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Sexual dimorphism and assortative mating in Black Terns.—Members of the family Laridae exhibit monomorphic plumage, and sex is difficult to determine by observation. In gulls, it is well-established that males generally are larger than females, and within mated pairs males are almost always larger than their mates (Shugart 1977, Ryder 1978, Fox et al. 1981, Hanners and Patton 1985). In terns, however, size dimorphism between the sexes has been documented only in Common Terns (*Sterna hirundo*) (Coulter 1986). Coulter (1986) also used these sexually dimorphic size traits to identify patterns of assortative mating in Common Terns. Patterns of assortative mating as it relates to body size have not been recorded for other Laridae. We report here on sexual dimorphic size traits and assortative mating of Black Terns (*Chlidonias niger*).

Methods.—In 1984, at Sycan Marsh, Lake Co., Oregon, individual Black Terns were captured in cylindrical nest traps (Dunn 1979). Thirty-seven terns, including 16 pairs, were trapped and sexed by laparotomy. We measured culmen length (CL) and total head length (THL-back of the head to the tip of the beak) with vernier calipers to the nearest 0.1 mm. We used paired t-tests to examine differences among pairs of known sex (Snedecor and Cochran 1980). An additional 88 pairs of terns were trapped and measured, but sex was not determined. For these 88 pairs, we assumed the tern with the larger total head length and culmen length within the pair to be the male and the smaller individual the female; this pattern of sexual dimorphic size traits within pairs of mated terns was consistent with the individuals of known sex in this study.

We used multivariate analysis of variance (MANOVA) with interaction to assess differences in the means of linear measurements between males and females and between groups of known sex individuals and of presumed sex individuals (SAS 1986).

Subsequently, we used the two morphological measurements of 37 terns of known sex to derive a discriminant function which predicted the sex of terns. We used Wilks stepwise discriminant function analysis (DFA) to identify the relative importance of the two variables, and we then used direct DFA which forced the inclusion of both variables to maximize the predictability of the discriminant functions (Klecka 1975). We used the 88 pairs that were sexed by their relative size within pairs as an independent sample and employed V1 validation procedures to test the accuracy of the discriminant functions (Frank et al. 1965, Fox et al. 1981). We examined patterns of assortative mating by assessing the Pearson correlation coefficients of the total head length and culmen length within each pair of mated terns.

Results.—For 16 mated pairs of Black Terns which were sexed by laparotomy, males had significantly larger total head length and culmen length than females (Table 1). Moreover, within each of the 16 pairs, males were always larger than their mates for both body traits.

Subsequently, we compared these two body traits for all Black Terns of known sex and the 88 pairs of Black Terns of presumed sex (Table 2). First, we tested for interaction between sex of terns (male/female) and method of sexing (known sex/presumed sex) and found no significant interaction between the two (MANOVA, $F = 1.098$, df = 2,208, $P > 0.336$). Second, we conducted a MANOVA without interaction and found there was a significant size difference between sexes (MANOVA, $F = 53.12$, df = 2,208, $P < 0.001$). Third, we conducted a second MANOVA without interaction between the two sample groups (known sex vs presumed sex) and found there was a statistically significant difference (but just barely) between the two groups (MANOVA, $F = 2.84$, df = 2,208, $P = 0.0493$). Using the two sexual dimorphic size traits, we generated two discriminant functions (Table 3). In both the Wilks and direct methods of DFA, total head length had the highest standardized discriminant coefficient (0.82 and 1.00, respectively) and was the most discriminating variable;

TABLE 1

MAGNITUDE OF THE DIFFERENCE BETWEEN MATED PAIRS OF BLACK TERNS OF KNOWN SEX (N = 16)

Characteristic	Mean difference[a]	SD	t[b]	P
Total head length (mm)	2.72	1.17	9.29	<0.0001
Culmen length (mm)	2.04	1.03	7.90	<0.0001

[a] Female from male.

[b] Paired t-test.

culmen length had a standardized discriminant coefficient of 0.22. The direct DFA resulted in the function with the highest accuracy (89%) of correctly classifying terns according to sex. This function for the 37 birds of known sex was:

$$41.80 = 0.63\text{THL} + 0.20\text{CL}$$

Terns with discriminant scores greater than 41.80 were classified as male, and terns with lesser scores as female. Using this function, 17 of 20 males (85%) and 16 of 17 (94%) females were correctly classified. When testing this function with the independent validation sample, however, only 78% (137/176) of the terns were correctly classified according to sex, 91% (80/88) of the females and 65% (57/88) of the males.

Patterns of assortative mating were evident for both total head length and culmen length (Figs. 1, 2). There were significant correlations for both linear measurements within mated pairs. The pattern was more pronounced for culmen length ($r = 0.34$, N = 104, $P < 0.001$) than total head length ($r = 0.21$, N = 104, $P = 0.032$).

