Corella, 2007, 31(1): 15-18

MORPHOMETRIC MEASURES AS A MODERATE PREDICTOR OF GENDER IN THE WHITE-BROWED BABBLER *Pomatostomus superciliosus gilgandra*

SUZANNE OPPENHEIMER[1], LEE ASTHEIMER[2], MARTI JANE ANDERSON[3] and BILL BUTTEMER[4]

[1]Department of Biology, Albertson College of Idaho, 2112 Cleveland Blvd.,Caldwell, ID 83605, USA
[2]Department of Biomedical Sciences, University of Wollongong, Northfields Ave.,Wollongong, NSW 2522 Australia.
E-mail: leeba@uow.edu.au
[3]Department of Statistics, University of Auckland, Private Bag 92019, Auckland, New Zealand
[4]Department of Biological Sciences, University of Wollongong, Northfields Ave., Wollongong NSW 2522, Australia.

Received: 30 July 2006

White-browed babblers have monomorphic plumage but exhibit size and weight dimorphism. Males are heavier, have longer tarsi, wings, and culmens than females. Two hundred and eighty-three White-browed Babblers from the central western region of NSW were sexed using laparotomy, and discriminant function analysis was used to determine the extent to which morphometric data could be used to identify gender. Cross-validation using a jackknife procedure indicated that 81 percent of males and 84 percent of females were correctly identified using the resultant discriminant function. Culmen length contributed most to the classification of gender, followed by wing length and tarsus length. The discriminant function is presented as a potentially useful, non-invasive, and inexpensive tool for gender identification in White-browed Babblers.

INTRODUCTION

White-browed Babblers (*Pomatostomus superciliosus*) are an ideal species for behavioural, ecological, and physiological studies. They are widespread across much of Australia (Simpson and Day 1996), they are boisterous and bold, they exhibit many interesting (and sometimes comical) social behaviours, and social groups are easily captured by mist nests. However, many studies require the identification of gender, but White-browed Babblers' monomorphic plumage makes gender determination relatively difficult.

White-browed Babblers' gender can be determined, in some cases, by behavioural observations (e.g. incubation behaviour, dueting with a partner of known gender) or the presence of a brood patch, but these techniques are not always possible, especially outside the breeding season. Surgical (i.e. laparotomy) and genetic techniques can also be used but both require expertise: laparotomies are invasive and genetic techniques are expensive. In many avian species, morphometric indices aid in gender determination (e.g. Brennan *et al.* 1984; Counsilman *et al.* 1994; Genovart *et al.* 2003; Shephard *et al.* 2004). In some, a single morphometric feature predicts gender with high reliability, but in others multiple measures must be utilised for accurate assignment of gender. In this communication, we present gender-specific morphometric data on birds sexed by laparotomy. In addition, we provide a discriminant function using multiple morphometric measurements that can be used to predict gender with moderate reliability in White-browed Babblers, as a non-invasive tool for field biologists.

METHODS

Between June 1996 and July 1999, 283 White-browed Babblers (*P.s. gilgandra)* were caught in Back Yamma State Forest (ENE of Forbes, NSW) and Warredary State Forest (NW of Grenfell, NSW) in the central western region of New South Wales. Birds were captured in all months of the year using mist nests. Tarsus and culmen lengths were measured to the nearest 0.01 millimetre with Vernier calipers, flattened wing cord (from the bend of the wing to the tip of the longest primary) to the nearest 0.5 millimetre with a wing rule, and body mass to the nearest 0.5 gram with a 50 gram Pesola spring scale. Breeding condition and moult was also noted. Birds moulting primary wing feathers were excluded from these analyses.

Gender was evaluated by unilateral laparotomy (Gaunt *et al.* 1997). Methoxyfluorane inhalation was used to lightly anaesthetise the birds. Birds' wings and legs were gently restrained with rubber bands that were secured with pushpins to a cardboard box. Alcohol was used to cleanse the left flank area and a few feathers were plucked. A small incision (5-7 mm) was made in the flank, the skin and intestines were gently reflected using forceps, and the gonads were examined, allowing determination of gender.

