Use of spider silk for nest building by the Regent Honeyeater *Anthochaera phrygia* and the Helmeted Honeyeater *Lichenostomus melanops cassidix*

Petah A. Low[1], Warrick J. Angus[2], Amie Wagner[2], Dave Wilkin[2], Michael Shiels[2], Robert Dockerill[2] and Dieter F. Hochuli[1]

[1] School of Biological Sciences, Heydon-Laurence Building (A08), The University of Sydney, NSW, 2006, Australia

[2] Taronga Zoo, PO Box 20 Mosman, NSW, 2088

Correspondence to PAL: Email: petah.low@sydney.edu.au

ABSTRACT

The Regent Honeyeater *Anthochaera phrygia* and Helmeted Honeyeater *Lichenostomus melanops cassidix* have both suffered a dramatic decline in number and reduction in range as a result of extensive habitat clearance. As part of recovery plans aimed toward reintroduction to the wild, both species are part of an intensive captive breeding program being conducted at a number of institutions, including Taronga Zoo, Sydney. These honeyeaters incorporate arthropod silk into their nests, as has been reported for other small passerines. However, little is known about how birds choose and use the silk that they collect during nest building. We presented breeding pairs with cribellate silk from the Black House Spider *Badumna* sp. and ecribellate silk from the Golden Orb-weaver *Nephila plumipes* or 'clean/fresh' and 'dirty/old' *Badumna* sp. silk and observed which were taken by the birds. *Lichenostomus melanops cassidix* showed a preference for the cribellate silk of *Badumna* sp., always selecting this silk type first. Nevertheless, the ecribellate silk of *N. plumipes* was also taken occasionally. *Anthochaera phrygia*, on the other hand, showed no clear preference for the silk of either *Badumna* sp. or *N. plumipes*, though they did display a preference for clean/fresh *Badumna* sp. silk, which was selected more often than dirty/old *Badumna* sp. silk. Dissection of an *A. phrygia* nest indicated that silk is used within the nest to help bind the other nest materials. These observations suggest that passerines may select silk non-randomly for use within their nests, possibly preferring clean/fresh cribellate silk.

Key words: captive breeding program, cribellate silk, ecribellate silk, honeyeater, nest, passerines, spider silk.

DOI: http://dx.doi.org/10.7882/AZ.2013.001

Introduction

Captive breeding programs can play an important role in the recovery of endangered species by providing a source of individuals for release into the wild (Conde *et al.* 2011). However, to successfully maintain and breed a species in captivity requires an adequate understanding of the species' needs and behaviour to establish effective captive breeding protocols (Snyder *et al.* 1996; Zhang *et al.* 2004; Swaisgood 2007). The development and continued refinement of husbandry techniques constitutes an essential part of all captive breeding programs (Snyder *et al.* 1996; Bradley *et al.* 1999).

The Regent Honeyeater *Anthochaera phrygia* (formerly *Xanthomyza phrygia*) and the Helmeted Honeyeater *Lichenostomus melanops cassidix* are both currently the subject of intensive captive breeding programs (Menkhorst *et al.* 1999a and 1999b). Both species are classified as endangered under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and have suffered a significant decline in number and contraction in range as a result of habitat clearance and competition for remaining resources (Higgins *et al.* 2001). *Anthochaera phrygia* has disappeared from South Australia and western Victoria and now has only a scattered distribution along the inland slopes of the Great Dividing Range in New South Wales and north-eastern Victoria (Menkhorst *et al.* 1999a). *Lichenostomus melanops cassidix* has a restricted and patchy distribution which is confined to the mid-Yarra and Western Port catchments of southern Victoria (Menkhorst *et al.* 1999b). It is estimated that fewer than 1500 *A. phrygia* (Webster and Menkhorst 1991) and 103 *L. m. cassidix* (Menkhorst *et al.* 1999a) remain in the wild. The captive breeding programs, which are being conducted at a number of institutions including Taronga Zoo in Sydney, are designed to supplement these dwindling wild populations.

