J. Field Ornithol., 67(3):428–433

AGE AND SEX DETERMINATION OF MONOMORPHIC NON-BREEDING CHOUGHS: A LONG-TERM STUDY

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Abstract.—We present criteria for sexing and aging non-breeding Choughs (*Pyrrhocorax pyrrhocorax*) based on nine years of capture-recapture data. Shape of the rectrices, intensity of plumage colour and iridescent brightness, and the contrast between old flight feathers and freshly molted ones allowed us to distinguish three age classes (first-year, second-year, and after-second-year). For sex determination we selected morphological characters that (1) were independent of breeding status and (2) did not change with age. Tarsus length and bill width, repeteable measurements in both sexes, met both of these criteria. A discriminant analysis performed with these variables from breeding adults of known sex predicted with an accuracy of 100% the sex of non-breeding Choughs that were subsequently captured as breeding adults of known sex. This methodology may be applicable to other species with delayed maturation where monomorphic plumage precludes discrimination of age and sex.

DETERMINACION DE LA EDAD Y EL SEXO EN CHOVAS PIQUIRROJAS *PYRRHOCORAX PYRRHOCORAX* NO REPRODUCTORAS: UN ESTUDIO A LARGO PLAZO

Sinopsis.—Presentamos criterios para determinar la edad y el sexo de la Chova Piquirroja (*Pyrrhocorax pyrrhocorax*) en sus primeros años de vida, basados en una larga serie de años de captura-recaptura. La coloración y forma de las plumas de vuelo permite diferenciar tres clases de edad (primer año, segundo año, y tres o más años). Para la determinación del sexo se han seleccionado aquellas variables biométricas que (1) son independientes del estatus reproductor y (2) no varían con la edad, siendo asímismo repetibles. Con ellas, tarso y anchura del pico en el caso de esta especie, se ha obtenido una función discriminante con adultos reproductores que permitió determinar el sexo correctamente del 100% de las chovas capturadas primero como no reproductoras y posteriormente como reproductoras de sexo conocido. Proponemos la posibilidad de aplicar dicha metodología a otras especies que no presenten diferencias aparentes en coloración entre sexos ni edades, y que puedan llegar a tardar varios años en alcanzar su madurez sexual.

The Chough (*Pyrrhocorax pyrrhocorax*) is a monomorphic corvid that starts breeding at an age of 2–4 yr or later (Roberts 1985; E. Bignal, pers. comm.). It has a fragmented distribution in the Palearctic and a history of declining populations and extinction over much of its European range (Bignal and Curtis 1989, Blanco et al. 1991, Guillou 1981). Understanding the ecology and behavior of sub-adults Choughs is essential in addressing factors limiting survival and viability of populations (Bignal et al.

1989). However, at present there is no published information permiting reliable discrimination of age and sex for non-breeding Choughs. This hinders studies on age distribution, dispersal, differential age and sex mortality, and sex ratios. In this paper, we develop methods and criteria for sexing and aging non-breeding Choughs and present a methodology that could be applied to other species with similar characteristics.

METHODS

Between 1983 and 1995, 1732 Choughs were captured with large butterfly nets while roosting inside abandoned buildings located in Los Monegros (41°20′N, 0°11′W), NE Spain (Tella and Torre 1993; Tella et al. 1996). Choughs were captured throughout the night and were released where caught. Breeding Choughs were captured at their nesting sites where both members of the pair roost together. Non-breeding Choughs were captured in communal roost sites holding a variable number of birds. In addition, 750 nestling Choughs were banded in the same area. At capture, each Chough was measured for several morphological variables (see Tella & Torre 1993 for methods and definitions).

The age classification presented here was established on the basis of detailed observations of molt and plumage of captured or recaptured Choughs, 81 of which were banded as nestlings and subsequently recaptured (34 as first-year, 25 as second-year, and 22 as after-second-year).

Breeding Choughs were accurately sexed by behavior after marking them with colored PVC bands because only females incubate and are fed by the male (Tella and Torre 1993). In order to develop sexing criteria for non-breeding Choughs, we first tested for differences in body measurements between breeding and non-breeding Choughs since body size in corvids can be influenced by age and breeding status (Richner 1989a, Slagsvold 1983). We examined oseal traits (tarsus, bill depth, and bill width) that presumably reach adult length at an early age, usually before fledgling (O'Connor 1984). We rejected other morphological traits (wing, tail, culmen, nail, and mass), which are subject to continued growth during the first years of life as well as to seasonal and daily variations and/or different degrees of wear and tear (Ferrer and De le Court 1992, Francis and Wood 1989, Gosler 1987, Slagsvold 1983). Second, we quantified variation in oseal variables for non-breeding Choughs caught in two or more age classes. Finally, a repeatability analysis (Lessells and Boag 1987) was conducted on sexed adult birds to assess the amount of variation attributable to temporary changes or measurement error (Boag and van Noordwijk 1987). Those variables that did not vary based on any of these three criteria were entered in a discriminant function analysis (DFA).

RESULTS

Age determination.—During the first year the plumage was completely black but became dull brown, almost without iridescent brightness, from their first summer (especially evident in the flight feathers). The rectrices were rounded in shape compared to the squared rectrices of older age

TABLE 1. Results of the comparison between tarsus length and bill width for individual Choughs measured in two different age classes within the non-breeding stage (Wilcoxon matched-pairs test).

