Sex Determination in Eurasian Sparrowhawks (Accipiter nisus)

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SEX DETERMINATION IN EURASIAN SPARROWHAWKS (*ACCIPITER NISUS*)

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ABSTRACT.—The sex determination of Eurasian Sparrowhawks (*Accipiter nisus*) is not apparently a problem, as sexual dimorphism seems to be evident, at least in adults. However, there is a clinal geographic variation expressed as increasing size and decreasing color saturation from west to east. Hence, in wintering regions such as the Iberian peninsula, where migrant birds headed toward Africa also occur, sedentary birds are mixed with migrant and wintering birds from September to April. Here, we would expect to find birds from different breeding areas and therefore, possessing notable differences in biometrics, body mass, or color. We trapped eighteen adult sparrowhawks during the breeding seasons between 2001 and 2007 in Bizkaia, northern Spain, and we measured 91 dead and 38 rehabilitated sparrowhawks from Spanish Wildlife Rehabilitation Centers (WRC) between 1999 and 2007. A total of 147 full-grown sparrowhawks were sexed, aged, and measured. Some overlap between sexes was found for all but four measurements (eighth primary length [P8], wingspan, forearm, and mass). Only bill length differed significantly between age classes (juvenile/adults) and wingspan differed between sedentary and wintering birds for both sexes. Three variables: bill length, forearm, and P8 were retained in the discriminant function, allowing us to determine the sex with 100% accuracy. It is possible to correctly sex sparrowhawks, both adults and juveniles, using the three measures, even when the origin of the bird is unknown.

KEY WORDS: *Eurasian Sparrowhawk*; Accipiter nisus; *biometry*; *discriminant function analysis*; *morphometrics*; *reversed sexual dimorphism (RSD)*; *sexing.*

DETERMINACIÓN DEL SEXO EN *ACCIPITER NISUS*

RESUMEN.—La determinación del sexo del gavilán *Accipiter nisus* no resulta un problema ya que el dimorfismo sexual es evidente, al menos en adultos. No obstante, parece darse una variación geográfica gradual en la que aparece un incremento de tamaño y una reducción de la saturación de color de Oeste a Este. Como consecuencia, en las áreas de invernada, como la península Ibérica, donde además ocurre un flujo de migrantes hacia África, las aves sedentarias conviven con las invernantes desde septiembre hasta abril. En tales circunstancias, cabe esperar encontrar aves procedentes de diferentes regiones de reproducción en las que se observarían notables diferencias de tamaño, peso y color. Durante el periodo reproductivo de 2001 a 2007 atrapamos 18 gavilanes adultos en Bizkaia, norte de España y, además, entre 1999 y 2007 medimos 91 ejemplares muertos y 38 rehabilitados en centros de recuperación de especies silvestres (CRES) de España. Se determinó el sexo, se obtuvieron datos y se midieron un total de 147 gavilanes totalmente desarrollados. Se encontró un ligero solapamiento entre sexos en todas las variables excepto en cuatro (longitud de la octava primaria [P8], envergadura, antebrazo y peso). Tan sólo la longitud del pico fue diferente entre las clases de edad (juveniles/adultos) y la envergadura fue diferente en ambos sexos considerando las aves sedentarias/invernantes. La longitud del pico, el antebrazo y la P8 fueron retenidas en la función discriminante, permitiendo determinar el sexo correctamente en el 100% de la muestra. Por lo tanto, resulta posible determinar el sexo correctamente de gavilanes adultos y juveniles empleando las tres medidas, incluso cuando el origen del ave es desconocido. Además, la envergadura y el peso pueden ayudar a establecer una determinación definitiva.

