Jap. J. Ornithol. 45: 187-190, 1996

Sexual Size Dimorphism and Sex Determination of a Brown Shrike subspecies, *Lanius cristatus superciliosus*

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A majority of Laniinae species are sexually dimorphic (GRIME 1985). Some of them have conspicuous sexual dimorphism in plumage, e.g., Bull-headed *Lanius bucephalus*, Thick-billed *L. tigrinus* (YAMASHINA 1934), Gray-backed Fiscal *L. excubitorius*, and Common Fiscal *L. Collaris* Shrikes (ZACK & LIGON 1985). In contrast, Brown Shrikes *L. cristatus*, which breeds in the Temperate and sub Frigid-Zone in Asia (HOWARD & MOORE 1980), is one of the sexually inconspicuous species in plumage (YAMASHINA 1934, KIYOSU 1965, but see TAKAGI in press). So, it has been difficult to determine the sex of this species when no incubation patch exists. Thus, I describe the sexual differences in terms of the morphological traits of a Brown Shrikes subspecies, *L. c. superciliosus* breeding in Hokkaido, and report a discriminant function analysis using external characteristics designed to discriminate sex.

The study was conducted in Oyafuru (43°13'N, 141°20'E) about 15 km north of Sapporo. Nineteen males and sixteen females of *L. c. superciliosus* subspecies were captured using mist-nets from May through July in 1992-1996. Sex was determined by the presence of an enlarged incubation patch, because only females incubate the eggs in Brown Shrikes (HANEDA & TAKAHASHI 1967). Since Brown Shrikes could not be distinguished by age during the breeding season, data for individuals in each sex were combined in this paper. It was suggested that any differences in plumage among age classes could be discounted (see TAKAGI in press). Nine characters were measured to the nearest 0.01 mm using vernier calipers as described by YAMASHINA (1934), SVENSSON (1984) and TAKAGI (in press). These characteristics were the following: (1) length of unflattened wing chord, (2) tail length, (3) tarsus length, (4) bill length, length from the tip of the bill to the feathering, (5) bill depth, (6) width at the posterior edge of nostril, (7) length of gape, (8) length of total head, the maximum length from the tip of the bill to the back of the skull, and (9) width of white band on forehead. Body mass was determined by a digital platform, or a balance, to the nearest 0.1 g. I used a discriminant function analysis for sex determination. In the analysis, total head length was excluded, as the number of individuals for which total head length was measured was insufficient. Body mass was also excluded, because measuring of mass in each individual were not conducted in a same breeding stage. It has been shown in Loggerhead Shrikes that, due to the fluctuation in body mass during a breeding season, mass could not be used for discriminant analysis (COLLISTER & WICKLUM 1996). Statistical and discriminant function analyses were performed by using STATISTICA® (THREE'S COMPANY. INC.).

Males were significantly larger than females for tail length and width of white band on forehead, although considerable overlaps in range occurred (Table 1). Body mass of females was significantly heavier than of males (Table 1). There was no significant difference in length of wing chord or in size of skeletal parts between sexes (Table 1).

I performed linear discriminant analyses between sexes using the single variables, tail length and width of white band on forehead showing significant sexual differences, separately. Using discriminant analysis with variable tail length, 84.2% (16/19) of the males and 75% (12/16) of the females were correctly identified. Using this

Table 1. Morphological measurements (mm) and body mass (g) in Brown Shrikes during breeding season.

	Male				Female				t-test	
	Mean	SD	Range	n	Mean	SD	Range	n	t-value	P-value
Wing length	88.1	1.9	83.3-91.2	19	87.4	2.0	85.4-89.6	16	1.08	NS
Tail length	86.6	2.3	84.6-93.6	19	83.3	2.7	82.1-91.0	16	3.9	0.005
Tarsus length	24.0	0.6	22.8-25.0	19	23.9	0.7	22.9-25.4	16	0.39	NS
Bill length	15.6	0.5	14.8-16.4	18	15.7	0.7	15.2-16.7	16	-0.52	NS
Bill depth	8.0	0.2	7.7-8.3	18	8.0	0.2	7.5-8.4	16	0.26	NS
Bill width	5.8	0.3	5.3-6.4	18	5.9	0.3	5.6-6.4	16	-0.83	NS
Length of gape	22.4	0.6	21.5-23.4	16	22.1	0.9	21.6-23.8	16	1.25	NS
Length of total head	41.3	0.5	40.7-42.2	9	40.5	0.8	40.5-41.9	10	2.33	NS
Width of white band on forehead	6.7	1.6	3.5-10.5	19	3.3	0.8	2.6-4.3	16	8.06	<0.000
Body mass	30.1	2.7	27.4-34.3	19	34.0	4.0	28.0-37.2	14	-3.34	0.002

Sample sizes for the analysis of each character differed according to the dimensions measured, as it was not obtained for several individuals.

analysis with width of the white band on the forehead, 89.5% (17/19) of the males and 93.8% (15/16) of the females were correctly identified. In both sexes, width of white band on forehead was a better discriminator of sex than tail length.

