ORNITOLOGIA NEOTROPICAL 9: 103–110, 1998
© The Neotropical Ornithological Society

DISTINGUISHING SEX OF SOCORRO MOCKINGBIRDS BY BODY MEASUREMENTS

Juan E. Martínez-Gómez[1] & Robert L. Curry

Department of Biology, Villanova University, Villanova, PA 19085, U.S.A.

Key words: Sexing, Mimodes graysoni*, Socorro Island, Revillagigedo Archipelago, Mexico.*

The Socorro Mockingbird (*Mimodes graysoni*) is an endangered species endemic to Socorro Island, México (Collar *et al.* 1992). Although, widely distributed on Socorro in the past (Jehl & Parkes 1982), a population of about 300 mockingbirds is now restricted to areas where sheep impact has been slight or absent (Martínez-Gómez & Curry 1995, 1996). This neotropical species has one of the highest conservation and research priorities (Parker *et al.* 1996). Distinguishing both age and sex is critical to the study of Socorro Mockingbird population structure and demography. Estimates of age-specific parameters can be obtained from field observations and banding records because it is easy to distinguish between adult and first-year Socorro Mockingbirds based on plumage patterns; subadults have spotted breasts, greyish irides, and a yellowish gape, whereas adults have unspotted breasts, reddish irides, and a dark gape (Martínez-Gómez & Curry 1995). Estimating parameters such as sex ratios, sex-specific dispersal, site fidelity, and survival, however, is problematic: visual sex identification is not possible because Socorro Mockingbirds lack sexual dichromatism and no discriminant functions to sex this species using morphometric measurements have been reported previously.

Morphometric characters have been used in the past to sex other Mimids. Galápagos Mockingbirds have been sexed using data collected from museum specimens (Swarth 1931), and classification criteria based on wing length have proven sufficient (Curry 1988, 1989; Curry & Grant 1989, Kinnaird & Grant 1982). Such non-invasive approaches for sex determination are appropriate in studies of endangered species because invasive techniques, such as laparotomy and laparoscopy, entail risk of injury or death (Delany *et al.* 1994). Our objective was to determine the best classification functions based on mass and external measurements that can be used to identify the sex of Socorro Mockingbirds,

[1]*Present address:* Department of Biology, University of Missouri - St. Louis, 8001 Natural Bridge Road, MO 63121–4499, U.S.A.

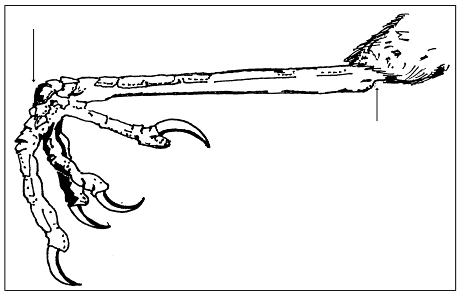

FIG. Diagram of tarsus with arrows showing reference points for measuring our modified tarsus length.

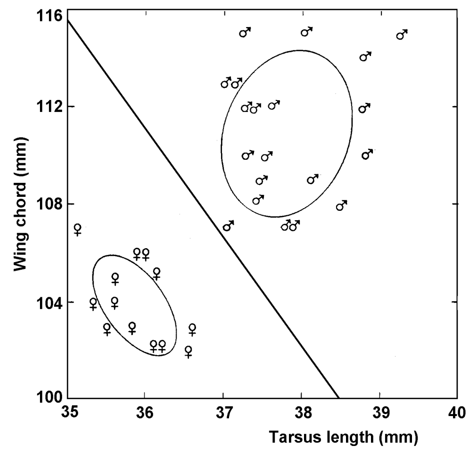

FIG. 2. Bivariate plot of wing chord (mm) and tarsus length (mm) with 50% confidence ellipses. The line describes the classification function based on two variables. The number of symbols is less than the number of birds used in the analysis because two females had a wing chord of 104 and a tarsus length of 35.6, and two other had a wing chord of 102 and a tarsus of 36.2.

and will facilitate further population analyses of this species.