One of the challenges of captive breeding programs is providing the right materials to captive birds, including materials required for nest building. The use of silk in nest building has been recorded in species from 25 of the 45 passerine families (Hansell 1993; Hansell 2005). Silk may serve a number of functions within a nest. For example, silk can be an important structural material, used to attach the nest to surrounding branches or within the nest for holding other nest materials together (Collias and Collias 1984). Silk is also used in nest lining because it is an ideal insulator, conferring softness and enhancing thermal conditions, important for the adequate development and care of eggs and nestlings (Calvelo *et al.* 2006). A potential function in nest concealment has also been proposed to explain observations in some species of the application of silk to the external surface of the nest for no obvious structural or mechanical reason (Hansell 1996; Calvelo *et al.* 2006). Alternatively, the external covering of silk may act as a temperature-controlling device by reflecting radiation (Hansell 2000). Despite the widespread use and importance of silk in nest building, little is known about how selective birds are in their choice of silk for use within their nests.

Spiders produce many different types of silk that they use for various purposes, including the wrapping of prey items and the construction of retreats, cocoons and capture devices (Foelix 1996). There are two types of capture silk used in spider webs: those produced by cribellate and by ecribellate spiders (Hansell 1993). Cribellate spiders have a spinning organ known as the cribellum, in addition to the six spinnerets possessed by most spiders, which is a small plate situated in front of the spinnerets (Vollrath 2006). The silk produced by the cribellum is drawn out by combs on the spider's back legs to form dry capture threads composed of a hackled band of tiny coiled threads (Vollrath 2006). Insects are captured when their hairs or spines become ensnared in the tangle of fine cribellar threads (Hansell 1993). Ecribellate spiders, on the other hand, lack a cribellum and instead produce wet capture threads which capture insects via viscid, sticky droplets of water-based glycoprotein glue (Hansell 1993; Vollrath 2006). In addition to their different capture principle, ecribellate silks are generally thicker, more extensible and lower in strength than cribellate silk (Hansell 1993; Blackledge and Hayashi 2006; Swanson *et al.* 2007). These fundamental differences between the properties of cribellate and ecribellate silk could influence their suitability for use by birds in nest building.

Anthochaera phrygia and *L. m. cassidix,* like many other small passerines, incorporate arthropod silk into their nests (Beruldsen 2003), however little is known about the role of silk within their nests or the specialisation in choice that may be involved. The aim of this study was therefore to investigate silk use for nest-construction by these two species of endangered honeyeater. In particular we aimed to make observations on (1) whether silk type (cribellate vs. ecribellate) or silk condition/age could influence selection and (2) how silk is employed within the nest.

Materials and Methods

The study was undertaken at Taronga Zoo, Sydney, where both honeyeater species are being bred. Four *A. phrygia* breeding pairs and two *L. m. cassidix* breeding pairs were available for study.

Silk type

To investigate whether the type of silk could influence its selection by birds, we presented two *A. phrygia* breeding pairs and two *L. m. cassidix* breeding pairs with cribellate silk from the Black House Spider *Badumna* sp. and ecribellate silk from the Golden Orb-weaver *Nephila plumipes*, the two most abundant and locally available spider species. Each breeding pair was presented with silk on five occasions during August and September 2008. On each occasion similar amounts of both silk types were presented, twisted around the ends of forked implements constructed from wire and sturdy sticks (Figure 1). The birds were subsequently watched for 30 minutes and their selections recorded. A silk was recorded as having been 'selected' when the bird collected some from the fork and returned with it in the direction of the nest, which was often concealed among the foliage within their enclosures. We examined (i) the number of times each silk type was selected and (ii) the number of times each silk type was selected first, however due to small sample sizes it was not possible to compare these statistically.

Figure 1. Regent Honeyeater *Anthochaera phrygia* taking silk which has been twisted around a forked implement constructed from wire and a strong stick. Photo, P. Low.

Silk condition/age

To investigate whether the condition/age of the silk could influence its selection by birds, another series of observations were made on three *A. phrygia* breeding pairs during September and October 2008. On each occasion, breeding pairs were presented with six forks, three of which held 'clean/fresh' cribellate silk, while the other three held 'dirty/old' cribellate silk (all silk was from *Badumna* sp.). Dirty/old silk was characterized by the accumulation over time of small particles of dirt and debris, which was absent from freshly produced 'clean' silk. The birds were again observed for 30 minutes to record their selections. Silk was presented a total of 11 times; one breeding pair was presented with silk on four occasions, another on five occasions and the third on two occasions. We examined the number of times each silk type was selected, but again did not perform any statistical analyses due to limited replication and non-independence of data points.