Each morphometric variable was compared between males and females (sexed by laparotomy) using Student *t* tests. Discriminant function analysis (DFA) followed by cross-validation with a jackknife procedure was used to examine the reliability of assigning gender to White-browed Babblers based on morphometric data alone. DFA generates a linear combination of variables (in this case morphometric measures) that best separates cases into predefined groups (in this case gender) (Fisher 1936; Lachenbruch and Mickey 1968; Lachenbruch and Goldstein 1979; Quinn and Keough 2002). After verifying the required assumptions of the discriminant model (normality, equal variance and covariance structures within each group), SYSTAT™ 7.0 for Windows (1997) was used to formulate an equation that best predicted gender in White-browed Babblers. All combinations of three measures (wing length, culmen length, and tarsus length) were examined to determine which produced the best discriminant model. The adequacy of each model was checked using a jackknife procedure, in which each individual was classified based on a function calculated when the focal individual was omitted and only the remaining individuals were used to formulate the function (Lachenbruch and Mickey 1968; Quinn and Keough 2002; Genovart *et al.* 2003). Data used for the DFA were taken only from those birds for which we had measurements for all three variables (n=248 individuals). Because of their small size, juveniles (recognised by having yellow gapes) were not included in these analyses.

White-browed Babblers were captured and banded with permission from State Forests of NSW (Special Purposes Permit No. 05341), National Parks and Wildlife Service (Scientific Investigation Licenses B1581and C415), and ABBBS (Authority No. 2186). All capture, handling, and sampling protocols (including laparotomy) were approved by the Animal Ethics Committee of the University of Wollongong (Ethics No. AE96/04).

RESULTS

Adult White-browed Babblers show definite sex-dimorphism with males being heavier and having longer wings, culmens, and tarsi than females (Table 1). Although males were significantly heavier than females, we did not pursue gender discrimination based upon body mass, because mass can vary with ovarian condition in females (Oppenheimer 2005) and also presumably varies with time since last food ingestion.

Discriminant function analysis followed by cross-validation with a jackknife procedure indicated that culmen length was the best single predictor of gender, followed closely by wing length, and finally by tarsus length; however, a combination of all three measures most accurately predicted gender in White-browed Babblers (Table 2). Using a combination of these three measures, males were correctly classified in 81 percent of cases, and females were accurately identified in 84 percent of cases.

Using wing, culmen, and tarsus lengths, the canonical discriminant score (DF1) was calculated with the following equation:

DF1= -46.840+ (0.367*wing length)+ (0.234*tarsus length)+ (0.456*culmen length).

There was a significant difference between males and females when combining lengths of wing, culmen, and tarsus into a single DF1 (Pillai's Trace: $F_{3,244}$ =62.72, P<0.001). However, there is substantial overlap of male and female DF1s between –1 and 0 (Fig. 1), resulting in a zone of unreliable gender prediction. To clarify the range of DF1s over which morphometric gender determination is most reliable, we calculated the DF1 cutoff points needed to accurately identify gender with 95 percent and 99 percent reliability. Reliability of correctly sexing 95 percent of cases can be achieved when DF1 falls above or below the following values:

males: DF1 > 0.72
females: DF1 < -1.64

Reliability of correctly sexing 99 percent of cases can be achieved with the following values:

males: DF1 > 1.28
females: DF1 < -1.99

DISCUSSION

Many avian studies require or benefit from gender determination of individuals, but not all species exhibit obvious sexual dimorphism. However, on closer examination, there are often discrete differences that can be used to determine gender in many species (e.g. Pyle 1997). In the White-browed Babblers, gender cannot be determined based on plumage characteristics, but careful measurements of body size can be used to ascertain gender in many instances. Size and weight

TABLE 2

Morphological variables used in discriminant function analyses to identify gender of White-browed Babblers and the percent of birds correctly classified for gender using single variables or a combinations of variables. Cross-validation performed with a jackknife procedure.

Variables	% Correct
Wing length	76
Wing + tarsus lengths	76
Wing + culmen lengths	81
Culmen length	77
Culmen + tarsus lengths	77
Tarsus lengths	66
Wing, culmen, tarsus lengths	82

TABLE 1

Morphometric measurements of male and female White-browed Babblers sexed by laparotomy. Data presented as mean and standard error for each measure. Statistical comparisons of gender differences for each variable were tested using Student's *t* test.

