Sex Differentiation of Yellow-legged Gull (*Larus michahellis lusitanius*): the Use of Biometrics, Bill Morphometrics and Wing Tip Coloration

JUAN ARIZAGA[1,2*], ASIER ALDALUR[2], ALFREDO HERRERO[2] AND DAVID GALICIA[1]

[1]Department of Zoology and Ecology, University of Navarra, Irunlarrea 1, E-31080 Pamplona, Spain

[2]Department of Vertebrates, Aranzadi Sciences Society, Zorroagagaina 11, E-20014 San Sebastián, Spain

*Corresponding author; Internet: jarizaga@alumni.unav.es

Abstract.—We used feathers and skeletal measurements, white and black areas at the wing tip and bill morphometrics of Yellow-legged Gulls (*Larus michahellis lusitanius*) in order to test for possible sex-differences. Overall, 157 individuals from the eastern Bay of Biscay (N Spain) were measured, and the sex determined in 155 individuals, by means of DNA-analyses. All feathers and skeletal-associated measurements, except the distance between each primary (P1 to P5) feather and the wing tip in a folded wing varied between the sexes, with males being larger than females. Sexual selection is discussed to be the major cause explaining these differences. A discriminant function is provided to separate sexes. By contrast, both wing tip patterns of coloration and bill morphology did not vary between sex classes. *Received 17 May 2007, accepted 26 November 2007.*

Key words.—Yellow-legged Gull (*Larus michahellis lusitanius*), sex, biometrics, morphometrics, wingtip coloration pattern, the eastern bay of Biscay.

Waterbirds 31(2): 211-219, 2008

A number of biological processes in birds, such as diet and foraging (Holmes 1986; Durell *et al.* 1993; Clarke *et al.* 1998), parental care (Pierotti 1981) or migration (Swanson *et al.* 1999; Rubolini *et al.* 2004; Cristol *et al.* 1999), differs between the sexes. Accordingly, sex-identification is basic to understanding adequately all these processes which, overall, give us key clues about the life history of species. The Yellow-legged Gull (*Larus michahellis*) is a circum-Mediterranean gull, breeding from Iberia to the Black sea (Olsen and Larsson 2004). In Iberia two subspecies currently breed (Bermejo and Mouriño 2003; Olsen and Larsson 2004): *L. m. michahellis*, occurring along Mediterranean coast, up to central Portugal in W Iberia, and *L. m. lusitanius*, in Atlantic coasts from northwest Iberia, up to south central Portugal (Pons *et al.* 2004). *L. m. atlantis*, present in Macaronesia and the northwest coasts of Africa, do not breed in Iberia (Bermejo and Mouriño 2003; Pons *et al.* 2004).

Among the large gulls (largest of *Larus* spp.), sexes differ in their size with males being larger (Ingolfsson 1969; Coulson *et al.* 1983; Bosch 1996), and there are a number of studies dealing with discriminating methodologies used to distinguish between sex classes. Discriminating functions vary not only between species, but often also among populations (Evans *et al.* 1993). A number of studies have focused on biometrics of a number of Mediterranean Yellow-legged Gull populations (Carrera *et al.* 1987; Bosch 1996) in relation to sex, whereas studies on the Cantabrian Yellow-legged Gull are scarce and analyses on sex-differences are virtually lacking.

In addition to biometrics, the wing-tip coloration patterns in several gull species have been described to vary not only between species, but among age and sex classes and populations (Coulson *et al.* 1982; Allaine and Lebreton 1990; Saks and Rattise 2006). Although in a number of large gulls these patterns are thought to be independent of sex (Mierauskas *et al.* 1991; Snell 1991), we have no data on the Cantabrian Yellow-legged Gull populations. Bill size in gulls is highly dimorphic between sex classes (Ingolfsson 1969; Coulson *et al.* 1983; Bosch 1996). However, it is virtually unknown if this dimorphism is also observed in relation to bill morphology (shape), as it is observed in other seabird species (Kaliontzopoulou *et al.* 2006). Our aim was to obtain useful criteria to distinguish sex in a population of Yellow-legged Gull *L. m. lusitanius* in the eastern Bay

of Biscay, in relation to (1) classical biometric variables, (2) wing-tip patterns of coloration (black and white areas at the wing tip) and (3) bill morphology.

MATERIALS AND METHODS

Sampling Area and Data Collection

Data on 155 dead adults (EURING code A, birds with more than five years) of Yellow-legged Gull collected in a dump in Zarauz (43°17'N, 02°10'W, N Spain), in the eastern Bay of Biscay, were used as a part of a government culling program. After labelling the specimens, they were kept frozen (see for a similar method Bosch 1996) and, before taking measurements, they were thawed. Only data on adults collected from early April to early July were used to guarantee that measured gulls were local. Thus, birds from other non-local populations, such as the Mediterranean Yellow-legged Gull (*L. m. michahellis*), a relatively common winter visitant in the Bay of Biscay (Yesou 1985; Martínez-Abraín *et al.* 2002) were avoided.

