination of all wintering birds, as opposed to just past and present breeders (a small and unrepresentative proportion of the wintering chickadees), and does not require spring-time observations. The results show that discriminant analysis is more useful than univariate or behavioral methods for year-round use with Black-capped Chickadees. Additionally, the correct classification rate with three body size measures (94%) was higher than that of any combination of two measures. As Maron and Myers (1984) pointed out, it does not follow from a 94% classification rate that the likelihood of correct classification (L) of any individual was 94%. L is proportional to the absolute value of the discriminant score, and statistical programs like SPSS (Norusis 1986) can calculate individual values of L when the probability of correct classification of a given individual is needed. In the present analysis, L was greater than 99% and 95% in 26% and 47% of the individuals, respectively. For comparison, I could only determine the sex of 36% of individuals with a 95% level of confidence, when I used wing length as the only predictor of sex.

Despite the low resolution of the present study, compared to that of more dimorphic species (e.g., Green 1982, Reese and Kadlec 1982), the use of a discriminant function is still advantageous for banders, since once the discriminant function is computed, discriminant scores can be obtained "in the field" with a pocket calculator. Confidence limits for male and

TABLE 3. Percentage of individuals correctly classified with different combinations of measures. A 50% classification rate would result from random classification.

| Variables | Percent correct classifications |
|---|---|
| Rectrix | 78.7 |
| Mass | 79.8 |
| Mass and rectrix | 82.7 |
| Wing | 89.6 |
| Wing and rectrix | 91.7 |
| Wing and mass | 93.3 |
| Wing, mass and rectrix | 93.7 |

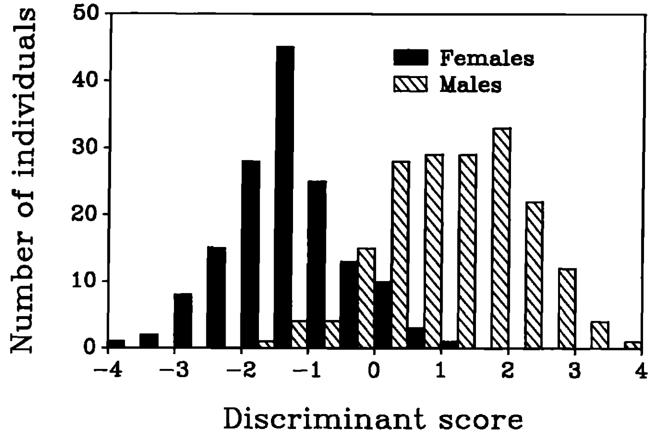


FIGURE 1. Frequency distribution of canonical discriminant scores (D) for male and female Black-capped Chickadees.

female scores can also be obtained, enabling the field worker to determine the sex of individuals with a 95% confidence level.

All discriminant analyses between two groups are based on predefined group membership likelihoods resulting from the relative abundance of the two groups (in this case, sex ratio). In this study, I did not have data suggesting that the sex ratio was skewed, and I assumed a sex ratio of 1: 1. Since sex ratio estimates take part in discriminant analyses (as "prior probabilities of membership"), it would be circular to use classification results to estimate the sex ratio of the sample population. However, the discriminant function can be used to estimate the sex ratio of a future population in the same area, if individuals that were used in the calculation of the discriminant function represent only a small proportion of the future population.

Yearlings in the present study did not have longer wings in their second year. However, yearlings in some populations of Black-capped Chickadees may have shorter wings than older conspecifics (C. M. Weise, pers. comm.), as frequently noted in other passerines, including *Parus* (e.g., Alatalo et al. 1983, Laaksonen and Lehikoinen 1976). When adults of both sexes are larger than yearlings of the same sex, banders should correct data for age before computing and using a discriminant function, to obtain homogeneous samples of male and female body measures.

As sampling for this study was restricted to one population, the discriminant function obtained here cannot be used on other populations because of intraspecific geographic variation in *Parus* morphology (e.g., Duvall 1945, Gustafsson 1988, Haftorn 1976) and differences between banders in the methods of measurement. However, sexual size dimorphism has been reported in several Black-capped Chickadee populations (e.g., Clark Brittingham and Temple 1988, Glase 1973, Smith 1984);

thus it is likely that the multivariate approach shown here will be useful in other studies.

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