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SEXUAL SIZE DIMORPHISM AND DETERMINATION OF SEX IN ATLANTIC YELLOW-LEGGED GULLS *LARUS MICHAHELLIS LUSITANIUS* FROM NORTHERN SPAIN

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SUMMARY.—*Sexual size dimorphism and determination of sex in Atlantic yellow-legged gulls* Larus michahellis lusitanius *from Northern Spain.*

Aims: We evaluate sexual size dimorphism in Atlantic yellow-legged gulls *Larus michahellis lusitanius* and provide a discriminant function to sex gulls in hand.

Location: Two islands of the Basque Country (Northern Spain).

Methods: Incubating gulls were trapped, banded, weighted and measured. A drop of blood was extracted for molecular sexing. After testing for sex differences in body size and weight, discriminant function analyses were performed to identify the best traits for sexing.

Results: Body measurements in males were significantly larger than in females. Within each pair, males had larger head length, bill depth, long bill length and body mass. Discriminant analysis indicated than the combination of three measurements (head length, bill depth and wing length) predicted correctly the sex of 98.5 % of individuals.

Conclusions: The discriminant function described by Bosch (1996) cannot be used to identify sex properly in Atlantic Iberian yellow-legged gulls because they are significantly smaller than their Mediterranean counterparts. No significant differences were found with yellow-legged gull populations from Western extreme of Cantabrian coast (Galicia). Therefore, we conclude that the developed discriminant function can be applied to other Atlantic yellow-legged gull populations from Northern Iberian Peninsula, thus, providing a highly accurate, inexpensive and fast method for sexing in hand this Iberian gull subspecies.

Key words: *Larus michahellis lusitanius*, Iberian Peninsula, discriminant function analysis, sexual dimorphism.

RESUMEN.—*Dimorfismo sexual y determinación del sexo en gaviotas patiamarillas* Larus michahellis lusitanius *del norte de España.*

Objetivos: Se evalúa el dimorfismo sexual de una población atlántica de gaviota patiamarilla *Larus michahellis lusitanius* del norte de España y se ofrece una función discriminante para la determinación del sexo.

Localidad: Dos islas del País Vasco (Norte de España).

Métodos: Se capturaron gaviotas incubadoras que fueron anilladas, pesadas y medidas. Se extrajo una gota de sangre para el sexado molecular. Tras examinar las diferencias entre sexos en medidas corporales y peso, se aplicó análisis discriminante para establecer las mejores medidas de determinación de sexo.

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Resultados: Las medidas corporales de los machos fueron significativamente mayores que las de las hembras. Dentro de cada pareja los machos siempre fueron mayores en la longitud de la cabeza, la anchura y la longitud larga del pico, y el peso. El análisis discriminante indicó que la combinación de tres medidas (longitud de la cabeza, anchura del pico y longitud del ala) predecía correctamente el sexo del 98,5 % de los ejemplares.

Conclusiones: La función discriminante descrita por Bosch (1996) no puede utilizarse para sexar correctamente las gaviotas patiamarillas atlánticas ibéricas al ser éstas significativamente menores que las mediterráneas. No se encontraron diferencias significativas con las gaviotas patiamarillas del extremo oeste cantábrico (Galicia). Por ello, se concluye que la función discriminante obtenida podría ser aplicada a otras poblaciones atlánticas de gaviota patiamarilla del norte de la península Ibérica, constituyendo por tanto una herramienta precisa, económica y rápida para determinar el sexo en mano de esta subespecie ibérica.

Palabras clave: *Larus michahellis lusitanius*, península Ibérica, análisis de función discriminante, dimorfismo sexual.

Introduction

Most gull species have no obvious sexual dimorphism in plumage but males and females differ in size (*e.g.*, Harris & Hope Jones, 1969; Cramp and Simmons, 1983). Several studies have described predictive functions based on external measurements to discriminate between sexes in gulls (Coulson *et al*., 1983; Migot, 1986; Bosch, 1996; Chochi *et al*., 2002). These functions are usually specific for each gull species or even for some gull populations within a single species (Evans *et al*., 1993 and 1995).