Comparison	Tarsus			Bill width		
	Z	*n*	*P*	Z	*n*	*P*
First-year–second-year	1.35	19	0.18	0.36	31	0.85
Second-year–after-second-year	1.05	8	0.29	0.31	10	0.76
First-year–after-second-year	0.42	6	0.67	0.22	11	0.82

classes. The tip of the bill was sometimes dark orange in color, slightly contrasting with the deep red of the rest of the bill. Most juveniles retained remnants of their white beak flanges during a variable part of their first year, which was easy to verify by pushing aside the feathers that cover it. Choughs retained their juvenal flight feathers until about 12 mo after leaving the nest (first flights occur in May–June). Thus, from May–October, when Choughs more than 1-yr-old molt their flight feathers, Choughs in their first summer and autumn were aged readily by the absence of molt in these feathers.

During their second year of life, Choughs molting their flight feathers for the first time were aged easily by differences in color and brightness between the old juvenal flight feathers and the new freshly molted ones. Old feathers were dull brown and contrasted with the glossy black of the new feathers. This technique could be applied as long as the molt lasted from May–October. Subsequently, birds in their second year were aged after a detailed examination searching for remnants of the dull brown juvenal plumage, especially in alula, mantle, head, and rump.

During molt, Choughs of three or more years of age showed no differences in color between old and new flight feathers and only slight differences in brightness. All the body feathers showed a glossy black color.

Sex determination.—We assessed variation in length of the tarsus, bill width, and bill depth for breeding Choughs previously captured as nonbreeding individuals. Comparison of these paired measurements (Wilcoxon matched-pairs test) showed that there was no difference in the length of tarsus ($n = 10$, $P = 0.17$) and bill width ($n = 18$, $P = 0.19$) from nonbreeding to breeding stage. Tarsus and bill width also did not change in individual Choughs captured in two different age classes (Table 1). Furthermore, these two variables were repeatable measures in both sexes (Table 2).

On the basis of these results, we performed a DFA on tarsus length ($\bar{x} \pm SD = 55.7 \pm 1.8$ and 51.5 ± 1.7 for males and females, respectively) and bill width ($\bar{x} \pm SD = 12.8 \pm 0.5$ and 12.0 ± 0.6 for males and females, respectively) of known-sex breeding Choughs (79 males, 92 females). Because both characters were repeatable, the mean of all individual measurements was used. The obtained discriminant function was:

$$D = 0.49939\ (\text{TARSUS}) + 1.00010\ (\text{BILL WIDTH}) - 39.0516$$

TABLE 2. Analysis of variance (*F*-ratios) and repeatabilities (*r* values) of tarsus length and bill width among adult breeding Choughs. *n* is total sample size and n_0 is the mean number of observations for each individual case.

	r	*F*	*n*	n_0	*P*
Females					
Tarsus length	0.879	7.47	38	2.11	0.0000
Bill width	0.424	2.99	79	2.69	0.0004
Males					
Tarsus length	0.613	4.16	24	2.00	0.0106
Bill width	0.297	2.00	52	2.36	0.0407

where D is the discriminant score. Choughs with negative scores were classified as females (mean discriminant score = −1.2995), and those with positive scores were classified as males (mean discriminant score = 1.5134). This discriminant function correctly classified 100% of a small sample (n = 10) of non-breeding Choughs that were subsequently captured as breeding adults of known sex.

DISCUSSION

Shape of flight feathers, plumage brightness, and color have been used as characters for distinguishing age classes in black-colored corvids (Caffrey 1992, Slagsvold 1979, Svensson 1984). Our age-clasification criteria are based mainly on molting patterns and plumage features of Choughs molting flight feathers. Age determination of molting birds can be succesfully carried out until loss of the last flight feather. Therefore, we suggest that capture effort of non-breeding Choughs should be directed toward the molting period (May–October) when all individuals can be accurately included in one of three age classes. The color and molt patterns found here are similar in other populations of Choughs in Spain (pers. obs.); our age criteria can probably be applied across the range of the species. In addition, we suggest the possible application of these criteria to other black-colored corvids. The differentiation of three age classes could be an useful tool in studies of the ecology and behavior of corvids, where only juvenile and adult classes are normally considered (e.g., Caffrey 1992, Clark et al. 1991, Richner 1989b, Slagsvold 1983).

A discriminant function based on measurements of tarsus length and bill width provides an acceptable means of determining the sex of breeding Choughs. Since tarsus length and bill width appear to be size dimensions that do not change with age and breeding status, we suggest that this discriminant function will be useful for sexing non-breeding Choughs. When a stepwise DFA was performed with eight body-size variables (mass excluded), tarsus length and bill width were selected together with wing and tail lengths in a function allowing reliable sex determination of breeding Choughs (Tella and Torre 1993). However, the discriminant function achieved here can be used at any season of the year be-

cause it does not include any character subjected to molt or age-related variation.

The procedure used here to develop a discriminant function to sex non-breeding Choughs from measurements of breeders could be applied to a range of monomorphic species. It requires morphological characters that do not change with breeding status or with age. The length of skeletal structures such as tarsus and forearm, which normally develop to reach adult length at an early age (Ferrer and De le Court 1992, Slagsvold 1983), are probably best for this purpose. Although this methodology requires a large sample size and considerable time in order to obtain a sufficient number of recaptures, it could be an alternative to sexing non-breeding birds of rare species by invasive or destructive techniques.

ACKNOWLEDGMENTS

We are very grateful to J. A. Cuevas, J. Morato, M. C. Blanco, J. A. Fargallo, F. Gómez, F. Martínez, A. Arenas, C. Sánchez, M. Villarroel, I. Olza and specially to J. Blasco and R. López for their help in capturing choughs across the years. L. M. Carrascal made helpful previous suggestions and J. Potti, J. F. Glahn, M. Ferrer, and R. Chandler commented and improved the manuscript.

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Received 11 May 1995; accepted 19 Oct. 1995.