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GENDER DETERMINATION OF EURASIAN EAGLE-OWLS (*BUBO BUBO*) BY MORPHOLOGY

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Gender determination is an important prerequisite to studies on many aspects of avian biology such as foraging ecology (e.g., Anderson and Norberg 1981), evolutionary ecology (e.g., Clutton-Brock 1986), survivorship (e.g., Newton et al. 1983), and conservation genetics (e.g., Griffith and Tiwari 1995). Many avian species show no sexual dimorphism in plumage, but the gender of individuals may be determined by body measurements. Most raptors are dimorphic in size, which allows for the development of gender determination methods based on morphometric data. Nonetheless, this method has been applied to a relatively small number of species (e.g., Bortolotti 1984a, 1984b, Garcelon et al. 1985, Edwards and Kochert 1987, Ferrer and De Le Court 1992, Balbontín et al. 2001).

The Eurasian Eagle-Owl (*Bubo bubo*) is a sexually monomorphic species and, although females are bigger than males (i.e., reversed sexual dimorphism) gender determination in the field is only possible through detection of gender-specific calls (Penteriani 1996). Due to its conservation concerns, the high density of this species in several Mediterranean areas of its breeding range (e.g., Penteriani et al. 2002, Delgado et al. 2003, Penteriani et al. 2004), its eclectism in habitat preferences (e.g., Penteriani et al. 2001, Marchesi et al. 2002, Martínez et al. 2003), its complex social communication (e.g., Penteriani 2002, Penteriani 2003), and its impact on bird communities (e.g., Sergio et al. 2003), this species has been the subject of increasing research in the last few years. In this context, determination of gender for this species represents a useful tool in future studies examining intersexual and intrasexual patterns. Our objective was to provide an inexpensive and practical tool to determine the gender of eagle-owls in the field using a minimum number of morphometric measurements.

METHODS

We measured 13 morphological characteristics of 50 skins of Eurasian Eagle-Owls (N = 22 males and N = 28 females) from the collections of the Estación Biológica de Doñana (Andalusia, Spain) and the Natural Science Museum of Madrid. All eagle-owls analyzed came from Spain and gender was previously determined by internal examination of reproductive organs. To avoid the confounding effect of age, we only used skins of adult individuals when morphometric differences seem to be mostly related to gender rather than age.

Length of claws, tarsus, bill including cere, exposed culmen without cere, and bill depth were taken using a caliper (±0.1 mm) (Bortolotti 1984a, 1984c). The four claws of the left foot were measured from the hallux claw (toe number one) to the outer claw (toe number four). Length of wing chord, tail, ear tufts, and forearm (the length from the front of the folded wrist to the proximal extremity of the ulna) were measured with a metal ruler to the nearest mm (Bortolotti 1984a, 1984c). To minimize measurement errors, each specimen was measured three times. For analyses, we used the mean values of these three measurements.

To determine which morphometric variables were the best predictors for gender determination, we conducted a two-step analysis. First, a t-test was conducted for the 13 variables to identify the descriptors for which the between gender variance was higher. Secondly, we used a discriminant function analysis (DFA) to obtain the function best discriminating between males and females. Chi-square analysis was employed to test the significance of the gender classification established by the DFA procedure (Sokal and Rohlf 1995). DFA has been widely used for gender determination in bird species with monomorphic plumage (e.g., Scolaro et al. 1983, Maran and Myers 1984, Hanners and Patton 1985, Malacalaza and Hall 1988). A DFA produced a linear combination of several morphometric variables that best discriminated samples of individuals of known gender. This function was then used to predict the sex of unknown birds (Sokal and Rohlf 1981, Norusis 1988). Because large discriminant functions can be cumbersome (McCloskey and Thompson 2000), we established a level of significance of $P <$ 0.0001 as a threshold to select the significant t-test variables that were used in the DFA.

RESULTS AND DISCUSSION

The t-test revealed that females were significantly larger than males in all the variables measured except tail, wing chord, and ear tufts (Table 1). Second claw, forearm, length of exposed culmen without cere, and bill depth were the most dimorphic variables ($P < 0.0001$). The DFA produced the following discriminant equation:

$$D = -28.740 + 0.204(\text{second claw}) + 0.714(\text{forearm}) + 0.158(\text{culmen without cere}) + 0.113(\text{bill depth}).$$

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Table 1. Morphometric of study skins of males and female Eurasian Eagle-Owls (*Bubo bubo*) from Spain. Claws are numbered according to toe numbers (hallux = 1, outer claw = 4).

