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A method for differentiating between sedentary and migratory Blackcaps *Sylvia atricapilla* in wintering areas of southern Iberia

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We used the morphological differentiation of southern, sedentary Iberian Blackcaps Sylvia atricapilla *to distinguish them from migratory Blackcaps during the winter. To do so, we studied three morphometric traits (wing length, wing shape and tail length) of three migratory Iberian populations and two sedentary ones during the breeding season. We obtained a discriminant function which allowed us to differentiate the two population types (>90% correct classifications). We discuss the utility of the method for differentiating between sedentary and migratory Blackcaps in their sympatric wintering areas, as well as the implications of our results for the study and conservation of sedentary, perhaps differentiated Blackcaps in southern Iberia.*

Although the Mediterranean basin is the main wintering ground for most pre-Saharan migrant passerines, it also sustains sedentary populations of many of these species. Despite the interest in differences between migratory and sedentary populations during the winter in traits such as habitat use, diet, body condition or survival, these subjects remain insufficiently understood. Several studies have searched for differences in winter behaviour between subspecies, sexes or age classes, these groups being always easily distinguishable (see refs 1 and 2 for examples with Nearctic migrants). However, few studies have pointed out how different populations of a given species perform in sympatry during the winter,[3–5] even when these populations may show different morphological traits, possibly related to different patterns of resource exploitation.[6–9] Such studies are limited by the lack of suitable methods that allow differentiation between such populations when distinction is not straightforward. In this paper, we use a combination of different morphological traits of Blackcaps *Sylvia atricapilla* to develop a simple procedure for differentiating between sedentary and migratory individuals in the sympatric wintering areas of southern Iberia. The Blackcap should be a good model on which to undertake such studies, since most of their Mediterranean breeding grounds receive a considerable influx of migrants in autumn.[10,11]

METHODS

During June and July 1997, we mist-netted 146 Blackcaps in five localities distributed along the Iberian Peninsula. We captured 99 young and 47 adult birds (28 males and 19 females). Three of the localities were in the northern part of Iberia (Álava, 42º55′N, 2º29′W, in northern Iberia; Sierra de Guadarrama, 40º54′N, 3º53′W, and Madrid, 40º30′N, 3º40′W, both in central Iberia), and the other two on its southern edge (Sierra de Ojén and Tarifa, 36º01′N, 5º36′W; see ref. 12 for details). Blackcap populations are migratory at the northern and central localities, which they abandon during the winter.[9] Ringing recoveries show that Blackcaps are sedentary at the southern localities.[6,11,13] Thus, we grouped these five populations as northern (migratory) and southern (sedentary).[9] Because it is known that Blackcaps show migratory

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polymorphism,[9,14,15] we used some traits relevant for migratory flight performance (wing length, wing shape and tail length),[16,17] that could allow us to differentiate such population types in their wintering grounds. Wing maximum chord and length of the eighth primary feather (descendant) were strongly correlated ($r = 0.85$, $n = 146$, $P < 0.001$), thus we selected the latter measurement as related to wing length.[18] We also considered the difference $P_1 - P_9$ as an index of wing shape (where P_1 and P_9 are the distances from the tip of the first and ninth primary feathers to the wing-tip). In Blackcaps, this difference increases as the wing becomes more pointed[9,14,19,20] (Fig. 1). Finally, we recorded tail length (straightened), because northern populations have shorter tails than southern ones.[9,20] All measurements were recorded by the same person (R.C.) to the nearest 0.5 mm (see ref. 21 for details).