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Knowing the sex of individuals in a population greatly facilitates the study of behavior, evolutionary ecology, breeding and feeding systems, migration, and genetics (Widen 1984, Sacchi et al. 2004, Bildstein 2006). In the case of Eurasian Sparrowhawks (*Accipiter nisus*), sex determination would seem not to be a problem because sexual dimorphism is visibly evident, at least in adults (Cramp 1985, Newton 1986). Sex identification has commonly been based on plumage characteristics; in both sexes, the upper surface is bluish-grey and the underside is mainly whitish, with dark horizontal bars. The males also have some orange coloration on the chest and flanks (Newton 1986), though this varies from almost solidly rufous on throat, sides, breast, flanks, and thighs to, rarely, very little rufous at all but simply grey-brown barring as found in adult females (Ferguson-Lees and Christie 2001). Moreover, females often display rufous flanks and occasionally the rest of the barring is slightly tinged rufous; thus, more-rufous females can look rather like less-rufous males, other than their white supercilia, large whitish nape-patch, and larger size (Ferguson-Lees and Christie 2001). However, juveniles do not show this chromatic dimorphism: both males and females are brownish, with undersides lacking orange, and both sexes have white supercilia (Newton 1986). Thus, juvenile sparrowhawks can only be sexed using biometric measures or molecular methods. Nevertheless, almost all published data come from two specific areas where specific research projects were conducted (Britain: see Cramp 1985, Newton 1986; and Israel: Gorney et al. 1999). In addition, Gorney et al. (1999) assumed the British dimorphism pattern to hold in Israel and did not test the validity of the biometrics with molecular methods. Since then, these data seem to have been adopted by the scientific community for the whole European distribution area (see Cramp 1985, Baker 1993, Forsman 1999).

The sparrowhawk breeds in the Palearctic from Madeira and western Europe (excluding Iceland) to eastern Siberia, Sakhalin, and Japan (Zollinger 1997). The nominate *nisus* overlap with *nisosimilis* in western Siberia (Cramp 1985, Ferguson-Lees and Christie 2001). In western and central Europe, the species is mostly resident, but the extent of dispersive and migratory movements increases progressively to the north and northeast, especially among juveniles (Zollinger 1997).

Despite its extensive range, the sparrowhawk shows little geographical variation in size or color, and populations hardly vary from one edge to the other of the Eurasian landmass (Newton 1986). However, it seems that there is a clinal (gradual) geographic variation involving increasing size and decreasing color saturation from west to east (Baker 1993). Hence, in wintering regions such as the Iberian peninsula, where migrating birds headed toward Africa also occur, from September to April, sedentary resident birds are mixed with migrant and wintering birds from central and northern European countries (Diaz et al. 1996). Here in Spain, we would expect to find birds from different breeding areas, with some differences in biometrics, body mass, or color.

Our primary objective was to test the sexual-size dimorphism of sparrowhawks in Spain in order to develop a useful and accurate sexing tool for field sites where birds from different breeding areas might be found together.

METHODS

From 2001 to 2007, eighteen adult (11 females and 7 males) sparrowhawks were trapped, ringed, and measured during the breeding season in Bizkaia, Spain. We trapped the adults using a special mist net for small raptors and an eagle-owl (*Bubo bubo*) as a lure at the nest sites in July, after young have fledged (see Zuberogoitia et al. 2008). Individuals were sexed by the presence (females) or absence (males) of a brood patch and from observation of breeding behavior.

Moreover, 91 dead and 38 rehabilitated sparrowhawks from Wildlife Rehabilitation Centers (WRC) were measured between 1999 and 2007, including individuals from Bizkaia and Alava (northern Spain), Madrid, Guadalajara, Salamanca and Toledo (central Spain), and Granada and Jaén (southern Spain). Dead birds were sexed by gonad examination, and live birds were sexed by molecular means using a blood sample taken from the brachial vein.

All sparrowhawks were aged according to their molt patterns (Newton and Marquiss 1981, Forsman 1999, Zuberogoitia et al. 2009).

