Corella, 2018, 42: 50-54

Use of alula shape for ageing Noisy Miners *Manorina melanocephala*: a critical evaluation

Jacob A. T. Vickers[1], Richard E. Major[2], Walter E. Boles[2] and Kris French[1]

[1]Centre for Sustainable Ecosystem Services, School of Biological Sciences,
University of Wollongong, Northfields Avenue, Wollongong, NSW 2522, Australia.
Email: jatvickers@gmail.com
[2]Australian Museum Research Institute, Australian Museum, 1 William St, Sydney, NSW 2010, Australia

Received: 14 September 2017
Accepted: 16 February 2018

We evaluated the use of the shape of the longest alula feather as an ageing characteristic for Noisy Miners *Manorina melanocephala* through the examination of 316 mature and 147 immature individuals that were independently aged using internal characteristics. Our results contrast with those of a previous study that suggested that the shape of the alula feather is diagnostic of age – juveniles were suggested to have a broad alula with a rounded tip, whilst matures have a narrow, pointed alula. We found that although immature Noisy Miners were more likely than matures to display a round alula, a round alula was also frequently recorded on mature individuals. We determined that the use of alula shape is an insufficient and unreliable ageing characteristic for this species.

INTRODUCTION

Ecological studies focussing on understanding the population processes of birds often require knowledge about the age of individuals (Sun 2001). Consequently, the ability to age birds has been the backbone of many studies on species conservation, invasive species management, survivorship, demography and the impacts of environmental stressors on avian populations (Brook *et al*. 2003; Sun *et al*. 2011; King *et al*. 2013; Shao *et al*. 2015; Diller *et al*. 2016). Many methods exist for age determination of passerines, including assessment of an individual's plumage, degree of skull pneumatisation, colour of bill and bare-skin patches, and behaviour (Miller 1946; Norris 1961; Counsilman and King 1977; Gargallo and Clarabuch 1995; Higgins *et al*. 2001; Jenni and Winkler 2011). Plumage is a popular ageing characteristic, as it is easy and quick if persistent plumage differences are present. However, in species that undergo a complete post-juvenile moult into an adult-like, first immature plumage, ageing using plumage is constrained to a simple assessment of adult versus juvenile. In such species, non-juvenile plumages can be particularly difficult to age, and require alternative ageing techniques.

The Noisy Miner *Manorina melanocephala*, like many other passerines, fledges in a distinct juvenile plumage (Higgins *et al*. 2001). Sometime after fledging, the first immature plumage is acquired through either a partial or complete post-juvenile moult, which may be dependent upon fitness, diet, and environmental conditions (Jenni and Winkler 2011; Minias and Iciek 2013; Kiat and Izhaki 2016). Complete post-juvenile moult results in plumage indistinguishable from that of adults, whilst a partial post-juvenile moult is adult-like, but distinguishable by retained juvenile inner primaries, secondaries, and/or alula (Dow 1973; Higgins *et al*. 2001). When about one year old, most Noisy Miners undergo the second pre-basic moult from immature to adult plumage (Higgins *et al*. 2001). As the Noisy Miner displays no alternative clear indicator of age, such as the eye-patch colour of the closely related Bell Miner *M. melanophrys* (Clarke and Heathcote 1988), the development of alternative ageing techniques for field identification is necessary.

Differences between juveniles and adults in the shape of the longest feather of the alula have been proposed as an alternative method of identifying adult-like first immatures (Matthew 1999): it is suggested that juveniles have a broad alula with a rounded tip, whereas birds with a narrow, pointed alula are thought to be adults. Matthew (1999) proposed that this was the case for 43 species of Meliphagidae, including the Noisy Miner, and found it 'probable that these birds replace the juvenile alula in the second pre-basic moult, when about one-year old'. His study used museum skins of immature and adult birds to assess differences in the shape of the alula. Although alula shape was shown to be an accurate ageing characteristic for live birds of closely related species (Clarke *et al.* 2002), there has been no critical evaluation of its reliability as an ageing characteristic for Noisy Miners that are not aged as museum specimens.

Whilst undertaking a study involving the dissection of Noisy Miners, the opportunity arose to record both external characteristics and internal anatomy to investigate ageing criteria. The aim of this study is to determine whether the shape of the longest feather of the alula is a reliable characteristic for age determination of live Noisy Miners.

