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TESTING THE VALIDITY OF DISCRIMINANT FUNCTION ANALYSES BASED ON BIRD MORPHOLOGY: THE CASE OF MIGRATORY AND SEDENTARY BLACKCAPS *SYLVIA ATRICAPILLA* WINTERING IN SOUTHERN IBERIA

Iván DE LA HERA* [1], Javier PÉREZ-TRIS* and José Luis TELLERÍA*

SUMMARY.—*Testing the validity of discriminant function analyses based on bird morphology: the case of migratory and sedentary blackcaps Sylvia atricapilla wintering in southern Iberia.*

Aims: This study introduces a method for validating the suitability of discriminant function analyses (DFA) based on morphological differences among groups of birds, using migratory and sedentary blackcaps *Sylvia atricapilla* wintering in southern Iberia as a case study.

Location: During five summers between 1997 and 2005, migratory blackcaps were studied in Álava and Madrid, and sedentary blackcaps were studied in the Campo de Gibraltar area. Wintering birds were also studied in the Campo de Gibraltar area (nine winters: 1997 - 2006), where migratory and sedentary blackcaps occur in sympatry.

Methods: Morphological traits (wing length, wing pointedness and tail length) of birds captured during summer were used to carry out a DFA for distinguishing between migratory and sedentary individuals during winter. The performance of DFA was tested by (1) observation of the percentage of correct classifications of sedentary blackcaps (ringed birds captured in both seasons), and (2) analysing variation between summer and winter in posterior classification probabilities (P_C) of birds classified as either migratory or sedentary.

Results: The DFA correctly classified 88 % of summer blackcaps, and it still worked well in winter as shown by 20 out of 21 wintering birds known to be sedentary (by ringing recoveries) being correctly classified. P_C increased during winter in birds classified as migratory, due to the arrival to southern Iberia of northern birds with higher migratory-like trait values. As expected from the fact that the sedentary population stays in the area through the year, sedentary blackcaps were classified with similar P_C in both seasons.

Conclusions: DFA based on the morphological differentiation between migratory and sedentary blackcaps correctly classifies individuals during sympatric wintering periods, which is when the DFA is meant to be used. This study shows that a suitable way to validate morphological DFA is comparing the P_C of birds used to generate the functions with the P_C of birds that need to be classified. Analysis of P_C is suggested as a routine test of the performance of DFA in ornithological research.

Key words: Campo de Gibraltar, Discriminant Function Analysis (DFA), migration-related morphology, posterior classification probability, sympatric wintering grounds.

RESUMEN.—*Una prueba de la validez de los análisis de funciones discriminantes para diferenciar aves por sus rasgos morfológicos: el caso de las currucas capirotadas* Sylvia atricapilla *migradoras y sedentarias invernantes en el sur ibérico.*

* Departamento de Zoología y Antropología Física, Facultad de Biología, Universidad Complutense de Madrid, Madrid, E-28040 Spain.

[1] Corresponding author: idelahera@bio.ucm.es

Objetivos: Este estudio propone una nueva aproximación para examinar la validez de los análisis de funciones discriminantes (AFD) utilizados para separar grupos de aves a partir de sus diferencias morfológicas, usando como modelo las poblaciones migradoras y sedentarias de Curruca Capirotada *Sylvia atricapilla* invernantes en el sur de la Península Ibérica.

Área de estudio: Durante cinco veranos, entre 1997 y 2005, se capturaron currucas migradoras en Álava y Madrid, y currucas sedentarias en el Campo de Gibraltar. En esta última área, también se estudiaron individuos durante nueve inviernos (1997 - 2006), durante el periodo en que las currucas migradoras y sedentarias coinciden en simpatría.

Métodos: A partir de los rasgos morfológicos (longitud y forma del ala y longitud de la cola) de los individuos reproductores ibéricos, cuyo comportamiento migrador es conocido, se realizó un AFD para distinguir las currucas migradoras de las sedentarias. Posteriormente, se valoró si dicho método seguía siendo válido durante el invierno, para lo cual se siguieron dos aproximaciones complementarias. En primer lugar, se determinó el porcentaje de clasificaciones correctas durante el invierno de aves anilladas que pudieron ser identificadas inequívocamente como sedentarias, por haber sido controladas en la misma zona en ambas estaciones. En segundo lugar, se compararon las probabilidades posteriores de clasificación (P_C, derivadas del AFD) de las aves clasificadas como migradoras y como sedentarias en ambas estaciones.

