Sexing juvenile Goldfinches *Carduelis carduelis* by plumage colour

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Sexing juvenile birds can be very valuable for ringers and researchers, and of critical importance in ecological studies about sexual differences in mortality, dispersal strategies or sex-ratio variation at nests. However, juveniles of many passerine species are typically not sexed by ringers and researchers, often because they have a rather dull plumage colour that shows little individual variation. This paper suggests an easy method of identifying the sex of juvenile Goldfinches by measuring maximum wing length and the number of rectrices with an oval white spot; the method has proved accurate in 91% of the cases studied. Furthermore, we have validated the classification function provided here with a data set of Swiss birds, of which 96% of individuals were correctly classified using this system.

Key words: Goldfinch, *Carduelis carduelis*, sexing juveniles, colour traits, postjuvenile moult.

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Young birds in juvenile plumage of many passerine species display a rather dull plumage colour that shows little individual variation, which makes them difficult to sex in the field before postjuvenile moult (Jenni & Winkler 1994, Svensson 1998). Establishing sex-specific characters that can be used for sexing juvenile birds requires a previous study in which plumage characters of a representative sample of juveniles of known sex are measured and compared. There are two alternative ways to proceed. The first involves invasive methods such as blood extraction or dissection of specimens (Harder & Kirkpatrick 1994, Ellegren 1996, Lessells & Mateman 1996). The second involves keeping track of the juveniles until their postjuvenile moult has ended and sexing becomes straightforward (Borràs *et al.* 1993, Senar *et al.* 1998, Domènech *et al.* 2000). In both systems, plumage characters of sexed juveniles can be measured directly. There is, however, a further way to proceed: in many passerines, the flight-feathers (of both wing and tail) are not all replaced during postjuvenile moult (Jenni & Winkler 1994), so these retained feathers can be measured after the completion of moult, when the birds are easily sexed. The information thus gained may indicate measurements that are suitable for sexing juveniles (Mariné & Copete 1994).

In the period July-October, juvenile Goldfinches *Carduelis carduelis* undergo a partial moult, during which they acquire a typical red mask; the extent of this trait and the colour pattern of the marginal coverts are the main guides for sexing first-winter birds and adults in this species. Postjuvenile moult usually involves the replacement of all body feathers, lesser and median wing coverts, and a variable number of greater coverts and flight-feathers. Birds with a more extensive moult can renew most, or even all, of their remiges and rectrices (Jenni & Winkler 1994, Gargallo & Clarabuch 1995). The aim of this paper is to show which traits of the retained juvenile plumage can be used to determine the sex of Goldfinches, so that this information can then be used to sex birds before their postjuvenile moult.

Material and methods

A total of 59 first-winter Goldfinches were mist-netted during November, December and January from 1999 to 2002, and January 2003 at two localities in north-east Spain (Clariana-Lleida and Barcelona) and three localities in north-west Spain (Baldaio-A Coruña, Barreiros-Lugo, and Foz-Lugo). For each bird we noted the maximum wing length (Svensson 1998), the number of rectrices with white oval spots, the length of the yellow wing patch, and the area of the oval white tail spots.

We considered as "white tail spots" the large oval white spots on the inner vanes of the outermost tail feathers, but not those terminal or subterminal white spots shown by every new rectrix. Most of the birds had white tail spots on the outermost pairs of rectrices (hereafter R5 and R6); less frequently R4 was also spotted, whereas in some birds only R6 had white spots. Herein, the number of spotted rectrices are referred to as 1 (only R6), 2 (R6 and R5) or 3 (R6, R5 and R4). Although 5% of the birds had R4 spotted on only one side of the tail, these individuals were considered as having three white spots.

The yellow wing patch is produced by a series of yellow spots on several of the primaries and secondaries, beyond the tip of each covert. In the first 46 Goldfinches captured, we measured the visible length of the yellow spots on the outer vane of primaries P3 to P10 (numbered ascendently) from the tip of the overlaying primary covert; in each case, only the right wing was measured. A Principal Component Analysis resulted in a PC1 which was highly correlated to the measured yellow spot on P6 (Table 1). Hence we used the length of the yellow spot in this primary as a good predictor of the total patch area, with the additional advantage that it can be measured quickly and accurately. When the rest of the Goldfinches were captured, afterwards, we measured only the length of the yellow spot on P6.

Table 1. Correlation coefficients for the length of the visible yellow spot on each primary (numbered ascendently) and the PC1 that represents the total area of the yellow wing patch (n=46).
Coeficients de correlació per a la longitud de la taca groga visible a cada primària (numerada ascendentment) i la PC1 que representa l'àrea total de la taca de groc a l'ala (n=46).

