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# A SEXING TECHNIQUE FOR CALIFORNIA GULLS BREEDING AT BAMFORTH LAKE, WYOMING

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Abstract.—We used morphological characteristics to determine the sex of California Gulls (*Larus californicus*) nesting at Bamforth Lake, Wyoming. Using univariate and multivariate techniques, we evaluated sexual dimorphism in five external measurements taken from 614 California Gulls: bill length, bill depth, head-bill length, tarsus length, and body mass. Males were significantly larger than females for all measurements. The greatest difference between the sexes occurred in head-bill length, bill depth, and tarsus length. A multiple logistic regression model was used to assign individuals to a sex class. Sex could be accurately determined using only three variables: head-bill length, bill depth, and tarsus length. Using the logistic function generated from our initial sample, we obtained correct classification of sex in 99.2% and 97.0% of the gulls in two additional validation samples.

**UNA TECNICA PARA DETERMINAR SEXOS EN *LARUS CALIFORNICUS* REPRODUCIENDOSE EN EL LAGO BAMFORTH, WYOMING.**

Sinopsis.—Utilizamos las características morfológicas para determinar el sexo en una población de *Larus californicus* anidando en el Lago Bamforth de Wyoming. Evaluamos el dimorfismo sexual en la especie utilizando técnicas de univarianza y multivarianza en cinco medidas externas (largo del pico, profundidad del pico, largo de cabeza y pico, largo del tarso y masa corporal) tomadas en 614 aves. Los machos fueron significativamente más grandes que las hembras en todas las medidas. La mayor diferencia entre los sexos se encontró en largo de cabeza y pico, profundidad del pico y largo del tarso. Se usó un modelo de regresión logística multiple para asignar individuos a un grupo genérico. El sexo se podía determinar con precisión utilizando solo tres variables: largo de cabeza y pico, profundidad del pico y largo del tarso. Usando la función logística generada por nuestra muestra inicial, obtuvimos la clasificación al género correcto en 99.2% y 97.0% de las aves en dos muestreos adicionales de validación.

Gull species are frequently subjects of life history and behavior studies because they are highly colonial, have stereotyped displays, are long-lived, exhibit fidelity to their natal area, and are relatively easy to observe (Pierotti 1981, Pugesek 1993, Pugesek and Diem 1990, Pugesek and Wood 1992, Schnell et al. 1985, Smith and Diem 1972). One of the obstacles in studying free-living gulls is the difficulty in determining the sex of individuals. In general, sex cannot be assigned consistently or accurately between investigators (Schnell et al. 1985, Stern and Jarvis 1991). For California Gulls (*Larus californicus*), extensive observations during the breeding season when both members of the pair are present at the nest has been the only method by which sex may be assigned. We explored an alternative method by which researchers can consistently and reliably sex California Gulls at times when gulls are away from the breeding colony. The method involves analysis of morphometric measurements using multiple logistic regression.

## METHODS

*Morphometric measurements.*—The study was conducted on a population of California Gulls breeding at Bamforth Lake, Wyoming (41°25′N, 105°41′W). A total of 614 gulls was captured with a rocket net approximately 0.8 km from the breeding island. Each bird was banded with a numbered U.S. Fish and Wildlife Service steel band. For each bird, we recorded bill length (BL), bill depth (BD), head-bill length (HB), tarsus length (TL), and body mass (BM). Bill length was measured from the tip of the upper mandible in a straight line to the base of the feathers on the forehead. Bill depth was the maximum distance from the top to the bottom edge of the bill, measured at the base of the bill. Head-bill length was measured from the tip of the bill to the occipital crest (Lucas and Stettenheim 1972, Proctor and Lynch 1993). Tarsus length was measured from the point of the joint between the tibia and metatarsus to the point of the joint at the base of the middle toe in front (see Pettingill 1970). Bill and tarsus measurements were taken with a dial caliper to the nearest 0.1 mm. Body masses were taken to the nearest 1 g on a triple beam balance.

