J. Field Ornithol., 64(2):199-204

SEXING FLEDGLINGS OF CARDUELINE FINCHES BY PLUMAGE COLOR AND MORPHOMETRIC VARIABLES

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Abstract.—The typically streaked brownish plumage of fledglings of many species of Passerine birds makes it difficult to discriminate the sexes. Here discriminant analysis on a set of plumage color and morphometric characters of an *a posteriori* sexed sample of Citril Finch (*Serinus citrinella*) fledglings is used to show that their plumage color is dimorphic, allowing for the correct sexing of 69% of individuals (brown-ochreish birds tended to be males, and brown-greyish birds tended to be females). Use of morphometric characters allowed an additional 28% of birds to be correctly classified, so that most of the fledglings (97%) could be sexed. It is suggested that this plumage color dichromatism might appear in other species, and investigators are encouraged to measure fledgling birds on capture and retain a sample of them in captivity until the completion of post-juvenal molt.

SEXADO DE LOS JUVENILES DE LOS FRINGILIDOS CARDUELINOS MEDIANTE EL COLOR DEL PLUMAJE Y VARIABLES MORFOMÉTRICAS

Sinopsis.—El típico plumaje parduzco listado en juveniles de muchas especies de Paseriformes hace que muchas de estas aves no puedan ser sexadas. El análisis discriminante sobre una serie de caracteres de color del plumaje y morfométricos de una muestra de juveniles de Verderón serrano (*Serinus citrinella*), sexados a posteriori, muestra que el color del plumaje es dimórfico. Esto permite un sexado correcto del 69% de los individuos (los pájaros pardo-ocráceos tienden a ser machos, mientras que las hembras muestran, generalmente, un plumaje pardo-grisáceo). La utilización de caracteres biométricos permitió aumentar en un 28% el número de pájaros sexados correctamente, de forma que la mayoría de los juveniles (97%) pudo ser sexado. El dicromatismo en el color del plumaje podría aparecer en muchas otras especies, por lo que se anima a otros investigadores a medir a los juveniles en el momento de su captura, reteniendo una muestra en cautiverio hasta que completen la muda postjuvenil.

Fledglings of many species of birds show a typical, streaked brownish plumage, which does not allow discrimination of sexes (Busse 1984, Pyle et al. 1987, Svensson 1984). This difficulty has hindered studies on differential parental investment and dispersal or mortality of males and females during their early stages, so that in comparison to mammals, very little is known about birds (e.g., Breitwisch 1989, Clutton-Brock 1986). Our studies of cardueline finches showed some variation in the plumage color of fledglings, however, which we thought could be related to sex. In this paper, we use data gathered on Citril Finches (*Serinus citrinella*) to evaluate whether fledgling plumage color or morphometric variables can be used to identify the sex of fledglings and to identify measurements that can be taken in the field to sex correctly individual birds.

MATERIALS AND METHODS

Citril Finch fledglings (EURING age 3J) were captured using mist nets in the Port del Comte mountains (Pre-Pyrenees, in northeastern Spain) during the summer of 1991. For each of 34 birds we scored plumage color as either brown-ochreish or brown-greyish. We also measured mass (to the nearest 0.5 g), wing length (maximum chord), tail and tarsus length (following Svensson 1984), first and third primary length (P1 and P3, respectively) (following Jenni and Winkler 1989), and distance between the tips of the first eight primaries (excluding P1) and the tip of the wing (following Svensson 1984). All measurements were made by the same investigator. We also calculated an index of body condition as the bird's mass divided by the cube of wing length × 1000 (Clark 1979, Johnson et al. 1985), and three indexes of pointedness and symmetry of the wing: P3 − P1 (primary 3 minus primary 1, see Alatalo et al. 1984), and P and S, obtained approaching (wing length minus each of the distances between the tips of the primaries and the tip of the wing) to a frequency distribution; this resembles to some degree a normal distribution, and kurtosis (P) and skewness (S) can be computed (Mlikovsky 1978). The formulas for P and S are as follows:

$$P = \frac{\Sigma\left(n_i - \frac{\Sigma n_i(W - d_i)}{\Sigma(W - d_i)}\right)^4\left(\frac{W - d_i}{\Sigma(W - d_i)}\right)}{\left[\Sigma\left(n_i - \frac{n_i(W - d_i)}{\Sigma(W - d_i)}\right)^2\left(\frac{W - d_i}{\Sigma(W - d_i)}\right)\right]^2}$$