In order to distinguish sexes more precisely, a multivariate discriminant function analysis was performed. To exclude the effect of multicollineality caused by highly correlation among variables, I eliminated a variable, length of wing chord, from the analysis, in as much as the correlation coefficient between tail length and length of wing chord was 0.74 ($P<0.001$). Correlation coefficients among the other variables were smaller than 0.53. As a result, seven variables, tail length, tarsus length, length of exposed culmen, bill depth, bill width, gape, and width of the white band on forehead were included in the analysis. To simplify the function, yet keep high discriminant power, I performed an increasing stepwise discriminant analysis. Consequently, two variables, width of white band on forehead and tail length, were selected. The discriminant function is as follow;

$$Z = 23.8 - 0.66x_1 + 0.24x_2 \quad (F=40.28, \text{dfs}=2, 29, P<0.0001) \quad (\text{Fig. 1})$$

x_1 : length of white band on forehead (WB), x_2 : tail length (TL).

The two variables contributed to the function significantly (WB; $F=34.3$, $\text{dfs}=1$, 29, $P<0.0001$, TL; $F=7.80$, $\text{dfs}=1$, 29, $P=0.009$). When the equation is applied to an individual, $0<Z$ and $Z<0$ represent female and male, respectively. The discriminant scores overlapped in $0.59<Z>0.99$. The probability in discriminating males was 89.5% (17/19), females was 100% (16/16), and for both sexes was 94.3%. These percentages are within the upper range of percentages yielded in previous research studies of sex discrimination with other avian species, which varied from 77.4-98% (BORTOLOTTI 1984, MURATA *et al.* 1988, PÉPIN 1985, CHARADINE & MORRIS 1989, MAKAMURA *et al.* 1989, COLLISTER & WICKLUM 1996). Hence, the function of stepwise analysis containing two variables was applicable to sex determination in *L. c. superciliosus*.

Because they have not yet develop an incubation patch when *L. c. superciliosus*

Fig. 1. Relationship between width of white band on forehead and tail length. ● and ○ show males and females, respectively. The line ($Z=0$, $Z=23.8-0.66x_1+0.24x_2$) illustrates the boundary which separates males from females.

females first arrive at their breeding ground, their sex can not be identified. Hence, the discriminant function is useful for sex determination in *L. c. superciliosus*, especially in the early breeding season. I was unable to ascertain whether or not the equation could be applied to sex determination during the period from post- to pre-breeding molts. Because *L. c. superciliosus* molt completely during the pre-breeding season (MEDWAY 1970, STRESEMANN & STRESEMANN 1971), they must have already gotten fresh plumage in the breeding season.

I am greatly indebted to Drs. H. Abe, Y. Watanuki, and Y. Saito for their variable comments and criticism of this manuscripts. I also express my thanks to the Bird Migration Research Center, Yamashina Institute for Ornithology, for its kind supporting of my bird banding research.

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アカモズ雌雄の外部計測値における差異と雌雄判別. アカモズは羽色の性的二型が不明瞭なので、形態計測値の雌雄比較、および判別分析による雌雄判別を試みた。調査は1992～1996年の5～7月に北海道石狩郡で行なった。抱卵斑の有無によって性判別をしたアカモズの雄19個体、雌16個体について、10箇所の外部形態の計測、および体重測定を行なった。その結果、尾長と額の白色帯の幅は雄で有意に長い傾向が認められたが、自然翼長、ふしよ長、露出嘴峰長、嘴高長、嘴幅長、口角長、全頭長には有意な雌雄差は認められなかった。

計測値間で高い相関関係が認められなかった6変数、すなわち尾長、ふしよ長、露出嘴峰長、嘴高長、嘴幅長、額の白色帯の幅を説明変数として、変数増加式の変量線形判別分析を行なった。その結果、尾長と額の白色帯の幅の2変数が選択され、以下の判別式が得られた。

$$Z = 23.8 - 0.66x_1 + 0.24x_2 \quad (F = 40.28, \text{dfs} = 2.29, P < 0.0001)$$

x_1 は尾長 (mm), x_2 は白色帯の幅 (mm) を示し、判別値 $Z < 0$ で雄, $Z > 0$ で雌として判別される。この判別式を用いたときの雄の判別率は89.5%, 雌の判別率は100%, 両性では94.3%であり、雌雄の判別がほぼ可能であることがわかった。繁殖地に渡来したばかりの雌は抱卵斑を発達させていないので、その時期の雌雄の識別にこの判別式は効果的である。

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(Accepted 15 November 1996)