Resultados: El AFD clasificó correctamente el 88 % de las currucas capturadas en verano, siendo igualmente eficaz durante el invierno, como puso de manifiesto la clasificación correcta de 20 de las 21 currucas invernantes identificadas como sedentarias (por haber sido controladas en ambas estaciones). La P_C aumentó durante el invierno en las aves clasificadas como migradoras, debido a la llegada al sur de la península Ibérica de aves norteñas con rasgos morfológicos de tipo migrador más acentuados que los de las poblaciones migradoras ibéricas. Sin embargo, los individuos clasificados como sedentarios mostraron similares valores de P_C en ambas estaciones, como cabía esperar dado que permanecen en la zona durante todo el año.

Conclusiones: El AFD basado en la diferenciación morfológica existente entre currucas migradoras y sedentarias reproductoras sigue clasificando las currucas correctamente durante el invierno, que es cuando su uso es pertinente. En este trabajo se demuestra que el análisis de las P_C es una prueba útil para valorar si los AFD mantienen su eficacia durante los periodos del año en que es imposible comprobar directamente si las clasificaciones son correctas. Por ello, se sugiere su uso rutinario por parte de los ornitólogos que utilizan AFD en sus investigaciones.

Palabras clave: Análisis de Funciones Discriminantes (AFD), áreas de invernada simpátricas, Campo de Gibraltar, morfología asociada a la migración, probabilidades posteriores de clasificación.

INTRODUCTION

A large body of ornithological knowledge depends on methods that allow researchers to accurately distinguish among groups of individual birds, such as the two sexes, birds with different migratory behaviour, or cryptic species (e.g., Svensson, 1992; Jenni and Winkler, 1994; Pérez-Tris *et al.*, 1999; Bensch *et al.*, 2002). Such research has greatly benefited from discriminant function analyses (DFA) of morphological traits, which are developed at times when the different groups to be distinguished are easily told apart, for example the two sexes during the breeding season (e.g., Svensson, 1992) or birds with different migratory behaviours when they are captured at their corresponding breeding areas (Copete *et al.*, 1999; Pérez-Tris *et al.*, 1999, 2000). Although molecular markers or stable isotope ratios can greatly help to identify the sex, the species, or the geographic origin of birds (Griffiths, 1998; Webster *et al.*, 2002; Hobson *et al.*, 2004; Bearhop *et al.*, 2005), such techniques are not readily accessible to many field ornithologists. As a consequence, DFA based on morphological traits is still widely used for distinguishing among groups of birds (Copete *et al.*, 1999; Pérez-Tris *et al.*, 1999; 2000; Martín *et al.*, 2000).

Classification methods based on morphological differences among groups need to be validated by testing the performance of DFA on individuals other than the ones used to develop such methods. The usual procedure consists of gathering two independent samples of individuals, developing the DFA from one of the samples, and testing it on the other one. Because both samples are obtained at the time when the method is developed, all individuals can be unambiguously assigned to either group, making it possible to observe the rate of correct classification. However, it has rarely been examined whether DFA still works fine when the groups cannot be readily told apart. At that time, the problem is that whether classifications of individuals are correct or wrong is unknown by definition.

The problem with classification of birds based on morphological differences may be particularly relevant if the traits used to separate among groups change seasonally. For example, commonly used traits such as feather dimensions, colour, or body mass can greatly change due to moult, plumage wear or physiological adjustments (Blem, 1990; Jenni and Winkler, 1994), thereby compromising the performance of DFA developed and applied at different times of year. Although this may be an important problem in many cases, it has rarely been acknowledged, let alone explicitly evaluated.