We considered sedentary/resident birds to include those we trapped during the breeding season close to their nest and those birds received at the WRCs from May to August. All sparrowhawks received at WRCs from September to April were considered wintering birds, based on Diaz et al. (1996) who found that the earliest captures of birds banded outside of Spain were during the first weeks of

September and the latest ones were in May. In the wintering group, both local sedentary birds and migratory conspecifics were pooled together because it proved impossible to distinguish between them (De la Hera et al. 2007). In total, we analyzed measurements of 43 sedentary birds and 98 wintering birds.

The birds were measured following a standardized protocol by four researchers (IZ, RA, LP, and Ainara Azkona). We measured 10 morphological traits for each bird. Skeletal measures (tarsus length, minimum tarsus width, cranium size, bill and forearm length) were measured with a calliper to the nearest 0.1 mm. Wing chord, wingspan, eight primary length (P8) and tail were measured with a ruler to the nearest 1 mm. Mass was measured using precision dynamometers to the nearest 1 g. We did not include in our dataset the mass in dead or injured birds, nor those measures involving damaged bones.

Maximum flattened wing chord, wingspan, and P8 were measured following protocols described by Svensson (1974), Jenni and Winkler (1989), or Baker (1993). Bill length was taken from the tip to the cere (nostrils), cranium size was measured from the center of the back of the skull to the distal extreme of the bill and tarsus length was the distance from the rear of the tibia to the joint of the tarsus-metatarsus with the toes (Baker 1993). Minimum tarsus width was measured following Walls and Kenward (1995; stop pressing as soon as the skin is touched) and forearm was measured following Ferrer and De le Court (1992). Tail length was measured by bending the tail at a perpendicular angle to the dorsal and using a butted ruler. The butt was placed on the base of the tail in the junction with the back and the rectrices were then flattened to the ruler and measured to the tip of the longest feather. For adult birds, we recorded mantle color, the presence/absence of rufous feathers in the flanks and breast, the main color in the barring pattern, and the presence/absence of white supercilia (i.e., Ferguson-Lees and Christie 2001). Photographs were typically taken (n = 82).

Statistical Analysis. Reversed sexual dimorphism (RSD, in %) was calculated as an index:

$$100 * [(\text{mean value of the male character}/\text{mean value of the female character}) - 1]$$

(Krüger 2005, Vögeli et al. 2007).

We used one-way ANOVA to detect sex differences in morphological traits (De la Hera et al. 2007, Hermosell et al. 2007, Vögeli et al. 2007). We then used a multivariate analysis of variance (MANOVA) to evaluate (1) differences in body size between sexes and geographical areas, and (2) differences in body size between sexes and age classes (juveniles and adults).

The Wilcoxon test for matched samples was used to detect differences in the RSD, considering all the biometrics traits, between sedentary and wintering birds.

Finally, we used forward stepwise discriminant function analysis (DFA) to determine the best measurements for identifying the sex of both juveniles and adults (n = 84). We also validated the model using 39 previously sexed birds not included in the former analysis. Analyses were made with SPSS 15.0.

RESULTS

In total, we measured 43 sedentary/resident birds (26 females, 17 males), and 98 wintering birds (76 females, 22 males). Most of the female sparrowhawks examined (93.1%) had two ovaries (tested in 29 females). Sixteen juvenile females presented immature ovaries, very similar to immature testicles, although slightly larger.

For adult birds for which we recorded coloration, 11.8% of the adult males (n = 17) lacked rufous barring in the underbody feathers and therefore looked like females; 2.2% of the adult females (n = 45) were reddish in the breast, looking like males.

All the measured parameters differed significantly between sexes (Table 1), but most parameters also exhibited a small overlap between sexes. The four exceptions were P8, wingspan, forearm, and mass. Body mass and minimum tarsus width were the most dimorphic variables in sparrowhawks (Table 1).

Our multivariate analysis of variance (MANOVA) indicated that there were no differences in the measurements between sexes, considering the three regions of Spain (MANOVA, $P > 0.05$) and only one measure (wingspan) differed significantly between sedentary and wintering birds considering both sexes (MANOVA, $F = 6.961$, $P = 0.01$). There were no differences in the RSD scores between wintering and sedentary birds (Wilcoxon test for matched samples, $z = -1.572$, $P = 0.116$, df = 9), although measurements of sedentary birds overlapped in only three measurements (tail, bill, and minimum tarsus width, Table 2).

