

Sex- and age-related biometric variation of Black-headed Gulls *Larus ridibundus* in Western European populations

LUIS E. PALOMARES¹, BEATRIZ E. ARROYO^{*2}, JAVIER MARCHAMALO³, JUANJO J. SAINZ⁴ and BEREND VOGLAMBER⁵
¹Jaime el Conquistador 13, Portal 1, 2° D, 28045 Madrid, Spain, ²Edward Grey Institute, Department of Zoology, Oxford OX1 3PS, UK, ³C/ Tomás Borrás 12, 28045 Madrid, Spain, ⁴C/ Puerto de Santa María 51, 28043 Madrid, Spain and ⁵Spijkenissestraat 1, 6843 GL Arnhem, The Netherlands

*A multivariate discriminant analysis was performed with biometric data from 583 Black-headed Gulls *Larus ridibundus* of known sex, either wintering in central Spain or wintering and breeding in The Netherlands. The discriminant function calculated from these birds was applied to 1158 Black-headed Gulls trapped in Madrid; age, sex and temporal differences in biometrics were analysed for those birds. All measurements taken varied significantly between the sexes, but head-and-bill length and bill depth were the best discriminant variables. Bone measurements (bill length, head-and-bill length, and tarsus length) did not vary between first- or second-winter birds or adults. In contrast, wing length, length of the eighth primary, mass and bill depth increased significantly with age for both sexes, although females attained their final size quicker than males. Both wing length and body condition increased throughout the winter. Possible explanations for these results are discussed.*

Methods for sexing Black-headed Gulls *Larus ridibundus* have been reported by several authors. Coulson *et al.*¹ showed that total head-and-bill length was the best variable with which to sex several gull species, including Black-headed Gulls. For this species, they offered a single discriminant value to distinguish males from females, calculated using probability functions from data for birds of unknown sex. Subsequently, other discriminant values, for total head-and-bill length or a combination of that and another variable, have been presented, using the same methodology.^{2–4} However, the use of only one discriminant value might lead to mis-sexing a relatively large proportion of birds, if there is a large overlap in measurements between the sexes. Other authors^{4,5} have proposed the use of two values: individuals with values above the larger value would be males, and those

below the lower value would be females. This eliminates any overlap between sexes, decreasing the proportion of potentially mis-sexed individuals. However, if the number of birds with intermediate values is high, the proportion of unsexed birds might also be large.

No detailed information is readily available on the range of overlap in measurements between the sexes in Black-headed Gulls, as none of the previously mentioned studies was based on known-sex individuals (although Hein & Martens⁴ subsequently tested their discriminant value in 43 known-sex birds). Allaine & Lebreton⁶ applied a discriminant multivariate function to measurements of known-sex individuals, following the method of Coulson *et al.*¹ for other gull species. Their equation (combining total head-and-bill length and bill depth) correctly sexed 94.5% of birds, but their sample size was relatively small (45 females and 46 males) and only included adult birds.

*Correspondence author.

Three different age groups can be differentiated in Black-headed Gulls: first-winter, second-winter and adult.^{5,7} No published study discusses biometric differences in this species between age groups, although these have been reported for Herring Gulls *Larus argentatus*.⁸

Our study analyses age and sex differences in biometry for the Black-headed Gull, using data from Spain and The Netherlands. We attempted to obtain a sample of the Western European breeding populations as diverse as possible, in order to develop a formula applicable to birds regardless of their origin. Data from central Spain were obtained from the wintering population of Black-headed Gulls in Madrid, central Spain, which comprises birds mainly from France and the Low Countries, and in a smaller proportion from the Baltic and Nordic Countries, England and the Spanish breeding population. Data from The Netherlands were collected both in the breeding season and in winter. The Dutch wintering population includes mainly birds from Baltic and Fennoscandinavian populations.

METHODS

Sexing was carried out by dissection of 203 freshly dead gulls (117 females and 86 males) found at a roosting place in the Madrid area (Spain) between November and March, and 380 freshly dead gulls (199 females and 181 males) found mainly in the lake Ysselmeer area (The Netherlands) throughout the year. Juveniles found dead before the end of July were not included in the analysis. The following measurements were taken: maximum wing length (to a precision of 1 mm using a butted rule); length of the eighth primary (P8 descendant) (to 1 mm using a specially adapted rule⁹); tarsus length, total head-and-bill length, bill length, and bill depth at the gonys (to 0.1 mm using vernier callipers). Of all the measurements, only bill length was taken differently in Spain and The Netherlands (to skull in Spain, and to feathering in The Netherlands), so these were not directly comparable and were analysed separately. Not all measurements were taken in all individuals, therefore sample sizes vary slightly.