Acquisition of silk for presentation to birds

Approximately twenty *Badumna* sp. were collected from the wild and housed in glass jars. An empty film canister had been glued to the bottom of each jar to provide somewhere for the spiders to retreat during the collection of silk. Black netting was used to cover the opening of the jars to allow ventilation and this was secured with a rubber band. The jars were kept on their sides to encourage the production of silk along their length. Each spider was fed a single meal worm each week and sprayed lightly with water. The silk produced by these spiders was used for the first series of observations on 'silk type' and as the clean/fresh silk for the second series of observations on 'silk condition/age'. *Nephila plumipes* silk was collected from wild webs, while the dirty/old *Badumna* sp. silk was collected mainly from abandoned wild webs.

Nest Dissection

A close examination and dissection of an *A. phrygia* nest, from a previous year's breeding season, was made to investigate the possible function served by any silk used in nest construction. Observations were made with the aid of a dissection microscope.

Results

Silk type

Anthochaera phrygia took the silk of both *Badumna* sp. and *N. plumipes* approximately equally, while *L. m. cassidix* took the cribellate silk of *Badumna* sp. more often than the ecribellate silk of *N. plumipes* (Figure 2). *Badumna* sp. silk was always selected first by *L. m. cassidix*, while the two *A. phrygia* breeding pairs displayed different preferences; *Badumna* sp. silk was selected first all five times by one pair (RH1) but was selected first on only one of five occasions by the second pair (RH2) (Figure 3). Only female birds of both species were observed collecting silk.

Silk condition/age

All three *A. phrygia* breeding pairs appeared to prefer clean/fresh *Badumna* sp. silk over dirty/old silk (Figure 4).

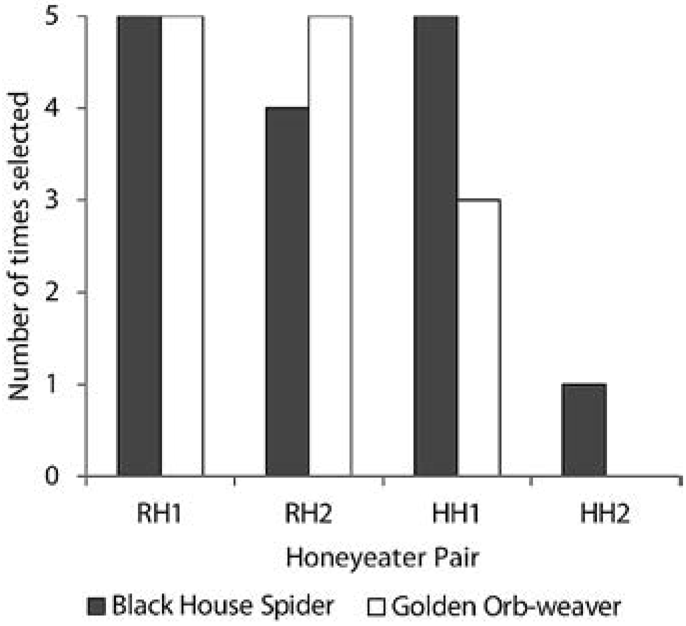

Figure 2. Selection of Black House Spider *Badumna* sp. (cribellate) and Golden Orb-weaver *Nephila plumipes* (ecribellate) silk by Regent Honeyeater *Anthochaera phrygia* (RH) and Helmeted Honeyeater *Lichenostomus melanops cassidix* (HH) breeding pairs. The two silk types were offered to each breeding pair a total of five times.