The DFA developed for differentiating between sexes was statistically significant (Wilk's lambda =

Table 1. Morphometric measures for male and female Eurasian Sparrowhawks considering all the measured individuals (sedentary and wintering birds). Results of the reversed sexual dimorphism (RSD) index (%) and results of the ANOVA comparing variables between sexes.

MEASUREMENT		MEAN	SD	MIN	MAX	*n*	RSD	*F*	*P*
Eighth primary length (mm)	male	137.9	6.3	116	147	22	−17.12	259.74	<0.001
	female	166.4	7.6	147	189	77			
Wing chord (mm)	male	200.9	10.3	182	234	36	−14.79	613.13	<0.001
	female	235.8	5.8	224	255	99			
Wingspan (mm)	male	618.7	10.5	600	639	14	−15.03	341.21	<0.001
	female	728.2	21.5	686	773	56			
Tail length (mm)	male	166.8	12.6	152	213	30	−13.12	184.47	<0.001
	female	192.0	7.1	178	217	89			
Forearm (mm)	male	63.0	3.1	54.4	67.2	17	−17.14	297.92	<0.001
	female	76.0	2.7	69.8	82.6	73			
Cranium size (mm)	male	43.6	1.1	41.2	45.5	17	−11.81	120.80	<0.001
	female	49.4	2.1	40.6	54	75			
Bill length (mm)	male	11.4	0.6	10.3	12.3	19	−19.56	146.53	<0.001
	female	14.2	0.9	11.1	16.3	77			
Tarsus (mm)	male	58.3	3.2	54.7	60	31	−11.38	229.96	<0.001
	female	65.8	2.0	60.4	70.2	89			
Minimum tarsus width (mm)	male	3.0	0.3	2.5	4.2	30	−21.48	155.38	<0.001
	female	3.8	0.3	3.2	4.7	82			
Body mass (g)	male	138.2	24.2	105	155	19	−43.29	214.60	<0.001
	female	243.6	27.5	185	292	49			

0.085, X^2_3 = 102.261, $P < 0.001$). The parameters that best correlated with sex were bill length (canonical correspondence 0.641), forearm (canonical correspondence 0.616), and P8 (canonical correspondence 0.579). The final canonical correlation was 0.957. The discriminant function with these variables classified correctly 100% of the individuals (n = 84; Fig. 1). The following function was generated:

$$D = -42.990 + 0.911 * (\text{bill}) + 0.226 * (\text{forearm}) + 0.087 * (\text{P8}).$$

Centroid for males = −6.411, centroid for females = 1.603.

We tested this function using measurements from 39 sparrowhawks (31 females and 8 males) that were not included in the previous analysis. All of them were sexed correctly.

DISCUSSION

Molecular sexing is generally considered the most accurate method to sex wild birds, although it is expensive (see Sacchi et al. 2004, Vögeli et al. 2007, Hermosell et al. 2007). The presence of testosterone or estrogen in blood or excreta may also be used but is also expensive (Saint Jalme 1999). For dead animals, mainly from wildlife rehabilitation centers, gonad examination can be used to accurately sex birds (Martínez et al. 2002, Kenward 2006). However, sparrowhawk females have two functional ovaries, while many other raptor and owl species have only one, normally situated on the left side (Martínez et al. 2002, Blanco et al. 2007), and immature ovaries may look like testicles during the first six–eight months. In March or April, ovaries start to mature, growing in size and developing the typical granulated texture due to the follicles. Until then, it is only possible to differentiate between ovaries and testicles because the former are relatively large, and so it is very easy to incorrectly sex immature sparrowhawks during their first few months. After the first breeding season, ovaries are always granulated and much bigger than testicles.

