Sexing juvenile Great Tits *Parus major* on plumage colour

J. DOMÈNECH, J. C. SENAR & E. VILAMAJÓ

The Great Tit Parus major has been the target of many kinds of studies. Unfortunately, as in many other passerine species, juveniles (3J) show a duller plumage, less intensely coloured than that of adults, which do not allows sexing of the birds; this prevents many kinds of studies in which the sex of the birds is of importance. Given that in cardueline finches body plumage coloration, in conjunction with wing length, has been proved to be useful for sexing juvenile birds (EURING age 3J), in this paper we test the usefulness of these characters for sexing juvenile Great Tits. The data are based on 127 juvenile Great Tits (28 of them with colour data) captured in a suburban area of Barcelona (NE Spain) from 1997 to 1999. When using wing length, the percentage of individuals correctly classified by discriminant analysis was 74%. Using colour data alone allowed correct classification in 89% of cases. Stepwise discriminant analysis including plumage colour data and wing length classified 93% of cases correctly. The results show the presence of plumage dichromatism in juvenile Great Tits. This supports our earlier suggestion that plumage colour may be used to sex juveniles in several species, as in cardueline finches and probably other tits (e.g. Blue Tit Parus caeruleus). This paper also shows the usefulness of a digital chromameter for field measurement of colour, since it allows the user to obtain quantitative data that can improve the percentage of correctly sexed juveniles.

Key words: Great Tit, Parus major, sexing juveniles, plumage colour, discriminant analysis, chromameter.

Jordi Domènech*, Joan Carles Senar & Ester Vilamajó,
Museu de Zoologia, Ap. correus 593, Barcelona 08080.
* e-mail: (jordi.dg@teleline.es)

INTRODUCTION

Juveniles of many passerine species display duller plumage, less intensely coloured than the adults, and this prevents sexing (Busse 1984, Pyle et al. 1987, Svensson 1992, Jenni & Winkler 1994). This can be a constriction for stud-

ies on parental investment, heritability, dispersal or survival, where knowing the sex of juvenile birds may be of importance (Blank & Nolan 1983, Breitwisch 1989, Marzluff & Balda 1989, Stamps 1990, Payne 1991, Weatherhead & Teather 1991, Gowaty 1993).

The Great Tit *Parus major* has been a very popular species in this kind of study (e.g. Bulmer & Perrins 1973, Dhondt 1979, Greenwood et al. 1979, Garnett 1981, Clobert et al. 1988, Norris 1990, Slagsvold & Amundsen 1992, Norris 1993, Cichon & Lindén 1995, Verhulst & Hut 1996). Perrins (1979) suggested that with practice, the sex of juveniles may be discriminated on the basis of slight differences between the colour of outer fringes of the primary coverts, and Dhont (1970) even suggested that these differences could be used to sex fully grown pulli, but differences are far from clear (Svensson 1992, A.Gosler pers. comm.).

In cardueline finches, contour body plumage coloration has been proved to be useful for sexing juveniles (Borras et al. 1993, Senar et al. 1998). In this paper we test the usefulness of this character for sexing juvenile Great Tits.

MATERIAL AND METHODS

The data come from 127 juvenile Great Tits (EURING age 3J) captured with special funnel traps (Senar et al. 1997) in a suburban area of Barcelona (NE Spain) from 1997 to 1999. Each bird was ringed with numbered aluminium rings, and aged according to Svensson (1992). For each individual we measured maximum chord wing length (Svensson 1992) and plumage colour of the crown, breast, back and abdomen using a Cr200 Minolta chromameter, fitted with an 8-mm diameter sensor and a standard illuminate condition settled to D_{65} (6504K) (Senar et al. 1998).

For each bird, the chromameter provides colour measurements according to different systems (e.g. Munsell, CIE Yxy, CIE Lab, CIE LCH). Here we use the CIE LCH colour system, which provides independent values of hue, chroma and lightness, the parameters generally used to define a colour. Hue corresponds to wavelength of light: blue for short wavelengths, red for longer wavelengths. In the CIE LCH system, however, hue is transformed to cylindrical coordinates: $0°$ refers to pure red, $90°$ to pure yellow, $180°$ to green, $270°$ to pure blue, and $360°$ ($=0°$) to pure red again. Therefore, for instance, a colour with a hue angle of $45°$ is orange. Chroma (also called saturation or intensity) refers to spectral variance, and therefore to colour purity; the more monochromatic a colour is, the higher its chroma value. Lightness (also called brightness) is correlated with physical light intensity and refers to the percentage of white, in other words the position on a grey-scale between black and white (Booth 1990, Senar et al. 1998, Figuerola et al. 1999).