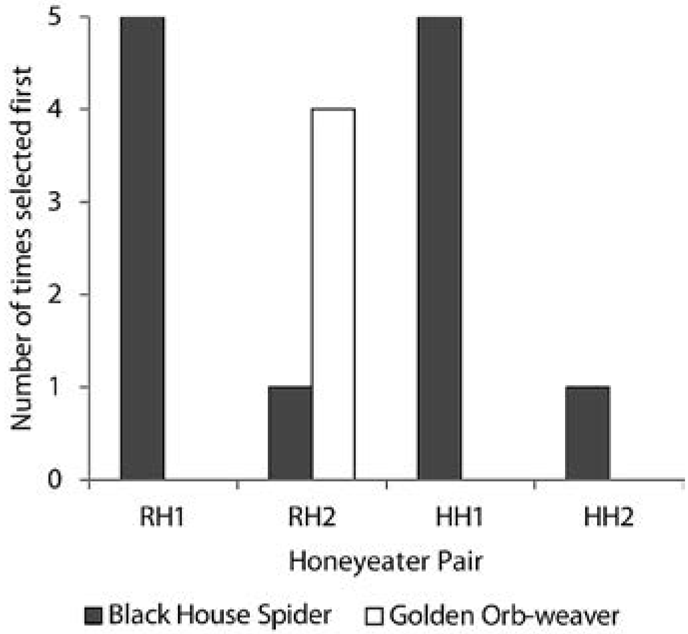

Figure 3. First choices made by Regent Honeyeater *Anthochaera phrygia* (RH) and Helmeted Honeyeater *Lichenostomus melanops cassidix* (HH) breeding pairs when offered Black House Spider *Badumna* sp. (cribellate) and Golden Orb-weaver *Nephila plumipes* (ecribellate) silk. Silk was offered to each breeding pair five times.

Dirty/old silk was generally only taken when no clean/fresh silk remained, except on one occasion when all of the dirty/old silk was taken first. Unusually, with this pair (RH1) it was the male that was collecting the silk and constructing the nest.

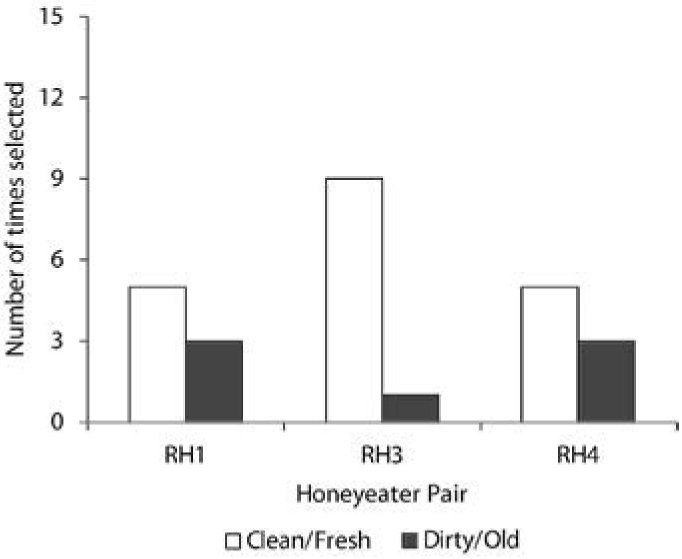

Figure 4. Selection of clean/fresh and dirty/old Black House Spider *Badumna* sp. silk by Regent Honeyeaters *Anthochaera phrygia.* A test involved presenting a breeding pair with three forks of clean/fresh silk and three forks of dirty/old silk. RH1 was tested on four occasions, RH3 on five occasions and RH4 on two occasions. Thus each silk type could be selected by each breeding pair a maximum of 12, 15 and 6 times respectively.

Nest dissection

The nest of *A. phrygia* was small and cup-shaped with no well-defined layers and was composed mostly of twigs, with strips of bark, dried leaves and silk also present (Figure 5a). Silk was observed throughout the nest in small clumps from which strands were extended and tangled around twigs and other nest materials (Figure 5c and d). The integration into the nest of the small hackled fibres of the silk, which readily catch on other nest materials, appeared to play a role in binding nest materials. In addition to its use within the nest, silk appeared to have been used to help attach the nest to the leaves of the branch that supported it (Figure 5b). The silk observed in the nest was most likely that of *Badumna* sp.

Discussion

Our observations suggest that honeyeaters may select silk non-randomly for use as a structural material within their nests. *Lichenostomus melanops cassidix* appeared to show a preference for the cribellate silk of *Badumna* sp. over the ecribellate silk of *N. plumipes*, always selecting the cribellate silk first. While *A. phrygia* showed no clear preference for the silk of either *Badumna* sp. or *N. plumipes*, they did display a preference for clean/fresh *Badumna* sp. silk, which was selected more often than dirty/old *Badumna* sp. silk. Our dissection of an *A. phrygia* nest suggested that silk is used within the nest for structural purposes, helping to bind the nest materials together via entanglement.

The apparent preference for cribellate silk shown by *L. m. cassidix* in our study is consistent with the findings of a study in the UK examining the choice and use of silk for nest building by chaffinches (*Fringilla coelebs*) which were reported to make exclusive use of cribellate silk in their nests (Storer and Hansell 1992). However, it should be noted that our interpretation is based predominantly on one breeding pair, since the second *L. m. cassidix* breeding pair took silk on just one occasion (this pair was not expected to breed since the male had only one leg and this was anticipated to prevent him from mating).

