Butll. GCA 14: 1-8, 1997

Age- and sex-related differences in the wing shape of Bluethroats *Luscinia svecica* in south-east Spain

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Two main treatments of the analysis of wing shape obtained from primary lengths and primary distances were used by means of principal components analysis (PCA) in order to assess age and sex differences in a sample of wintering Bluethroats in SE Spain. A size-independent technique, developed by Chandler & Mulvihill (1988, Ornis Scand. *19: 212-216), which does not control for body size and allometry, was used on the original variables. A statistical modification that controls for allometric effects and body shape (Senar* et al. *1994,* J.Avian Biol. *25: 50-54) was subsecuently used on the standarized primaries. Wing shape of Bluethroats could be summarized by three Principal Components (PCA) which explained 80% of the total variation. The two techniques differed in their ability to detect age- or sex-related differences in the wing shape of Bluethroats.*

Key words: Bluethroat, *Luscinia svecica*, wing-shape variation, SE Spain.

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Rebut: 27.01.97; Acceptat: 05.06.97

INTRODUCTION

It is known that migratory strategies differ between and within species (Gauthreaux 1982, Ketterson & Nolan 1976, Chandler & Mulvihill 1990, Spina *et al* 1994). These differences may depend on age (e.g. Hussel *et al.* 1967, Morton & Pereyra 1994) or sex (e.g. Francis & Cooke 1986, Gill *et al.* 1995, Stolt & Fransson 1995), or may occur among individuals of different geographical origin (e.g. Lövei 1983, Tiainen & Hanski 1985, Lo Valvo *et al.* 1988).

The concept of an adaptive relationship between wing shape and migratory strategies is based on the generalizations that migrants have longer, more pointed wings than more sedentary birds (Stegmann 1962, Mulvihill & Chandler 1991, Mönkkönnen 1995) and that ages and sexes differ in their wing shapes (Lövei

1983, Tiainen & Hanski 1985, Heddenström & Pettersson 1986, Chandler & Mulvihill 1990).

The Bluethroat *Luscinia svecica* is a polytypic species, in which the Western Palearctic races have shown different migratory strategies (Cramp 1988), and ages and sexes may differ in the speed of migration (Ellegren 1990) or in stopover ecology (Ellegren 1991). However, the wing morphology of this species has not been studied, and this is a necessary step in attempting to evaluate the relationships between migratory strategy and wing shape within this species.

In this study, the wing shapes of Bluethroats trapped in the autumn and winter months in south-east Spain are analysed in order to investigate intraspecific differences in wing morphology and their possible relationship with migratory strategies.

MATERIAL AND METHODS

Bluethroats (n=87) used in this study were captured in two reedbeds of different structure and composition at Hondo Natural Park, Elche, in the province of Alicante, SE Spain (38°16N 00°41W) from August to March in the 1992/93 and 1993/94 seasons. Most birds belonged to the white-spotted form *Luscinia svecica cyanecula* (Peiró 1997) suggesting a central European origin for those birds. Birds were sexed on plumage features and aged as first-years or adults according to the presence or absence of rusty-buff spots on the greater coverts and inner primary coverts (Svensson 1992).

For each bird, the wing length and wing formula were measured. The wing length (maximum chord method, Svensson 1992) was recorded to the nearest 0.5 mm and the wing formula on the left wing was recorded to the nearest 0.5 mm measuring the primary distances from the wingtip (P3 or P4) to the tip of each of the nine primaries P2-P10 (numbered ascendantly) on the folded wing, using a transparent ruler. Primary lengths were calculated by substracting each primary distance from the wing length (see Evered 1990). Primary lengths were corrected for body size and allometry and transformed into standarized primary lengths using the method proposed by Senar *et al.* (1994).

Two principal components analyses (PCA) were used: a first PCA was used following Chandler & Mulvihill (1988), on the correlation matrix of the original variables (wing length and primary distances) in order to obtain the sources of variation in the feather-length data, taking into account allometric relationships between variables. A second PCA was then performed on the primary lengths standarized for body size and allometry using a mean wing length of 72.95 mm (Table 1). This allowed us to

Table 1. Mean standarized primary lengths, numbered ascendantly, of Bluethroats (n=87) and the allometry regression coefficient for each primary according to the growth model indicated in Senar *et al.* (1994).

Taula 1. Longitud mitjana estandarditzada de les primàries, numerades ascendentment, de la Cotxa Blava (n=87) i el coeficient de regressió alomètrica per a cada primària d'acord amb el model de creixement indicat per Senar et al. (1994).

Primary length	Mean ± SE	r
P2	67.20 ± 0.08	0.9344
P3	72.80 ± 0.03	0.9927
P4	72.87 ± 0.03	0.9928
P5	71.94 ± 0.06	0.9597
P6	69.37 ± 0.09	0.9086
P7	66.22 ± 0.10	0.8645
P8	63.78 ± 0.10	0.8504
P9	61.76 ± 0.09	0.8443
P10	59.50 ± 0.12	0.7381

obtain PCA wing-shape components independent of these two factors. Allometric transformations were made using the *Sizestd* program (Senar *et al.* 1994) and PCA analyses were performed using the *Statistix* package (Analytical Software 1986). The factor scores from the two PCA analyses were then used to test for differences between ages and sexes in the Bluethroat.