*Field observations.*—Our sample was divided into individuals of either "confirmed sex" or "assumed sex". Twenty-four confirmed-sex gulls (12 males and 12 females) were captured and sexed by laparotomy in 1979. Five hundred and ninety assumed-sex gulls (278 males and 312 females) were sexed according to observation of behavior and morphology. Annually from 1979–1992, we conducted daily searches from mid-April to late-May for banded birds in the colony and made observations of their behavior and morphology. Sex of these individuals was confirmed on at least two separate occasions. Sex was assigned to individuals only when both members of the pair were present at the nest. The member that had a distinctively larger body size, larger head, and stouter bill was assumed to be the male and the smaller member the female. The dimorphism between males and females in these traits has been confirmed in California Gulls and other larids (Dunning 1993, Jehl 1987, Schnell et al. 1985, Smith and Diem 1972). Copulation was observed on occasion and used as an aid in sexing individuals. Birds in juvenal plumage, here designated as <6-yr-old birds (Behle 1958), were excluded from the analysis.

An additional sample of 33 gulls that died on the breeding colony was obtained in 1994. These individuals were laparotomized for sex determination.

*Data analyses.*—All analyses were conducted by using Statistical Package of the Social Sciences (Norusis 1990). Arithmetic means and standard deviations were calculated for each sex. We used Student's *t*-test to assess differences in the means of the five discriminant measurements between

TABLE 1. A comparison of means of external measurements of California Gulls from Bamforth Lake, Wyoming.

| Variable | Male mean | SD | Female mean | SD | *t* | *P* |
|---|---|---|---|---|---|---|
| Bill depth | 16.7 | 0.959 | 14.6 | 0.712 | −27.69 | <0.001 |
| Bill length | 48.2 | 2.257 | 43.2 | 2.036 | −25.53 | <0.001 |
| Head-bill | 110.1 | 2.661 | 100.7 | 3.359 | −34.40 | <0.001 |
| Tarsus | 57.6 | 2.805 | 53.3 | 2.862 | −16.61 | <0.001 |
| Mass | 644.0 | 63.186 | 538.0 | 53.655 | −19.94 | <0.001 |

males and females and between groups of confirmed-sex and assumed-sex individuals.

Normality plots showed a systematic curved pattern suggesting lack of multivariate normality in the data (Johnson and Wichern 1988:158–160). Because multiple logistic regression (MLR) use is appropriate when assumptions of multivariate normality are violated, we used MLR to classify sex (Cooley and Lohnes 1971, Hosmer and Lemeshow 1989, Kleinbaum and Kupper 1978, Press and Wilson 1978).

As with all inferential techniques based on sample data, the percentage of correct prediction tends to over-estimate the power of the classification model. Over-estimation occurs because the validation is based on the same data used to derive the classification model. We randomly split the sample of 614 captured birds into two subsets in order to build the classification model and then test it appropriately. Of the 614 birds, 491 individuals (80%) randomly drawn (Snedecor and Cochran 1967) from our assumed- and confirmed-sex samples were assigned to an analysis subset to derive a discriminant function for MLR that would predict the sex of gulls; the remaining 123 individuals (20%) formed a validation subsample to obtain an unbiased estimate of the accuracy of the discriminant function. The additional sample of 33 birds that died on the colony obtained in 1994 were used as a sample for a second validation.

We used the forward stepwise variable selection procedure of the logistic model to determine which of the five measurements (in combination) provided maximum discrimination between males and females. The variables were entered and removed based on the likelihood-ratio criteria. To be more conservative, the independent variables were tested for entry into the function one at a time, with a 0.05 level of significance for entry and a 0.10 level for removal.