METHODS

We analysed Noisy Miner carcasses collected from a study involving the experimental removal of this species from remnant *Eucalyptus* woodlands (Davitt 2016). The removals took place in August and September 2015 and April 2016 near Fifield, New South Wales (-32.808 S, 147.463 E), within the Western Slopes Bioregion of south-eastern Australia. Carcasses were frozen until this study commenced in February 2017.

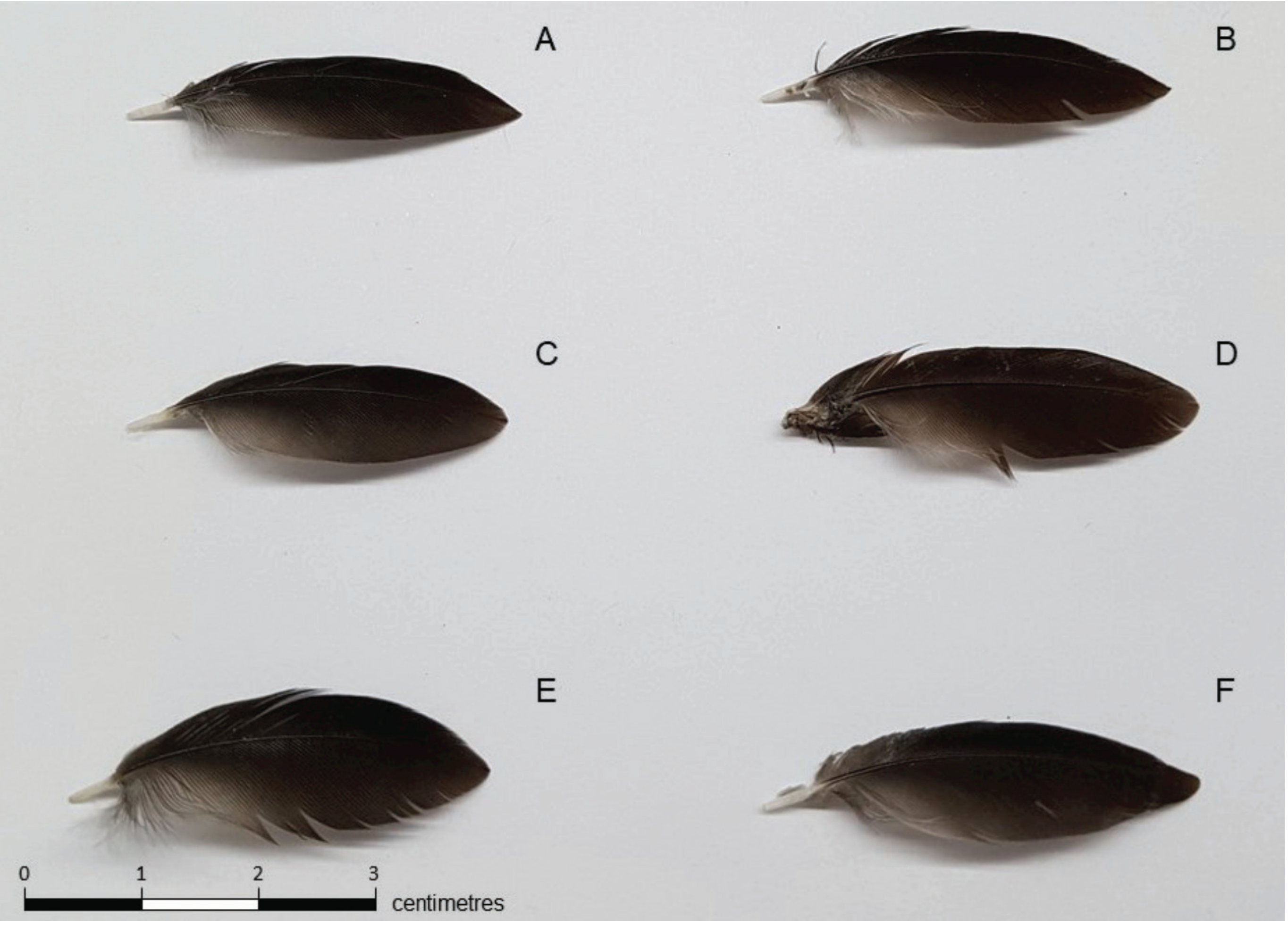

Figure 1. *Examples of the longest feather of the right alula taken from individuals of different ages as defined by dissection. A) Sharp alula taken from an immature; B) Sharp alula taken from a mature; C) Round alula taken from an immature; D) Round alula taken from a mature; E) Ambiguous alula classed as round; F) Ambiguous alula classed as sharp.*