Within each gull, measures were taken of (1) 25 feathers and skeletal-associated measurements (Table 1, Fig. 1), (2) 14 records associated with the size and features of white and black areas at the tip of the outermost primaries (Table 2, Fig. 2; feather areas were taken with a mesh to 1.0 mm^2 accuracy, and lengths were recorded with a digital calliper to ± 0.5 mm) and (3) bill morphology, for which seven landmarks were established (Fig. 1). Within each landmark, two variables were recorded: the x and y coordinates, so 14 records related to bill morphology were obtained. In the first two sets of measurements, data on disarranged or growing feathers were omitted. All measurements were recorded by a single author (AA). Most of the measurements had a low proportion of fleshy tissue, so shrinkage should be minimal after freezing (Bosch 1996).

Images of the head and bill, stored in JPEG format, were taken with a six Mpx digital still camera. Bill was the only suitable structure that could be analyzed from a geometric perspective, due to its rigidity and well-defined outline. The landmarks were digitized over the bill images, using the Tps-Dig v.2.05 software (Rohlf 2006a). All landmarks were recorded on the left side for each individual. Images where landmarks could be affected by broken areas and bad focusing were removed from the study.

Sex Determination

DNA-analyses were used in order to sex gulls (Griffiths *et al.* 1998; Gutiérrez-Corchero *et al.* 2002). Within each bird, a sample from the rachis base from one to two primaries was taken and, thereafter, stored in a 1.5 ml vial, refilled with 99% ethanol. In the laboratory the DNA sequence relative to the CHD-protein, present in both Z and W sex chromosomes, was amplified by means of a Polymerase Chain Reaction (PCR) technique. PCR fragments were separated by electrophoresis on a 2.5% agarose gel. According to Griffiths *et al.* (1998), a single band of DNA on the gel indicated that a bird was male (corresponding to CHD-Z gene), while two bands were present in females (corresponding to both CHD-Z and CHD-W). From 157 gulls, sex was determined in 155 cases (98.7%). Accordingly, the two unsexed birds were removed from further analyses.

Data Analyses

Both data on feathers and skeletal-associated measurements followed normal distributions (K-S test, $P > 0.05$), except P1, P2, HB and LML among males, and P1 and BODY in females. Student t-tests were found to be robust to departures from the normal distribution (Sokal and Rolf 1995), since similar results were found with a non-parametric Mann-Whitney U-test. Hence, we used the Student t-test to analyze differences between sexes.

Table 1. Measurements associated with primary feathers and skeletal parts taken in adults of Yellow-legged Gull in the eastern bay of Biscay.

Abbreviation	Variable	Error
WLEN	Wing length.	± 1.0 mm
WSPA	Wing span.	± 1.0 mm
P1 to P10	Lengths of primary feathers to the wing tip, in a folded wing. Numbered from outermost to innermost.	± 1.0 mm
TAIL	Tail length.	± 1.0 mm
BODY	Body length.	± 1.0 mm
TARL	Tarsus length.	± 0.5 mm
TARW	Minimum tarsus width, measured laterally.	± 0.5 mm
HB	Length of head and bill.	± 0.5 mm
BILL1	Bill length, from the distal tip up to the point where it joins the skull.	± 0.5 mm
BILL2	Bill length, up to the feathers base (culmen).	± 0.5 mm
BILL3	Bill length, up to the frontal nostril edge.	± 0.5 mm
BILLD	Bill depth.	± 0.5 mm
G1	Length from the tip of the lower mandible until the gonys lower point.	± 0.5 mm
G2	Gonys maximum height.	± 0.5 mm
G3	Length from the gonys lower point until the lower mandible base.	± 0.5 mm
LML	Lower mandible length.	± 0.5 mm

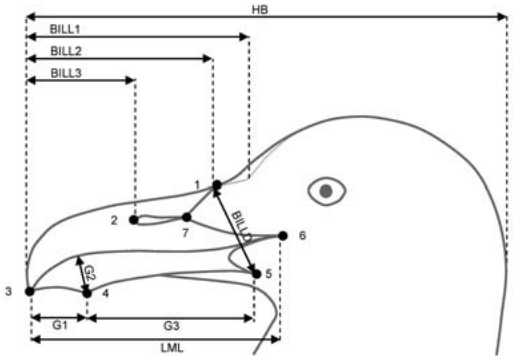

Figure 1. Head and bill-associated measurements (arrows) and landmarks (dots 1 to 7) measured in each individual.

In order to quantify the overlap between sex classes and to obtain a discriminant function to identify them, a Discriminating Function Analyses (DFA) was performed (Hair *et al.* 1999). In this DFA all the biometric variables were included, except the primary distances P1 to P10, for which no significant differences were found between sexes. The stepwise DFA allows the determination of a discriminating function including only those variables which contribute to improving the discriminating capacity significantly. Also, the DFA was used to study which measurements had the greatest discriminating power, for which the standardized coefficients from the discriminating function were used (Dillon and Goldstein 1984).