This study suggests an indirect test of the performance of DFA in ecological studies, based on the posterior classification probabilities (P_C) derived from DFA. The P_C represents the likelihood that a particular individual belongs to a specific group given its morphology. For each group, one can determine the location of the point that represents the means for all variables in the multivariate space defined by the morphological traits (namely the group centroids). The probability (P_C) that a new individual belongs to a group is inversely proportional to the distance from its location in the multivariate space to the centroid of such group (measured as Mahalanobis distance to take into account correlations among variables; Statsoft, 2002). Thus, birds are assigned to the group for which they have the highest P_C, but such assignments will be made with variable likelihood, which in the particular case with two groups ranges from $P_C \approx 0.5$ (when misclassifications often occur), to $P_C \approx 1$ (when misclassifications are extremely unlikely). Ideally, DFA should classify individuals of unknown group with equal or higher P_C than the observed on the individuals used to develop the functions. However, seasonal morphological changes may make individuals being assigned to groups with different P_C at different times of year, so that the possibility that a DFA developed during a given season is no longer working in other seasons should be carefully considered.

In order to illustrate and value the problems described above, the differentiation between migratory and sedentary blackcaps *Sylvia atricapilla* in sympatric wintering areas of southern Iberia can be used as a case study (Pérez-Tris *et al.*, 1999). Many bird species have sedentary populations in Iberia, which coexist in winter with a large contingent of wintering migrants from central and northern Europe (Pérez-Tris and Santos, 2004). The Blackcap has become a model for the study of interactions between migratory and sedentary conspecifics in sympatric wintering areas (Pérez-Tris and Tellería, 2002). This species is a common forest passerine in the Palearctic, where it shows great diversity of migratory patterns, ranging from long-distance migratory populations in northern Europe to completely sedentary populations in southern Mediterranean areas (Shirihai *et al.*, 2001). Migratory blackcaps have longer and more pointed wings, and shorter tails than sedentary blackcaps (Tellería and Carbonell, 1999; Fiedler, 2005), which made it possible to develop a DFA for differentiating between both population types during their sympatric occurrence in winter (Pérez-Tris *et al.*, 1999). Such DFA was developed using Iberian blackcaps, which have less marked migratory traits than northern European blackcaps (Tellería and Carbonell, 1999; Fiedler, 2005). Therefore, the method might work better in winter (which is when birds need to be classified by morphology) than in summer, because northern blackcaps arriving to the Iberian Peninsula have longer and more pointed wings than Iberian migratory blackcaps. However, it is also possible that body measurements show latitudinal allometric change, causing a distortion of the correlation matrix of the morphological variables considered for classification, which would seriously hamper the performance of DFA during winter. For example, northern blackcaps have relatively longer tails than Iberian migratory blackcaps (Tellería and Carbonell, 1999; Fiedler, 2005). In turn, whether the DFA developed from Iberian breeding blackcaps works better or worse on wintering birds remains to be explicitly tested.

In this study, to value the suitability of DFA for distinguishing between migratory and sedentary birds during winter, new discriminant functions are first produced, based on flight related morphology (wing length, wing shape and tail length) of Iberian migratory and sedentary blackcaps, but using a more complete database than the one used previously (Pérez-Tris *et al.*, 1999). Then, the DFA is used to classify wintering blackcaps as either migratory or sedentary. The performance of the method is finally assessed by directly observing the percentage of correct classifications in wintering sedentary birds, which could be unambiguously identified as such by ringing recoveries. The latter approach is complemented with an analysis of posterior classification probabilities (P_C) derived from the model, which is used to value the ability of the method to correctly classify migratory birds during sympatric wintering periods.

MATERIAL AND METHODS

Generating discriminant functions

Blackcaps of known migratory behaviour were mist-netted during the breeding season (May-August, summer hereafter, in 1997, 1998, 1999, 2004 and 2005) at three Iberian localities. Migratory blackcaps ($n = 245$) were sampled in Álava (northern Spain) and Madrid (central Spain), whereas sedentary birds ($n = 226$) were captured in the Campo de Gibraltar region in southern Spain (for further details about the study sites, see Carbonell and Tellería, 1998).

Each bird was measured for three morphological traits that show variation in relation to migratory behaviour in blackcaps: wing length, wing pointedness and tail length. Migratory blackcaps have longer and more pointed wings, and proportionally shorter tails, than sedentary blackcaps (Tellería and Carbonell, 1999). The length of the eighth primary feather (counting from the inner to the outer primaries) was used as a surrogate of wing length, because feather length is easier to measure in the field than wing chord (Jenni and Winkler, 1989). Also for the sake of simplicity, the difference between primary distances P1 and P9 was used as a measure of wing pointedness (P1 and P9 are the distances from the tip of the first and the ninth primary feather to the wing tip, respectively). The tail was measured from the base to the tip of the rectrix feathers, with feathers stretched. All measurements were taken with 0.5-mm precision. Individuals with growing or severely damaged feathers were not measured.