	PC1
P3	0.802
P4	0.876
P5	0.888
P6	0.957
P7	0.920
P8	0.855
P9	0.795
P10	0.673
Eigenvalue	5.78
Variance explained	0.72

To calculate the area of the white tail spots we measured the maximum length and width of each white oval spot on the right side of the tail. There were also some asymmetries in the size of the spots between the two sides of the tail. Given that the aim of this work is to provide a practical tool for ringers, we measured both left and right spots only if the asymmetry in an individual was obvious, in which case the mean values of length and width of the two spots were used. In addition, in all cases we collected the right R6 feather in order to calculate the area of the white spot. We wanted to know if the areas measured from digital photographs of these collected feathers were reliably predicted using the elliptical equation [Ellipse area = π (Length/2) (Width/2)]. If this were the case, it would be easier in practice to calculate the area of the white spots from just length and width. As we obtained a good predictive value in a regression between the area taken from digital photographs and the elliptical area ($r=0.92$, $R^2=0.85$, $p<0.001$, $n=80$), the actual variables included in the analyses were the elliptical areas of R6, R5 and R4.

Table 2. Measured plumage traits [mean ± SE (95% confidence interval)] in first-winter Goldfinches, according to sex.
Resultats segons sexe de les variables del plomatge que s'han mesurat [mitjana ± SE (95% interval de confiança)] en caderneres de primer hivern.

	FEMALES (n=26)		MALES (n=17)		
Variable	Mean ± SE	95% C.I.	Mean ± SE	95% C.I.	test
Wing length (mm)	76.73 ± 0.34	76.03-77.44	80.06 ± 0.56	78.88-81.24	-5.39*** ¥
Number of spotted rectrices	2	1-2	2	2-3	8.82*†
Length of yellow spot on P6 (mm)	18.68 ± 0.21	18.26-19.11	20.15 ± 0.26	19.60-20.71	-5.15*** ¥
Spot area on R6 (mm^2)	61.63 ± 3.84	53.71-69.55	64.37 ± 3.09	57.81-70.92	-0.51 ¥
Spot area on R5 (mm^2)	30.21 ± 4.15	21.62-38.79	40.64 ± 4.49	31.02-50.26	-1.65 ¥
Spot area on R4 (mm^2)	0	---	1.42 ± 0.90	(0-3.35)	---

Analysed by t-test (¥) or χ^2 (†): *p<0.05; **p<0.01; ***p<0.001

In all the analysis, we used only birds in which all the feathers taken into account were not renewed during the post-juvenile moult (n=43; 75% of sampled birds).

We analysed the percentage of correctly sexed first-winter birds using a discriminant analysis, including each of these measured variables. Finally, in order to verify the obtained classification function, we carried out a cross-validation using a museum data set composed of 15 male and 15 female first-winter Goldfinches from Switzerland.

Results

First-winter males had significantly longer wings than first-winter females (80.06 *vs* 76.73 mm; Table 2). Confidence intervals at 95% of mean values for each sex did not overlap. First-winter males had a significantly larger number of rectrices with white spots than did females, with most females showing 1 and 2 white-spotted tail feathers and a larger proportion of males showing 3 white-spotted tail feathers (Table 2). First-winter males had significantly longer yellow spots on P6 than did females (20.15 *vs* 18.68 mm; Table 2), and the 95% confidence intervals of means did not overlap. Males tended to show larger white spots on their R6 and R5 than did females (64.37 *vs.* 61.63 mm^2, and 40.64 *vs* 30.21 mm^2 respectively; Table 2), although differences were not significant. Finally, no female showed a white spot on R4 (Table 2).

Discriminant analysis of sex by these traits resulted in a function that classified 90.70% of birds correctly. None of the variables on its own provided a higher percentage of correctly classified birds than this function (Table 3 and Table 4):

$$Y = 77.819 - 0.911 * \text{wing length} - 2.945 * \text{number of spotted rectrices}$$

where positive values of Y correspond to females, and negative values correspond to males.

Measurements of Swiss Goldfinches did not differ from those of the captured Goldfinches, except in the area of the white spot on R6, which was larger in Swiss males than in the male birds

Table 3. Discriminant models for sexing juvenile Goldfinches by plumage traits. N=43 (26 females and 17 males). The last model is the best one obtained.
Models discriminants per sexar Caderneres juvenils segons les característiques del plomatge. N=43 (26 femelles i 17 mascles). L'últim model és el millor obtingut.

	% Correctly classified		
	Total	Females	Males
Maximum wing length	86.05	92.31	76.47
Nº spotted rectrices	69.77	100.00	25.53
Length of yellow spot on P6	74.42	84.62	58.82
Spot area on R6	58.14	96.15	0
Spot area on R5	64.10	87.50	26.67
Spot area on R4	69.23	100.00	20.00
Wing length * nº spot. rect.	90.70	96.15	82.35

Table 4. Summary of the sex-discriminant function analysis by plumage traits measured on first-winter Goldfinches ($F_{2,40}$=20.94, p<0.001, n=43).
Resum de l'anàlisi de la funció discriminant del sexe respecte a les variables del plomatge mesurades en caderneres de primer hivern ($F_{2,40}$=20.94, p<0.001, n=43).

	Wilk's Lambda	$F_{1,40}$	p
Wing length	0.81	25.95	<0.001
Nº spotted rectrices	0.59	7.91	<0.01

measured by us in the field (t-test: t=–3.89, p<0.001, Table 5). A cross-validation of the classification function provided above yielded 95.65% of correctly classified individuals (90.91% of females and 100% of males were correctly classified).