	Males			Females					
	Mean	S.E.	n	Mean	S.E.	n	t	df	P
Body mass (g)	39.6	0.18	171	38.9	0.29	108	2.35	277	0.020
Wing length (mm)	80.5	0.15	168	78.1	0.16	106	10.74	272	<0.001
Culmen length (mm)	25.8	0.11	151	24.2	0.13	98	9.76	247	<0.001
Tarsus length (mm)	26.7	0.08	168	26.0	0.08	104	6.23	270	<0.001

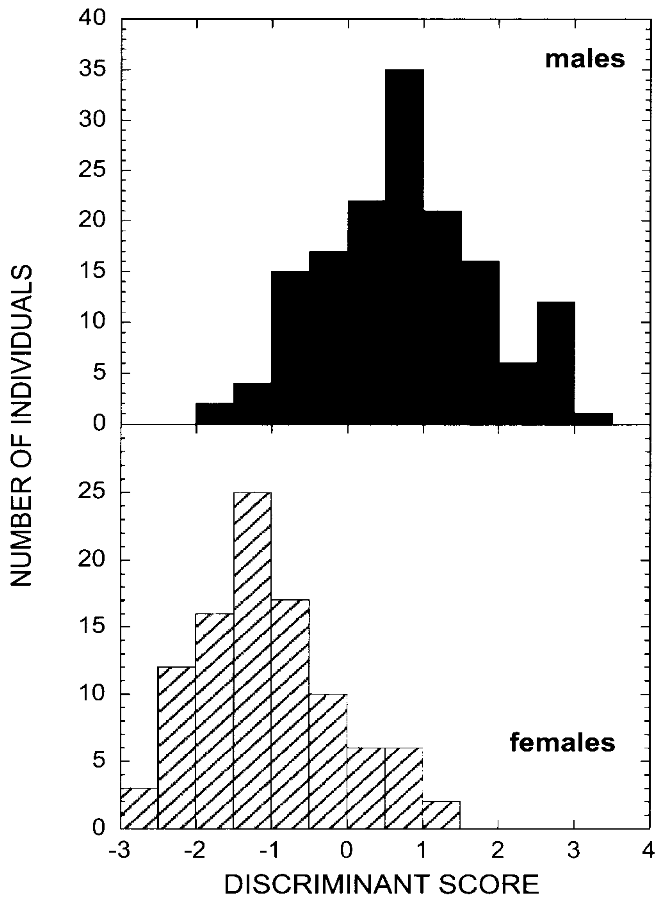

Figure 1. *Frequency distribution of DF1 (canonical discriminant scores) among male (n=151) and female (n=97) White-browed Babblers.*

dimorphisms are common in birds, and among passerines, males are typically larger than females (Gill 2003). White-browed Babblers conform to this pattern, as males are typically heavier and larger than females, an observation that is clarified by this study, in contrast to previous inconsistent reports (Rogers *et al.* 1986, Higgins and Peters 2002). Morphometric measurements, coupled with laparoscopic gender determination, enabled us to test whether discriminant function analysis was a useful method for non-invasively determining gender in White-browed Babblers. This equation uses a combination of wing length, tarsus length, and culmen length to determine gender. Field measurements of these variables are simple, and many researchers may already have these data, facilitating utilisation of this DFA for both past and future captures.

Others have presented DFAs useful for gender determination in a number of species but generally have reported higher levels of accuracy than those reported for the White-browed Babbler (Table 3). DFA could be a useful tool to identify gender in White-browed Babblers in conditions where long-term studies were being conducted and gender in a proportion of the populations could be confirmed by other means. Because the overlap in size measurements between small males and large females renders the DFA unreliable for these birds, alternate measures are necessary to determine gender. For instance, presence of a brood patch, dueting with a partner of known gender, or a comparison of measurements with a breeding partner may enable researchers to accurately sex White-browed Babblers.

Geographic variations in body size are apparent in White-browed Babblers, which occur as four subspecies in various parts of their extensive range (Higgins and Peters 2002). Such variation has been noted in other species (Zink and Remsen 1986; Clarke and Heathcote 1988), and in such situations, use of morphometric-based relationships to determine gender requires local confirmation. Thus, the DFA equation for White-browed Babblers would need to be validated for use at locales outside the central western region of New South Wales. We tried this for a small sample of birds from Western Australian (*P.s. ashbyi*, P. Cale pers. comm.) and NE Victorian (*P.s. superciliosus*, S. Taylor pers. comm.) babbler populations. Among a sample of 20 babblers from Western Australia, only six (30%) were correctly sexed and 14 (60%) fell within the zone of unreliability. Among a sample of six babblers from NE Victoria, four (66%) were correctly sexed, one (17%) male was incorrectly sexed, and one (17%) bird fell within the zone of unreliability. From these small datasets, the utility of the DFA outside central western NSW appears limited.