METHODS

We captured and banded Socorro Mockingbirds during four years. We began banding from 6 to19 January 1993, and one of us (JEMG) made subsequent observations in the field from 6 June to 5 August 1993, 18 February to 4 June 1994, 20 March to19 May 1995, and 18 January to 4 April 1996. Socorro Mockingbirds are fearless and curious, making it easy to catch them in wire treadle traps. Except for body mass (BM), we obtained the following measurements from the right side of each individual: bill length (BL), from the anterior end of the nostril to the tip of the bill; wing chord (WC), from the carpal joint to the tip of the longest primary; tail length (TL), from the base of the two middle rectrices to the tip of the longest rectrix; and modified tarsus length (T), from the joint between the tibiotarsus and the tarsometatarsus to the bent joint between the tarsometatarsus and metatarsals (Fig. 1). We measured tarsus length and bill length with Vernier calipers. We measured tarsus length by first obtaining the length with a drawing compass and then measured the distance between the compass points with the caliper. We measured wing chord with a ruler with a perpendicular stop at zero, tail length with a flexible plastic ruler, and body mass with a 100 g Pesola spring balance. We made approximations to the nearest 1.0 g and 0.05 mm except for estimates of tail and wing, which were measured to the nearest 1.0 mm. One of us (JEMG) measured all individuals.

We used data from 389 banded individuals to test for significant differences between age groups. Of these individuals 35 were definitively sexed based on field observations to determine how these morphometric measures differ between males and females. We performed two-tailed, two-sample t-tests for all measurements in both groups; except in those cases where the structure to be measured was absent or damaged. We used the most recent set of measurements available for individuals

TABLE 1. Comparative measurements (mm) and body mass (g) of adult and subadult Socorro Mockingbirds.

Variable	Adults				Subadults				t[1]	df	*P*
	n	Mean	SD	Max.–Max.	n	Mean	SD	Min.–Max.			
Wing chord	120	107.95	4.17	100.0–115.0	240	105.09	3.61	98.0–112.0	6.73	358	< 0.0005
Tarsus length	143	37.14	1.06	34.7–39.7	240	37.07	1.02	34.4–40.4	0.66	381	0.5110
Tail length	116	121.59	5.21	110.0–134.0	239	118.23	4.24	103.0–128.0	6.50	353	< 0.0005
Bill length	146	14.51	0.68	11.8–16.9	243	13.82	0.58	11.7–15.9	10.49	387	< 0.0005
Body mass	145	66.64	5.82	55.0–85.0	242	61.43	3.90	52.0–74.0	10.53	385	< 0.0005

[1] t-value from a two-tailed, two-sample, t-test.

measured more than once. Statistical tests had a significance level of $P = 0.05$.

Each year, we visited a minimum of 25 territories and observed occupants regularly to determine their sex. We watched previously banded birds at each territory at least two hours per week. We identified males (n = 20) based on their extensive singing and territorial behavior, and females (n = 15) based on incubation, delivery of distinctive calls (J. E. Martínez-Gómez & L. F. Baptista unpubl. data), and on the absence of harassment by males sharing the same territory (e.g., Martínez-Gómez & Curry 1995, Ralph *et al.* 1993). We sought to meet several of the criteria mentioned before assigning a sex category because female Socorro Mockingbirds give songs similar to those of males (J. E. Martínez-Gómez, pers. obs.). However, female songs differ in duration and intensity, and females give sex specific calls. In addition, females can be identified reliably from incubating behavior because, as in other mockingbird species [(e.g., *Mimus polyglottos*, Bent (1948), Derrickson & Breitwisch (1992); *Mimus gilvus*, Laurent (1990); *Nesomimus* spp., R. L. Curry, pers. observ.)], only female Socorro Mockingbirds incubate (Martínez-Gómez & Curry 1995). After inspecting several individuals of known sex, we noticed extensive variation in cloacal protuberance and only one female showed a clear brood patch, even during incubation; therefore, we did not use these characters to sex individuals.