Additionally, 1158 Black-headed Gulls were trapped, measured and weighed at a rubbish tip at Colmenar Viejo, Madrid, between

September and March over three winters (1992/93 to 1994/95). These gulls were sexed with the discriminant function obtained from the known-sex birds.

Birds were aged as either first-winter, second-winter or adults.^{5,7} Some second-winter birds in an advanced stage of moult and/or bright bare-part coloration might have been included in the 'adult' category. The analyses of age- and sex-related biometric differences were performed only on the birds trapped in Madrid, as second-winter birds were not differentiated from adults in samples from The Netherlands.

For the analysis of biometric differences throughout the season, date were analysed by week, where week 1 = first week of August, and week 36 = end of April. Only live birds (thus those trapped at Madrid) were considered. The proportion of males and females in Madrid was similar throughout the winter (Palomares *et al.*, unpubl. data). Thus data from both sexes were combined, but each age group was analysed independently. Mass differences were analysed correcting for size, calculating the residuals of the regression of mass and wing length for each bird.

RESULTS

Discriminant analysis

All measurements taken showed significant differences between the sexes in the dissected birds. The highest discriminant power for a single variable corresponded to head-and-bill length (HBL). The discriminant value for this variable was 81.2 mm, similar to that found by Coulson *et al.*¹ However, the best sex discrimination was found in the combination of HBL and bill depth (BD), which correctly sexed 92.2% of birds (all data pooled). As in the study of Coulson *et al.*,¹ the addition of other variables did not greatly improve the discriminant power. The discriminant function obtained from all known-sex birds was $Z = 0.35 \text{ HBL} + 0.90 \text{ BD} - 35.68$.

We also calculated two different discriminant functions for known-sex birds from each country, and tested the accuracy of each function on the other group. The discriminant power of the equation calculated from Madrid birds was 96.8%, but it incorrectly sexed 11.0% of males

and 9.5% of females from The Netherlands. Conversely, the discriminant power of the equation calculated from Dutch birds only was 90.8% and, when applied to known-sex birds in Madrid, it incorrectly sexed 9.4% of females (no males were incorrectly sexed). The proportion of juveniles varied significantly between groups ($\chi^2 = 8.68$, $df = 1$, $P < 0.005$), being higher in the group from The Netherlands. An equivalent analysis including only second-winter and adult birds showed similar results (the discriminant functions had similar discriminating powers, and the proportion of incorrectly sexed birds on the other group was of the same order). However, separating juveniles from older birds improved the overall discriminating power of the latter to 94.4%

(Table 1), whereas that of juveniles was lower (Table 2). The discriminant functions obtained from each age group were $Z = 0.35 \text{ HBL} + 0.81 \text{ BD} - 34.85$ for juveniles, and $Z = 0.33 \text{ HBL} + 1.12 \text{ BD} - 35.75$ for second-winter birds and adults. Thereafter, all trapped birds were sexed with these two equations; they were classed as males if Z values were greater than zero and as females if Z values were less than zero.

Age-related differences in biometry

No age differences were found for bill length, head-and-bill length and tarsus length in males (Table 3). Females increased bill length with age (but not total head-and-bill length) (Table 3).

Wing-length, P8, mass and bill depth

Table 1. Sexing accuracy of the discriminant functions made from various measurements in second-winter and adult Black-headed Gulls.

Variable	Males correct (%)	Females correct (%)	Total correct (%)	No. males	No. females
HBL	92.1	93.8	93.1	177	241
BD	87.2	88.8	88.1	179	240
BLM	92.7	90.2	91.7	41	55
BLN	81.5	85.8	83.9	119	155
WL	80.8	85.9	83.8	167	234
P8	74.3	76.9	75.9	35	52
TL	81.2	85.4	83.6	181	246
HBL+BD	94.9	94.1	94.4	175	236

HBL, total head-and-bill length; BD, bill depth at the gonys; BLM, bill length, measurements from Madrid; BLN, bill length, measurements from The Netherlands; WL, wing length; P8, length of the eighth primary; TL, tarsus length.

Table 2. Sexing accuracy of the discriminant functions made from various measurements in juvenile Black-headed Gulls.