ACKNOWLEDGEMENTS

Thanks to P. Cale and S. Taylor who provided additional data on which to test the DFA. Assistance in the field was provided by Paul McDonald, Karen Fildes, Michael Jarmin, and Peter O'Brien. We appreciate permission and assistance provided by State Forests of NSW, and especially Ann Walton, Bill Faulkner, and Andrew Dean.

TABLE 3

Accuracy of gender determination by DFA (discriminant function analysis) in five avian species.

Species	Model accuracy (%)	Reference
Bell Miner *Manorina melanophrys*	94.6	Clarke and Heathcote 1988
Black-capped Chickadee *Parus atricappillus*	94	Desrochers 1990
Rockhopper Penguin *Eudyptes chrysocome*	93.2	Hull 1996
Royal Penguin *Eudyptes schlegeli*	97.1	Hull 1996
White-bellied Sea Eagle *Haliaeetus leucogaster*	92-100	Shephard *et al.* 2004
White-browed Babbler	82	N/A

REFERENCES

Brennan, L. A., Buchanan, J. B., Schick, C. T., Herman, S. G., and Johnson, T. M. (1984). Sex determination of Dunlins in winter plumage. Journal of Field Ornithology 55: 343-348.

Counsilman, J. J., Nee, K., Jalil, A. K., and Keng, W. L. (1994). Discriminant analysis of morphometric characters as a means of sexing Mynas. Journal of Field Ornithology 65: 1-7.

Clarke, M. F. and Heathcote, C. F. 1988. Methods for sexing and ageing the Bell Miner Manorina melanophrys. Emu 88: 118-121.

Desrochers, A. (1990). Sex determination of Black-capped chickadees with a discriminant analysis. Journal of Field Ornithology 61: 79-84.

Fisher, R. A. (1936). The use of multiple measurements in taxonomic problems. Annals of Eugenics 7: 179-188.

Gaunt, A. S., Oring, L. W., Able, K. P., Anderson, D. W., Baptista, L. F., Barlow, J. C. and Wingfield, J. C. (1997). 'Guidelines to the the use of birds in research'. (Eds A. S. Gaunt and L. W. Oring.) Pp. 1262 (Ornithological Council: Washington D.C.)

Genovart, M., McMinn, M., and Bowler, D. (2003). A discriminant function for predicting sex in Balearic Shearwater. Waterbirds 26: 72-76.

Gill, F. B. (2003). 'Ornithology.' (W.H. Freeman and Company: New York.)

Higgins P. J. and Peters, J. M. (Eds.). 2002. 'Handbook of Australian, New Zealand and Antarctic Birds. Vol. 6. Pardolotes to shrike-thrushes'. (Oxford University Press: Melbourne.)

Hull, C. L. (1996). Morphometric indices for sexing adult Royal Eudyptes schlegeli and Rockhopper E. chrysocome penguins. Marine Ornithology 24: 23-27.

Lachenbruch, P. A., and Goldstein, M. (1979). Discriminant analysis. Biometrics 35: 69-85.

Lachenbruch, P. A., and Mickey, M. R. (1968). Estimation of error rates in discriminant analysis. Technometrics 10: 1-11.

Oppenheimer, S. D. (2005). Endocrine correlates of social and reproductive behaviours in a group-living Australian passerine, the White-browed Babbler. PhD Thesis, University of Wollongong, Wollongong, Australia.

Pyle, P. (1997). 'Identification Guide to North American Birds- Part I.' (Slate Creek Press: Bolinas, CA).

Quinn, G. P., and Keough, M. J. (2002). 'Experimental Design and Data Analysis for Biologists.' (Cambridge University Press: Cambridge, UK.)

Rogers, K., Rogers, D. Lane, D and Male, B. 1986. 'Bander's Aid: A guide to ageing and sexing bush birds'. (A. Rogers: St.Andrews, Victoria).

Shephard, J. M., Catterall, C. P., and Hughes, J. M. (2004). Discrimination of sex in the White-bellied Sea-Eagle, Haliaeetus leucogaster, using genetic and morphometric techniques. Emu 104: 83-87.

Simpson, K. and Day, N. (1996). 'Field Guide to the Birds of Australia.' (Penguin Books Australia Ltd.: Ringwood, Victoria.)

SYSTAT™ 7.0 for Windows. (1997) SPSS, Inc.

Zink, R., and Remsen, J. (1986). Evolutionary processes and patterns of geographic variation in birds. In 'Current Ornithology'. (Ed. R. Johnston.) Pp. 1-69. (Plenum Press: New York.)