Blackcaps cannot be sexed by plumage before post-juvenile moult, and many full-grown birds captured in summer are difficult to age as second-year – which still retain juvenile flight feathers – or older birds (Svensson, 1992; Jenni and Winkler, 1994). However, variation between sexes and age classes in the traits studied was small and not significant (Table 1).

TABLE 1

Results of ANOVA comparing tail length, length of the eighth primary feather, and wing pointedness (the index P1-P9) between sexes, age classes and populations (Iberian populations of migratory and sedentary blackcaps). No interaction was significant. The sample size is reduced in this analysis because only birds of known age and sex are considered.
[Resultados del ANOVA comparando la longitud de la cola, la longitud de la octava primaria, y el apuntamiento alar (índice P1-P9) entre sexos, clases de edad y poblaciones ibéricas de currucas capirotadas migradoras y sedentarias. Ninguna interacción fue significativa. En este análisis, el tamaño muestral es menor porque sólo se incluyen aves de edad y sexo conocidos.]

	Tail *[Cola]*		**Eighth primary feather** *[Octava primaria]*		**Wing pointedness** *[Apuntamiento alar]*	
	$F_{1,176}$	*P*	$F_{1,176}$	*P*	$F_{1,176}$	*P*
Sex *[Sexo]*	0.58	0.45	1.69	0.20	0.01	0.91
Age *[Edad]*	0.01	0.93	3.22	0.074	0.76	0.38
Population *[Población]*	6.03	0.015	39.44	<0.001	56.9	<0.001

More importantly, such differences were negligible compared to differences between birds with different migratory behaviours (Table 1). Therefore, variation among sexes or ages was not considered in the DFA, which simplified the method, also making it possible to include in the analysis many birds that could not be aged or sexed. The DFA was conducted using the same procedures utilised by Pérez-Tris *et al.* (1999).

Classifying wintering blackcaps

Blackcaps were captured and measured during the wintering period (between December and early February) in the same way as in summer. Wintering blackcaps were sampled at the southernmost locality (Campo de Gibraltar), where local sedentary birds coexist with northern migratory conspecifics. Wintering birds were studied during nine consecutive seasons (1997 - 2006). The DFA developed from blackcaps captured during summer was applied to wintering birds, whose migratory behaviour was unknown, except for ringed birds captured in both seasons at the study site, which could be unambiguously identified as sedentary individuals (21 birds), and three ringed birds that were controlled outside the wintering area, and therefore could be identified as migratory individuals.

Validating the DFA

The reliability of the DFA for distinguishing sedentary blackcaps could be directly assessed by observing the rate of correct classification of sedentary birds, which had been identified as such by ringing recoveries. However, very few blackcaps could be unambiguously identified as migratory (only three, all of which were correctly classified), and therefore the performance of the method on migratory birds could not be directly observed. Because of this reason, an analysis of posterior classification probabilities (P_C) derived from the DFA was used as an alternative approach. Given that the sedentary population is the same

TABLE 2

Morphological traits of Iberian migratory and sedentary blackcaps (means, standard errors and sample sizes, all birds grouped).
[Rasgos morfológicos de las currucas capirotadas migradoras y sedentarias ibéricas (medias, errores estándar y tamaños muestrales, todas las aves agrupadas).]

	n	**Tail** *[Cola]*	**Eighth primary feather** *[Octava primaria]*	**Wing pointedness** *[Apuntamiento alar]*
Migratory blackcaps *[Currucas migradoras]*	245	60.76 ± 0.13	54.93 ± 0.10	8.20 ± 0.09
Sedentary blackcaps *[Currucas sedentarias]*	226	61.99 ± 0.14	53.26 ± 0.10	5.80 ± 0.09

through the year, whereas the migratory population changes due to the arrival of northern migrants, any change from summer to winter in P_C should entirely depend on the ability of the DFA to correctly classify migratory birds. Thus, if the performance of DFA is worse in winter than in summer, then birds classified as migratory would have lower P_C during winter than during summer. However, if the DFA performs equally well or better in winter than in summer, then the P_C of birds classified as migratory would be similar or higher, respectively, in winter compared to summer. In either case, birds assigned to the sedentary group should have similar P_C in both seasons, which can be used as an internal quality control in the analysis of seasonal variation in P_C.