$$S = \Sigma\left(n_i - \frac{\Sigma n_i(W - d_i)}{\Sigma(W - d_i)}\right)^3\left(\frac{W - d_i}{\Sigma(W - d_i)}\right) \div \left[\Sigma\left(n_i - \frac{n_i(W - d_i)}{\Sigma(W - d_i)}\right)^2\left(\frac{W - d_i}{\Sigma(W - d_i)}\right)\right] \times \sqrt{\Sigma\left(n_i - \frac{n_i(W - d_i)}{\Sigma(W - d_i)}\right)^2\left(\frac{W - d_i}{\Sigma(W - d_i)}\right)},$$

where n_i = number of the ith primary minus 1, W = wing length, and d = distance between the tip of the ith primary and the tip of the wing.

Following completion of the measurements, the birds were transferred to a cage of 2 × 2 × 2 m, where they were maintained for 2 mo. Food was provided *ad libitum*, and consisted of a canary mixture enriched with vitamins; we also added some wild seeds when possible. Water, which included additional vitamins and an anticoccidiostatic complex, was provided in small ponds where birds could drink and bathe. Once post-juvenal molt was completed, the sex of each bird (except two individuals that died before the completion of the study) was determined using plumage characteristics (Svensson 1984). All the individuals were then released at their areas of capture.

Once the sex of each bird was known, we tested for differences between the sexes in each of the morphometric variables. We then used discrim-

TABLE 1. Means of morphometric variables for female and male fledgling Citril Finches.

Variable	Female Mean	Female SD	Male Mean	Male SD	t	P
Plumage color[1]	0.39	0.05	0.79	0.04	2.37	0.025
Pointedness (P)[2]	18.01	0.04	18.04	0.06	1.68	0.103
Wing length	76.42	1.46	77.46	1.55	1.96	0.059
Tail length	55.00	1.32	55.75	1.59	1.46	0.155
Mass	11.81	0.57	12.32	1.05	1.78	0.085
Tarsus	14.61	0.33	14.51	0.43	0.76	0.453
Symmetry (S)[3]	10.24	0.83	10.67	0.77	1.52	0.141
P3	60.94	1.22	62.00	1.36	2.31	0.028
P3 − P1	53.44	1.34	54.57	1.47	2.27	0.031
P1	7.50	0.62	7.43	0.39	0.38	0.708
Body condition	2.65	0.21	2.66	0.28	0.47	0.964

[1] Plumage: brown-greyish = 0, brown-ochreish = 1.
[2] Pointedness = P•10.
[3] Symmetry = S•100.

inant analysis (Norusis 1986) to determine if fledgling plumage color and morphometric measurements could be used to correctly sex fledgling birds.

RESULTS

Completion of molt revealed that our sample of Citril Finch fledglings included 18 females and 14 males. Fledgling plumages of males were generally brown-ochreish, whereas females tended to be brown-greyish (69% of birds were classified correctly by this character; $G = 5.26$, df = 1, $P < 0.05$). Of the variables measured, only plumage color, P3 and P3 − P1 showed significant ($P < 0.05$) differences between the sexes (Table 1). In stepwise discriminant analysis (Norusis 1986), plumage color contributed most to the discrimination by sex. The addition of wing point-

TABLE 2. Percentage of individuals correctly classified when increasing the number of variables entered into the discriminant function. A 50% classification rate would result from random classification. Wilks' Lambda and significance are also shown for each variable.

Variable	% correct classification	Wilks' Lambda	P
Plumage color[1]	69	0.843	0.025
Pointedness (P)[2]	72	0.690	0.005
Wing length	81	0.548	<0.001
Tail length	84	0.464	<0.001
Mass	84	0.418	<0.001
Tarsus length	94	0.370	<0.001
Symmetry (S)[3]	97	0.337	<0.001

[1] Plumage: brown-greyish = 0, brown-ochreish = 1.
[2] Pointedness = P•10.
[3] Symmetry = S•100.