Yellow-legged gull (*Larus michahellis*), now considered a separate species from herring gull (*Larus argentatus*) (Yesou, 1991; Wink *et al*., 1994; Crochet *et al*., 2002), shows a great amount of variation among its populations (Liebens *et al*., 2001; Pons *et al*., 2004). Although several taxonomic options could be adopted to account the observed variation, two yellow-legged gull subspecies have been commonly accepted: *L. m. atlantis*, inhabiting the Macaronesian archipelagoes and *L. m. michahellis*, breeding in the Mediterranean basin and Atlantic Northern African and Iberian coasts, from Morocco to the Basque Country (Liebers *et al*., 2001).

Several studies have shown further differences between yellow-legged gulls from Atlantic Morocco and Atlantic Iberia and also that some of the ethologic and phenotypic characteristics of the Atlantic Iberian populations are more similar to Herring gull *Larus argentatus* populations than to the yellow-legged populations breeding in the Mediterranean basin (Teyssèdre, 1983, 1984; Mínguez, 1988; Munilla, 1997a, 1997b; Beaubrun, 1988). Furthermore, Pons *et al*. (2004) provided additional evidence to support that Atlantic Iberian yellow-legged gulls are closer to herring gull than to Mediterranean yellow-legged gulls in size and shape. These authors also documented significantly differentiated neutral molecular markers between Atlantic Iberian populations and their Mediterranean counterparts that could be explained by the barrier to current gene flow that the delay in breeding phenology and the isolation by distance may constitute. Taking all this into account, it has been suggested to recognise Atlantic Iberian yellow-legged gull as a distinct subspecies named *Larus michahellis lusitanius* (Joiris, 1978), pending a more complete treatment of genetic and morphologic characters (Bermejo and Mouriño, 2003; Pons *et al.,* 2004).

Yellow-legged gulls from Northern Atlantic Iberia are significantly smaller than yellow-legged gulls from the Mediterranean basin

(Carrera *et al.*, 1987; Liebers *et al.*, 2001; Pons *et al.*, 2004), therefore the discriminant function described by Bosch (1996) cannot be used to identify sex properly in Atlantic Iberian populations.

The aims of this paper are (1) to evaluate sexual size dimorphism in an Atlantic yellow-legged gull population from Northern Spain and (2) to provide a reliable method for determining the sex of yellow-legged gulls from this population.

Material and methods

During the breeding period of 2005 and 2006, 67 incubating yellow-legged gulls from Izaro Island (43º 25' N, 02º 41' W) and 12 from San Nicolás Island (43º 22' N, 02º 30' W), (Biscay, Basque Country, Northern Spain) were collected with a drop trap (Mills and Ryder, 1979). All the birds showed complete adult plumage. According to Bermejo and Mouriño (2003) these gulls belong to the Cantabrican population *Larus michahellis lusitanius*. All birds were ringed with a metal and an engraved colour ring, measured, weighted and released. A small blood sample (< 0.1 ml) was taken from the brachial vein for sexing by molecular techniques at the Department of Zoology and Ecology of the University of Navarra, according to the protocol used by Gutiérrez-Corchero *et al.* (2002).

Nine body variables were measured: flat wing and tail length were measured to the nearest 1 mm using a ruler, head length (distance from the tip of the bill to the posterior ridge formed by the parietal-supraoccipital junction), bill depth (maximum depth of the bill posterior to the nostril), short bill length (distance from the tip of the bill to where rhinoteca meets with the skin), long bill length (distance from the tip of the bill to the corner of the mouth), nalospi (distance from the tip of the bill to the nostril), tarsus length and middle toe length were measured using a digital calliper to the nearest 0.01 mm. Birds were weighted to the nearest 10 g with a hand-held 2,000 g balance.

Variables were checked for normality using the One-Sample Kolmogorov-Smirnov test. We used two-tailed *t*-test to evaluate intersexual differences for each variable in the population from Izaro Island and to test differences in head length, bill depth and weight between this population and Atlantic yellow-legged gull populations from Galicia (Carrera *et al.,* 1987). We could not compare the variables between sexes because these authors gave statistic values for the whole population.