The sex of breeding adult sparrowhawks is easy to differentiate using plumage color dimorphism and the presence/absence of a vasculized brood patch. The brood patch is present in females from mid-May to mid-July. However, color dimorphism can sometimes be deceptive; we have seen female-colored males and male-colored females, although ac-

Table 2. Morphometric measures for male and female Eurasian Sparrowhawks considering only sedentary (resident) birds. Results of the reversed sexual dimorphism (RSD) index (%) and results of the ANOVA comparing variables between sexes.

MEASUREMENT		MEAN	SD	MIN	MAX	*n*	RSD	*F*	*P*
Eighth primary length (mm)	Male	137.1	8.3	116	144	10	−16.74	65.86	<0.001
	Female	164.7	8.7	152	188	17			
Wing chord (mm)	Male	198.9	4.6	192	208	16	−14.97	413.54	<0.001
	Female	234.0	5.5	224	244	20			
Wingspan (mm)	Male	622.9	9.2	614	639	8	−12.63	215.71	<0.001
	Female	712.9	15.8	689	746	14			
Tail length (mm)	Male	165.9	7.6	155	181	13	−14.25	112.71	<0.001
	Female	193.5	7.1	178	208	20			
Forearm (mm)	Male	64.1	3.0	59.8	67.2	6	−15.45	72.35	<0.001
	Female	75.9	2.7	71	79.7	13			
Cranium size (mm)	Male	44.0	1.2	42.4	45.5	6	−12.41	141.83	<0.001
	Female	50.3	1.0	48	52	14			
Bill length (mm)	Male	11.7	0.7	10.3	12.3	8	−19.14	37.53	<0.001
	Female	14.5	1.2	11.1	15.8	18			
Tarsus (mm)	Male	57.8	1.5	55.2	60	13	−12.30	133.52	<0.001
	Female	66.0	2.2	61	70.2	22			
Minimum tarsus width (mm)	Male	3.1	0.4	2.6	4.2	13	−20.34	45.11	<0.001
	Female	3.8	0.3	3.2	4.3	22			
Body mass (g)	Male	135.3	7.5	120	145	10	−45.66	440.27	<0.001
	Female	249.0	15.9	212	270	15			

cording to Forsman (1999) and Ferguson-Lees and Christie (2001), the sexes can usually be distinguished by more prominent white supercilia and nape-patch and bigger size in females (Forsman 1999).

Immature sparrowhawks do not show plumage dimorphism. Both sexes are very similar, with both males and females showing a prominent white supercilium. To date, the most frequently used sexing technique has been morphological measures based on the reversed sexual dimorphism (Cramp 1985, Newton 1986). However, the baseline data used to sex sparrowhawks were obtained from a few studies located primarily in Scotland and England (Newton et al. 1983, Cramp 1985, Newton 1986) and then extrapolated to the rest of the European countries (Baker 1993, Forsman 1999).

The Iberian peninsula is a wintering area for birds from all of Europe. Ringing recoveries indicate that most of the birds come from central Europe, although there are recoveries from northern Scandinavia and eastern Europe (Zuberogoitia et al. 2009). Therefore, during the migration and wintering periods, the Spanish population is increased by birds from other populations, which may differ in size and color saturation according to the clinal geographic variation that has been observed (Baker 1993). However, we found only a slight difference between breeding and wintering birds in a single characteristic, the wingspan. (As a caveat, we note that we were unable to separate the sedentary from the wintering sparrowhawks between September and May, and it is possible that correct designation of these birds in winter may have resulted in larger or more differences.) Palomares et al. (1997) reported similar results for a wintering population of Black-headed Gull (*Larus ridibundus*) in central Spain, in which the mean wingspan was larger in winter due to an influx of larger northern birds. Differences in wing or primary length have been largely studied in passerines, with long-distance migrating populations showing larger wings than short-distance or sedentary populations (Pérez-Tris and Tellería 2002, Pérez-Tris et al. 2004, De la Hera et al. 2007).