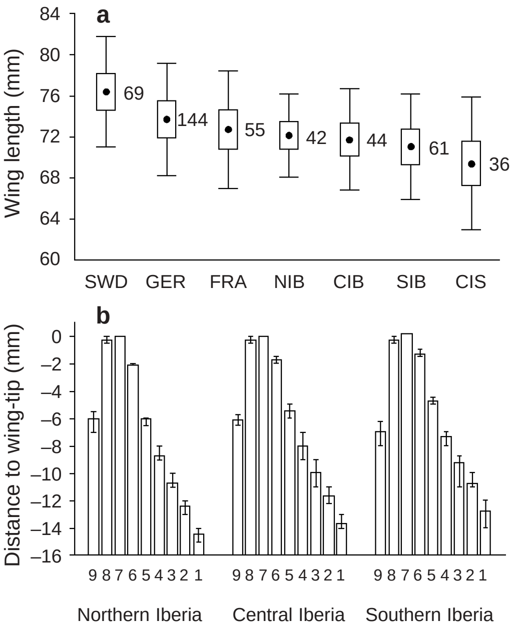

Figure 1. (a) Geographic variation in wing length of European Blackcaps (mean, standard deviation, theoretical range (mean ± 3 sd) and sample size). Measurements are from Sweden (SWD), southern Germany (GER), southeastern France (FRA), northern Iberia (NIB), central Iberia (CIB), southern Iberia (SIB) and Canary Islands (CIS). (b) Mean and range of the distances from the tip of each primary feather (first to ninth, numbered descendantly) to the wing tip of Iberian Blackcaps (negative values are shown to simplify the perception of wing shapes). All measurements, except those from Iberia (this study), have been taken from refs 10 and 11.

We used discriminant function analysis (DFA)[22,23] to classify birds as migratory or sedentary. Neither sex nor age showed a significant effect on any of the variables we measured (Table 1), so we pooled all sex and age classes in the DFA. Since migratory individuals outnumber residents in wintering areas,[24] a given Blackcap of unknown origin is, *a priori*, more likely to be migratory than sedentary. However, because the abundance of migratory Blackcaps varies between winters while presumably the resident population does not,[24–26] we cannot objectively assess the true proportion of sedentary birds in the winter population, so we settled *a priori* probabilities of population membership proportional to sample sizes.[22,23] To test the effectiveness of our model, we simulated a series of 50 DFA trials using pairs of half-sample random groups.

Table 1. Results of two-way ANOVAs for between-age (first-year versus adult birds) and between-sex differences for all the variables considered in this study.

	$P_1 - P_9$		*Tail length*		*Length of eighth primary*	
	F	P	F	P	F	P
Age (all df = 1,142)						
Between-groups	86.06	<0.001	18.34	<0.001	30.60	<0.001
Between-age	0.27	0.61	0.03	0.86	0.66	0.42
Interaction	2.95	0.09	1.30	0.26	0.64	0.42
Sex (all df = 1,43)						
Between-groups	9.60	0.003	6.48	0.01	4.33	0.043
Between-sex	0.001	0.98	0.80	0.38	0.25	0.62
Interaction	1.00	0.32	0.12	0.73	0.06	0.80

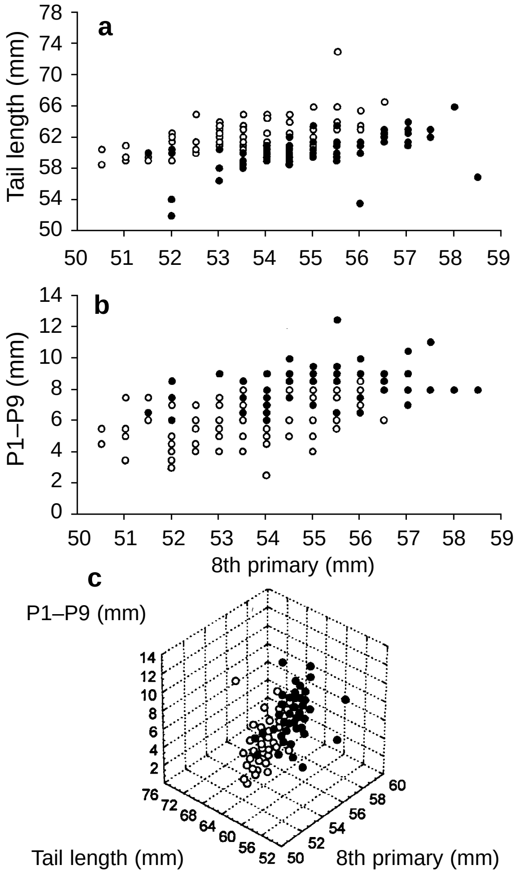

Figure 2. Morphological features of Blackcap population types studied (●, migratory birds; ○, sedentary birds). Controlling for wing length (measured as length of the eighth primary feather), migratory Blackcaps (n = 85) show shorter tails (a) and more pointed wings (b) than sedentary ones (n = 61), which makes their near-absolute discrimination possible when all variables are combined (c).