The longest feather of the right alula of each Noisy Miner was examined and classed as either 'round' or 'sharp', following the diagram in Matthew (1999). However, this classification was problematic, as the alula's shape was often ambiguous (Fig. 1). Following this, dissections were used to determine the age of birds by assessing the degree of skull pneumatisation, the presence of a bursa of Fabricius (hereafter bursa) and the state of the oviduct in females. Skull pneumatisation was assessed by peeling back the skin after making an incision in the crown, and classified as either 'minimal', 'partial', or 'complete'. The bursa was classed as 'present' or 'absent', and oviducts were examined and classed as 'straight' or 'convoluted'. A convoluted oviduct indicates that the bird has previously laid an egg (Christians and Williams 1999; Vézina and Williams 2003).

Noisy Miners are capable of breeding after their first year (Dow 1978), and the minimum breeding age of the closely-related Bell Miner is 8.3 months (Clarke and Heathcote 1990). Therefore, Noisy Miners with convoluted oviducts were assumed to be at least eight months old. As it is not known at what age the Noisy Miner's skull becomes completely pneumatised, or at what age the bursa regresses, an exact age could not be determined from these characteristics. They are good candidates for assessing the state of maturity, however, as songbirds generally complete pneumatisation by 4-8 months of age (Serventy *et al*. 1967), and the bursa (an immunosuppressive organ in young birds) generally regresses after 2-6 months, depending on the species (Glick 1983; Ciriaco 2003). Therefore, all individuals with a bursa were considered 'first immatures', as were all Noisy Miners with minimal or partial skull pneumatisation (Dow 1978). For the purposes of this study, all other birds were classified as 'mature', recognising that this category will be over-represented.

After a training phase to develop consistent categorisation and measurement, which involved dissection and analysis of 271 specimens in consultation with experienced museum ornithologists, data were collected on 476 individual miners by a single researcher (JV). Data were analysed and significance was tested using contingency tables and associated Chi-square and Fisher's Exact tests. Statistical analyses were performed using JMP Pro software version 11 and IBM SPSS software version 21.

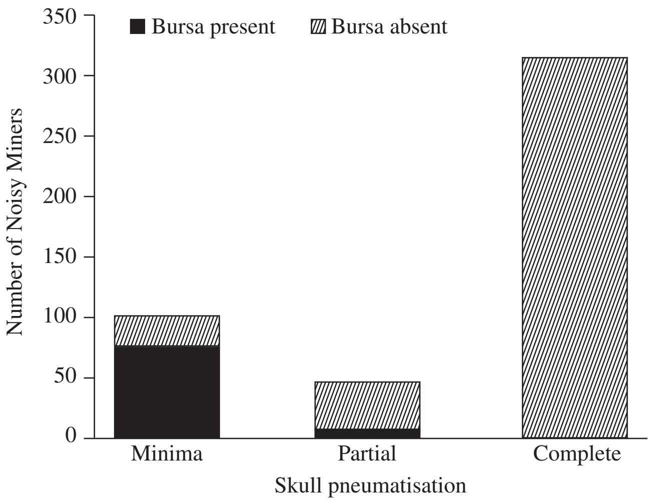

Figure 2. *The number of Noisy Miners with various degrees of skull pneumatisation – Minimal, Partial and Complete. Black bars represent birds with a bursa of Fabricius; striped bars represent birds with a regressed bursa.*