RESULTS

Discriminant Function Analysis

Considering all birds in the summer sample, migratory blackcaps had longer and more pointed wings, and shorter tails, than sedentary blackcaps (Table 2). As a consequence, the DFA developed for differentiating between both population groups was statistically significant (Wilk's Lambda = 0.42, Rao's approximation: $F_{3,467} = 217.49$, $P < 0.001$). The following classification functions were obtained:

$$M = -719.13 + 6.05 * T + 19.92 * P8 - 2.98 * WP$$
$$S = -703.20 + 6.95 * T + 18.73 * P8 - 4.01 * WP$$

where T is the tail length, P8 is the length of the eighth primary feather, WP is the index of wing pointedness P1-P9 (all measures in mm), and M and S represent classification scores for migratory and sedentary groups, respectively. Thus, a bird of unknown migratory behaviour is assigned to the group for which it produces the highest classification score.

The percentage of correct classifications was very similar in both groups (Table 3). No significant difference was observed in the frequency of misclassifications between population groups ($\chi^2 = 0.39$, df = 1, $P = 0.53$), age classes ($\chi^2 = 1.08$, df = 1, $P = 0.3$) or sexes ($\chi^2 = 0.03$, df = 1, $P = 0.86$), which confirmed the fact that grouping all data together did not affect the results.

Classification of wintering blackcaps

The above DFA was used to classify 1257 wintering blackcaps captured in southern Iberia. The model classified 324 birds as sedentary,

TABLE 3

Classification matrix obtained by DFA with blackcaps captured in summer. Total sample sizes (*n*), the number of blackcaps correctly and incorrectly classified, and the percentage of correct classifications are shown.
[Matriz de clasificación obtenida a partir del AFD aplicado a las currucas capirotadas capturadas en verano. Se muestra, para cada población y para el conjunto, el tamaño muestral total (n), el número de currucas clasificadas correcta e incorrectamente, y los porcentajes de clasificaciones correctas.]

		Predicted classifications *[Clasificaciones esperadas]*		**Correct classifications** *[Clasificaciones correctas]*
	n	**Migratory** *[Migradoras]*	**Sedentary** *[Sedentarias]*	
Migratory blackcaps *[Currucas migradoras]*	245	213	32	86.9%
Sedentary blackcaps *[Currucas sedentarias]*	226	25	201	88.9%
Both groups *[Ambos grupos]*	471	238	233	87.9%

and 933 birds as migratory. Out of 21 wintering blackcaps that could be unambiguously identified as sedentary based on ringing recoveries, 20 were correctly classified. This represented 95 % success, which was similar to the rate of correct classifications observed in the summer sample.

An ANOVA comparing P_C between population groups and seasons revealed significant effects for both group ($F_{1,1725} = 58.57$, $P < 0.001$) and season ($F_{1,1725} = 45.63$, $P < 0.001$). However, there was a significant interaction between both factors ($F_{1,1725} = 33.26$, $P < 0.001$; Fig. 1). Thus, both migratory and sedentary populations were assigned to their corresponding group with similar P_C during summer (post-hoc group effect: $F_{1,470} = 0.94$, $P = 0.33$). However, in the winter sample, putatively migratory blackcaps were assigned to their group with much higher P_C than in summer (post-hoc season effect: $F_{1,1170} = 117.71$, $P < 0.001$), whereas putatively sedentary blackcaps showed a much lower P_C (post-hoc group effect: $F_{1,1255} = 161.59$, $P < 0.001$), which was not significantly different from the P_C observed in summer (post-hoc season effect: $F_{1,555} = 0.29$, $P = 0.59$). Such an interaction was due to the occurrence in winter of many birds with exaggerated migratory-like morphology (Fig. 2), which were consequently classified as migratory with very high P_C. However, the morphological space occupied by birds classified as sedentary did not change substantially from summer to winter (Fig. 2).