Data on the white and black areas at the tip of the primaries (see Table 2 for abbreviations and descriptions) were analyzed with (1) χ^2-based tests (dimensionless measurements; P-exact values were used) or (2) t tests (quantitative data). The software SPSS v.13.0 for Windows was used in all these cases.

Bill images were analyzed with a specific software available at the F. J. Rohlf website (http://life.bio.sunysb.edu/morph). The original landmark records (x and y coordinates) were scaled and transformed according to a standard procedure in geometric morphometrics (Procrustes procedure), following the software TpsRelw v.1.44 (Rohlf 2006b). This program also provided the shape variables matrix. These shape variables were then analyzed in a Principal Component Analysis (PCA) in order to understand the main morphological patterns of variation and a MANOVA in order to search for sex-associated variations. In such cases, the software SPSS v.13.0 for Windows was used.

RESULTS

Biometrics

All biometric variables except distances of outermost primaries P1 to P5 to the wing tip in a folded wing varied between sexes with males being larger than females (Table 3). The DFA provided a discriminating function statistically significant for each variable (Table 4). Overall, BODY was the variable with highest discriminating power to distinguish between sex classes (88.9% of specimens correctly classified), with individuals with a body length over 649 mm being males, and with lower than 580 mm, females. There-

Table 2. Measurements of white and black areas at the tip of the outermost primaries in adults of Yellow-Legged Gull sampled in the eastern bay of Biscay. Non-dimensional measurements have no unit. As a consequence of wear, the white areas at the tip of the two outermost primaries were not measured.

Abbreviation	Variable	Error
PPB	Number of primary remiges (PP) with black band.	—
PPB_iVB	Within the innermost PP with black band, number of vanes with black: 0 = a single vane, 1= 2 vanes.	—
PPB_iV_o	Within the innermost PP with black band, extension of black in outer vane: 0 = no band, 1 = partial, 2 = complete.	—
PPB_iV_i	Within the innermost PP with black band, extension of black in inner vane: 0 = no band, 1 = partial, 2 = complete.	—
WMP1	Presence of a white mirror in P1: 0 = no mirror, 1 = mirror only in a single vane, 2 = both vanes with mirror, 3 = mirror and white tip area at the tip of P1 fused.	—
WMP2	Presence of a white mirror in P2: 0 = no mirror, 1 = mirror only in a single vane, 2 = both vanes with mirror, 3 = mirror and white tip area at the tip of P2 fused.	—
WM_aP1_i*	In P1, inner vane mirror area.	± 5.0 mm^2
WM_aP1_o*	In P1, outer vane mirror area.	± 5.0 mm^2
WM_aP2_i	In P2, inner vane mirror area.	± 5.0 mm^2
WM_aP2_o	In P2, outer vane mirror area.	± 5.0 mm^2
WM_lP1_o*	In P1, mirror length in the outer vane.	± 0.5 mm
WM_lP1_i*	In P1, mirror length in the inner vane.	± 0.5 mm
WM_lP2_o	In P2, mirror length in the outer vane.	± 0.5 mm
WM_lP2_i	In P2, mirror length in the inner vane.	± 0.5 mm

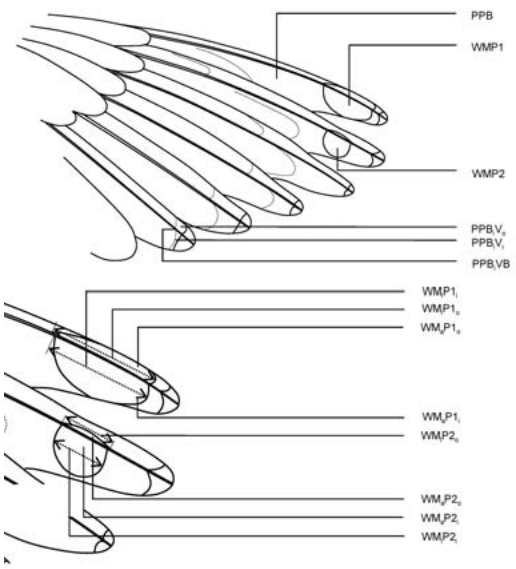

Figure 2. Measurements taken at the wing tip (primary feathers) to study the white and black areas between sexes.

after, a stepwise DFA provided a combined equation where four variables were included: Y = 0.023 BODY + 0.094 BILL2 + 0.215 BILLH + 0.121 G3 – 28.213 (λ_{Wilk} = 0.397, P < 0.001, 89.5% of cases correctly classified). Positive Y-values in this equation showed that a bird was male, while negative values, female. In this equation, BODY was the most discriminating variable, according to the standardized coefficients (BODY: 0.448, G3: 0.305, BILLH: 0.288, BILL2: 0.284). Taking a sub-sample of 20 gulls (ten males and ten females) chosen by random from the data set used to make up the DFA, the proportion of specimens correctly classified was 85.0%.

The head and bill length was the most discriminating variable in a Mediterranean Yellow-legged Gull population (Bosch 1996). Considering this variable, Mediterranean gulls were larger than those from our Cantabrian population (males: t_{85} = 10.857, P < 0.001; females: t_{68} = 6.015, P < 0.001). Also, Cantabrian males were 6.9% larger than females, while Mediterranean males were 9.3% larger.

