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Methods for sexing and ageing the Bell Miner *Manorina melanophrys*

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In the course of behavioural studies of several marked colonies of the Bell Miner *Manorina melanophrys* at Bundoora, 16 km NNE of Melbourne, Victoria (see Smith & Robertson [1978] for site details), methods for determining the sex and age of individuals were developed.

The plumage of Bell Miners is sexually monomorphic, as is typical of meliphagids. Both sexes possess brood patches and neither cloacal examination nor laparotomy were found to be useful in sexing individuals. Before this study an individual's sex could be determined only if it were observed copulating or performing the strictly female behaviours of building a nest, incubating eggs or brooding nestlings (Swainson 1970).

Similarly, before this study, it was not possible to reliably determine the age of a Bell Miner whose date of leaving the nest was unknown. Swainson (1970) defined three age-classes in Bell Miners based upon the colour of the patch of skin behind the eye. He (p. 183) recorded that 'in juveniles up to three months old this skin was olive-yellow, and then slowly became orange until the birds were six to eight months old, when it changed to red.' Birds with orange eye-patches were classified as immatures and those with red as adults. This paper presents the results of accurately monitoring these changes in eye-patch colour as birds aged.

Methods

Determining sex

Morphometric methods No single measurement was found which could be used to reliably differentiate between the sexes (Table 1). Measurements were taken of the closed wing, culmen, tail, tarsus and total body length (Disney 1974). The maximum vertical depth of the culmen (Fig. 1) and the total head length from the tip of the bill to the cerebellar prominence on the back of the head (Rogers *et al.* 1986) were also measured. The head and tarsus measurements were taken with calipers to 0.1 mm. The wing, tail and total length were measured with a ruler to 1 mm. Weight was too seasonally variable to be of value in discriminating between the sexes (see Rogers *et al.* 1986).

Rogers *et al.* (1986) attempted to discriminate between the sexes of birds using differences in the length of the wing between the sexes, using a method based on a curve-fitting approach (MacDonald & Pitcher 1979). They identified two distributions among their measurements of wing lengths of birds of unknown sex. Means and confidence limits for each of the two distributions were then estimated. One of the distributions was taken to represent males and the other females, based on their similarity to measurements obtained from known-sex birds held in museum collections. Only 38.5% of birds could be accurately sexed using this method (Rogers *et al.* 1986).

Discrimination using only one measurement is limited by the degree of overlap between the sexes for that measurement. There

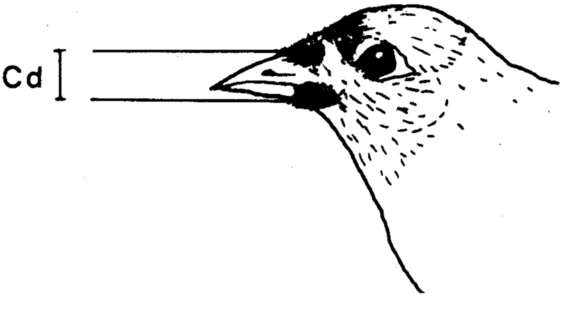

FIGURE 1 Culmen depth (Cd) was defined as the maximum vertical depth of the culmen, and measured to 0.1 mm using calipers.

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TABLE 1 Differences between the sexes in seven morphometric measurements. The data were taken from birds whose sex had been determined by observation of their behaviour or dissection (n = 24 for females and n = 13 for males).

Measurement	Female		Male	
	Mean (mm)	*s.d.*	Mean (mm)	*s.d.*
Wing length	92.9	1.9	98.2	1.8
Culmen length	14.4	1.2	15.1	0.6
Tail length	83.1	2.2	86.4	3.3
Tarsus length	21.9	1.4	23.2	2.1
Culmen depth	6.5	0.3	7.5	2.6
Total head length	37.0	1.2	38.3	0.9
Total body length	179.3	5.7	186.5	8.5

was overlap between the wing lengths of female and male Bell Miners of known sex sampled at Bundoora (wing lengths of females were as large as 97 mm and of males as small as 95 mm). The method of Rogers *et al.* (1986) also ignores the greater discriminating power that can be achieved by simultaneously using a combination of measurements to differentiate between the sexes.

Discriminant analysis was used in this study. It utilises the discriminating power of a combination of measurements of a bird to objectively predict its sex (Hanners & Patton 1985); other methods that have been applied to members of the genus *Manorina* have been poorly documented (e.g. Dow 1978).

Discriminant analysis enables a classification function to be determined, using a combination of measurements from birds of known sex, which can then be used to predict the sex of birds of unknown sex. The absolute magnitude of the classification score can be used by the program to calculate the probability (certainty) that a bird's sex has been correctly predicted (a feature not easily obtained from the method of Rogers *et al.* [1986]). The accuracy of the classification function can be tested by using it to identify the sex of known-sex birds and determining how many it identifies correctly.