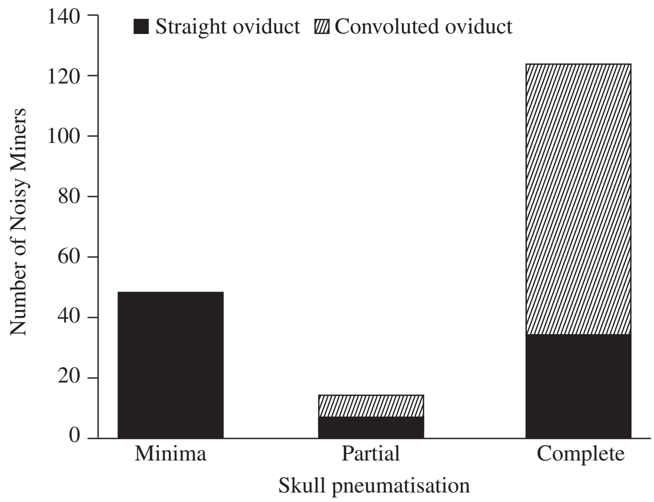

Figure 3. *The frequency of straight and convoluted oviducts among 186 female Noisy Miners with minimal, partial and completely pneumatised skulls.*

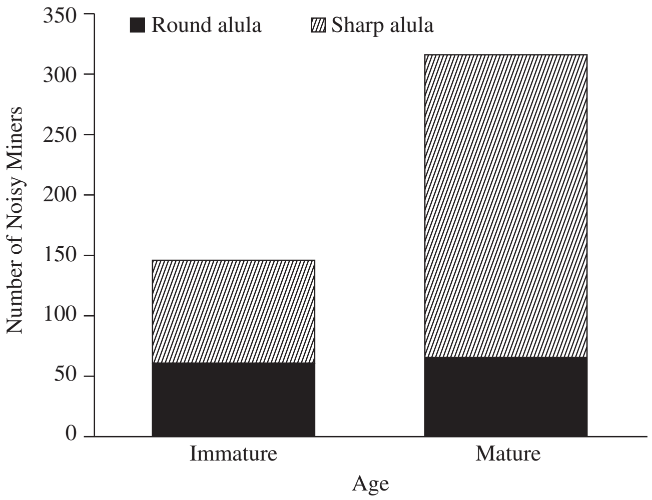

Figure 4. *The number of immature and mature Noisy Miners (as defined by dissection) with a round or a sharp alula.*

RESULTS

Of the 476 birds examined, 101 (21.2%) showed minimal pneumatisation (clear skull), 46 (9.7%) showed partial pneumatisation, and 316 (66.4%) showed complete pneumatisation, with 13 (2.7%) being unclassifiable due to excessive damage (Fig. 2). The probability of an individual having a bursa declined with degree of skull pneumatisation ($\chi^2_2 =$ 289.8, N = 463, $p < 0.001$), as it was present in 74.3%, 15.2% and 0% of birds with minimal, partial, and complete pneumatisation, respectively. Using the criterion that mature birds had both a regressed bursa and full skull pneumatisation, 316 miners were classed as mature, with the remaining 147 being classed as immature.

All birds were anatomically sexed, and the state of the oviducts in 186 females was determined. There was a difference in the proportion of females with convoluted oviducts between birds of different ages, based on skull pneumatisation (χ^2_2 = 73.1, N = 186, $p < 0.001$). None of the 48 birds showing minimal pneumatisation had convoluted oviducts, 50% (n = 14) of individuals showing partial pneumatisation had convoluted oviducts, and 72.6% (n = 124) of individuals exhibiting complete pneumatisation had convoluted oviducts (Fig. 3). No birds that showed any sign of a bursa had a convoluted oviduct.

Using the criterion that mature birds had both a regressed bursa and a fully pneumatised skull, the probability of an immature Noisy Miner having a round alula (Fig. 4) was greater than that for an adult (Fisher's Exact, p < 0.0001, n = 460; Fig. 4). Round alulas were found on 40.7% (n = 145) of immature miners and on 20.3% (n = 315) of mature miners (Fig. 4).

There was a seasonal difference in the proportion of birds with round alulas (Fisher's Exact, p = 0.0129, n = 460; Fig. 5). Immature birds sampled in spring 2015 had a greater proportion of round alulas than did matures (Fisher's Exact, p < 0.0001, n = 283; Fig. 5), with 66.7% (n = 27) of immature and 18.0% (n = 163) of mature miners having round alulas. However, birds sampled in autumn 2016 showed no difference in the proportion of round alulas between age classes (Fisher's Exact, p = 0.615, n = 177; Fig. 5), with 34.8% (n = 118) of immatures having round alulas, compared with 30.5% (n = 59) of matures. Additionally, the probability of an individual having a round alula did not differ between sexes (Fisher's Exact, p = 0.667, n = 447).