Wing Tip Coloration

No significant differences between sex classes were found for the dimensionless measurements in relation to the black and white areas at the tip of primaries (see for abbreviations Table 2): PPB$_i$VB: χ^2_1 = 0.529, P = 0.547; PPB$_i$V$_o$: χ^2_2 = 2.123, P = 0.418; PPB$_i$V$_i$: χ^2_2 = 0.429, P = 0.832; WMP1: χ^2_1 = 0.200, P = 0.684; WMP2: χ^2_2 = 3.777, P = 0.162. Consequently, 80.0% of the gulls had a black band in both vanes in the innermost primary feather with black band, while 20.0% of the gulls had a band in only one of the vanes, with this difference being significant (χ^2_1 = 55.800, P < 0.001). In this same innermost primary feather, 78.7% and 72.9% had complete black bands in the outer and inner vanes, respectively, with this proportion being higher than that of the gulls which had either partial black bands or no black bands in the outer and inner vanes (PPB$_i$V$_o$: χ^2_2 = 150.671, P < 0.001; PPB$_i$V$_i$: χ^2_2 = 111.110, P < 0.001). In P1, all the gulls had a white mirror which was extended along both vanes. In addition, 19.0% of the gulls had the mirror and the white tip fused, with no significant differences between sexes (χ^2_1 = 0.200, P = 0.684). Considering P2, 34.0% of the gulls had no mirror, 28.1% had the mirror extended only in a single vane, and 37.9% had the mirror extended along both vanes. No significant differences between sexes were found in these proportions (χ^2_1 = 3.777, P = 0.162).

Overall, gulls had on average six primaries with black areas, with no significant differences between sexes (Table 5). By contrast, white areas in males tended to be longer and larger than in females (Table 5), though this difference was significant only for the mirror length and area at the inner vane of P1 (WM$_a$P1$_i$, WM$_i$P1$_i$). An ANCOVA revealed that, in these two cases, significant differences were due to the body size (Table 6): with a higher body size, males showed larger white areas than females.

Bill Morphometrics

Bill morphology was analysed in 55 specimens (34 males, 21 females). In the PCA, the first two components (PC1 and PC2) accounted for c.a. 60% of variance (Table 7). Bill morphology patterns of variation were deduced from the deformation grids associ-

Table 3. Sex-associated biometrics (all in mm) of Yellow-Legged Gulls in the eastern bay of Biscay.

	Males			Females			Statistics	
Variable	*N*	mean ± SE	range	*N*	mean ± SE	range	*t* values	*P*
WLEN	86	441.2 ± 1.2	410-471	69	422.5 ± 1.7	400-470	9.219	<0.001
WSPA	86	1,452.3 ± 4.6	1,340-1,550	69	1,379.3 ± 5.9	1,260-1,525	9.879	<0.001
P1	85	0.3 ± 0.1	0-8	69	0.1 ± 0.1	0-5	0.802	0.424
P2	85	4.9 ± 0.3	0-14	67	4.7 ± 0.3	0-13	0.387	0.700
P3	85	21.2 ± 0.5	10-35	69	21.5 ± 0.7	10-45	0.311	0.757
P4	85	48.4 ± 0.7	30-65	69	47.7 ± 0.7	35-70	0.706	0.481
P5	86	75.5 ± 0.7	56-92	69	73.7 ± 0.8	52-94	1.538	0.126
P6	86	104.7 ± 0.8	86-120	69	101.8 ± 0.7	84-120	2.730	0.007
P7	86	133.3 ± 0.8	115-150	67	127.9 ± 0.8	110-141	4.661	<0.001
P8	80	162.7 ± 1.1	136-187	60	157.0 ± 1.1	131-176	3.656	<0.001
P9	56	191.8 ± 1.4	175-220	44	182.5 ± 1.1	163-199	5.393	<0.001
P10	47	217.1 ± 1.4	197-240	30	208.6 ± 1.4	195-229	4.101	<0.001
TAIL	86	180.5 ± 0.8	163-202	68	169.2 ± 0.9	156-197	9.061	<0.001
BODY	85	628.4 ± 1.8	580-665	68	588.8 ± 2.6	520-649	12.642	<0.001
TARL	86	65.0 ± 0.3	58.0-71.0	69	60.7 ± 0.3	55.5-71.0	10.067	<0.001
TARW	86	4.4 ± 0.03	3.5-5.0	69	4.2 ± 0.03	3.5-4.5	6.357	<0.001
HB	86	123.5 ± 0.6	104.0-132.0	69	115.5 ± 0.6	107.5-128.5	9.402	<0.001
BILL1	85	72.1 ± 0.4	58.5-77.0	69	65.9 ± 0.4	60.5-78.0	11.252	<0.001
BILL2	85	57.3 ± 0.3	50.0-71.0	69	51.8 ± 0.4	42.0-59.0	11.501	<0.001
BILL3	86	26.0 ± 0.2	21.5-30.0	69	24.1 ± 0.2	18.5-27.5	7.985	<0.001
BILLD	86	20.6 ± 0.1	17.0-23.5	69	18.5 ± 0.2	14.0-24.0	9.719	<0.001
G1	85	16.9 ± 0.1	14.0-20.0	69	15.7 ± 0.1	13.0-19.0	6.619	<0.001
G2	86	10.2 ± 0.1	8.0-12.0	69	9.3 ± 0.1	8.0-11.5	9.367	<0.001
G3	86	40.2 ± 0.3	34.0-50.0	69	35.5 ± 0.3	31.0-40.0	11.650	<0.001
LML	86	85.8 ± 0.5	68.5-93.5	69	80.0 ± 0.5	60.0-90.0	0.511	<0.001