For the positively sexed birds, we performed discriminant analyses on the original variables, using SYSTAT 6.0 for Windows (Engelman 1996), with equal prior probability assigned to each sex. We conducted stepwise backward discriminant function analyses using the program's default settings, and interactive discriminant analyses. In both cases, the optimization criterion was the minimization of Wilk's Lambda. We checked for the assumption of equality of group covariance matrices and obtained estimates of classification rates through jackknife procedures.

RESULTS

Overall, adults were larger than subadults, and males larger than females. Univariate statistics showed significant differences between the age groups in all measurements except tarsus length (Table 1). Likewise, univariate tests showed males to be significantly larger than females in all measurements except bill length (Table 2). Despite these differences in

TABLE 2. Comparative measurements (mm) and body mass (g) of male and female Socorro Mockingbirds.

Variable	Males (n = 20)			Females (n = 15)			t[1]	*P*
	Mean	SD	Min.–Max.	Mean	SD	Min.–Max.		
Wing chord	110.90	2.77	107.0–115.0	103.87	1.64	102.0–107.0	–8.73	< 0.0005
Tarsus length	37.80	0.68	37.0–39.3	35.88	0.43	35.1–36.6	–9.65	< 0.0005
Tail length	124.20	6.68	110.0–133.0	118.73	3.37	115.0–125.0	–2.90	< 0.0005
Bill length	14.63	0.90	11.8–16.1	14.11	0.46	13.4–14.9	–2.01	0.053
Body mass	67.55	6.46	56.0–80.0	63.47	5.17	55.0–74.0	–2.08	0.045

[1] t-value from a two-tailed, two-sample, t-test with 33 df.

average size between the sexes, multivariate methods provided better resolution.

The first discriminant function generated by the stepwise backward routine included all variables:

$$-0.426\ BM + 2.706\ BL - 1.224\ TL + 9.085\ T + 3.727\ WC = 597.195 \quad (1).$$

This function yielded the smallest Wilk's Lambda ($\Lambda = 0.094$), indicating a significant difference between the two groups ($F = 55.33$, df = 5, 29, $P < 0.0005$). Individuals that scored 597.195 or greater were classified as males and those scoring lower as females. This function correctly classified all individuals in the sample from which it was derived. However, jackknife procedures were required to obtain better estimates of classification rates because the assumption of equal group covariance matrices was not met ($\chi^2 = 42.02$, df = 15, $P < 0.0005$). The jackknifed classification matrix also presented a classification rate of 100%.

The final classification function produced by the stepwise backward procedure included only three variables:

$$-0.958\ TL + 7.919\ T + 2.868\ WC = 483.455 \quad (2).$$

with $\Lambda = 0.113$, $F = 81.02$, df = 3, 31, $P < 0.0005$. Individuals that scored 483.455 or higher were classified as males and those scoring lower as females. This function correctly classified all individuals in the sample from which it was derived. Jackknife procedures were still required because the assumption of equal group covariances again was not met ($\chi^2 = 26.30$, df = 6, $P < 0.0005$). The jackknifed classification matrix also classified correctly all of the individuals.

From this point, we continued through a stepwise interactive search, looking for a compromise to obtain a classification function using only a few variables that would be easy to use in field conditions. We did not attempt any quadratic models, which are robust against departures from the assumption of equal group covariances (Engelman 1996), because they would create more terms to be estimated, and because such an approach would also require a larger sample size to compute the classification function. Thus, we searched for a simplified function yielding classification rates comparable to those obtained from the models presented above. We found that Socorro Mockingbirds could be sexed reliably with a classification function based only on wing chord and tarsus length:

$$1.234\ WC + 5.524\ T = 336.024 \quad (3).$$

This function yielded the smallest Wilk's Lambda among functions derived from any two characters ($\Lambda = 0.166$, $F = 80.34$, df = 2, 32, $P < 0.0005$). Individuals that scored 336.024 or higher were classified as males and those scoring lower as females. This function correctly classified all individuals in the sample from which it was derived (Fig. 2). Although the assumption of equality of group covariances was not met ($\chi^2 = 13.44$, df = 3, $P = 0.0038$), the jackknifed classification yielded a 100% success rate.