DISCUSSION

Current ornithological research is witnessing the combination of different tools for separating population groups, with morphological methods being complemented by sophisticated genetic or biogeochemical techniques (Webster *et al.*, 2002; Bairlein, 2003; Rubenstein and Hobson, 2004; Bearhop *et al.*, 2005). However, before such practices become widely accessible, DFA will remain a cornerstone technique (Pérez-Tris *et al.*, 1999; 2000; Copete *et al.*, 1999; Martín *et al.*, 2000). The reliability of research based on the assignment

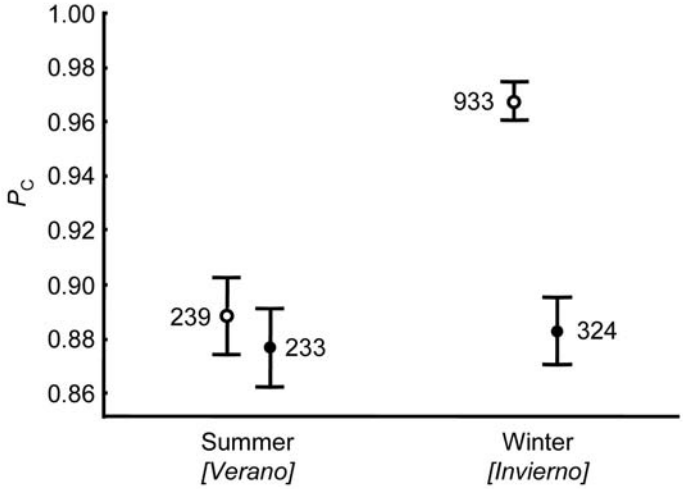

FIG. 1.—Variation in posterior classification probabilities (P_C: mean, standard error and sample sizes) between seasons and population groups (open dots: migratory blackcaps, filled dots: sedentary blackcaps). *[Variación de las probabilidades posteriores de clasificación (P_C: media, error estándar y tamaños muestrales) entre estaciones y poblaciones (puntos blancos: currucas migradoras, puntos negros: currucas sedentarias.]*

of individuals to different population groups depends on the accuracy of classification methods, so that testing the performance of DFA-based methods at the time they need to be applied becomes critical.

This study shows that a suitable way to validate morphological DFA is comparing the P_C of birds used to generate the functions with the P_C of birds that needed to be classified. The usefulness of the analysis of P_C was confirmed taking advantage of the possibility to observe the percentage of correct classifications in individually marked birds. The analysis of P_C can be applied to any DFA used in field ecology, such as those devised for sexing individuals, identifying species, or other purposes. Researchers are encouraged to use analysis of P_C as a routine check of the performance of classification methods.

Many Palearctic bird species have migratory and sedentary populations that occur together during part of the annual cycle (Berthold, 2001). Distinguishing between migratory and sedentary conspecifics is necessary for understanding how they share common food resources, whether they occupy different habitat types, and other important questions (Pérez-Tris and Tellería, 2001, 2002). This study demonstrates that a previously published DFA (Pérez-Tris *et al.*, 1999) is highly effective for correctly distinguishing between migratory and sedentary blackcaps in sympatric wintering areas of southern Iberia. Remarkably, the study also illustrates the problem that turns up when the mean trait values of the groups change from the time at which classification methods are generated to the time at which they are desired to be used for classifying individuals. In the case of blackcaps, seasonal morphological variation was introduced by the occurrence in the winter sample of northern individuals, which have exaggerated migratory-like morphology compared to Iberian migratory birds used to generate the model (it