ated with the highest and lowest scores of the first two principle components (Fig. 3). Grid dots are shown in Fig. 1 (the dot on the left hand side is that corresponding with the bill tip), with their relative position representing changes in bill morphology. In general, in both components most differences were observed in the relative location of the dorsal landmarks one to three. Thus, higher scores in the first component were associated with bills with upper mandibles relatively less deep (Fig. 4). In the second component, higher scores were associated with a relatively longer bill (Fig. 3). However, according to the distribution of sexes in the plot derived from the PCA, both components seem to be independent of sex (Fig. 3). Accordingly, no significant differences between sexes were found in the MANOVA test ($F_{10,44} = 1.616$, $P = 0.134$). Also, no significant differences were found when shape variables were regressed on BODY (i.e., a record assessing body size) in a multivariate regression.

DISCUSSION

Biometrics

A high sexual size dimorphism was found, with significant differences between sex classes in 20 of 25 feather- and skeletal-associated measurements. Thus, overall, males were larger than females, as found for other Yellow-legged Gull populations (Isenmann 1973; Bosch 1996) and in general for other large gulls (Ingolfsson 1969; Coulson *et al.* 1981, 1983; Fox *et al.* 1981; Pierotti 1981). Sexual dimorphism in large gulls is likely promoted by sexual selection (Székely *et al.* 2000).

A stepwise DFA provided a discriminating equation (89.5% of sexes correctly classified; 85% when only a sub-sample of the total was considered) including the following four variables: body length, bill length (measured from the distal tip of the upper mandible until the point where feathers appear; i.e. culmen length), bill depth and the

Table 4. Classification matrix of the sex of Yellow-legged Gulls derived from a Discriminating Function Analysis (DFA). The Wilk's Lambda (for all cases, $P < 0.001$) and the proportion of birds correctly classified by the DFA are shown for each case.

Variable	λ_{Wilk}	Males (%)	Females (%)	Overall (%)
WLEN	0.643	86.0	72.5	80.0
WSPA	0.611	83.7	78.3	81.3
TAIL	0.649	84.9	76.5	81.2
BODY	0.486	91.8	85.3	88.9
TARL	0.602	84.9	81.2	83.2
TARW	0.791	76.7	60.9	69.7
HB	0.634	88.4	79.7	84.5
BILL1	0.546	90.6	84.1	87.7
BILL2	0.535	88.2	82.6	85.7
BILL3	0.706	82.6	66.7	75.5
BILLD	0.618	89.5	79.7	85.2
G1	0.776	80.0	66.7	74.0
G2	0.636	83.7	79.7	81.9
G3	0.530	84.9	82.6	83.9
LML	0.679	86.0	81.2	83.9

length from the gonys lower point to the lower mandible basal point (BODY, BILL2, BILLH and G3 in Fig. 1). Therefore, it is apparent that measurements on bill size (3 from 4 in this equation) have a high probability in distinguishing between sex classes in the Yellow-legged Gull, as observed Bosch (1996) in a Mediterranean colony in eastern Iberia, as well as in other gulls (Fox *et al.* 1981; Coulson *et al.* 1983; Migot 1986; Evans *et al.* 1993; Palomares *et al.* 1997). However, in contrast to previous studies, we observed that body length showed a higher discriminating power than the bill-associated measurements. Indeed, although the function including four variables was significantly better than functions including a single variable, that including only body length classified correctly the sex of 88.9% of individuals. Thus, from a practical viewpoint, body length should be enough to sex Yellow-legged Gulls in the Bay of Biscay in the field. Body length was previously not measured in most studies dealing with discriminating functions to distinguish between sex classes using biometrics (e.g., Bosch 1996).

Our discriminating equation allowed us to classify correctly the sex of 89.5% of gulls (or less when not all the birds were taken into account). Since the data set used to make up the DFA was the same used to test for the success of the function, this percentage of sexes correctly classified could have been overestimated, with the real success being likely lower than found. This contrasts with the 100% of correct classifications achieved in Mediterranean Yellow-legged Gulls (Bosch 1996), in spite of the fact that the four most discriminating measurements obtained by Bosch (1996) in a stepwise DFA were also recorded by us: head and bill length, bill depth, wing length, tail length. Accordingly, these differences could be due to some variations in sexual size-dimorphism between the Cantabrian and Mediterranean Yellow-legged Gull populations with the Cantabrian one presenting a higher overlap between sexes. Thus, while Bosch (1996) found no overlap between sexes in the head and bill length, we observed for this same variable that males ranged from 104.0 to 135.0 mm, while females from 107.5

Table 5. Sex-associated records on white and black areas at the wing tip of Yellow-Legged Gulls in the eastern bay of Biscay.