Nevertheless, there are a number of reasons why it might be expected that birds prefer the cribellate silk of *Badumna* sp. over ecribellate silk of *N. plumipes*. First, it could be based on the different properties of the silks. Ecribellate silk, while often thicker and more extensible than cribellate silk, is also generally lower in strength (Hansell 1993; Blackledge and Hayashi 2006; Vollrath 2006; Swanson *et al.* 2007), which combined with its viscosity could not only make it more difficult for birds to manipulate but also render it less effective long term if the sticky droplets of water-based glycoprotein glue dry out and lose their adhesiveness with age (Hansell 1993; Vollrath 2006). Cribellate silk, on the other hand, which consists of dry capture threads composed of a hackled band of tiny coiled threads (Vollrath 2006), may be more persistently adhesive (Hansell 2000) and can be repeatedly separated and refastened, a technique that has been termed the 'Velcro' mechanism (Hansell 1993). This Velcro mechanism appears to have been employed within the nest dissected in this study, where silk threads were observed to have been entangled with other components of the nest.

A second reason why birds may be expected to prefer the cribellate silk of *Badumna* sp. over the ecribellate silk of *N. plumipes* relates to differences in web structure and accessibility. *Nephila plumipes* and *Badumna* sp. display very different web architectures. *Nephila plumipes* produces an elaborate web consisting of radial and frame threads and an elastic, sticky capture spiral which they suspend amongst shrubs (Foelix 1996). The supporting branches are often flimsy and unlikely to hold the weight of a honeyeater, which, in addition to the irregular barrier networks of web spun either side of the web, would make it difficult for a bird to gain access to adequate amounts of silk. In contrast, *Badumna* sp. produces untidy sheet-webs constructed in window frames, crevices and tree trunks (Marks *et al.* 2005; Vollrath 2006) which are likely to be more accessible to birds. Thus, over evolutionary time these birds could have developed a preference for *Badumna* sp. silk based on their ability to gain access to the silk.

Given the difficulty of conducting adequately replicated experiments with endangered species, future studies could investigate preferences through examination of nests from museum collections. Choice tests, conducted on a range of more common bird species, in which individuals are presented with cribellate and ecribellate silks from multiple spider species would also be valuable in indicating whether a preference for cribellate silk is consistent across bird species that utilise silk in their nests. These choice tests could incorporate a test of the importance of web structure or context on silk selection by presenting silk to the birds in different ways that replicate how silk is encountered in nature. It would also be possible to tease