The percentage of dimorphism between sexes in each measure was calculated as

$\%D = (X_m - X_f) / X_m$

where X_m and X_f are the mean values in males and females respectively. We also compared measurements between the members of each pair in Izaro island to assess how often the male was larger than the female.

Finally, a stepwise discriminant function was calculated using all the measurements of the individuals from Izaro island, entering at each step the variable that best reduce overlapping between the centroids corresponding to the two sexes. The effectiveness of the discriminant function was assessed by a Jacknife -cross validation technique, in which sex classification was estimated using all individuals except the case being classified. We also validated the discriminant function using the sample of individuals from San Nicolás Island (6 males and 6 females). All the analyses were performed with the SPSS 11.0 statistical package.

Results

All measurements were significantly larger in males than in females (Table 1). The degree of sexual dimorphism differed depending on the variables; mass being the most dimorphic one and wing the least (Table 1). Paired comparisons of variables between members of the pairs revealed that males were always larg-

TABLE 1

Body measurements of female and male yellow-legged gulls from Izaro Island. C.V.: coefficient of variation, *t*: Student-t statistics, %D: dimorphism percentage.
[Medidas corporales de hembras y machos de gaviota patiamarilla de la isla de Izaro. C.V.: coeficiente de variación. t*: estadístico t de Student, %D: porcentaje de dimorfismo.]*

	Females (n = 36)		**Males (n = 31)**		*t*	*P*	**%D**	**Wilk's lambda**
	Mean ± SD (range)	**% C.V.**	**Mean ± SD (range)**	**% C.V.**				
Head length (mm)	115.51 ± 3.4 (110.2 - 123.6)	2.9	128.6 ± 3.1 (119.2 -135.5)	2.4	-16.4	< 0.001	10.2	0.19
Bill depth (mm)	17.6 ± 0.7 (15.9.-.18.8)	3.9	20.1 ± 0.8 (18.3 - 22.3)	4.0	-13.4	< 0.001	12.4	0.26
Short bill length (mm)	51.9 ± 2.8 (39.9 - 55.9)	5.4	58.6 ± 2.1 (52.7 - 62.1)	3.6	-10.7	< 0.001	11.4	0.36
Long bill length (mm)	72.6 ± 2.5 (67.0 - 78.7)	3.4	79.9 ± 2.4 (75.0 - 85.3)	3.0	-12.2	< 0.001	9.1	0.30
Nalospi (mm)	22.0 ± 1.7 (18.7 - 25.2)	7.7	23.8 ± 1.7 (20.2 - 27.7)	7.1	-4.4	< 0.001	8.2	0.77
Tarsus length (mm)	68.9 ± 2.2 (64.2 - 73.9)	3.2	74.2 ± 4.8 (54.8 - 80.5)	6.5	-5.5	< 0.001	7.5	0.65
Middle toe length (mm)	63.7 ± 2.7 (59.6 - 74.1)	4.2	68.6 ± 4.7 (47.4 - 74.3)	6.8	-5.3	< 0.001	7.1	0.70
Wing (mm)	417.4 ± 9.1 (399 – 438)	2.2	440.0 ± 9.1 (423 – 458)	2.1	-10.1	< 0.001	5.1	0.39
Tail (mm)	166.9 ± 9.1 (151 – 192)	5.4	178.9 ± 10.8 (160-211)	6.0	-4.9	< 0.001	6.7	0.72
Mass (g)	803.0 ± 56.2 (670 – 940)	7.0	983.8± 71.7 (850-1150)	7.3	-11.5	< 0.001	18.3	0.32

er than females in head length, bill depth, long bill length and mass, but not in other variables (Table 2).

