J. Field Ornithol., 56(2):158–164

SEXING LAUGHING GULLS USING EXTERNAL MEASUREMENTS AND DISCRIMINANT ANALYSIS

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Discriminant analysis has been used for determining the sex of gull species not readily separable on the basis of a single mensural character. Application of a mathematical function speeds identification of sex in the field without necessitating laparotomy. Discriminant analyses have proven useful for sexing Ring-billed Gulls (*Larus delawarensis*; Shugart 1977, Ryder 1978), Herring Gulls (*L. argentatus argentatus*; Harris and Hope Jones 1969, and *L. a. smithsonianus*; Shugart 1977, Ryder 1978), and Silver and Red-billed gulls (*L. novaehollandiae novaehollandiae*; Wooller and Dunlop 1981, and *L. n. scopulinus*; Mills 1971).

In this paper we use discriminant analyses to derive a classification function that permits accurate sex identification of a population of Laughing Gulls (*L. atricilla*). We describe other useful information that can be garnered from discriminant scores and coefficients and comment on potential sampling bias that we have observed in the field and encountered in the literature.

Terminology associated with discriminant analysis has been used inconsistently in the ornithological literature. We define our terms using the approach suggested by Pimentel (1979). "Discriminant analysis" is a general term for a statistical procedure used to distinguish between two or more groups. In this paper, we are discriminating between two sexes, and we use the standardized model for canonical analysis of discriminance to derive the standardized discriminant function. The standardized discriminant function computes a variable which is a linear function of the discriminating variables. This function is of the form:

$$D_i = d_{i1}Z_1 + d_{i2}Z_2 + \ldots + d_{ip}Z_p$$

where D_i is the score on the discriminant function i, the d_i's are standardized coefficients, and the Z's are the standardized values of the p discriminating variables used in the analysis (Klecka 1975). A classification function is derived from the standardized function and uses raw data rather than cumbersome standardized data. The classification function takes the form:

$$C_i = c_{i1}V_1 + c_{i2}V_2 + \ldots + c_{ip}V_p + c_iO$$

where C_i is the classification score, the c_i's are the classification coefficients with C_iO being the constant, and the V's are the raw scores on the discriminating variables (Klecka 1975).

STUDY POPULATION AND METHODS

We restricted our sample of gulls to full adults, that is, birds in definitive plumage (Humphrey and Parkes 1959). Most of the gulls (n = 136) came from the Bayway Laughing Gull colony in Boca Ciega Bay, Pinellas County, Florida (described by Dinsmore and Schreiber 1974). From 1981–1983, 77 gulls found sick or dead in the colony were collected, measured, and dissected to determine sex. During the 1982 breeding season we captured 42 adults in the study colony using walk-in nest traps (Weaver and Kadlec 1970). These gulls were measured, sexed by unilateral laparotomy, and released. An additional 17 adults were trapped, measured, and released without laparotomy. Subsequent observation of copulations and pre-copulatory behavior allowed us to determine the sex of these individuals. The Suncoast Seabird Sanctuary, located nearby, provided us with 30 dead gulls in 1982 which were measured and dissected.

All gulls used in this study were collected and/or captured and measured between April and October in an effort to eliminate geographic variation as a factor in our analyses. We excluded birds collected from November through March to avoid incorporating migrant Laughing Gulls from regions north of Florida that may reach Florida by November (Southern 1980). Most Laughing Gulls from northern latitudes present in Florida during summer are immatures and subadults (Southern 1980) and were not included in our sample.

The variables used in the analyses were linear measurements as described by Baldwin et al. (1931). These included height of bill at angle of gonys (gonys depth hereafter), length of exposed culmen, length of tarsus, length of closed wing (standard wing length), and length of tail. Additionally, we measured total head length from the tip of the bill to the cerebellar prominence on the back of the head. The head and tarsus measurements were taken with dial calipers to the nearest 0.1 mm. The wing and tail were measured with a ruler to the nearest 1 mm. Gulls captured in walk-in nest traps or killed by predators but not consumed were weighed with a 500-g pesola spring balance to the nearest 5 g. The sample size for weight data was considerably smaller than those of other measurements and therefore we excluded those data from our analyses. All measurements were taken by the authors; prior to data collection we standardized our technique to insure replicability.

All measurements were subjected to stepwise discriminant analysis using Rao's V as programmed in the Statistical Package for the Social Sciences (SPSS; Klecka 1975). A standardized discriminant function was derived using all of the linear measurements described above. We then selectively removed characters from the analysis to identify the combination of characters that best discriminated between the sexes. We used 122 gulls to derive our discriminant function, and tested its accuracy using the V1 validation procedure described by Frank et al. (1965) and discussed by Fox et al. (1981). To perform this test we used an independent sample of 43 gulls. The difference in accuracy of the original function from that of the test sample provides a measure of sampling bias in the group of birds used to derive the original function. Having established that the bias in our sample was minimal, we combined the groups of 122 and 43 gulls and calculated a new function based on this increased sample size. This function was then transformed to a classification function (i.e., unstandardized form) which is more practical to use, and the one we will emphasize in our discussion.