RESULTS

Results of the first PCA on the original variables (wing length and primary distances, Table 2) show three principal components which accounted for 81.9% of the total variation in the original data. PC1 could be associated with a decrease in wing length and the associated distances of proximal primaries (P4-P10). This axis accounted for 56.5% of the total variation and could be related to an overall wing-length size axis, which is independent of the PCA model used (Shea 1985, Rising & Somers 1989). PC2 and PC3 accounted for 25.4 % of the total variance and could be related to a an increase of the distances of distal primaries (P2-P3) and to an increase of wing length and most proximal primary (P10) versus a decrease in P4 (and to a lesser extent P2, P5).

Results of the second PCA, standardizing for allometric effects on primary lengths, showed three principal components which accounted for 80.4% of the total variation in the standarized primary lengths (Table 3). PC1 represented a shape axis related to an associated decrease of

Table 2. Principal components analyses in Bluethroats (n= 87) based on the primary distances (P2-P10, numbered ascendantly). Wing length is included as a variable, as described by Chandler & Mulvihill (1988). Note that in this method we use distances for each primary to wing tip.

Taula 2. Anàlisi de Components Principals en la Cotxa Blava (n=87) basada en les distàncies de les primàries (P2-P10, numerades ascendentment). La longitud de l'ala s'ha inclòs com a variable seguint Chandler & Mulvihill (1988). Noteu que aquest mètode utilitza les distàncies de cada primària fins a la punta de l'ala.

	Factor loadings/ *Valors dels components principals*		
Variable	PC1	PC2	PC3
Wing length	-0.2825	0.1888	0.4571
P2	-0.0704	0.6427	-0.3787
P3	0.0584	0.7129	0.0210
P4	-0.2710	-0.1283	-0.5549
P5	-0.3478	-0.0459	-0.3636
P6	-0.3734	-0.0916	-0.2193
P7	-0.3908	-0.0253	0.0229
P8	-0.3923	-0.0300	-0.1678
P9	-0.3970	0.0248	-0.2120
P10	-0.3374	0.1182	0.2922
Eigenvalue/ *Vector propi*	5.646	1.504	1.038
% variance explained/ *% Variança explicada*	56.5	15.0	10.4
Cumulative variance/ *Variança acumulada*	56.5	71.5	81.9

Variable	Factor loadings / *Valors dels components principals* PC1	PC2	PC3
P2	- 0.0312	- 0.7203	- 0.1584
P3	0.1287	- 0.6782	0.1606
P4	- 0.2914	- 0.0126	- 0.6228
P5	- 0.3689	- 0.0885	- 0.3520
P6	- 0.4032	- 0.0044	- 0.2002
P7	- 0.4121	- 0.0139	0.0970
P8	- 0.4097	0.0404	0.2597
P9	- 0.4122	- 0.0133	0.3120
P10	- 0.3022	- 0.1060	0.4722
Eigenvalue / *Vector propi*	4.811	1.451	0.972
% variance explained / *% Variança explicada*	53.5	16.1	10.8
Cumulative variance / *Variança acumulada*	53.5	69.6	80.4

Table 3. Principal components analysis in Bluethroats (n=87) based on the relative lengths of the primary feathers (P2-P10, numbered ascendantly) standardized for body size (wing length) and allometry as described by Senar *et al.* (1994).

Taula 3. Anàlisi de Components Principals en la Cotxa Blava (n=87) basada en la longitud relativa de les primàries (P2-P10, numerades ascendentment) estandarditzades segons la mida de l'ocell (longitud de l'ala) i l'alometria seguint Senar et al. (1994).

	Adults *Adults*		First-years *1r any*		Males *Mascles*		Females *Femelles*		Method *Mètode*
	Mean/ *Mitjana*	S.D	Mean/ *Mitjana*	S.D	Mean/ *Mitjana*	S.D	Mean/ *Mitjana*	S.D	
PC1	- 0.547	3.037	0.487	1.440	- 0.709	1.105	1.105	1.903	Primary distances/ *Distàncies de les primàries*
	0.102	2.768	- 0.091	1.538	0.023	2.300	- 0.037	2.049	Standarized primary lengths/ *Longitud estandarditzada de les primàries*
PC2	- 0.104	1.240	0.093	1.220	0.101	1.261	- 0.158	1.171	Primary distances/ *Distàncies de les primàries*
	- 0.166	1.197	- 0.148	1.205	-0.029	1.194	0.045	1.237	Standarized primary lengths/ *Longitud estandarditzada de les primàries*
PC3	0.050	1.224	- 0.045	0.805	0.247	1.115	- 0.385	0.703	Primary distances/ *Distàncies de les primàries*
	0.148	1.144	-1.132	0.810	-0.053	1.024	0.083	0.931	Standarized primary lengths/ *Longitud estandarditzada de les primàries*
n	41		46		53		34		

Table 4. Mean PCA scores for the different age and sex classes obtained from the primary distances or standardized primary lengths.

