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Intraspecific Variation in Loggerhead Shrikes: Sexual Dimorphism and Implication for Subspecies Classification

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The Loggerhead Shrike (*Lanius ludovicianus*), a passerine bird of medium size ($\bar{x}$ = 55.75 ± SD of 0.27 g, *n* = 129, unpubl. data) preys on large insects, rodents and small birds. Numbers and the breeding range of Loggerhead Shrike have been steadily declining in North America since at least 1966 (Morrison 1981, Erskine et al. 1992). Reasons proposed for these declines include pesticide contamination (Morrison 1979), an increase in human disturbance (Hands et al. 1989), climatic change (Cadman 1985), and depletion of both breeding and wintering habitat (Telfer 1992).

Miller (1931) defined 11 subspecies of Loggerhead Shrike on the basis of overall color patterns and linear measurements. Miller (1931) suggested that the wing-chord-to-tail-length ratio (WC:TL) is an especially important variable for identification of subspecies in Loggerhead Shrike. Some studies have used the WC:TL as a means of differentiating among *L. l. excubitorides*, *L. l. ludovicianus* and *L. l. migrans*, which are central, southeastern, and northeastern North American subspecies, respectively (Haas 1987). However, Miller (1931) presented characteristic ratios for subspecies as simple means without measures of variation among individual birds. As Haas (1987) pointed out, small variation within a subspecies would severely diminish the value of this ratio as an aid in subspecific delineation. Since Miller's (1931) treatment of Loggerhead Shrike taxonomy, there have been few studies investigating morphological differences of subspecies.

In Canada, legal protection has been extended to individual populations of Loggerhead Shrike due to the difficulty in ascertaining subspecies. Loggerhead Shrikes in eastern Canada have been designated endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC; World Wildlife Fund 1993), while the Canadian prairie population has been designated by COSEWIC as threatened. In response to the COSEWIC listing, a Canadian recovery plan has been prepared (Johns et al. 1994), which identifies the need for immediate inventories of remaining populations.

A complete inventory would ideally include the subspecific and sexual demography of studied populations. However, the sex of Loggerhead Shrikes can only be determined with complete confidence during the breeding season. At that time behavioral observations (i.e. singing by males, incubation by females, or a male carrying food to a begging female) or the presence of a brood patch or cloacal protuberance can be used for sex determination. Female shrikes in Alberta generally have browner primaries than males (Collister pers. obs.), and Graber et al. (1973) suggested that winter specimens of *L. l. migrans* in Illinois can be sexed consistently based on gray vermiculations on the breast of females, while males are more nearly immaculate on the breast. However, these criteria are subjective and may not be reliable under all field conditions and across age classes. A reliable method of determining the sex of Loggerhead Shrikes based on external characters is desirable, but has not yet been developed.

We investigated morphological differences in a population of Loggerhead Shrikes in southeastern Alberta to: (1) quantify sexual dimorphism of Loggerhead Shrikes on the Canadian prairies; (2) determine if a discriminant function using morphometric characters can be constructed that correctly indicates the sex of Loggerhead Shrikes on the Canadian Prairies; and (3) determine if, as asserted by Miller (1931), use of WC:TL is a valid method for differentiating between subspecies of Loggerhead Shrike.

Methods.—From April 1992 through August 1993, 131 adult Loggerhead Shrikes were captured in southeastern Alberta (50°50′N, 110°56′E) using mist nets as well as bal-chatri, Potter and modified bow traps (Collister and Fisher 1994) baited with laboratory mice (*Mus musculus*). Nine linear measurements were recorded for each bird following Baldwin et al. (1931): (1) wing chord (WC), from wrist to tip of wing, with wing unflattened and flexed at wrist; (2) tail length (TL), from distal end of uropygial gland to tip of longest rectrix; (3) hind-toe length (HTL), from point where upper edge joins tarsus to proximal end of claw; (4) middle-toe length (MTL), taken in same manner as hind-toe length; (5) bill length (BL), from anterior margin of nares to tip of upper mandible; (6) bill width (BW), from outside edges of bill opposite anterior end of nares, with mandibles closed; (7) bill depth (BD), greatest dorso-ventral distance at nares,

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TABLE 1. Sex variation in size in Loggerhead Shrikes (*Lanius ludovicianus*) from southeastern Alberta, Canada ($\bar{x} \pm$ SD, with n in parentheses). All measurements except ratio in centimeters.

Variable	Male	Female	P[a]
Wing chord	9.7 ± 0.8 (62)	9.5 ± 0.2 (69)	***
Tail length	10.0 ± 0.4 (61)	9.6 ± 0.3 (66)	***
Hind-toe length	1.07 ± 0.05 (62)	1.05 ± 0.06 (69)	*
Middle-toe length	1.63 ± 0.09 (62)	1.59 ± 0.10 (69)	*
Bill length	1.19 ± 0.08 (62)	1.15 ± 0.06 (68)	***
Bill width	0.56 ± 0.03 (62)	0.55 ± 0.03 (68)	*
Bill depth	0.83 ± 0.03 (62)	0.81 ± 0.02 (69)	***
White on primaries	5.5 ± 0.3 (62)	5.3 ± 0.2 (69)	***
White on rectrices	3.48 ± 0.44 (39)	3.14 ± 0.42 (44)	***
Wing-chord-to-tail-length ratio	0.978 ± 0.035 (61)	0.994 ± 0.023 (69)	*