Discussion.—Like gulls and Common Terns, sexual dimorphic size differences were also apparent in Black Terns and, similarly within mated pairs, male Black Terns were always larger than their female mate. The ranges of the two morphometric measurements employed here overlapped, however, and it was not possible to sex individual Black Terns on the basis of a single trait.

TABLE 2

MORPHOMETRIC MEASUREMENTS OF BLACK TERNS AT SYCAN MARSH, OREGON, 1984

	Males		Females	
	N	$\bar{x} \pm$ SD	N	$\bar{x} \pm$ SD
Known sex				
Total head length[a]	20	59.60 ± 1.18	17	57.05 ± 1.44
Culmen length[b]	20	27.30 ± 1.14	17	25.37 ± 1.18
Presumed sex				
Total head length	88	58.83 ± 1.14	88	56.82 ± 1.25
Culmen length	88	26.59 ± 1.12	88	25.24 ± 1.11

[a] See methods for sex determination.

[b] All linear measurements in mm.

TABLE 3
DISCRIMINANT FUNCTION ANALYSIS FOR CLASSIFYING BLACK TERNS ACCORDING TO SEX, SYCAN MARSH, OREGON, 1984

			Classification accuracy			
			Original sample		Validation sample	
Method	Variables available	Variables retained	N	%	N	%
Wilks	THL[a], CL[b]	THL	37	87	176	79
Direct	THL, CL	THL, CL	37	89	176	78

[a] THL = total head length.
[b] CL = culmen length.

Interestingly, there was a significant differences in the size of the two body traits between the two sample groups (known sex vs presumed sex). Reasons for this are uncertain. The relatively small sample size of terns of known sex were all from a single nesting colony, while the larger sample of individuals of presumed sex came from nesting colonies throughout the study area. Intrapopulation differences in sizes were observed in Herring Gulls (*Larus argentatus*) (Threlfall and Jewer 1978), and possibly inter-colony size differences occur for terns nesting within the same localized breeding area. The discriminant functions for Black Terns yielded predictive functions which were lower (89% vs 94–99%) than similar functions derived for Herring Gulls (Shugart 1977, Fox et al., 1981), Ring-billed Gulls (*L. delawarensis*) (Ryder 1978) and Laughing Gulls (*L. atricilla*) (Hanners and Patton 1985). In those studies of gulls, total head length, and bill depth at the gonys generally were the best discriminating criteria.

Two factors may have contributed to lower predictive accuracies of the discriminant functions derived for Black Terns compared to gulls. One, Black Terns have poorly developed gonys on their bill, and though bill depth at the gonys is one of the most discriminating criteria in distinguishing the sex of gulls, it was not applicable to Black Terns. Second, we used only two measurements; additional variables might have improved the predictive accuracy.

Predictive functions for Black Terns were higher (89% vs 80%), however, than functions derived for Common Terns by Coulter (1986) who used bill depth, bill length, bill width, and body weight (but not total head length). Predictive discriminant functions for Common Terns might have been similar to those for Black Terns if total head length had also been included.

In Black Terns, the lack of agreement between the predictive accuracies of the original discriminant function and the V1 validation scores (89% vs 78%) may best be explained by the previously noted differences between the sample groups of known sex and presumed sex birds. The group of presumed sex individuals were slightly smaller ($P = 0.0493$) in morphometric traits than individuals from the group of known sex terns. When the linear measurements for individuals from the presumed sex group were inserted into the original discriminant function, the relatively smaller females in the presumed sex group were likely to have a discriminant score of less than 41.80 and be classified correctly. However, the comparatively smaller males from the presumed sex group were more likely than males of the known sex group to a have discriminant score of less than 41.80 and be classified incorrectly. Consequently, males in the validation group were incorrectly classified as to sex

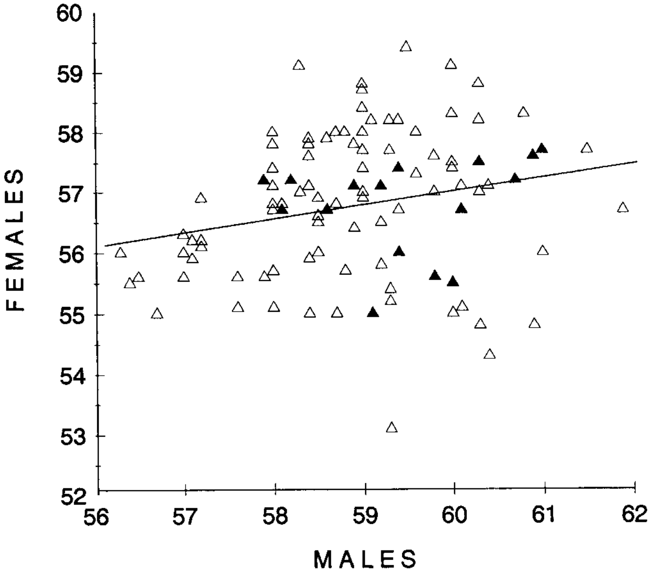

FIG. 1. Comparison of total head length (mm) between 104 pairs of mated Black Terns. Sixteen pairs were sexed by laparotomy (filled triangles) while the remaining 88 pairs (open triangles) were sexed by their relative size within mated pairs (males larger than females). Lines of best fit were determined by least squares regression ($r = 0.21$, N = 104, $P = 0.0032$).