	Males			Females			Statistics	
Variable	*N*	mean ± SE	range	*N*	mean ± SE	range	*t* values	*P*
PPB	86	6.3 ± 0.1	6.0-7	69	6.2 ± 0.1	5.0-7	1.575	0.117
WM_aP1_o	67	102.5 ± 3.0	35.0-150	57	100.7 ± 3.6	10.0-150	0.392	0.696
WM_aP1_i	67	435.0 ± 11.8	160.0-645	57	395.2 ± 10.2	245.0-585	2.499	0.014
WM_aP2_o	84	14.8 ± 2.7	0.0-95	69	10.2 ± 2.3	0.0-80	1.321	0.188
WM_aP2_i	84	79.1 ± 9.0	0.0-320	69	58.5 ± 8.6	0.0-240	1.641	0.103
WM_iP1_o	67	36.8 ± 0.7	18.5-46.0	57	35.9 ± 1.0	9.0-46.0	0.729	0.467
WM_iP1_i	67	37.2 ± 0.7	21.0-46.5	57	35.1 ± 0.7	20.0-46.0	2.169	0.032
WM_iP2_o	84	5.7 ± 0.8	0.0-29.0	69	4.2 ± 0.8	0.0-25.0	1.290	0.199
WM_iP2_i	84	8.7 ± 0.8	0.0-25.0	69	6.8 ± 0.9	0.0-23.0	1.618	0.108

Table 6. Analyses of Covariance (ANCOVA) on five quantitative measurements associated to white areas in the two outermost primaries, with body length (used as an estimator of body size) as a covariate.

Variable	Source of variation	F	*P*
WM_aP1_i	Sex	$F_{1,122} = 2.378$	0.126
	Body	$F_{1,122} = 0.005$	0.943
WM_lP1_i	Sex	$F_{1,122} = 1.644$	0.202
	Body	$F_{1,122} = 0.011$	0.916

to 128.5 mm. Causes explaining these variations are unknown to us, and we propose several hypotheses.

The degree of sexual size dimorphism between the Cantabrian and Mediterranean populations (they are separate subspecies) could be different, though to verify this hypothesis more sampling should be considered on both coasts. Second, gulls in northeast Iberia (Bosch 1996) were obtained from a colony during the breeding season, so most (if not all) of these birds were breeding when they were collected. By contrast, in our case the specimens were collected in a dump, so local, but non-breeding birds might have been collected. If a higher body size in males is positively selected by females at breeding colonies (Székely *et al.* 2000), at least some males collected out of these areas could be smaller than those from the breeding colonies, since the first ones could be a part of a non-breeding population of non-selected (smaller) males, resulting in a higher overlap between sex classes in our sample. However, compared with the Mediterranean population (Bosch 1996), difference in size between sex classes (analyzed for the head and bill length) was not much more marked in the Mediterranean population than in the Cantabrian one (9.3% *vs.* 6.9%, respectively). Thus, we have no strong support that this overlap between sex classes in our sample was solely due to a possible higher number of non-breeding males.

Table 7. Principal components derived from a Principal Component Analysis on the landmarks used to study bill shape.

Principal components	Eigenvalue (10^{-3})	Variance (%)
1	1.313	38.85
2	0.697	20.63
3	0.427	12.62
4	0.292	8.65
5	0.247	7.30
6	0.163	4.83
7	0.111	3.30
8	0.065	1.92
9	0.042	1.25
10	0.022	0.65

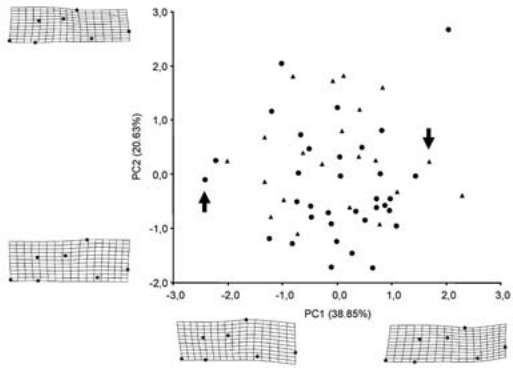

Figure 3. Scattered plot on the components one and two derived from a Principal Component Analysis on shape variables used to study bill shape. Dots: males. Triangles: females. The bill of the individuals marked with arrows has been drawn in the Figure 4. The deformation grids associated to highest and lowest values of the components are also shown.