RESULTS

Table 1 presents the sample sizes, means, standard deviations, coefficients of variation, and ranges for each measured character. Culmen, total head, and tarsus lengths were the least variable measurements (CV = 2.2–4.1%). Gonys depth, tail and wing lengths were slightly more variable (CV = 3.6–5.1%). As expected, weight was the most variable character (CV = 6.6% for females and 7.6% for males). Results of Student's *t*-tests presented in Table 1 indicate that males were significantly larger than females with respect to all 7 mensural characters ($P < 0.05$).

Total head length (THL) and gonys depth (GD) measured in millimeters were, in combination, the two most discriminating variables. The classification function using these variables correctly classified the sex of 95.1% of the Laughing Gulls used to derive the function. This function (n = 122) was:

$$46.278 = (0.442 \times \text{THL}) + (0.533 \times \text{GD}).$$

A Laughing Gull is classified as male if substitution of its raw measurements into the equation yields a value greater than 46.278; smaller values classify that gull as a female. Using this function, 64 of 67 males were correctly classified (95.5%), as were 52 of 55 females (94.5%). Using a test sample of 43 birds this function correctly classified 17 of 19 males and 24 of 24 females, providing an overall test accuracy of 95.3%.

The classification accuracies of our original sample (n = 122, 95.1%) and of our test sample (n = 43, 95.3%) were similar indicating that sampling bias was minimal. We combined these samples and derived the new classification function below:

$$45.985 = (0.433 \times \text{THL}) + (0.641 \times \text{GD}).$$

The classification accuracy of this function was 95.2%; this is the appropriate function to use in the field because it is derived from a larger sample size.

The relationship between total head length and gonys depth is shown in Figure 1. The magnitude of the coefficients of the standardized function indicates the relative contribution of each variable to discrimination between the sexes. In this case, the coefficients for total head length and gonys depth are 0.878 and 0.331, respectively, indicating that total head length was the most discriminating variable.

TABLE 1. Measurements[a] of male and female Laughing Gulls from Tampa Bay, Florida. All t values for comparison of sexes were significant ($P < 0.05$).

	Females			Males			
	n	$\bar{x} \pm$ SD (range)	CV	n	$\bar{x} \pm$ SD (range)	CV	t
Gonys depth	79	10.8 ± 0.5 (9.8–12.2)	4.5	86	11.6 ± 0.5 (10.5–13.0)	4.8	10.4
Culmen length	79	36.9 ± 1.5 (33.4–39.8)	3.8	86	40.3 ± 1.5 (36.3–43.5)	4.1	14.6
Total head length	79	86.4 ± 2.0 (80.1–90.2)	2.2	86	92.5 ± 2.1 (87.5–97.4)	2.3	19.3
Tarsus length	79	48.9 ± 1.6 (45.1–52.7)	3.6	86	52.8 ± 2.0 (47.3–57.1)	3.3	14.2
Tail length	74	114 ± 5 (103–122)	4.3	80	121 ± 5 (100–133)	4.0	8.5
Wing length	68	317 ± 12 (261–345)	5.1	77	328 ± 17 (271–354)	3.6	4.3
Weight	33	289 ± 41 (203–371)	6.6	37	327 ± 25 (249–366)	7.6	4.8

[a] All linear measurements are in millimeters; weights are in grams.

DISCUSSION

Although male Laughing Gulls were significantly larger than females in all 7 measurements, the overlap in ranges was too great to permit discrimination of sex by single characters. Schreiber and Schreiber (1979) collected linear measurements of culmen, tarsus, wing, and tail from Tampa Bay Laughing Gulls and found no significant differences in measurements between the sexes. Reanalysis of their data indicates that for all of their measurements the sexes were different at $P < 0.05$ and the Schreibers concur (pers. comm.).

Our analysis indicated that total head length and gonys depth were the two most useful characters for distinguishing between the sexes of Laughing Gulls. These characters together or in combination with other mensural characters have proven useful in discriminating between the sexes of other gull species (Ring-billed Gulls, Fox et al. 1981; Herring Gulls, Shugart 1977, Fox et al. 1981; Silver and Red-billed gulls, Wooller and Dunlop 1981, Mills 1971).