Thus, for each simulation, we randomly selected two equal groups from the original sample (73 birds in each one) in which all the localities were always equally represented. Then we used one of these groups to develop a discriminant function, with which we attempted to classify the birds of the second group. After repeating the same routine 50 times, we estimated the 95% confidence interval of the mean percentage of correct classifications. If the model was reliable, we could use the first discriminant function, obtained by including all the birds from the original sample, to assign new observations to one or other population.

Once the model was developed, we sampled the southern localities during December 1997 and January 1998, when wintering Blackcaps occur in this region together with residents.[11] European Blackcaps, consistently with their migratory behaviour, have more pronounced migratory-type traits than northern Iberian populations[10,20] (see Fig. 1), and are expected to be well classified by our discriminant function.[22] If the effectiveness of our model for discriminating Iberian population types is high, we should be able to distinguish resident and migrant birds in their wintering grounds and to estimate their relative numbers in the whole wintering population. Thus, we can obtain the probability of each Blackcap being sedentary,[23] and then use the sample mean (that is, the probability of a given Blackcap of the winter population being sedentary) as an estimate of the proportion of sedentary birds in the whole winter population.

RESULTS

The DFA conducted with the whole spring sample provided a significant function (Wilk's Lambda = 0.39, Rao's approximation: $F_{3,142}$ = 75.00, P < 0.001; see Table 2 and Fig. 2) whose percentage of correct classifications exceeded

Table 2. Descriptive statistics for the variables included in the discriminant function analysis. Pooled within-groups correlations between variables and the canonical discriminant function are also shown.

	Migratory Blackcaps (n = 85)		*Sedentary Blackcaps* (n = 61)		
	Mean	*sd*	*Mean*	*sd*	*Correlation with discriminant function*
$P_1 - P_9$	8.03	1.18	5.79	1.39	–0.70
Tail	60.60	2.15	62.46	2.33	0.33
Eighth primary	54.94	1.55	53.35	1.53	–0.41

Table 3. Classification matrix provided by discriminant function analysis (incorrect classifications in italics), a priori probabilities of classification (proportional to sample sizes, *p*), and percentage of correct classifications.

		Predicted classifications		
	Actual classifications (n)	*Migratory Blackcaps* (p = 0.58)	*Sedentary Blackcaps* (p = 0.42)	*Correct classifications (%)*
Migratory Blackcaps	85	80	*5*	94.12
Sedentary Blackcaps	61	*8*	53	86.89
Both groups	146	88	58	91.09

90% (Table 3). About 61% of the variation in the discriminant scores[23] was accounted for by between-population differences when all variables were considered together (canonical correlation: $r = 0.78$). Thus, we obtained the following classification functions:[23]

$$M = -696.432 - 6.098WS + 4.648T + 21.099F_8$$
$$S = -688.896 - 7.397WS + 5.617T + 20.018F_8$$

where WS is the wing-shape index $P_1 - P_9$, T is the tail length, F_8 is the length of the eighth primary feather and M and S are, respectively, the classification scores for migratory and sedentary population types. These functions can be used to classify new observations assigning each Blackcap to the group for which it has the highest classification score.[23] The model classified first-year birds better than adults (four out of 13 wrong classifications (Table 3) were first-year birds and nine were adults, $\chi^2_{\text{Yates}} = 7.20$, $P < 0.01$), but both sexes were equally well classified (five males and four females were misclassified, $\chi^2_{\text{Yates}} = 0.01$, $P = 0.92$). Frequency of misclassifications was also homogeneous for both population types (Table 3, $\chi^2_{\text{Yates}} = 1.49$, $P = 0.22$).