Sex-specific vocalisation Pilot studies suggested that one vocalisation of the Bell Miner, described as the 'chuk-a-choo' call, might be sex-specific. Hence, colour-banded birds giving the vocalisation were identified on an opportunistic basis over a period of 22 mo (at least ten hours a week spent in the field). The incidence of breeders (whose sex was known) giving the vocalisation was used to determine whether it was indeed sex-specific.

Recordings of the 'chuk-a-choo' call were obtained for analysis using a Sony TC D5PRO stereo cassette recorder (using TDK SA60 tape) with a Sennheisser MKH 816T directional microphone. Sound analyses were made on a Kay model 6061B Sonagraph with a frequency range of 85-16000 Hz. Sonagrams were made using the narrow band width at half speed.

Determining age

The age of a bird was recorded as the number of months after the date of fledging. Because it was difficult to distinguish shades of orange from shades of red, a colour-chart (Smithe 1975) was used in this study to standardise the description of eye-patch colour and to refine the ageing method of Swainson (1970).

Results

Determining sex

Morphometric method Seven morphometric measurements from 37 birds of known sex (as represented in Table 1) were subjected to a stepwise discriminant analysis using Rao's V as programmed in the sub-program 'Discriminant' in SPSS (Nie *et al.* 1975). Wing length, culmen depth and tail length were, in combination, the most discriminating variables between the sexes. The classification function derived using these three measurements was:

$$C = (0.475 \times \text{wing length}) + (0.179 \times \text{culmen depth}) + (0.089 \times \text{tail length}) - 53.742$$

The function correctly classified the sex of 94.6% of the known-sex birds whose measurements were used to generate the function. It was less successful in classifying an independent sample of known-sex birds from throughout Victoria that were obtained from the Museum of Victoria's collection (Table 2). This reduction in success may be due, in part, to geographical variation in body size over the species' range in Victoria. For example, the tail length ($\bar{X}$ = 85.0, *s.d.* = 2.1) and culmen depth ($\bar{X}$ = 7.6, *s.d.* = 1.6) of female Museum specimens were significantly larger than those of Janefield females (t = 2.14, *d.f.* = 30, $P < 0.05$ for tail length, and t = 7.2, *d.f.* = 7 modified due to non-homogeneity of variances, $P < 0.05$). Sample sizes from different localities were inadequate to test for geographical variation in body size.

Where the function incorrectly classified birds of known-sex, the average certainty of its incorrect classifications were 0.67 and 0.83 for the Janefield and Museum samples respectively. Hence, birds of unknown sex were accepted as being of a particular sex only if they were classified with a probability of being correctly sexed of $\geq$

TABLE 2 Percentage of known-sex birds correctly sexed using the discriminant analysis classification function outlined in the text. n is the number of individuals in each sample. The Janefield sample includes the measurements of birds from four colonies in the Bundoora area. The Museum sample includes the measurements of birds from Victoria, held in the Museum of Victoria's collection.

	Janefield sample		Museum sample	
	% correctly sexed	n	% correctly sexed	n
Females	95.8	24	100.0	8
Males	92.3	13	69.2	13
Total	94.6	37	81.0	21

0.85. This meant that individuals whose classification score was between 0.08 and 1.22 were not able to be sexed. In addition, only individuals that were four or more months of age were sexed by discriminant analysis due to the fact that males grow through the female size-class. An exception was made if an individual of less than four months of age was classified as being a male with a probability of being correctly classified of ≥ 0.85.

Sex-specific vocalisation Eleven of 12 adult females were recorded as giving the 'chuk-a-choo' call and one as giving the 'a-choo' portion only; none of 12 males gave the call. All breeders included in the sample were present in the colony for at least one month, hence the absence of the vocalisation being recorded for males is unlikely to be a result of insufficient observation time. Thus, the 'chuk-a-choo' call is a vocalisation restricted to the female sex.