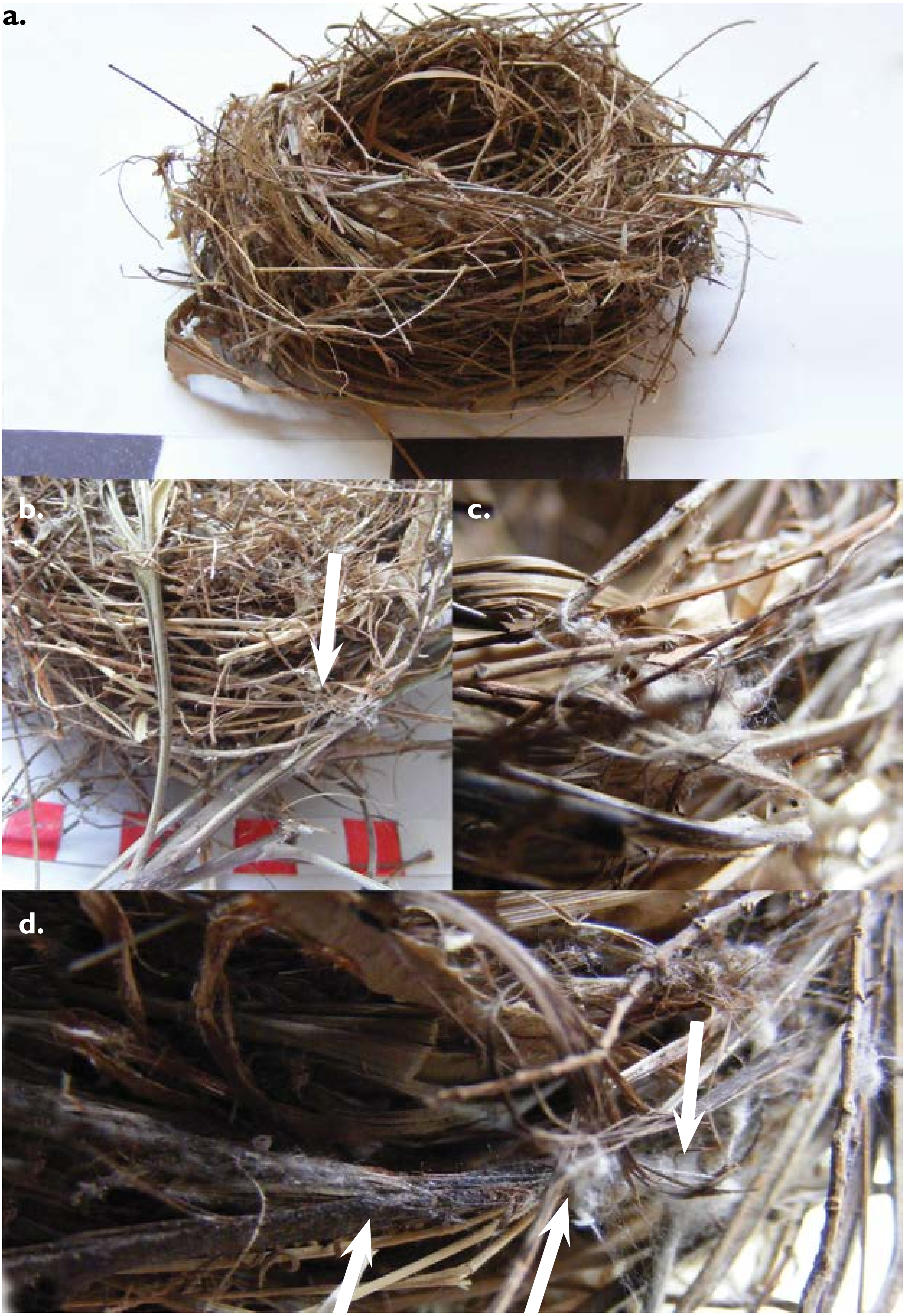

Figure 5. (a) Nest of a Regent Honeyeater *Anthochaera phrygia*. Black bar represents 5 cm. (b) Silk used for attachment of the nest to supporting branch and (c and d) within the nest to bind other nest materials. Red bar represents 1 cm. Photo, P. Low.

apart whether it is silk age and/or condition (the presence of dirt/debris) which influences selection by birds, since these were confounded in the present study.

A number of fundamental questions that also need to be considered include whether it is essential or just desirable for silk to be incorporated within the nests of these honeyeaters and other silk-utilising bird species and how the availability of nest construction materials in a natural setting (vegetative and silk) may influence whether or not birds choose to use silk. For instance, the relative availability of cribellate and ecribellate silk may constrain its use or the presence of alternative materials may obviate the need for silk altogether (for example, if certain bark types are more adhesive to each other). It would also be of interest to investigate, through year-round field surveys, whether the timing of nest building coincides with the period during which the availability of silk is greatest.

Research addressing the questions we have identified will not only provide valuable information on the factors influencing the choice and use of silk by birds in nest building but may also add to our understanding of other aspects of their breeding biology. For instance, during our study it was observed that in one of the *A. phrygia* breeding pairs collection of silk and construction of the nest was being undertaken solely by the male. Previous studies have all reported that these tasks were carried out exclusively by the female (Geering and French 1998; Oliver 1998) and thus our observation suggests that *A. phrygia* may be more like *L. m. cassidix* in that, while construction is generally undertaken by the female, direct involvement by the male is exceptional but sometimes extensive (Franklin *et al.* 1995). Perhaps most important, though, will be the contribution that such research will make to the success of captive management programs by ensuring that the appropriate nest materials are provided during the period of nest construction.

Acknowledgments

Thanks to V. Stebbings, Dr E. May, J., V. and C. Low and anonymous reviewers.

References

Beruldsen, G. 2003. *Australian Birds, their Nests and Eggs*. The Author, Kenmore Hills, Qld.

Blackledge, T.A. and Hayashi, C. Y. 2006. Unraveling the mechanical properties of composite silk threads spun by cribellate orb-weaving spiders. *The Journal of Experimental Biology* **209**: 3131-3140.