By means of the 50 DFA simulations, our model was effective in differentiating between both population types. We obtained almost 90% correct classifications (Table 4), even though we obtained the simulated discriminant functions from reduced samples, which should show less discriminating power.[22,23] Once the efficacy of the model was confirmed, we used it to classify Blackcaps captured during the winter. Five out of 36 captured birds were retraps of Blackcaps ringed during the spring at the same locality (13.9%). These birds were not considered for classification as they were not new individuals. Among the remaining 31 birds, 13 (41.9%) were classified as residents. By using the probabilities of each of these 31 Blackcaps being sedentary, we estimated the percentage of residents in the whole winter population, with 95% confidence, as 37.3% ± 16%.

DISCUSSION

In this work, we assessed the utility of DFA as a reliable tool to differentiate between sedentary and migratory Iberian Blackcap populations, which could be employed for differentiating between such populations in sympatric wintering areas (see also ref. 27). Our procedure has important advantages compared with other methods. The use of ringing recoveries, for instance, is often unsuitable for small

Table 4. Mean, standard error and 95% confidence intervals for the mean percentage of correct classifications obtained after 50 DFA simulations, using pairs of randomly selected half-sample groups (73 individuals in each one).

		Observed percentage of correct classifications	
	n	*Mean ± 1 se*	*95% confidence interval*
Migratory Blackcaps	50	91.78 ± 0.55	90.97–92.89
Sedentary Blackcaps	50	87.41 ± 0.74	85.93–88.90
Both groups	50	89.95 ± 0.40	89.16–90.75

passerines, because of the difficulty of recapturing enough birds to assess between-population differences that potentially occur at the sympatric wintering areas (see, however, ref. 4). On the other hand, single traits that overlap along the species' range offer limited opportunity to discriminate between birds belonging to different populations. For example, Blackcap is a leap-frog migrant in the western Palearctic,[10] so that most birds wintering in the Mediterranean basin will come from mid-latitudes,[11] where morphometrical traits largely overlap with those of southern populations (see Fig. 1). Thus, many of these birds would be misclassified as residents if their morphometric traits (e.g. wing length or wing formula; see refs 3, 24) were considered separately. Moreover, given the difficulty of ageing many Blackcaps during the winter,[28] our discriminant function showed further advantages since it was suitable to differentiate between local and overwintering Blackcaps independently of their age. The slightly poorer ability of the model to discriminate adult birds in summer is probably due to feather abrasion rather than between-age morphological differences (see Table 1), and hence it will not affect classification during the winter after the complete moult of adults.[21,28] In fact, it could be that the main shortcoming of our method might be its differential ability to classify Blackcaps of each population type correctly (see Tables 3 and 4). Sedentary birds, for instance, could be more likely to be misclassified and hence their contribution to the whole population could be underestimated. However, this bias does not seem to be too important, since we did not obtain significant between-population differences in frequency of mis- classifications.

Therefore, our results support the view that a high proportion of Blackcaps is sedentary in southern Iberia.[6,10,11,13] Our recoveries of resident Blackcaps, as well as the high percentage of birds classified as sedentary, support this conclusion. It should be noted, however, that the abundance of migratory Blackcaps varies in relation to food availability, both among and within winters,[24–26] and that food resources, especially olives *Olea europaea sylvestris*, were unusually scarce during the 1997/98 winter in which we sampled the mixed population of Blackcaps (pers. obs.). Thus, the proportion of sedentary birds, averaged over a longer period of several years, could be smaller than the estimate we obtained.

Since discrimination depends on the mophological variation existing among Blackcaps, it should be interesting to study potential differences in the use of resources between migratory and sedentary populations during the winter.[8,9] Furthermore, as it is known that the migratory behaviour of Blackcaps is heritable,[15] it would also be interesting to investigate how these southern birds prevent outbreeding with other surrounding migratory-type individuals which occur at the same wintering areas.[29,30] In short, the maintenance of characteristic morphological features in southern Iberian Blackcaps suggests the prospect of differentiated populations (and hence conservation units[31,32]) locally occurring in the southern edge of the species' range, which may be the subject of fruitful future investigations.

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