Because there were not significant differences in tarsus length between adult and subadult Socorro Mockingbirds ($P = 0.511$, Table 1), an additional classification function derived from tarsal measurements of adult birds can be used to sex juvenile and immature birds as well as molting adults:

$$5.634\ \mathrm{T} = 207.579 \quad (4).$$

This function still yielded a significant Wilk's Lambda ($\Lambda = 0.261$, $F = 93.13$, df = 1, 33, $P < 0.0005$). Individuals that scored 207.579 or higher were classified as males and those scoring lower as females. This function correctly classified all individuals in the sample from which it was derived. In this case, the assumption of equality of group covariances was met ($\chi^2 = 3.43$, df = 1, $P = 0.064$). Jackknifed procedures also yielded a 100% success rate.

DISCUSSION

Our study represents the first examination of sexual dimorphism in the Socorro Mockingbird. The classification functions presented are the first tools available to help in the estimation of sex-related demographic parameters for this species. The functions we present were not derived from measurements of museum specimens, which may not represent accurately the morphology of birds in the wild (e.g., Clench 1976, Winker 1993). We recommend the use of Equation 3 because of its high classification rate, and the ease of applying its bivariate plot (Fig. 2) in the field. Equation 4 is adequate for subadults and molting adults.

The efficiency of this classification function may be hampered because it is based on a small sample and a skewed sex ratio. Nonetheless, our sample represents a relatively large percentage of the small extant population of the Socorro Mockingbird (Martínez-Gómez & Curry 1995, 1996). Moreover, the slightly skewed sex ratio may reflect a real preponderance of males in the population, as occurs in many passerines (Breitwisch 1989), including Mimids (e.g., Curry 1989; Curry & Grant 1989, 1990). It can be argued that our classification functions may not apply to a significant portion of the population (e.g., floaters) because they were derived only from territorial breeding pairs. However, due to present government restrictions for this species, it is unlikely that data from techniques such as laparotomy or laparoscopy applied to a greater sample of the extant population will be gathered in the near future. Also, as previously mentioned, information on cloacal protuberance and brood patch may not be readily useful, especially during non breeding times. Our classification functions may lose applicability in the future if birds in a particular size range are more or less likely to survive, as is the case in other island bird species [(e.g., *Geospiza* finches, Gibbs & Grant (1987), Grant *et al.* (1985)]. In spite of this possibility, our functions can be used in the near future in gathering demographic information on the Socorro Mockingbird.

ACKNOWLEDGMENTS

We thank the Mexican Navy for generous logistical assistance and hospitality, and A. Flores and M. Ramos for their field assistance. We appreciate the comments of one anonymous reviewer, L. F. Baptista, and J. Lill on a previous version of the manuscript. Financial support was provided by the Frank M. Chapman Memorial Fund, the Cooper Ornithological Society, the Association of Field Ornithologists, the American Ornithologists' Union, the Department of Biology at Villanova University, and Sigma Xi - The Scientific Research Society.

REFERENCES

Bent, A. C. 1948. Life histories of North American nuthatches, wrens, thrashers, and their allies. U.S. Natl. Mus. Bull. 195.

Breitwisch, R. 1989. Mortality patterns, sex ratios, and parental investment in monogamous birds. Curr. Ornithol. 6: 1–50.

Clench, M. H. 1976. Possible pitfalls in museum specimen data. N. Am. Bird Bander 1: 2021.

Collar, N. J., L. P. Gonzaga,, N. Krabbe, A. Madroño Nieto, L. G. Naranjo, T. A. Parker III, & D. C. Wege. 1992. Threatened birds of the Americas. The ICBP/IUCN Red Data Book, Cambridge, U.K.