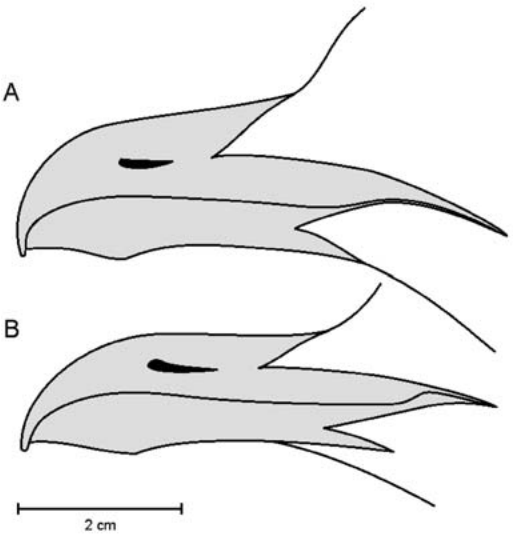

Figure 4. Bill drawings of the two individuals marked with arrows in Figure 3. A: a bill associated to lower scores in the component one; B: a bill associated to higher scores in the component one.

Third, in contrast to the Mediterranean example examined by Bosch (1996) our sample likely included more than a single breeding colony (Álvarez and Méndez 1995; A. A., per. obs.). Consequently, this could have promoted the presence of possible distinct phenotypes from a number of breeding colonies, resulting in a higher overlap between sex classes. However, measurements of gulls in southern France, north Africa and east and south Iberia were observed to be quite similar (Carrera *et al.* 1987; Bosch 1996), likely due to the movement among colonies in these areas. Similarly, Cantabrian gulls are known to move along the coast of northern Iberia (Munilla 1997), which could also promote a similar body size in the Yellow-legged Gull population which breeds along this coast. Fourth, differences in sample size should be excluded as a possible source of variations, since in both cases they were similar.

Wing-tip Coloration

No significant differences between sexes were observed in relation to the wing-tip patterns of coloration. This agrees with other studies where wing tip patterns of coloration in other large gulls have not been found to differ between sexes (Mierauskas *et al.* 1991; Snell 1991; but see Allaine and Lebreton 1990 for a small-sized gull). Thus, there is support that sex by itself is not enough to explain the relatively high variability of the wing-tip patterns of coloration in the Yellow-legged Gull. Other causes, such as age, should be considered in order to solve this question in future approaches (Saks and Rattiste 2006).

Bill Morphometrics

Bill morphology varied among individuals, with the first two components from a PCA accounting for 60% of variation. However, these differences were independent of sex. This contrasts with other seabird species, such as the Cory's Shearwater (*Calonectris diomedea*) (Kaliontzopoulou *et al.* 2006). Therefore, further studies should be done in order to find causes explaining variations in bill morphology, among which age could be of major interest.

ACKNOWLEDGMENTS

The gull samples were provided by J. Zulaika (Diputación de Guipúzcoa), with the permission of I. Mendiola (Diputación de Guipúzcoa). J. Unzueta and S. Urdanpilleta helped AA to take the measurements. C. Álvarez facilitated us some papers difficult to find. R. Miranda and K. Hobson provided some valuable comments that helped us to improve a first draft.

LITERATURE CITED

Álvarez, C. and M. Méndez. 1995. Alimentación de la Gaviota Patiamarilla *Larus cachinans* en dos localidades costeras asturianas. Chioglossa 1: 23-30.

Bermejo, A. and J. Mouriño. 2003. Gaviota Patiamarilla, *Larus cachinnans*. Pages 272-273 *in* Atlas de las Aves Reproductoras de España (R. Martí and J. C. del Moral, Eds.). Dirección General de la Conservación de la Naturaleza-Sociedad Española de Ornitología, Madrid.

Bosch, M. 1996. Sexual size dimorphism and determination of sex in Yellow-legged Gulls. Journal of Field Ornithology 67: 534-541.

Carrera, E., J. Trias, A. Bermejo, E. De Juana and J. Varela. 1987. Etude biométrique des populations ibériques et nord-africaine du Goéland leucophé *Larus cachinnans*. Oiseau et la Revue Française d'Ornithologie 57: 32-38.

Clarke, J., B. Manly, K. Kerry, H. Gardner, E. Franchi, S. Corsolini and S. Focardi. 1998. Sex differences in Adélie penguin foraging strategies. Polar Biology 20: 248-258.

Coulson, J. C., N. Duncan, C. S. Thomas and P. Monaghan. 1981. An age-related difference in the bill depth of Herring Gulls *Larus argentatus*. Ibis 123: 499-502.

Coulson, J. C., C. S. Thomas, J. E. L. Butterfield, N. Duncan, P. Monaghan and C. Shedden. 1983. The use of head and bill length to sex live gulls Laridae. Ibis 125: 549-557.

Cristol, D. A., M. B. Baker and C. Carbone. 1999. Differential migration revisited. Latitudinal segregation by age and sex class. Pages 33-88 *in* Current Ornithology, Vol. 15 (V. Nolan, E. D. Ketterson and C. F. Thompson, Eds.). Plenum Publishers, New York.

Dillon, W. R. and M. Goldstein. 1984. Multivariate Analyses: Methods and Applications. Wiley and Sons, New York.