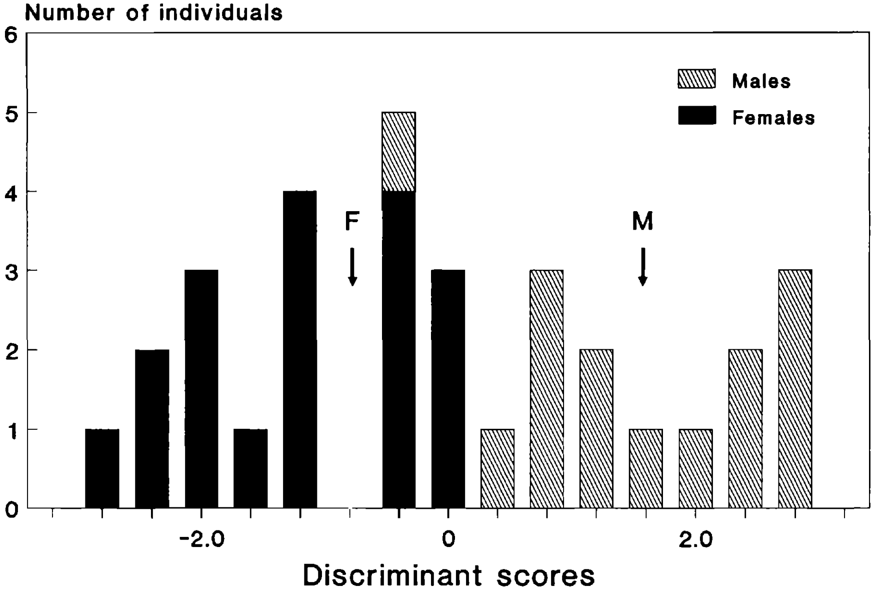

FIGURE 1. Frequency distribution of discriminant scores for male and female Citril Finches. Mean discriminant scores for males (M) and females (F) are shown with an arrow.

edness, wing and tail length, mass, tarsus, and wing symmetry, to the model increased the percent of individuals classified correctly to 97% (100% of 18 females, 93% of 14 males) (Table 2). After these variables were considered, P1, P3, P3 − P1 and body condition did not improve discrimination significantly. The linear function best discriminating males and females was:

$$D = -344.01 + 1.81 \text{ Color} + 162.03 \text{ Pointedness} + 0.46 \text{ Wing length} + 0.32 \text{ Tail length} + 0.75 \text{ Mass} - 1.39 \text{ Tarsus} + 71.20 \text{ Symmetry},$$

where D is the discriminant score. Mean discriminant scores for females and males were −1.20 and 1.54, respectively, with little size overlap between sexes (Fig. 1). Discriminant function based solely on morphometric variables classified correctly only 72% of birds.

DISCUSSION

Our results demonstrate the presence of plumage dichromatism in Citril Finch fledglings; females tend to show a brown-greyish color, whereas males display a brown-ochreish plumage. The difference is far from clear cut and intermediate individuals occur, but plumage categories are cleanly distinguished as just two, and with experience one can easily sex typical specimens. Sex discrimination was improved considerably by including morphometric variables in the discriminant function, because males are bigger and show more pointed wings. A reliable discrimination was not obtained if only morphometric variables were used, however, and this result stresses the importance of plumage color for the correct classification of sexes. This dichromatism, we think, may be general and can be extended to other species, especially cardueline finches and buntings (e.g., *Serinus serinus,* Senar, unpubl. data), and deserves more investigation (see Butcher and Rohwer 1989 for the role of plumage coloration on the social organization of birds).

The procedure we used (measuring a sample of birds on capture and retaining them in captivity until the completion of the post-juvenal molt, when sex can be reliably determined, and a discriminant function obtained), is very simple and affordable, and does not entail any risk for the bird. Other methods, such as laparotomies (e.g., Piper and Wiley 1991), or chromosome diagnosis from blood samples (e.g., Parker et al. 1991) may also produce good results, but are invasive, time consuming or expensive techniques. We encourage, therefore, other investigators to use our method to identify characteristics useful for sexing fledglings of other species, so that in the future, studies on differential dispersal, mortality or parental investment can be undertaken on a broader range of species.

ACKNOWLEDGMENTS

We are most grateful to Deanna K. Dawson and an anonymous reviewer for their helpful comments.

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Received 4 Feb. 1992; accepted 7 May 1992.