## RESULTS

*Body measurements.*—Based on the pooled samples of the confirmed-sex and assumed-sex subsets for males and females, we found statistically significant differences in all traits between the sexes (Table 1). Using all of the confirmed-sex birds (24) and a random sample of 24 assumed-sex birds, we found no significant difference in any body traits between the groups (Table 2). Because no differences between confirmed-sex and as-

TABLE 2. A comparison of means of external measurements for individual California Gulls of assumed and confirmed sex from Bamforth Lake, Wyoming.

| | Males | | | | Females | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Assumed sex | Confirmed sex | *t* | *P* | Assumed sex | Confirmed sex | *t* | *P* |
| Bill depth | 16.5 | 16.2 | 0.860 | 0.397 | 14.7 | 14.3 | 1.142 | 0.266 |
| Bill length | 47.7 | 48.0 | 0.506 | 0.618 | 43.6 | 42.7 | 0.927 | 0.364 |
| Head-bill | 109.6 | 109.1 | 0.488 | 0.630 | 100.9 | 99.4 | 1.198 | 0.244 |
| Tarsus | 56.8 | 58.0 | 1.101 | 0.287 | 52.1 | 53.6 | 1.189 | 0.247 |
| Mass | 624.0 | 576.0 | 1.599 | 0.124 | 534.0 | 533.0 | 0.035 | 0.973 |

sumed-sex individuals existed, the two samples were combined to generate the logistic function.

*Sexual size dimorphism.*—The stepwise procedure suggested that the best variables for classifying the sexes were, in order of importance, head-bill length, bill depth, and tarsus length ($\chi^2 = 587.8$; df = 3; $P < 0.001$). Bill length and mass did not significantly add to the discriminatory power of the function. Using the three discriminating variables, 98.0% (242 of 247 birds correctly classified) of the females and 98.4% (240 of 244 birds) of the males were placed into the proper category. Overall, 98.2% of the individuals were correctly classified. The three measurements gave the following estimate of the classification function:

$$\hat{y} = -117.241 + 2.286 \text{ BD} + 0.604 \text{ HD} + 0.319 \text{ TL}$$

where $\hat{y}$ is the discriminant score, classifying a bird as female if $\hat{y}$ is negative or male if $\hat{y}$ is zero or positive.

We used the validation samples to provide confirmation of the logistic function. The overall success rate of classification on the first validation sample was 99.2% (122 of 123 birds correctly classified). The overall success rate of classification on the second validation sample was 97.0% (32 of 33 birds correctly classified).

## DISCUSSION

An experienced biologist can determine the sex of mated pairs of California Gulls by the shapes of their bills and heads when the pair are together at the nest or captured together during the breeding season. Outside of the breeding season, away from the nest, or without the mate present, assessment of sex is virtually impossible. Using our discriminant function, however, the sex of an individual California Gull can be easily estimated from measurements taken with a caliper. Head-bill length, bill depth, and tarsus length were the most valuable variables in classifying the sex of California Gulls. Other studies have shown that head length and bill depth were the best discriminating measurements for Herring Gulls (*Larus argentatus*; Fox et al. 1981, Shugart 1977), Ring-billed Gulls

(*Larus delawarensis*; Ryder 1978, Shugart 1977), and Brown Noddy (*Anous stolidus*; Chardine and Morris 1989).

Mass and bill length were omitted from the logistic regression by the stepwise selection procedure. Pugesek and Diem (1990) found that the masses of the gulls change seasonally in both males and females. As the breeding season progresses, adults lose mass probably as a consequence of the energetic demands of defending and feeding the young. The stepwise logistic regression procedure probably omitted mass as a consequence of high seasonal variability. Bill length was a fairly good predictor of sex. However, it was highly correlated with head-bill length. When one or more variables share the same discriminating information, even though they are individually good discriminators, they are eliminated by the stepwise procedure because together they do not contain any new information. As bill and head-bill lengths are correlated, the stepwise procedure eliminated the variable with the least discriminating power (bill length), and selected the variable (head-bill length) that provided a better discrimination.

The three discriminant measurements needed for our method are easy to obtain and permit birds to be released unharmed. However, the usefulness of the logistic function on other populations should be confirmed since interpopulation differences in body measurements exist (Jehl 1987, Schnell et al. 1985). This caveat not withstanding, the logistic regression method provides a simple robust method for sexing gulls in the field.

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