Variable	Males correct (%)	Females correct (%)	Total correct (%)	No. males	No. females
HBL	87.2	89.4	88.2	86	66
BD	81.7	72.1	77.6	82	61
BLM	100.0	90.9	95.6	12	11
BLN	83.6	89.8	86.2	67	49
WL	74.4	85.9	79.3	86	64
P8	75.0	80.0	77.3	12	10
TL	72.1	72.3	72.2	86	65
HBL + BD	89.0	91.8	90.2	82	61

HBL, total head-and-bill length; BD, bill depth at the gonys; BLM, bill length, measurements from Madrid; BLN, bill length, measurements from The Netherlands; WL, wing length; P8, length of the eighth primary; TL, tarsus length.

Table 3. Values of the biometric variables of Black-headed Gulls wintering in Madrid according to age and sex groups.

Variable	First-winter	Second-winter	Adult	One-way ANOVA
Females				
Head-and-bill length	78.64 ± 1.68 (72.2–82.4) 175	78.64 ± 1.78 (72.3–83.1) 127	78.92 ± 1.54 (74.3–84.0) 296	$F_{2,595} = 2.20$ $P = 0.11$
Bill depth	7.62 ± 0.31 (7.0–8.3) 103	7.77 ± 0.29 (6.9–8.7) 99	7.75 ± 0.29 (6.7–8.5) 252	$F_{2,451} = 8.69$ $P = 0.0001$
Bill length	40.76 ± 1.43 (36.5–43.5) 87	40.96 ± 1.39 (38.0–43.3) 82	41.47 ± 1.45 (37.6–47.2) 132	$F_{2,300} = 7.19$ $P = 0.001$
Tarsus length	43.98 ± 1.70 (38.2–48.1) 116	43.44 ± 1.75 (39.8–47.7) 113	43.51 ± 1.69 (39.0–49.8) 228	$F_{2,454} = 2.99$ $P = 0.052$
Wing length	293.1 ± 11.1 (199–311) 140	300.7 ± 7.8 (286–317) 109	301.8 ± 8.1 (271–325) 232	$F_{2,478} = 43.61$ $P = 0.0001$
Length of P8	196.8 ± 7.2 (177–219) 127	201.6 ± 6.5 (185–223) 85	205.5 ± 7.2 (185–227) 189	$F_{2,398} = 57.79$ $P = 0.0001$
Mass	248.1 ± 25.9 (190–305) 121	259.3 ± 29.8 (200–350) 78	259.3 ± 25.5 (195–354) 152	$F_{2,348} = 6.93$ $P = 0.001$
Males				
Head-and-bill length	85.26 ± 2.15 (80.8–91.1) 205	84.78 ± 2.33 (79.9–90.9) 127	84.85 ± 2.16 (79.5–91.0) 284	$F_{2,613} = 1.98$ $P = 0.14$
Bill depth	8.36 ± 0.37 (7.2–9.2) 118	8.50 ± 0.39 (7.4–9.4) 112	8.62 ± 0.41 (7.7–9.7) 231	$F_{2,458} = 17.61$ $P = 0.0001$
Bill length	44.84 ± 1.63 (40.7–49.6) 99	45.29 ± 1.86 (40.5–48.7) 55	44.72 ± 1.90 (40.7–48.5) 140	$F_{2,291} = 2.00$ $P = 0.14$
Tarsus length	46.57 ± 1.97 (41.4–51.4) 157	46.16 ± 1.71 (41.7–51.6) 93	46.65 ± 2.10 (40.6–51.6) 193	$F_{2,440} = 2.03$ $P = 0.13$
Wing length	306.9 ± 8.7 (284–338) 169	311.4 ± 8.3 (286–330) 85	315.8 ± 8.6 (292–337) 206	$F_{2,457} = 50.4$ $P = 0.0001$
Length of P8	205.2 ± 7.2 (185–228) 148	209.2 ± 7.4 (184–223) 74	215.2 ± 7.2 (194–232) 163	$F_{2,382} = 73.2$ $P = 0.0001$
Mass	280.9 ± 28.1 (215–355) 136	288.4 ± 32.3 (210–365) 83	300.3 ± 27.4 (220–365) 176	$F_{2,392} = 17.9$ $P = 0.0001$

Means ± sd; range in brackets; sample sizes below range.

increased significantly with age in both sexes (Table 3). However, the sexes differed in the rate of increase for these variables. Measurements of second-winter males for

these variables were consistently smaller than those of adults (Table 3). In contrast, females had attained adult measurements by their second winter, except for P8, which was

significantly shorter in second-winter females than in adults (one-way ANOVA, $F_{1,272} = 18.57$, $P < 0.0001$, and see Table 3).

Seasonal variation in biometry

In first- and second-winter birds, the only

variable that varied significantly with date was mass (corrected for size) ($F_{1,291} = 41.01$, $P < 0.0001$, $r^2 = 12.1\%$ and $F_{1,143} = 13.65$, $P < 0.0001$, $r^2 = 8.1\%$, respectively), which increased significantly (although weakly) throughout the winter (Fig. 1).