Durell, S. E. A., L. E. V. Dit, J. D. Goss-Custard and R. W. G. Caldow. 1993. Sex-related differences in diet and feeding method in the oystercatcher *Haematopus ostralegus*. Journal of Animal Ecology 62: 205-215.

Evans, D. R., E. M. Hoopes and C. R. Griffin. 1993. Discriminating the sex of Laughing Gulls by linear measurements. Journal of Field Ornithology 64: 472-476.

Fox, G. A., C. R. Cooper and J. P. Ryder. 1981. Predicting the sex of Herring Gulls by using external measurements. Journal of Field Ornithology 52: 1-9.

Griffiths, R., M. C. Double, K. Orr and R. J. G. Dawson. 1998. A DNA test to sex most birds. Molecular Ecology 7: 1071-1075.

Gutiérrez-Corchero, F., M. V. Arruga, L. Sanz, C. García, M. A. Hernández and F. Campos. 2002. Using FTA cards to store avian blood simples for genetic studies. Their application in sex determination. Molecular Ecology Notes 2: 75-77.

Hair, J. F., R. E. Anderson, R. L. Tatham and W. C. Black. 1999. Análisis Multivariante. 5th ed. Prentice Hall Iberia, Madrid.

Holmes, R. T. 1986. Foraging patterns of forest birds: male-female differences. Wilson Bulletin 98: 196-213.

Ingolfsson, A. 1969. Sexual dimorphism on large gulls (*Larus* spp.). Auk 86: 732-737.

Isenmann, P. 1973. Biometrische untersuchungen an der gelbfüssigen Silbermöwe *Larus argentatus michahellis* aus der Camargue. Vogelwarte 27: 16-24.

Kaliontzopoulou, A., J. Navarro and J. González-Solis. 2006. Wing ornamentation reveals future survival in Common Black-headed Gulls. Journal of Ornithology 147 (suppl. 1). Abstracts XXIV International Ornithological Congress, Hamburg.

Martínez-Abraín, A., D. Oro, J. Carda and X. Del Señor. 2002. Movements of Yellow-Ledged Gulls (*Larus [cachinnans] michahellis*) from two small western Mediterranean colonies. Atlantic Seabirds 4: 101-108.

Mierauskas, P., E. Greimas and V. Buzun. 1991. A comparison of morphometrics, wing-tip patterns and vocalizations between Yellow-legged Herring gulls (*Larus argentatus*) from eastern Baltic and *Larus cachinnans*. Acta Ornithologica Lithuanica 4: 3-26.

Migot, P. 1986. Le Goéland argenté *Larus argentatus argentatus* Brehm en Bretagne: caractérisques biométriques des reproducteurs. Alauda 54: 268-278.

Olsen, K. M. and H. Larsson. 2004. Gulls of Europe, Asia and North America. Cristopher Helm, London.

Palomares, L. E., B. E. Arroyo, J. Marchamalo, J. J. Sainz and B. Voslamber. 1997. Sex- and age-related biometric variation of Black-headed Gulls *Larus ridibundus* in Western European populations. Bird Study 44: 310-317.

Pierotti, R. 1981. Male and female parental roles in the Western Gull under different environmental conditions. Auk 98: 532-549.

Pons, J. M., P. A. Crochet, M. Thery and A. Bermejo. 2004. Geographical variation in the yellow-ledged gull: introgression or convergence from the herring gull? Journal Zoological Systematics and Evolutionary Research 42: 245-256.

Rohlf, F. J. 2006a. TPS-Dig. Ver. 2.05. Department of Ecology and Evolution, State University of New York at Stony Brook.

Rohlf, F. J. 2006b. TPS-Relative Warp Analysis. Ver. 1.44. Department of Ecology and Evolution, State University of New York at Stony Brook.

Rubolini, D., F. Spina and N. Saino. 2004. Protandry and sexual dimorphism in trans-Saharan migratory birds. Behavioural Ecology 15: 592-601.

Saks, L. and K. Rattiste. 2006. Wing ornamentation reveals future survival in Common Black-headed Gulls. Journal of Ornithology 147 (suppl. 1). Abstracts XXIV International Ornithological Congress, Hamburg.

Snell, R. R. 1991. Interspecific allozyme differentiation among North Atlantic white-headed larid gulls. Auk 108: 319-328.

Sokal, R. R. and F. Rohlf. 1995. Biometry. Freeman, New York.

Swanson, D. L., E. T. Liknes and K. L. Dean. 1999. Differences in migratory timing and energetic condition among sex/age classes in migrant Ruby-Crowned Kinglets. Wilson Bulletin 111: 61-69.

Székely, T., J. D. Reynolds and J. Figuerola. 2000. Sexual size dimorphism in shorebirds, gulls, and alcids: the influence of sexual and natural selection. Evolution 54: 1404-1413.

Yesou, P. 1985. Le cycle de présence du Goeland leucophée sur le litoral atlantique français: l'example des marais d'Olone. L'Oiseau 55: 93-105.