In the analysis of colour variables we used 28 juveniles (9 females, 19 males) from the whole sample of 127 individuals; the sex of these birds was confirmed according to plumage characters (Svensson 1992), when they were later recaptured after completion of body moult. Once the sex of each bird was known, we used discriminant analysis (Norusis 1986) to test which variables could be used to sex juvenile birds correctly.

RESULTS

Juvenile male Great Tits showed longer wing lengths than females (males $\overline{X}=73.7$, sd$=2.1$, n$=74$; females $\overline{X}=71.6$, sd$=1.91$, n$=53$; t-student $=-5.91$, p<0.001). Discriminant analysis showed that the percentage of individuals correctly

classified using wing length alone was 74% (72% of females, 76% of males) (Wilks' Lambda = 0.78, P = <0.001).

Using a subsample of 28 birds (9 females, 19 males) for which we had recorded plumage coloration, seven variables were included in the discriminant model (Wilks' Lambda=0.47, P<0.05, n=28; Table 1). This model allowed us to classify 89% of cases correctly (89% of females, 89% of males).

Stepwise discriminant analysis including both plumage colour data and wing length showed five variables included in the model (Wilks' Lambda =0.46, p<0,01, n=28; Table 2). This model correctly classified 93% of cases (100% of females and 90% of males).

Classification functions for the last stepwise discriminant analysis and for wing length alone, which can be used directly to classify individuals, are provided in Table 3, and mean values for plumage coloration variables in Table 4.

Variable	Wilks' Lambda	P
Crown lightness	0.80	<0.05
Abdomen chroma	0.73	<0.05
Abdomen lightness	0.65	<0.05
Breast lightness	0.60	<0.05
Breast chroma	0.55	<0.05
Back hue	0.51	<0.05
Back chroma	0.47	<0.05

Table 1. Variables included in the model by discriminant function analysis, when only colour variables are used (n=28 individuals).

Taula 1. Variables incloses en el model de la funció de l'anàlisi discriminant a partir de totes les variables de color mesurades (n=28). (Crown = capell; breast = pit; back = esquena; lightness = lluminositat; chroma = saturació). El mot hue correspon a la transformació en coordenades cilíndriques de la longitud d'ona.

Variable	Wilks' Lambda	P
Wing length	0.74	<0.05
Crown lightness	0.64	<0.05
Abdomen chroma	0.57	<0.05
Breast lightness	0.52	<0.05
Breast chroma	0.46	<0.05

Table 2. Variables in the model of discriminant function analysis including wing length and all colour variables measured (n=28)

Taula 2. Variables incloses en el model de la funció de l'anàlisi discriminant a partir de la longitud alar i totes les variables de color mesurades (n=28). (Wing length = longitud de l'ala; crown = capell; breast = pit; lightness = lluminositat; chroma= saturació).

Capture day (as number of days from 1 April) did not show differences between sexes (t-student=-0.16, df=26, P=0.87).

These analyses were based on individuals sexed after moult, which means that they were survivors. For this reason we ran a MANOVA ($F_{5,42}$= 0.60, P=0.70) that did not show differences between original and surviving groups when comparing variables included in the best model (Table 2) between original and surviving groups.

Although this test is not definitive because it does not take into account the probability of recapture, we can be reasonably confident that our results were not biased.

DISCUSSION

Previous work by Dhondt (1970) and Perrins (1979) suggested that the sex of juvenile Great Tits and fully grown pulli may be discriminated on the basis of slight differences between the colour of the outer fringes of the primary coverts. However, considerable experience is necessary, and

Including wing length and plumage colour variables
Incloent la longitud de l'ala i variables de color

Female = $(WL * 20.76) + (CL * 3.18) - (ACh * 5.15) + (BL * 8.81) - (BCh * 3.68) - 984.04$
Male   = $(WL * 21.52) + (CL * 3.67) - (ACh * 5.55) + (BL * 9.32) - (BCh * 3.99) - 1070.85$

Including wing length alone
Incloent únicament la longitud de l'ala

Female = $(WL * 17.46) - 625.67$
Male   = $(WL * 13.99) - 663.83$

Table 3. Classification functions obtained from discriminant analysis. Each individual should be classified into the sex for which it has the higher classification score. (Variables: Wing length (WL); Crown Lightness (CL); Abdomen Chroma (ACh); Breast Lightness (Bl.) and Breast Chroma (BCh)).