Mass in adults also varied significantly with

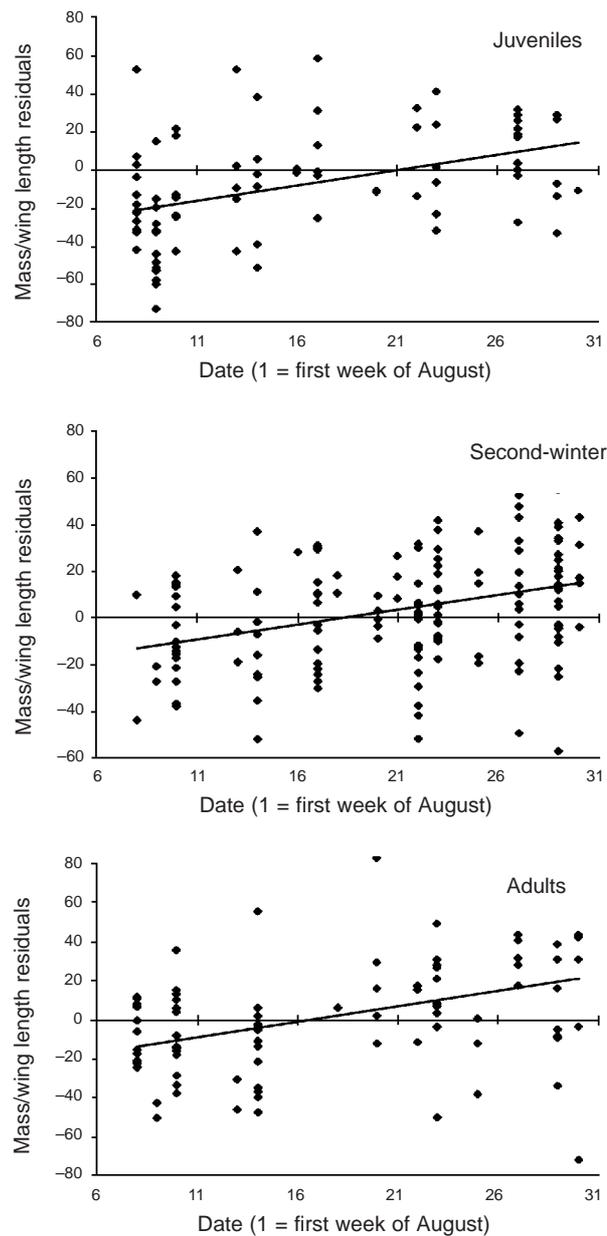


Figure 1. Seasonal variation of mass (corrected for size) in juvenile, second-winter and adult Black-headed Gulls wintering in Madrid.

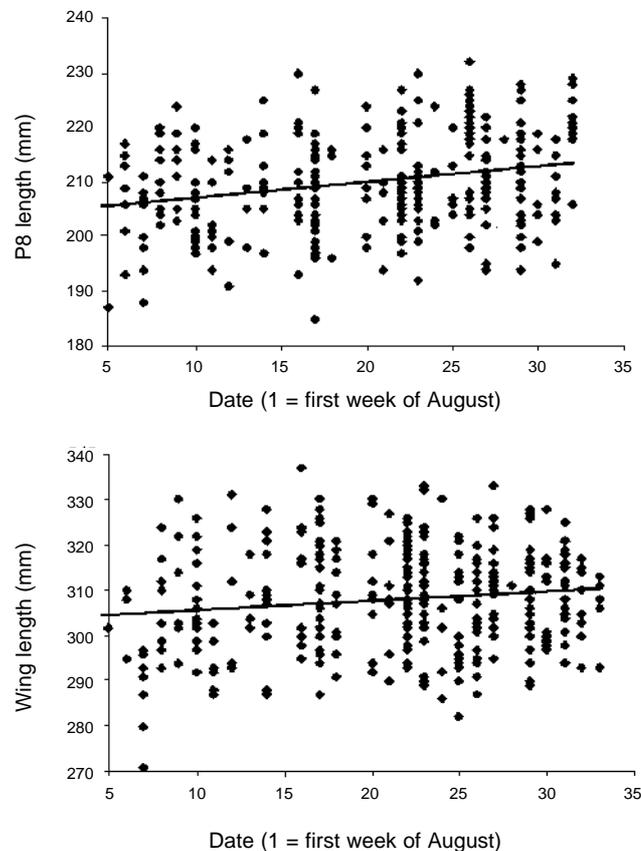


Figure 2. Seasonal variation of wing length and P8 length in adult Black-headed Gulls wintering in Madrid.

date ($F_{1,291} = 41.01$, $P < 0.0001$, $r^2 = 12.1\%$), increasing throughout the season (Fig. 1); in addition, wing length and P8 increased slightly but significantly with date ($F_{1,361} = 6.77$, $P = 0.01$, $r^2 = 1.6\%$ and $F_{1,313} = 21.43$, $P < 0.0001$, $r^2 = 6.1\%$, respectively, Fig. 2).