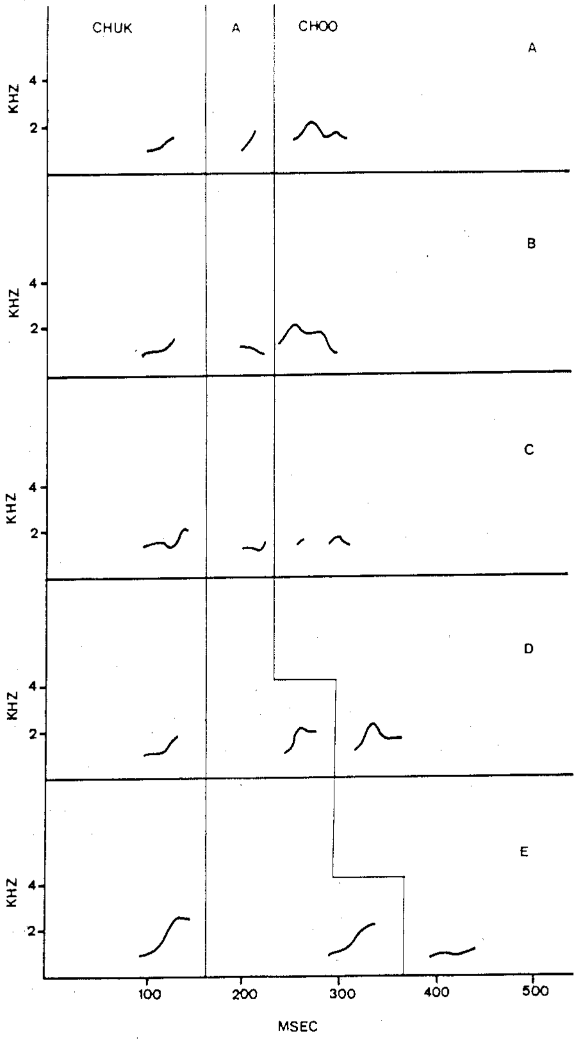

FIGURE 2 Tracings from sonagrams showing the fundamental frequency of the 'chuk-a-choo' call of five individuals. The syllables are separated by the vertical lines; the 'choo' syllable of individual C, though appearing to consist of two notes, is monosyllabic to the ear.

The spectral and temporal structure of the 'chuk-a-choo' call was found to be variable between individuals whilst relatively consistent within an individual. A representative tracing of fundamental frequency of the 'chuk-a-choo' call from each of five individuals, obtained from sonagrams, is shown in Figure 2.

The vocalisation is composed of three syllables and has a mean total duration of 240 ± 51 msec, with the first, second and third syllables being 39 ± 7 msec, 31 ± 12 msec and 54 ± 6 msec respectively. Confidence limits represent one standard error about the mean (n = 5), based upon the mean of five measurements from each of five individuals. The interval between the first and second syllable is 86 ± 28 msec, consistently longer than the interval between the second and third syllables (30 ± 14.5 msec). Fundamental frequency of the first syllable ('chuk') sweeps upward, as it does for the second syllable ('a'), with the exception of individual B. Fundamental frequency of the third syllable ('choo') has the shape of an inverted w, or part thereof.

Determining age

Six distinctive eye-patch colours were found to exist amongst 52 records of 41 different birds of known age (Table 3). The six eye-patch colours were clearly related to the age of the individuals and could therefore be used to estimate the age of birds whose date of fledging was unknown. Birds of unknown age that possessed flame scarlet eye-patches could only be classified as being at least

TABLE 3 Mean ages of birds possessing the indicated eye-patch colours. Age is given in months after fledging and colours are as represented and defined in Smithe (1975). The eye-patch colour of some birds was recorded before the use of the colour-chart, but only those birds with easily distinguishable eye-patch colours (i.e. colours 56, 54 and 18) were included in the analysis. 95% *c.l.* is the 95% confidence limit.

	Age		
Eye-patch colour (no.)	Mean	95% *c.l.*	*n*
Straw yellow (56)	0.92	0.19	6
Cream colour (54)	1.28	0.54	5
Orange yellow (18)	3.71	0.51	16
Spectrum orange (17)	5.58	0.72	8
Chrome orange (16)	9.12	2.33	10
Flame scarlet (15)	17.01	3.87	7

17.0 ± 3.87 months of age, as no change in eye-patch colour was detected beyond this age.

Discussion

Sexing

Two methods of sexing Bell Miners, not previously recorded in the literature, were developed. Discriminant analysis identified wing length, culmen depth and tail length when used in combination as the most discriminating characters for the identification of a bird's sex. Discriminant functions can be computed using a greater number of characters than three, as used here. Hence, collection of measurements of as many different, robust characters as possible (considering the comfort of the bird) should be encouraged, even when single characters may not appear to discriminate between the sexes.

The technique does have limitations, e.g. one sex may 'grow through' the size-class of the smaller sex, as is the case in Bell Miners; variation in morphometric measurements of birds from geographically separate populations may limit the applicability of the classification function calculated for birds from one region to birds from another region; and the accuracy of the classification function is limited by the consistency with which measurements are taken. Considering the small difference in wing and tail lengths between the sexes, the technique can not be used reliably to sex an individual that is undergoing moult or replacement of either its primary feathers 5-8 or its tail feathers.

Although discriminant analysis has been used in this way in several previous studies (e.g. Ryder 1978; Green 1982, Hanners & Patton 1985), this appears to be the first time the technique has been used to sex an Australian passerine. Considering the large number of sexually monomorphic passerine species in Australia and the increasing accessibility of computing facilities to field workers, the technique could have wide application.

A vocalisation restricted to the female sex was identified by long-term monitoring of the calling behaviour of known-sex individuals. This vocalisation can be recognised by its phonetic similarity to 'chuk-a-choo' pronounced very rapidly, even though there is measurable individual variation (recordings are available from the authors upon request). It is probable that other female-specific vocalisations also exist; whether such vocalisations are consistently sexually dimorphic throughout the species' range remains to be tested.

Ageing

Swainson's (1970) method of age determination based on eye-patch colour changes, was refined to include six distinguishable age-classes. This was achieved by using a colour-chart (Smithe 1975) to standardise the recording of eye-patch colour. Use of a colour-chart reduces the subjective nature of describing of body part colours, enabling greater discrimination between similar colours and, in the case of the Bell Miner, an increase in the number of distinguishable age-classes.

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