Because the population we studied in Spain in winter likely included birds from all over Europe (see Table 3), the protocol we created to sex sparrowhawks using biometrics should be valid for all or most of the continental range of *A.n. nisus*. Using

Table 3. Origin of ringed sparrowhawks which were ringed/encountered in Spain. Most encounters were in winter (n for Jan., 23; Feb., 11; Mar, 9; Apr., 7; May, 2; Jun., 2; Jul., 1; Aug., 0; Sept., 7; Oct., 15; Nov., 39; Dec., 26). Source: Ringing Offices of Ministerio Medio Ambiente (ESI) and Aranzadi (ESA).

COUNTRIES	n
Central Europe	
Germany	54
Belgium	17
France	5
Netherlands	22
Switzerland	9
Scandinavia	
Denmark	5
Finland	5
Sweden	6
Southeastern Europe	
Czech Republic	5
Italy	2
Northeastern Europe	
Estonia	2
Poland	2
Russia	8
Total	142

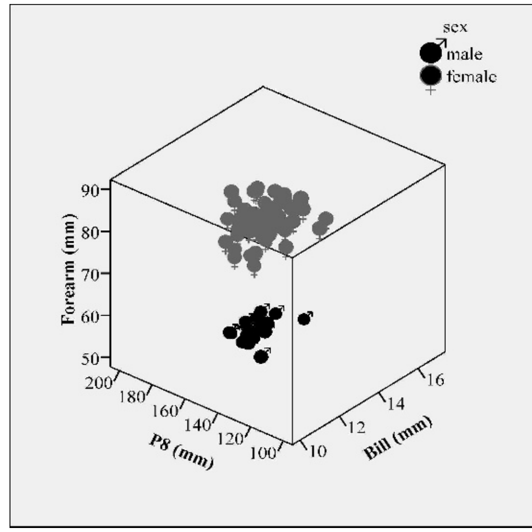

Figure 1. Morphological distribution of male (n = 17) and female (n = 67) Eurasian Sparrowhawks defined by the length of the eight primary (P8), the bill length, and the forearm length.

this entire sample of birds, we showed that most of the classical measurements used for sex determination actually have an evident overlap between sexes. Only the eighth primary length, the forearm, the wingspan, and the mass did not overlap between sexes. All of these measures other than mass have not been typically recorded in previous studies. However, if we had considered only the sedentary populations, the number of measures overlapping would have been much fewer, and we could legitimately have used the classical biometrics, following Newton et al. (1983), Cramp (1985) or Newton (1986) in order to correctly sex every bird. This may be why some measurements, such as wing chord and mass, are widely used to sex even nestlings, with no evident overlap (Bijlsma 1997, Vedder and Dekker 2004). Using the classical measures (wing chord, tail, or tarsus; i.e., Widen 1984, Gorney et al. 1999, Székely et al. 2004, McDonald et al. 2005, Krüger 2005) in wintering juvenile sparrowhawks may lead to misclassification if no other sexing method is used to confirm sex. In this case, large males would be classified as females, increasing the differentiation between sexes. One consequence could be a biometric difference between age classes as observed by Gorney et al. (1999), as large adult males would be correctly classified and differences between the sexes in adults would be less than that in juveniles.

The discriminant analysis on Spanish sparrowhawks resulted in selection of two of the nonoverlapping measures (the eighth primary and the forearm) and the bill. Considering only these easily-made measurements, 100% of the sparrowhawks were correctly classified. The forearm is a non-variable measurement that has recently been used in sexing birds of prey (Ferrer and De la Court 1992, Martínez et al. 2002, del Mar Delgado and Penteriani 2004). The eighth primary length has also been recently considered for sexing raptors (Cieślak and Dul 2006), whereas the bill length has been frequently used in the published literature (Cramp 1985, Newton 1986). In conclusion, the use of these three measures made it possible to correctly sex both adult and juvenile sparrowhawks throughout the year, even when the origin of the bird is unknown.

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