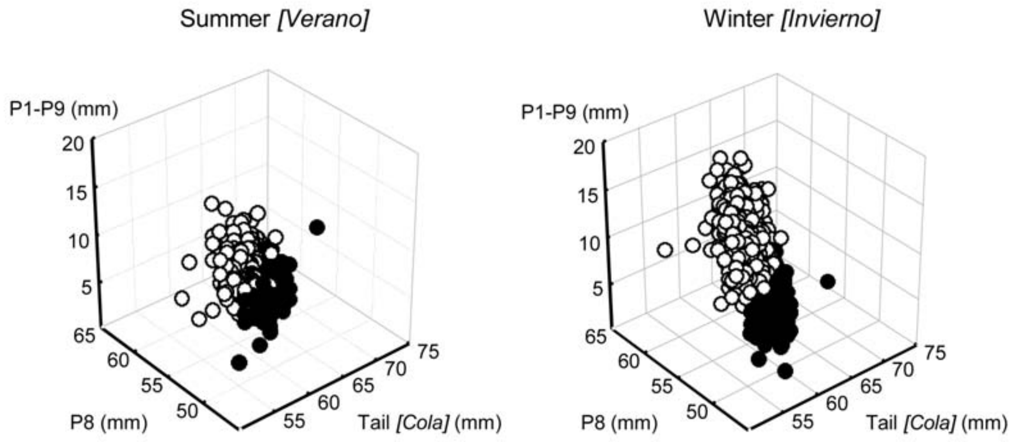

FIG. 2.—Variation from summer to winter in the morphological space defined by the length of the eighth primary feather (P8), the tail length, and the index of wing pointedness P1-P9, in sedentary (filled dots) and migratory blackcaps (open dots).
[Variación de verano a invierno del espacio morfológico definido por la longitud de la octava primaria (P8), la longitud de la cola, y el índice de apuntamiento alar P1-P9, en currucas capirotadas sedentarias (puntos negros) y migradoras (puntos blancos).]

should be noted that migratory populations with less marked migratory-like traits than the northern and central Iberian populations are unlikely to occur in wintering areas of southern Spain; Fiedler, 2005). Fortunately, such circumstance was advantageous in this case, causing a notable improvement in the ability of the DFA to correctly classify migratory blackcaps during winter. However, seasonal variation in morphological traits may impair the performance of DFA in other scenarios, and analysis of P_C may be a useful way to test whether this is actually the case.

As a collateral result of this study, a new DFA is proposed for distinguishing between migratory and sedentary blackcaps in sympatric wintering areas of southern Iberia. This new DFA has an increased reliability than the one proposed previously (Pérez-Tris *et al.*, 1999), because it is based on a larger sample size. Using the updated DFA, the majority of birds were correctly classified during summer (88 %), and the rate of correct classification apparently increased substantially when the method was applied to wintering blackcaps. Thus, P_C increased during winter in migratory blackcaps due to the arrival of northern individuals, which therefore were very unlikely to be misclassified. In addition, the rate of correct classification remained the same in sedentary blackcaps, for which similar P_C were obtained in summer and in winter. Sedentary blackcaps also showed a similar percentage of correct classifications during both seasons as observed on individually marked birds. Therefore, morphological traits can be safely used for distinguishing between migratory and sedentary blackcaps in sympatric wintering areas of southern Iberia.

The classification method tested in this study works fine although it does not consider the effects of sex, age of birds, or the influence of possible morphological variation due to moult or slight plumage wear. Perhaps its strongest limitation is imposed by the fact that the sedentary population studied here, which inhabits the forests in the Campo de Gibraltar area, represents a putative descendant of populations restricted to that region during the last glaciation, which has apparently remained independent from other blackcap populations during long historical periods (Pérez-Tris *et al.*, 2004). Perhaps as a consequence, such refugial populations have evolved morphological adaptations to a sedentary life style that are more extreme than the observed in other areas, such as the Atlantic Islands or other parts of the continent (cf. Fiedler, 2005), where blackcaps have lost migratory behaviour recently (Pérez-Tris *et al.*, 2004). Therefore, whether DFA can reliably identify sedentary individuals from other sedentary populations of blackcaps needs to be corroborated.

Nevertheless, the possibility to accurately tell apart local sedentary individuals in the Campo de Gibraltar area, arguably an evolutionarily unique population in the Blackcap's range (Pérez-Tris *et al.*, 2004), brings about excellent opportunities for detailed studies of the interactions between such individuals and their northern conspecifics during sympatric wintering periods. Such studies not only have important evolutionary implications (Pérez-Tris and Tellería, 2002), but they may also help to devise adequate strategies for the conservation of evolutionarily distinct entities (Moritz, 1994; Crandall *et al.*, 2000). In addition, such research may be particularly welcome because the interactions between migratory and sedentary blackcaps take place in areas where human activities might cause an important impact on the species' habitats, which might have different consequences for each population group (Tellería *et al.*, 2005).

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Iván de la Hera is doing his PhD on the interactions between migratory and sedentary populations of different bird species. **Javier Pérez-Tris** is interested in the ecological and evolutionary implications of variation in migratory behaviour of forest passerines. Their studies are framed within the research lines developed by the group lead by **José Luis Tellería** at Universidad Complutense de Madrid.