Curry, R. L. 1988. Group structure, within group conflict and reproductive tactics in cooperatively breeding Galápagos mockingbirds, *Nesomimus parvulus.* Anim. Behav. 36: 1708–1728.

Curry, R. L. 1989. Geographic variation in social organization of Galápagos mockingbirds: ecological correlates of group territoriality and cooperative breeding. Behav. Ecol. Sociobiol. 25: 147–160.

Curry, R. L., & P. R. Grant. 1989. Demography of the cooperatively breeding Galápagos mockingbird, *Nesomimus parvulus*, in a climatically variable environment. J. Anim. Ecol. 58: 441–463.

Curry, R. L., & P. R. Grant. 1990. Galápagos mockingbirds: territorial cooperative breeding in a climatically variable environment. Pp. 291–331 *in* Stacey, P. B. & W. Koenig (eds.). Cooperative breeding in birds. Cambridge Univ. Press, Cambridge, U. K.

Delany, M. F., C.T. Moore, & D. R. Progulske, Jr. 1994. Distinguishing gender of Florida grasshopper sparrows using body measurements. Fla. Field Nat. 22: 48–51.

Derrickson, K. C., & R. Breitwisch. 1992. Northern Mockingbird. Pp. 1–25 *in* Poole, A., P. Stettenheim, & F. Gill (eds.). The birds of North America, No. 7. Academy of Natural Sciences, Philadelphia, and American Ornithologists' Union, Washington, D.C.

Engelman, L. 1996. Discriminant analysis. Pp. 361–407 *in* Wilkinson, L. (ed.). SYSTAT 6.0 for Windows: Statistics. Chicago.

Gibbs, H.L., & P.R. Grant. 1987. Oscillating selection on Darwin's finches. Nature 327: 511—513.

Grant, P. R., I. Abbott, D. Schluter, R. L. Curry, & L. K. Abbott. 1985. Variation in the size and shape of Darwin's finches. Biol. J. Linn. Soc. 25: 1–39.

Kinnaird, M. F., & P. R. Grant. 1982. Cooperative breeding by the Galápagos mockingbird, *Nesomimus parvulus.* Behav. Ecol. Sociobiol. 10: 65–73.

Jehl, J. R., & K. C. Parkes. 1982. The status of the avifauna of the Revillagigedo Islands, México. Wilson Bull. 94: 1–104.

Laurent, E. 1990. Estudio del sistema de reproducción comunal y de algunos aspectos de la historia natural de la Paraulata Llanera (*Mimus gilvus*) en los llanos centrales de Venezuela. Tesis de licenciatura, Univ. Central de Venezuela, Caracas.

Martínez-Gómez, J. E., & R. L. Curry. 1995. First description of the nest and eggs of the Socorro Mockingbird. Wilson Bull. 107: 551–555.

Martínez-Gómez, J. E., & R. L. Curry. 1996. The conservation status of the Socorro Mockingbird *Mimodes graysoni* in 1993–1994. Bird Cons. Intl. 6: 271–283.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, & D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. General Technical Report. Pacific Southwest Research Station. Forest Service, USDA.

Parker III, T. A, D. F. Stotz, & J. W. Fitzpatrick. 1996. Zoogeographic and ecological attributes of bird species. Pp 131–291 *in* Stotz, D. F., J. W. Fitzpatrick, T. A. Parker III, & D. K. Moskovits (eds.). Neotropical Birds. Ecology and Conservation. Univ. of Chicago Press, Chicago.

Swarth, H. S. 1931. The avifauna of the Galápagos

Islands. Occas. Pap. Calif. Acad. Sci. 18: 1–299.

Winker, K. 1993. Specimen shrinkage in Tennessee Warblers and "Traill's" Flycatchers. J. Field. Ornithol. 64: 331–336.

Accepted 28 May 1997