35% of the time, while the error in misclassification for females was only 9%. Because of the differences in the two linear measurements between the two sample groups, the V1 validation was poor compared to the predictive values of the original function.

We assessed the limitations of having a small sample size from a single colony in the original discriminant functions by generating a second set of discriminant functions from the larger sized validation group (Table 4). The predictive accuracies of these functions (80–81%), however, were less than the original discriminant functions (87–89%). Thus, simply using a larger sized sample did not enhance the predictive powers of the discriminant function. Indeed, the lower predictive accuracies generated from the larger sample size indicate that a certain degree of variation may be characteristic of the population and that the degree of overlap in the size of the two sexes precludes 90–100% accuracy in distinguishing the sex of individuals throughout an entire breeding population.

In conclusion, Black Terns clearly were sexually dimorphic, and similar correlative patterns of sexual dimorphic size traits apparently exist in both gulls and terns. We suggest, however, that the sexually dimorphic size traits considered here in the Black Tern, a relatively small sized larid, are proportionately less pronounced compared to the larger species of gulls discussed previously. Accordingly, the measurements and discriminant function analysis techniques used to identify individuals by sex in larger gulls may lack the necessary precision to allow similar distinctions between the sexes in the small sized species of terns, particularly those which lack well-developed gonys (i.e., Black Terns and Common Terns). Investigation of sex dimorphic size traits in a small species of gull with poorly developed gonys (Bonaparte's

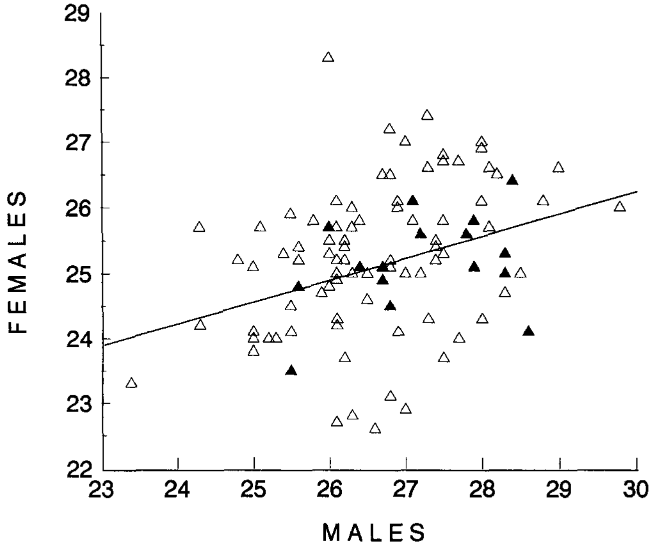

FIG. 2. Comparison of culmen length (mm) between 104 pairs of mated Black Terns. Sixteen pairs were sexed by laparotomy (filled triangles) while the remaining 88 pairs (open triangles) were sexed by their relative size within mated pairs (males larger than females). Lines of best fit were determined by least squares regression ($r = 0.34$, $N = 104$, $P < 0.001$).

Gull [*L. philadelphia*]) and a large species of tern (Caspian Tern [*Sterna caspia*]) would assist in further describing important sexual dimorphic size traits in larids.

Patterns of assortative mating for culmen length and total head length in Black Terns were similar to those observed in Common Terns (Coulter 1986). Coulter (1986) speculated that there is a positive correlation between age and size in Common Terns and suggested that Common Terns may, like other Laridae (Coulson and Thomas 1983, Nisbet et al. 1984), assortatively mate according to age. Thus, the pattern of assortative mating we found in

TABLE 4
DISCRIMINANT FUNCTION ANALYSIS OF A VALIDATION SAMPLE OF BLACK TERNS WHERE SEX WAS PRESUMED FROM THE RELATIVE SIZE OF MATES (MALES LARGEST)

			Classification accuracy			
Method	Variables available	Variables retained	N	Overall	Male	Female
Wilks	THL[a], CL[b]	THL	176	81%	84%	77%
Direct	THL, CL	THL, CL	176	80%	84%	75%

[a] THL = total head length.
[b] CL = culmen length.

Black Terns may be a function of a basic phenomena of assortative mating according to age in gulls and terns. Additional study of assortative mating by age and by size in Laridae is needed to clarify further these relationships.

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MARK A. STERN AND ROBERT L. JARVIS, *Dept. Fisheries and Wildlife, Nash 104, Oregon State Univ., Corvallis, OR 97331.* (Present address MAS: *Oregon Natural Heritage Program, 1205 NW 25th, Portland, Oregon 97210.)* *Received 21 Feb. 1989, accepted 25 Oct. 1990.*