Taula 3. Funcions de classificació obtingudes a partir de l'anàlisi discriminant. Classificarem un cas dins d'un grup concret (mascles o femelles) segons d'on s'obtingui com a resultat el valor numèric més alt. (Variables: Longitud de l'ala (WL); Lluminositat del capell (CL); Saturació del abdomen (ACH); Lluminositat del pit (BL); i Saturació del pit (BCh).

differences are not clear (Svensson 1992, A.Gosler pers. comm.). Work by Drent (1984) has shown that 13% of birds are misclassified when using this method.

Our results show the presence of plumage dichromatism in juvenile Great Tits with relation to contour feathers. Nevertheless, the use of the colour of contour feathers to discriminate the sex of juveniles provides a percentage of error (11%) similar to that obtained when using the primary coverts (13%). However, when adding wing length to the discriminant function, the percentage of correctly sexed birds increases to 93%. By the use of a chromameter (Senar et al. 1998) training is not necessary, so that any ringer can readily sex juvenile birds.

Variable	females		males	
	mean	sd	mean	sd
Lightness				
Crown	29.22	2.86	31.89	2.49
Breast	58.67	4.42	60.68	3.42
Abdomen	63.34	4.37	10.32	4.08
Chroma				
Breast	11.89	2.35	65.74	3.43
Abdomen	13.67	5.07	12.37	4.02
Back	4.78	2.05	4.26	1.69
Hue				
Back	87.00	9.50	80.16	21.20

Table 4. Mean and standard deviation values for plumage colour variables.

Taula 4. Valors mitjans i desviació estàndard per a les variables de color. (Crown = capell; breast = pit; back = esquena; lightness = lluminositat; chroma = saturació). El mot hue correspon a la transformació en coordenades cilíndriques de la longitud d'ona.

Although we worked with small sample sizes (especially in the case of females) the results seem to support our previous suggestion that contour plumage colour may be used to sex juveniles in several species, including cardueline finches (Borras et al. 1993, Senar et al. 1998) and probably other tit species (e.g. Blue Tit *Parus caeruleus*). •

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RESUM

Sexat de juvenils de Mallerenga Carbonera Parus major pel color del plomatge.

La Mallerenga Carbonera Parus major ha estat el subjecte de molts tipus d'estudis en el quals el coneixement del sexe dels juvenils pot ser important. Malauradament, con en moltes altres espècies de passeriformes, els juvenils tenen un plomatge apagat, menys intensament acolorit que el dels adults (ocells ja mudats), la qual cosa impedeix el seu sexat. Donat que s'ha provat que en alguns fringíl·lids la coloració del plomatge, juntament amb la longitud de l'ala, serveix per sexar els juvenils (edat Euring 3J), en aquest article comprovem la utilitat d'aquests caràcters per determinar el sexe de juvenils de la Mallerenga Carbonera. Les dades es basen en 127 ocells juvenils (28 d'ells amb dades sobre el color) capturats a la zona suburbana de Barcelona de 1997 a 1999. Utilitzant la longitud de l'ala, el 74% d'individus van ser correctament classificats per l'anàlisi discriminant. Utilitzant únicament el color del plomatge es va poder classificar correctament un 89% dels casos. L'anàlisi discriminant pas a pas, incloent la longitud de l'ala i les variables de color, va permetre classificar correctament un 93% dels casos. Els resultats mostren l'existència de dicromatisme en el plomatge dels juvenils de Mallerenga Carbonera. Això dóna suport al nostre suggeriment que el color del plomatge pot ser útil per determinar el sexe dels juvenils de diverses espècies, com és el cas dels fringíl·lids carduelins i probablement altres mallerengues (p.ex. Mallerenga blava Parus caeruleus). Aquest article addicionalment mostra la utilitat dels cromòmetres digitals per mesurar el color al camp, ja que permet obtenir dades quantitatives que milloren el percentatge de juvenils sexats correctament.

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