DISCUSSION

Evaluation of the discriminant variables and functions

The use of discriminant functions rather than probability functions for sexing birds is preferred due to the overlap of measurements between sexes (Table 3). By using a single discriminant value, the percentage of mis-sexed individuals is often large. Total head-and-bill length (HBL) was the best single variable to discriminate between the sexes for Black-

headed Gull (Tables 1 and 2). The discriminant value proposed by Coulson *et al.*¹ for this variable (birds with > 81 mm would be males) was similar to that found in this study. Applying that value to the known-sex birds in this study, 13% of 117 females in Madrid and 9% of 216 females in The Netherlands would be incorrectly sexed. It is worth noting that only females are mis-sexed with that discriminant value.

Other authors have offered intervals to sex individuals: Baker⁵ indicated 83 and 81 as the values above and below which birds could be sexed as males and females respectively, based on data from British birds. Looking at the ranges found in this study (Table 3), the values for a population of mixed origin would be > 84 and < 80 , respectively. However, the proportion of birds in this study that had values of HBL between those points was 32.5% ($n = 1123$).

The best discriminant function was obtained with the variables HBL and bill depth (BD), as Allaine & Lebreton⁶ had already showed. HBL did not vary with age (Table 3), and the available published data suggest that geographical variation is small (Table 4). However, the fact that formulae calculated from birds from one area did not have the same error when applied to birds from the other area, suggests that geographical variation might be larger than previously thought; it supports the idea that equations calculated from birds of mixed origin are probably more reliable when applied to birds of unknown origin. Bill depth varied with age, and thus its discriminating power differed between age groups. Sample size in this study did not make it possible to calculate a discriminant function for second-winter birds, and sample size for juveniles was relatively small. Given the variation of bill depth between age groups, it would be interesting to extend the work with these two age groups.

Biometric differences with age

No age-related biometric differences have been found among adult Black-headed Gulls.¹⁰ Thus we assumed that final size is attained from the third winter. Females appeared to achieve their final size faster than males, as no significant differences were found in most variables between second-winter females and adults.

In contrast, second-winter males were smaller than adults in most variables. As in other gulls, female Black-headed Gulls start breeding when younger than the males.¹¹ Thus it might be beneficial for the females to achieve their final size as early as possible. Males, which on average take longer to enter the breeding population, might spend more time growing in order to be able to compete better with other conspecifics.

The only difference between second-winter and adult females was found for P8 length, even though total wing length did not vary between these two age groups (Fig. 1 & Table 3). This difference suggests that wing structure differed between second-winter and adult females. More data (including wing formulae) would be needed to ascertain whether that difference is real or not.

Table 4. Mean values (\pm se) of total head-and-bill length for known-sex adult Black-headed Gulls in different areas of Europe.

Area	Females	Males
England ¹	78.0 \pm 1.9 (238)	85.0 \pm 2.3 (446)
France ⁶	78.8 \pm 0.3 (45)	84.8 \pm 0.3 (46)
Madrid	79.0 \pm 1.6 (253)	84.9 \pm 2.1 (240)
The Netherlands, wintering	79.3 \pm 3.1 (26)	85.0 \pm 2.5 (63)
The Netherlands, breeding	78.1 \pm 2.4 (124)	83.8 \pm 2.2 (51)

Sample sizes in brackets.

Biometric changes with date

Mass increased throughout the season, even correcting for size differences, which were expected and observed in other studies.¹² Birds arrived in the wintering areas with a minimum mass after the breeding and moulting period; they increased their mass consistently throughout the season, reaching a maximum before migrating northwards towards the breeding areas.

More surprising was the increase in wing length with date among adults (but not with other age groups), which was also found in a previous study in Madrid.¹³ This could be explained if wing length differed between populations from different geographical areas, and the proportion of birds from different populations changed through the season. However, available data suggest that wing length did not vary between geographical regions.^{2-4,6} It is therefore unclear why such an increase should be observed, although more data are needed to assess the geographical variation of biometrics in the Black-headed Gull.

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