For the measurements of each Laughing Gull used in the discriminant analysis, a classification score was calculated. These scores form a numerical continuum from small females (smallest = 41.293) to large males (largest = 49.878). The relative magnitude of the score may provide a measure of individual deviation from the classification score separating males from females (a midpoint of 45.985 in our function). It may be appropriate to exclude birds whose scores fall close to the midpoint, for studies in which positive determination of sex is critical. Using our data, the range of scores for incorrectly classified birds was 45.034 to 46.005.

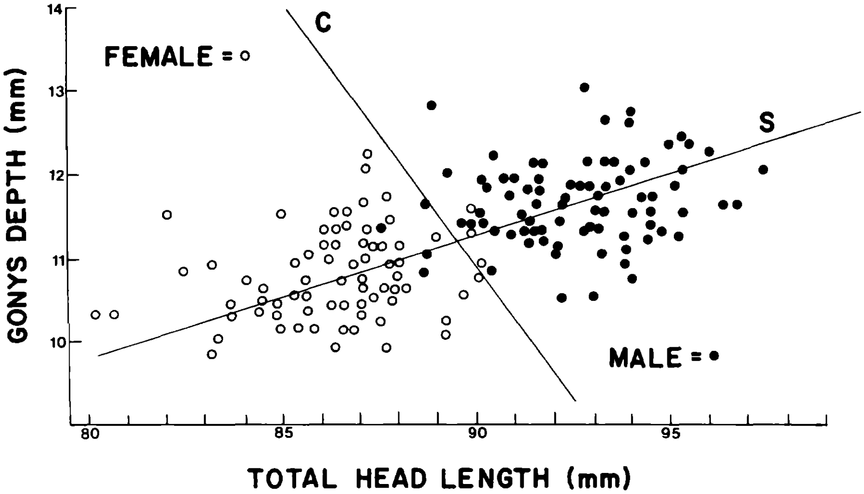

FIGURE 1. Relationship between total head length and gonys depth in male and female Laughing Gulls (n = 165). Line S represents the standardized discriminant function:

$$D_i = (0.331 \times THL) + (0.878 \times GD).$$

Line C represents the classification function:

$$45.985 = (0.433 \times THL) + (0.641 \times GD).$$

Seventeen of 165 birds correctly classified had scores that fell within this range. For some purposes these birds may be too close to the cutoff to be confident of their sex.

A discriminant function derived from a sample population maximizes the predictive power for that particular population and must be tested for accuracy with an independent sample. The V1 validation procedure provides an unbiased estimate of accuracy by using a sample of birds unrelated to the analysis sample. In their studies on the Herring Gull, Fox et al. (1981) used the V1 validation procedure but we question the composition of their samples. Fox et al. used "confirmed sex samples" (by gonadal inspection) and "assumed sex samples" (see below) to generate and test their functions. They obtained the assumed sex samples by trapping both members of a pair, and assigning a male designation to the member of the pair that was distinctly larger in the majority of measurements. If both individuals were similar in size, they were excluded from the analysis. Their purpose in using an assumed sex sample was to demonstrate the usefulness of this sample when a confirmed sex sample is not available. Unfortunately, this technique introduced a new bias. By selecting only birds that were distinctly size dimorphic, Fox et al. eliminated the overlapping tails of the normal curve of size variability for males and females (i.e., large females and small males). These extreme individuals will still be encountered when someone attempts to use their function. In our studies of Laughing Gulls we frequently have handled paired birds that were not obviously size dimorphic. Indeed even after these individuals were measured it was often difficult to assign a sex to each bird without laparotomy or direct observations of copulations. We caution investigators to recognize the limitations of discriminant analysis.

SUMMARY

Gulls are sexually dimorphic in size but are not distinguishable on the basis of a single mensural character. Laughing Gull adults (n = 165) from Tampa Bay, Florida, were measured to determine gonys depth, culmen length, total head length, tarsus length, tail length, wing length, and weight. Discriminant analysis identified total head length and gonys depth as the two most discriminating characters for identification of sex. The derived classification function was 95.1% accurate in assigning sex to individual birds and was 95.3% accurate in identifying the sex of an independent test sample of birds. We pooled the samples to derive a new function for use in the field. Classification scores may provide additional information about individual birds.

ACKNOWLEDGMENTS

We acknowledge the assistance of G. Thomas Bancroft, Wayne Hoffman, Eva B. Jones, Gary D. Schnell, and Glen E. Woolfenden for comments on this paper. Earl D. McCoy provided advice on our use of discriminant analysis. We thank the Suncoast Seabird Sanctuary for donation of specimens. This project was completed as part of a larger study funded in part during 1982 and 1983 by grants from the Frank M. Chapman Fund to L. Hanners.

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Received 1 Feb. 1984; accepted 7 Dec. 1984.