DISCUSSION

This study demonstrated that age determination in Noisy Miners using both anatomical and field characters is complex. The presence of a bursa of Fabricius and incomplete skull pneumatisation were clearly associated with younger birds, but neither character was completely reliable. Some birds with negligible pneumatisation had a regressed bursa and some with a large bursa exhibited partial pneumatisation. However, as the frequency of individuals having a bursa decreased from birds with minimal to partial pneumatisation, and was not

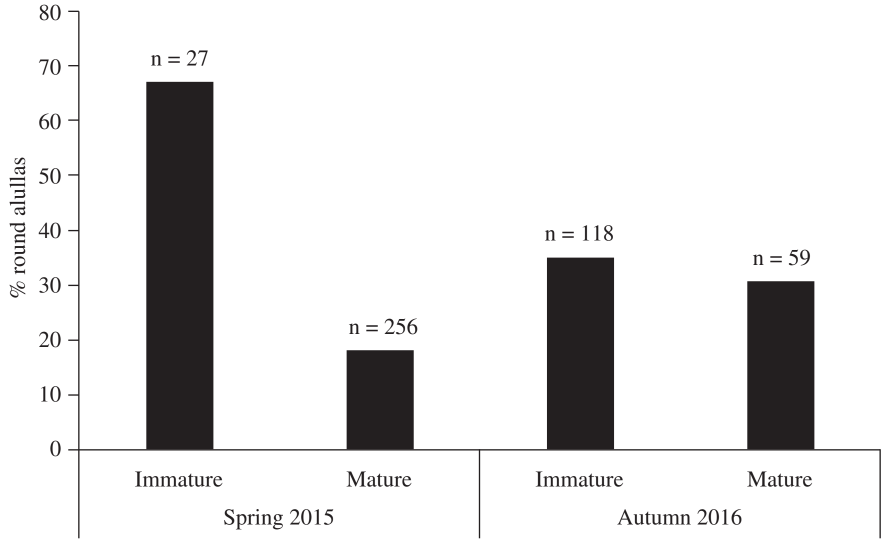

Figure 5. *Seasonal variation in the proportion of Noisy Miners with a round alula for birds of different age as defined by dissection.*

found at all in birds with complete pneumatisation, the bursa is probably regressing well before the skull becomes completely pneumatised. Additionally, as Noisy Miners with convoluted oviducts are assumed to be at least eight months old, and half the birds showing partial pneumatisation had convoluted oviducts, it appears that complete pneumatisation may occur after eight months of age. Alternatively, some females may breed when less than eight months old. Without known-age birds or reliable anatomical ageing characters, evaluating the reliability of alula shape as a field character for ageing miners proved to be challenging. Furthermore, many alula feathers were ambiguously shaped, and their assignment as ‘round’ or ‘sharp’ was difficult and subjective.

There was a significant association between age and alula shape, with immatures having twice the incidence of round alulas as matures. However, a significant proportion of mature individuals also had a round alula, demonstrating that this character is not diagnostic. Furthermore, the majority of immatures in the autumn sample, most of which hatched in the previous spring (Morris *et al*. 1981), displayed a sharp alula, suggesting that round alulas can be lost well before about six months of age. Although it is likely that a small proportion of birds were incorrectly classified as mature based on our anatomical definition, this discrepancy alone cannot explain the large number of mature Noisy Miners having a round alula. There was an unexpected seasonal effect on the proportion of individuals with a round alula, as immature miners were far more likely than matures to exhibit a round alula in spring compared with autumn, when the proportion of round alulas did not differ between ages. However, the small sample size of immatures in spring should be noted. It is plausible that the seasonal effect may be related to variation in the month in which post-juvenile moult occurs, associated with there being spring and autumn nesting peaks in this species (Higgins *et al.* 2001). Samples of known-age birds are necessary to resolve this uncertainty.