Bradley, M. P., Lambert, C., Power, V., Mills, H., Gaikhorst, G. and Lawrence, C. 1999. Reproduction and captive breeding as a tool for mammal conservation: the role of modern zoos. *Australian Mammalogy* **21**:47-54.

Calvelo, S., Trejo, A. and Ojeda, V. 2006. Botanical composition and structure of hummingbird nests in different habitats from northwestern Patagonia (Argentina). *Journal of Natural History* **40**:589-603.

Collias, N. E. and Collias, E. C. 1984. *Nest Building and Bird Behaviour.* Princeton University Press, Princeton.

Conde, D. A., Flesness, N., Colchero, F., Jones, O. R. and Scheuerlein, A. 2011. An emerging role of zoos to conserve biodiversity. *Science* **331**:1390-1391.

Foelix, R. F. 1996. *Biology of Spiders* (second edition). Oxford University Press, Oxford.

Franklin, D. C., Smales, I. J., Miller, M. A. and Menkhorst, P. W. 1995. The reproductive biology of the helmeted honeyeater, *Lichenostomus melanops cassidix*. *Wildlife Research* **22**: 173-191.

Geering, D. and French, K. 1998. Breeding biology of the regent honeyeater *Xanthomyza phrygia* in the Capertee Valley, New South Wales. *Emu* **98**:104-116.

Hansell, M. H. 1993. Secondhand silk. *Natural History* **102**:40-46.

Hansell, M. H. 1996. The function of lichen flakes and white spider cocoons on the outer surface of birds' nests. *Journal of Natural History* **30**:303-311.

Hansell, M. H. 2000. *Bird Nests and Construction Behaviour*. Cambridge University Press, Cambridge.

Hansell, M. H. 2005. *Animal Architecture*. Oxford University Press, Oxford.

Higgins, P. J., Peter, J. M. and Steele, W. K. (eds.). 2001. *Handbook of Australian, New Zealand and Antarctic Birds*. (Vol. 5) Oxford University Press, Oxford.

Marks, J., Mulquin, K., Rawkins, S. and Keating, S. 2005. *Encyclopedia of Australian Wildlife.* Readers Digest, Sydney.

Menkhorst, P., Schedvin, N. and Geering, D. 1999a. Regent honeyeater recovery plan 1999-2003. <http://www.environment.gov.au/biodiversity/threatened/publications/recovery/regent-h-eater/index.html> accessed May 2008.

Menkhorst, P., Smales, I. and Quin, B. 1999b. Helmeted honeyeater recovery plan 1999-2003. <http://www.environment.gov.au/biodiversity/threatened/publications/recovery/helmeted-h-eater/index.html> accessed August 2008.

Oliver, D. L. 1998. The breeding behaviour of the endangered regent honeyeater, *Xanthomyza phrygia*, near Armidale, New South Wales. *Australian Journal of Zoology* **46**:153-170.

Snyder, N. F. R., Derrickson, S. R., Beissinger, S. R., Wiley, J. W., Smith, T. B., Toone, W. D. and Miller, B. 1996. Limitations of captive breeding in endangered species recovery. *Conservation Biology* **10**:338-348.

Storer, N. P. and Hansell, M. H. 1992. Specialisation in the choice and use of spider silk in the nest of the chaffinch (*Fringilla coelebs*) (Aves, Fringillidae). *Journal of Natural History* **26**:1421-1430.

Swaisgood, R. R. 2007. Current status and future directions of applied behavioral research for animal welfare and conservation. *Applied Animal Behaviour Science* **102**:139-162.

Swanson, B. O., Blackledge, T. A. and Hayashi, C. Y. 2007. Spider capture silk: performance implications of variation in an exceptional biomaterial. *Journal of Experimental Zoology* **307A**: 654-666.

Vollrath, F. 2006. Spider silk: thousands of nano-filaments and dollops of sticky glue. *Current Biology* **16**:R925-R927.

Webster, R. and Menkhorst, P. W. 1991. The regent honeyeater (*Xanthomyza phyrgia*): Population status and ecology in Victoria and New South Wales. Unpublished report to National Parks and Wildlife Service, Canberra.

Zhang, G., Swaisgood, R. R. and Zhang, H. 2004. Evaluation of behavioral factors influencing reproductive success and failure in captive giant pandas. *Zoo Biology* **23**:15-31.