Discussion

Establishing the sex of juvenile birds is of great relevance in ecological studies concerned with sexual differences in mortality, dispersal strategies or sex-ratio variation at the nest (reviewed in Breitwisch 1989, Gowaty 1993, Lessells & Quinn 1999, Julliard 2000). A model that correctly classifies 91 percent of individuals is of some limited use, because of the remaining nine percent of wrongly classified individuals. However, our study provides some interesting findings. Specifically, no single female presented a white spot on R4, and the 95% confidence interval of the mean values of either sex for wing length and the length of the yellow spot on P6 did not overlap. Furthermore, we have verified the model with a data set of Swiss birds, which yielded an improved success percentage of 96%. This result suggests that, although there appears to be some geographical variation in the measured traits, the provided classification function could be of some general use within the whole range of the species. However, the size-related geographical variation shown by Goldfinches throughout Europe certainly limits the usefulness of our classification function. It should be noted that our sample of Goldfinches was probably formed mostly of wintering trans-Pyrenean birds, given the capture date and the similar mean wing length of the Swiss birds (cf. Tables 2 and 5). It is known that the central and northern European Goldfinch subspecies are larger than the Iberian form *C. c. parva* (Cramp & Perrins 1994), so the classification function provided here, because it includes wing length, would probably be of little or no use for native Iberian birds.

It has been suggested that wing length may allow the sexing of a large number of species (Svensson 1998). However, in our case this character by itself provided a poor sexing classification function, and it proved necessary to add some plumage coloration characters in the analysis in order to improve the model. Counting the number of spotted rectrices is very simple and straightforward and, added to wing length, provides the best classification function. Furthermore, it must be noted that, according to our results, juvenile Goldfinches with an oval white spot on R4 can safely be sexed as males.

Measuring the length of the yellow spot on P6 with a calliper gives an easy and good indication of the area of the whole of the yellow wing patch. Similarly, the areas of the white tail spots can easily be calculated from the elliptical equation area: π (Length/2) (Width/2). Although the addition of these variables did not

Table 5. Measured plumage traits [mean ± SE (95% confidence interval)] in Swiss first-winter Goldfinches, according to sex.
Variables del plomatge mesurades [mitjana ± SE (95% interval de confiança)] en caderneres de primer hivern suïsses segons el sexe.

	FEMALES (n=15)		MALES (n=15)	
Variable	Mean ± SE	95% C.I.	Mean ± SE	95% C.I.
Wing length (mm)	76.36 ± 0.45	75.39-77.32	80.50 ± 0.43	79.57-81.43
Nº spotted rectrices	2	---	2	2-3
Length of yellow spot on P6 (mm)	18.41 ± 0.36	17.66-19.18	20.78 ± 0.43	19.85-21.71
Spot area on R6 (mm^2)	58.03 ± 4.12	48.86-67.21	83.59 ± 3.93	74.93-92.26

improve the classification of cases, they could provide a valuable initial guidance to the sex of the juvenile bird in extreme cases.

A possible source of bias in our results could appear in the case of differential mortality of juveniles in relation to the measurements considered here (Domènech *et al.* 2000). Although we were not able to address this possibility, we think it is unlikely that the two variables included in the classification function were equally subjected to differential mortality, and in any case, it is clear that the suggested characters allow some good sex discrimination, which may be of use.

In summary, the discrimination function presented here allows a cheap and easy way for identifying the sex of most juvenile Goldfinches in western and central Europe, avoiding blood sampling or other intrusive techniques.

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Resum

Sexatge dels juvenils de Cadernera *Carduelis carduelis* pel color del plomatge

Els sexatge d'individus juvenils pot ser molt important per als anelladors i investigadors i de gran vàlua en estudis d'ecologia sobre diferències sexuals en mortalitat, estratègies de dispersió o percentatge de sexes a les llocades. No obstant això, els ocells juvenils de moltes espècies de passeriformes no es poden sexar pels anelladors ja que exhibeixen un plomatge pàl·lid amb molt poca variació individual. En aquest treball se suggereix un mètode fàcil que ha permès identificar el 91% dels joves de Cadernera amb la mesura de la longitud màxima de l'ala i el nombre de rectrius amb taca oval blanca. A més, la funció de classificació resultant s'ha comprovat amb dades d'ocells capturats a Suïssa i s'ha pogut classificar correctament el 96% dels individus.

Resumen

Sexado de los juveniles de Jilguero *Carduelis carduelis* por el color del plumaje

El sexado de las aves juveniles puede ser muy importante para los anilladores e investigadores y de gran valor en estudios de ecología sobre diferencias sexuales en mortalidad, estrategias de dispersión o porcentaje de sexos en las puestas. No obstante, las aves juveniles de muchas especies de paseriformes no pueden ser sexadas por los anillador porque exhiben un plumaje pálido con muy poca variación individual. En este trabajo se sugiere un método fácil que ha permitido identificar hasta el 91% de los jóvenes de Jilguero con la medida de la longitud máxima del ala y el número de rectrices con mancha oval blanca. La función de clasificación resultante se ha comprobado con datos de aves capturadas en Suiza y se ha podido clasificar correctamente el 96% de los ejemplares.

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