It is conceivable that the removal treatment itself may have had an unforeseen effect on the development of individuals, influencing the frequency distribution of alula shape in the autumn sample. Specifically, only one third of immature birds had a round alula in autumn, much less than the proportion in the initial spring removal sample. Birds sampled in autumn were collected from the same sites as the spring sample, so they were likely to be ‘re-colonisers’, rather than an independent sample of birds (Davitt 2016). Reduced intraspecific competition and the consequent increase in food availability per capita may influence the proportion of ‘first immatures’ that undergo complete post-juvenile moult (Minias and Iciek 2013; Kiat and Izhaki 2016), resulting in a lower proportion of immatures with a round alula. It could also be that an extensive post-juvenile moult is beneficial for immatures entering habitat free of well-established Noisy Miner colonies, because it reduces their juvenile characteristics, increasing their dominance status and hence their ability to compete in the following winter (Gosler 1994). Given the complexity of Noisy Miner social structure (Dow 1979; Higgins *et al*. 2001), it is possible that disruption of colonies may be a driver of unusual development patterns, in addition to the more usual factors of season, competition and food availability.

Alula feather shape is evidently an inconsistent ageing characteristic for Noisy Miners. Matthew (1999) suggested that it was a good ageing characteristic to use when an immature has moulted its juvenile primaries, secondaries and coverts and is identical to adults and he argued that it is broadly applicable to 43 species of Meliphagidae. Although Clarke *et al*. (2002) found that alula shape was an effective ageing characteristic in Black-eared *Manorina melanotis* and Yellow-throated *M. flavigula* Miners, this is not the case for the closely-related Noisy Miner. Whilst it is true that an immature Noisy Miner is more likely than a mature to have a round alula, the use of this feature as an ageing characteristic for either a single individual or a population is not appropriate; it should only be used as a rough guide, if at all.

The unexpected variability in anatomical characters observed in this study resulted in uncertain estimates of the reliability of alula shape as a field character. This variability also highlights the problem of defining maturity in Noisy

Miners. Our results imply that both 'plumage maturity' and 'sexual maturity' can be attained in a substantial proportion of individuals within the first eight months of age, based on our unquantified assumption that "physical maturity" reflected by bursa and skull development is complete by this age. Given this variability, it appears that reliability of alula shape as an ageing character could only be determined by an investigation of marked known-age birds, which will entail monitoring them from fledging. Such an approach is feasible, given that long-term colour-banding studies are in train (Barati *et al*. 2016), but it would be labour-intensive if reliable sample sizes are to be obtained. However, even without knowing the magnitude of error involved in alula-based age determination, it is clear this is not a reliable ageing character. Further studies are needed to determine the rate of skull pneumatisation in the Noisy Miner and the age at which the bursa of Fabricius begins to regress. With this information, a more accurate assessment of the utility of alula shape as an ageing criterion could be achieved and would allow future studies to explore the effects of intraspecific interactions, food availability and season on the shape of the alula feathers.

ACKNOWLEDGEMENTS

We would like to thank Farzaneh Etezadifar, Kim Maute, Shae Jones, Ebony Zderic, and Sabrina Velasco for preliminary assessment and evaluation of alula shape. This study used specimens collected from a project assisted by the New South Wales Government through its Environmental Trust. We are grateful to Ian and Moira Sirett for their assistance in collecting Noisy Miner carcasses. The initial study was authorised by scientific license S101522 under the NSW National Parks and Wildlife Act, with ethics approval granted by the Australian Museum Animal Care and Ethics Committee under the approval number 15/04.

REFERENCES

Barati, A., Etezadifar, F. and McDonald, P. G. (2016). Fragmentation in eucalypt woodlands promotes nest-tree occupancy by a despotic species, the noisy miner (*Manorina melanocephala*). *Austral Ecology* **41**: 897-905.

Brook, B. W., Sodhi, N. S., Soh, M. C. K. and Haw Chuan, L. (2003). Abundance and projected control of invasive house crows in Singapore. *Journal of Wildlife Management* **67**: 808.

Christians, J. K. and Williams, T. D. (1999). Organ mass dynamics in relation to yolk precursor production and egg formation in European starlings *Sturnus vulgaris*. *Physiological and Biochemical Zoology* **72**: 455-61.

Ciriaco, E. (2003). Age-related changes in the avian primary lymphoid organs (thymus and bursa of fabricius). *Microscopy Research and Technique* **62**: 482-487.

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

Clarke, M. F. and Heathcote, C. F. (1990). Dispersal, survivorship and demography in the co-operatively-breeding Bell Miner *Manorina melanophrys*. *Emu* **90**: 15-23.