	FEMALES (N = 28)			MALES (N = 22)					
	$\bar{x}$	SD	RANGE	$\bar{x}$	SD	RANGE	t	df	P
Claw of toe 1	34.62	3.56	26.74–40.10	30.60	3.33	21.66–33.98	−3.512	37	0.0010
Claw of toe 2	34.89	2.36	27.72–38.50	31.34	2.19	27.87–38.84	−5.252	44	0.0001
Claw of toe 3	30.53	3.12	25.32–36.84	28.35	2.42	24.99–33.67	−2.436	39	0.0201
Claw of toe 4	29.70	3.39	20.09–33.62	26.61	1.30	24.22–28.86	−3.806	38	0.0001
Tarsus (L)	102.5	6.58	83.98–112.00	93.8	4.5	80–104.00	−4.543	47	0.0001
Tail	258.76	14.73	229.67–293.67	250.36	15.70	232.33–293.00	−1.919	47	0.0613
Wing[a]	44.13	3.07	32.26–47.46	43.19	1.87	40.67–48.90	−1.260	47	0.2140
Forearm	20.04	0.84	18–21.93	18.83	0.72	17.06–19.76	−5.288	46	0.0001
BCER[b]	48.56	2.87	42.60–54.35	44.87	3.15	38.90–52.03	−4.280	47	0.0001
BCUL[c]	32.89	1.82	27.25–35.17	30.10	1.61	27.18–34.90	−5.523	46	0.0001
Bill depth	28.47	3.19	20.25–33.97	24.81	3.61	12.22–30.09	−3.750	47	0.0001
Ear tuft (left)	72.96	6.70	46–84	72.23	4.53	63.33–81.33	−0.421	44	0.6762
Ear tuft (right)	72.16	10.51	42.33–86.67	74.75	3.82	65–79.67	1.096	45	0.2790

[a] Wing chord.
[b] Bill including cere.
[c] Exposed culmen without cere.

A correct classification was obtained for 90.5% of males and 90.9% of females. Hence, overall 90.7% of cases were classified correctly. This classification was significantly better than random (chi-square = 41.360, P = 0.0001). There was a clear separation between males and females along the first discriminant axis (Fig. 1).

Variables used in this study were easy to measure in the field and have been shown to be good predictors of gender in several other bird species (e.g., Calvo and Bolton 1997, Renner and Davis 1999, Leader 2000). Also, in comparison with other proposed morphometric criteria for gender determination (e.g., wing and body mass), the descriptors we used were not influenced by molting, condition of specimens, or of the feathers.

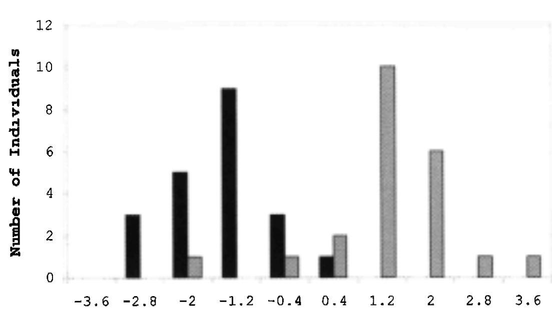

Figure 1. Discriminant Function Analysis (DFA) scores of male (N = 22) and female (N = 28) Eurasian Eagle-Owl study skins. The four variables used in classifying genders were: second claw, forearm, length of exposed culmen without cere, and bill depth.

The length of the forearm has been used successfully for gender determination in two other raptor species, Spanish Imperial Eagles (*Aquila adalberti*; Ferrer and De Le Court 1992) and Bonelli's Eagles (*Hieraaetus fasciatus*; Balbontín et al. 2001). In a similar study, Martínez et al. (2002) also considered this parameter to be the best predictor of gender for Eurasian Eagle-Owls. Additionally, our study revealed a small overlap between males and females. Finally, the forearm variable has two additional advantages: it is easy to measure, and repeated measurements taken by both the same and different observers show little variation (Ferrer and De Le Court 1992).

Gender determination by DFA is applicable to adults year round, when most alternative methods are limited by season (e.g., during the breeding season) or expensive (e.g., karyotyping). However, the application of our DFA model may be limited because of the pronounced geographical variation of body size exhibited by eagle-owls (Penteriani 1996). This factor needs to be taken into account when applying our DFA model to other populations. However, our approach could be used to derive similar DFA models for other Eurasian Eagle-Owl populations.

RESUMEN.—*Bubo bubo* es un ave rapaz nocturna grande que presenta dimorfismo sexual de tamaño revertido. A través del análisis de 13 parámetros morfológicos colectados de 50 especímenes de museo (N = 22 machos y N = 28 hembras), asignamos correctamente el género a 90.7% de los individuos por medio de análisis de función discriminante. Las variables morfológicas usadas para predecir el género incluyeron la profundidad del pico,

longitud de la segunda garra, longitud del antebrazo y longitud de la parte expuesta del culmen sin cera.

[Traducción del equipo editorial]

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