Stepwise discriminant analysis incorporated to the function three out of ten body variables. The resulting discriminant function was:

D = 0.206*Head Length + 0.461*Bill depth + 0.035*Wing Length – 48.788

(Wilk's lambda = 0.153; χ^2 = 119.26; df = 3; $P < 0.001$), where values of D > 0 identified males and values of D < 0 identified females. Function eigenvalue was 5.54, and the value of the function in the centroids for group 1 (females) was -2.152, and 2.499 for group 2 (males). Exact *F* test= 116.37 ($P < 0.001$) concluded that the function centroids were significantly different. The discriminant function classified correctly the sex of 98.5 % of the original grouped cases as well as 97.0 % of cross-validated grouped cases. Different randomly chosen subsamples were also used to evaluate the validation of the function (Leave one-cut classification in SPSS) resulting in 91.7 % to 100 % of the cases correctly classified. The function also classified correctly 91.6 % of the gulls from San Nicolás Island (one female failed in the prediction among the 12 individuals tested).

No significant differences were found between Basque and Galician populations in head length, bill depth and weight (Table 3). Other morphometric variables were not compared because of the different way of measuring used in both studies.

DISCUSSION

As it has been described in other yellow-legged gull populations (Isenmann, 1973; Bosch, 1996; Pons *et al*., 2004), we found marked sexual differences in body measurements. The accuracy of the discriminant function obtained was similar to those reported for other populations of the *Larus argentatus-cachinnans* group (Shugart, 1977; Fox *et al.,* 1981; Coulson *et al.,* 1983; Migot, 1986; Evans *et al*., 1995; Bosch, 1996) and predicted correctly the sex of most of yellow-legged gulls from our population. When values of the discriminant function (D) are near zero gulls are less likely to be properly sexed. In such cases, their sex could better be inferred by comparing head length, bill depth, long bill length or body mass with those of their partners if available. The highest accuracy of head length, bill depth and wing length in discriminating sex agree with the results obtained by Bosch (1996) for a Mediterranean yellow-legged colony, although in this case a single measurement (head length) was almost as efficient as the combined function. This variable seems to be the most informative for gull sex prediction since it is included as the most predictive variable in the discriminant function of all the studies mentioned above. The three biometric measurements entering in the function can easily be taken in the field with great accuracy, although bill depth should be used with caution, because it can vary with age (Coulson *et al*., 1981).

TABLE 2

Percentage of pairs from Izaro Island where males showed higher values than females for each measurement. (n = 28).
*[Porcentaje de parejas de la isla de Izaro en las que el macho tiene un valor superior a la hembra para cada variable medida (*n *= 28).]*

Measurement	**(%)**
Head length	100
Bill depth	100
Short bill length	92.3
Long bill length	100
Nalospi	83.3
Tarsus length	92.3
Middle toe length	96.3
Wing	83.3
Tail	72.7
Body mass	100

TABLE 3

Variation between yellow-legged gulls from Galicia (Carrera *et al.,* 1987) and Izaro Island, Basque Country (present study).
[Variación entre las gaviotas patiamarillas de Galicia (Carrera et al.*, 1987) y la isla de Izaro, País Vasco (presente trabajo).]*

	Galicia	***n***	**Basque Country**	***n***	**P**
Head length	122.78 ± 7.37	25	121.57 ± 7.33	67	> 0.05
Bill depth	18.16 ± 1.22	25	18.73 ± 1.46	67	> 0.05
Body mass	853.75 ± 168.39	16	886.72 ± 110.76	67	> 0.05

Mínguez *et al.* (1995) suggested the existence of a cline in size of yellow-legged gulls along the Cantabrian coast, being smaller the individuals breeding in the eastern extreme. However, no significant differences were found between Basque (eastern) and Galician (western) populations when head length, bill depth and body mass were compared. Such two gull populations are located in the extremes of the Cantabrian coast, so it can be suggested that no identifiable sexual differences in morphology exist throughout the coast of Northern Atlantic Spain. Therefore, we conclude that the developed discriminant function can be applied to incubating yellow-legged gulls all along Northern Iberian coast, providing a highly accurate, inexpensive and fast method for sexing this gull subspecies in hand which can help us to approach future questions about its ecology.

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