[a] Results of t-tests: *, $P < 0.05$; **, $P < 0.01$; ***, $P < 0.001$.

with mandibles closed; (8) white on primaries (WP), from distal edge of basal white area to wrist; (9) white on rectrices (WR), greatest length of white spot on inner web of the distal end of outer rectrix; (10) merged or not merged rectrix white (MNRW); and (11) wing-chord-to-tail-length ratio (WC:TL) following Miller (1931). We included MNRW as a variable as the distal white spot on the rectrix merges completely with the basal white spot on some birds, thereby not allowing a WR measurement. All measurements were taken to the nearest 0.01 cm with calipers, except for TL, WC and WP, which were taken to the nearest 0.1 cm with a wing-chord rule. Due to the fluctuations in body mass of females during the incubation period, mass was not included in the analysis. Sex was identified by the presence of a cloacal protuberance (male), or the presence of a brood patch (female).

After verifying the assumptions of normality and homoscedasticity, t-tests were conducted to test for differences between males ($n = 62$) and females ($n = 69$) for the nine linear variables and WC:TL. A stepwise discriminant function analysis (DFA) with backward selection using the first 10 recorded variables was used to identify which characters were most helpful in combination in distinguishing sex (Wilkinson 1990). A model predicting sex was then generated using 77% of the data set ($n = 100$) chosen randomly. The model was validated with the remaining 23% of the data set ($n = 31$). All statistical calculations were performed using SYSTAT (Wilkinson 1990).

Results.—Univariate analyses revealed that males were significantly ($P < 0.05$) larger than females for all measured linear morphological characters (Table 1). Little difference was found between the sexes in the incidence of merged white on the rectrices. Merged rectrix white was found in 35% of males and 36% of females.

DFA revealed that, in combination, the morphological variables WP, TL, and BD optimally predicted the sex of a bird. Equations 1 and 2 are discriminant functions for distinguishing between female and male Loggerhead Shrikes. When these equations are applied to a new shrike, the bird is assigned to the group represented by the equation with the largest value (y) for that case. For males the equation is:

$$y = -896.673 + 72.71(\mathrm{WP}) + 55.14(\mathrm{TL}) + 1013.8(\mathrm{BD}). \quad (1)$$

For females, the equation is:

$$y = -841.070 + 69.01(\mathrm{WP}) + 53.39(\mathrm{TL}) + 991.1(\mathrm{BD}). \quad (2)$$

When validated using new data, these equations correctly classified 80% of females (12 of 15 cases) and 75% of males (12 of 16 cases) for a combined value of 77.4%. The ranges of variables for each sex used to construct the discriminant functions were: male WP, 4.7–6.1 cm; male TL, 9.1–10.6 cm; male BD, 0.73–0.91 cm; female WP, 5.0–6.0 cm; female TL, 8.3–10.3 cm; female BD, 0.76–0.88 cm.

The mean WC:TL ratio for all birds measured (pooled male and female data) was 0.986 ± 0.03, range 0.906–1.145). The ratio for males was 0.978 ± 0.035 (range 0.906–1.145) and for females was 0.994 ± 0.023 (range 0.949–1.056). Females had a significantly ($P < 0.05$) higher WC:TL ratio than males.

Discussion.—There is significant sexual dimorphism in Loggerhead Shrikes on the Canadian prairies. Males were significantly larger than females in all measured variables. There may be selection for large male body size in passerine species where males engage in aggressive territorial defense (Van Wynsberghe et al. 1992).

In a two-group DFA (such as sex discrimination) it is expected that 50% of the individuals would be classified correctly by chance alone. The number of correctly classified cases above the chance classification rate, therefore, is a measure of the efficacy of discriminant functions. Our model correctly classified sex in 77.4% of 31 Loggerhead Shrikes tested, for an improvement of 54.8% above chance classification. WP was the variable that contributed most to the power of the discriminant functions, followed by TL and BD. WP has been shown to differ significantly between male and female Brown Shrikes (*Lanius crisatus*) in Japan (C. A. Haas pers. comm.). Whether our model is applicable to populations other than that sampled remains to be determined.

Miller (1931), when differentiating Loggerhead Shrike subspecies using the WC:TL ratio summed all the available measurements of wing length and divided by the sum of all the tail lengths. Ratios calculated in this manner were reported for males of: *L. l. ludovicianus*, 0.943:1; *migrans*, 1.001:1; and *excubitorides*, 0.999:1. Haas (1987), calculating individual WC:TL ratios for 37 Loggerhead Shrikes caught within the range defined for *L. l. excubitorides* (Miller 1931), found that fewer than one-third of the birds had WC:TL values closer to the value Miller (1931) presented for *L. l. excubitorides* than to those for the other two subspecies ($\bar{x}$ = 0.984 ± 0.033, range 0.895–1.044). Similarly, only 63% of WC:TL values calculated for our pooled male and female data were closer to the value presented for *L. l. excubitorides* than to the values for the other two subspecies. Even when calculating WC:TL ratio for only males, as Miller (1931) originally did, 39% of the male birds in our study would have been incorrectly identified to subspecies using Miller's (1931) WC:TL values.

Female Loggerhead Shrikes in our study had significantly larger ($P < 0.05$) WC:TL ratios than males. Thus, it appears that significant variation in WC:TL ratios within populations precludes its use in correctly identifying subspecies of Loggerhead Shrike.

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