Clarke, R. H., Boulton, R. L., Ewen, J. G., Moysey, E. and Clarke, M. F. (2002) Methods for ageing and sexing the Black-eared Miner *Manorina melanotis* and Yellow-throated Miner *M. flavigula*. *Emu* **102**: 339-344

Counsilman, J. J. and King, B. (1977). Ageing and sexing the Grey-crowned Babbler (*Pomatostomus temporalis*). *Bird Behavior* **1**: 23-41.

Davitt, G. P. (2016). The effectiveness of noisy miner removal in restoring diverse avian communities in woodlands of Central New South Wales. BEnvSc(Hons) thesis, University of Queensland, Brisbane.

Diller, L. V., Hamm, K. A., Early, D. A., Lamphear, D. W., Dugger, K. M., Yackulic, C. B., Schwarz, C. J., Carlson, P. C. and McDonald, T. L. (2016). Demographic response of northern spotted owls to barred owl removal. *Journal of Wildlife Management* **80**: 691-707.

Dow, D. D. (1973). Flight moult of the Australian honeyeater, *Myzantha melanocephala* (Latham). *Australian Journal of Zoology* **21**: 519-532.

Dow, D. D. (1978). Breeding biology and development of the young of *Manorina melanocephala*, a communally breeding honeyeater. *Emu* **78**: 207-222.

Dow, D. D. (1979). Agonistic and spacing behaviour of the noisy miner *Manorina melancephala,* a communally breeding honeyeater. *Ibis* **121**: 423-436.

Gargallo, G. and Clarabuch, O. (1995). Extensive moult and ageing in six species of passerines. *Ringing & Migration* **16**: 178-189.

Glick, B. (1983). Bursa of Fabricius. In: *Avian Biology* (Eds. J. R. King and K. C. Parkes). Pp. 443-500. Academic Press, San Diego.

Gosler, A. G. (1994). Mass-change during moult in the Great Tit *Parus major*. *Bird Study* **41**: 146-154.

Higgins, P. J., Peter, J. M. and Steele, W. K. (Eds.) (2001). *Handbook of Australian, New Zealand and Antarctic birds, Vol. 6. Tyrant-flycatchers to chats*. Oxford University Press, Melbourne.

Jenni, L. and Winkler, R. (2011). *Moult and ageing of European passerines*. 1st edn. A. & C. Black Publishers Ltd, London.

Kiat, Y. and Izhaki, I. (2016). Why renew fresh feathers? Advantages and conditions for the evolution of complete post-juvenile moult. *Journal of Avian Biology* **47**: 47-56.

King, R. S., Trutwin, J. J., Hunter, T. S. and Varner, D. M. (2013). Effects of environmental stressors on nest success of introduced birds. *Journal of Wildlife Management* **77**: 842-854.

Matthew, J. S. (1999). A new method for ageing some species of Meliphagidae. *Corella* **23**: 69-71.

Miller, A. H. (1946). A method of determining the age of live passerine birds. *Bird Banding* **17**: 33-5.

Minias, P. and Iciek, T. (2013). Extent and symmetry of post-juvenile moult as predictors of future performance in Greenfinch *Carduelis chloris*. *Journal of Ornithology* **154**: 465-8.

Morris, A. K., McGill, A. R. and Holmes, G. (1981). *Handlist of birds in New South Wales*. New South Wales Field Ornithologists Club, Sydney.

Norris, R. A. (1961). A modification of the Miller method of ageing live passerine birds. *Bird-Banding* **32**: 55-57.

Serventy, D. L., Nicholls, C. A. and Farner, D. S. (1967). Pneumatization of the cranium of the Zebra finch *Taeniopygia castanotis*. *Ibis* **109**: 570-578.

Shao, M., Chen, B., Cui, P., Dai, N. and Chen, H. (2015). Sex ratios and age structure of several waterfowl species wintering at Poyang lake, China. *Pakistan Journal of Zoology* **48**: 839-844.

Sun, R. Y. (2001). *Principles of Animal Ecology. 3rd edn.* Bejing University Press, Beijing.

Sun, Y., Bridgman, C. L., Wu, H., Lee, C., Liu, M., Chiang, P. and Chen, C. (2011). Sex ratio and survival of Mandarin ducks in the Tachia river of Central Taiwan. *Waterbirds* **34**: 509-513.

Vézina, F. and Williams, T. D. (2003). Plasticity in body composition in breeding birds: what drives the metabolic costs of egg production? *Physiological and Biochemical Zoology* **76**: 716-730.