Taula 4. Valors mitjans per a cada eix de l'Anàlisi de Components Principals segons classes d'edat i sexe obtinguts a partir de les distàncies de les primàries o la longitud estandarditzada de les primàries.

	Adults - First-years *Adults - 1r any*		Males - Females *Mascles - Femelles*		Method *Mètode*
	F	p	F	p	
PC1	4.26	*	13.88	***	Primary distances/ *Distàncies de les primàries*
	0.68	N.S	0.02	N.S	Standarized primary lengths/ *Longitud estandarditzada de les primàries*
PC2	0.56	N.S	0.92	N.S	Primary distances/ *Distàncies de les primàries*
	1.48	N.S	0.08	N.S	Standarized primary lengths/ *Longitud estandarditzada de les primàries*
PC3	0.19	N.S	8.67	**	Primary distances/ *Distàncies de les primàries*
	1.76	N.S	0.39	N.S	Standarized primary lengths/ *Longitud estandarditzada de les primàries*

Table 5. Values of the One-way ANOVA and associated probability for the mean PCA scores of the different age and sex classes obtained using primary distances or standardized primary lengths. (Significance level: * $p< 0.05$; ** $p< 0.01$; *** $p<0.001$).

*Taula 5. Valors de l'ANOVA unifactorial i probabilitat associada per als valors mitjans per cada eix de l'anàlisi de components principals segons les diferents classes d'edat i sexe, obtinguts utilitzant les distàncies de les primàries o les longituds estandarditzades de les primàries. (Nivells de significació: * $p< 0.05$; ** $p< 0.01$; *** $p<0.001$).*

proximal primary lengths (P4-P10). PC2 and PC3 accounted for 26.9% of the total variance. PC2 indicated a decrease in distal primaries (P2-P3) and PC3 represented an inverse relationship between distal (P4-P6) and proximal primaries (P8-P10).

Mean PC scores showed significant differences between ages and sexes for primary distances (Tables 4 and 5), but not when using primary lengths standarized for body size and allometry.

DISSCUSSION

This study shows the existence of age- and sex-related differences in the PCA analysis based on primary distances and wing length as original variables, according to the method proposed by Chandler & Mulvihill (1988). Age and sex differences in PC1 represent an overall size axis. PC1 accounted for most variance (56.5%), and the differences between age and sex classes could be due to slight differences in the wing shape represented in this axis, adults having shorter proximal primary distances than first years (mean PC1 score: adults= -0.547 [s.d. = 3.037]; first-years= 0.487 [s.d. = 1.440]; ANOVA, $F = 4.26$, $p <0,05$) and males having shorter proximal primary distances than females (mean PC1 score; males: -0.709 (s.d. = 1.105), females: 1.105 (s.d = 1.903); ANOVA, $F = 13.88$; $p < 0.001$). This feature gives a flying advantage to adult and males with more pointed wings versus juvenile and females with more rounded wings.

The remaining variation of the PCA could represent other unmeasured variables such as populations, subspecies or migratory status of Bluethroats trapped at the site. However, earlier analyses of wing shape in Bluethroats grouped by season (autumn, winter or spring) did not show differences in their PCA, showing that the wing shape of Bluethroats at this site is independent of the season.

Age and sex differences in wing shape using the methodological approach of Senar *et al.* (1994) have been found in some cardueline finches (e.g Siskin *Carduelis spinus*, Senar *et al.* 1994, Citril Finch *Serinus citrinella*, Borras *et al.* 1988) and wing-shape differences between age/sex classes using Chandler & Mulvihill's (1988) approach have been found in Dark-eyed Juncos (Chandler & Mulvihill 1990) and in this study. These differences can therefore occur in species of different genera and migratory status.•

ACKNOWLEDGEMENTS

I am grateful to Dr. F. Valera for his support and assistance in the statistical analysis. Dr. J.C. Senar provided me with the *Sizestd* program. I also thank Drs. R.S. Mulvihill and J.C.Senar for their useful comments which helped to improve earlier versions of the manuscript.

RESUM

Diferències relacionades amb l'edat i el sexe en la forma de l'ala de la Cotxa Blava* Luscinia svecica *al SE d'Espanya

Dos tractaments principals de l'anàlisi de la forma de l'ala a partir de la longitud de les primàries i la distància de les primàries utilitzant una anàlisi de components principals (PCA) va ser utilitzat, per establir les diferències entre edat i sexe en una mostra de cotxes blaves que hivernaven al SE d'Espanya. Una tècnica independent de la mida desenvolupada per Chandler & Mulvihill (1988, Ornis Scand. *19: 212-216), la qual no efectua un control sobre la mida del cos i l'alometria fou emprada en les variables originals. Una modificació estadística que controla els efectes alomètrics i la forma del cos (Senar* et al. *1994,* J.Avian Biol. *15: 50-54) fou utilitzada posteriorment sobre les primàries estandarditzades. La forma de l'ala de les cotxes blaves es podria resumir per tres components principals (PCA) els quals explicaren el 80% de la variació total. Ambdues tècniques difereixen en la seva habilitat per detectar diferències en l'edat o el sexe de la forma de l'ala de les cotxes blaves.*

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