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A mixed-species brood of wild Australian parrots (Eastern Rosella *Platycercus eximius* and Crimson Rosella *P. elegans*)—accident or brood-parasitism?

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Abstract. We report a novel case of a mixed-species brood in wild Australian parrots. Two Eastern Rosellas *Platycercus eximius* and one Crimson Rosella *P. elegans* were raised by a pair of Eastern Rosellas in the same nest-box in southern Victoria, Australia, in late 2016.

Introduction

The decrease in number of cavities available for nesting is a limiting factor for many hollow-nesting species, particularly in human-modified landscapes (Grarock *et al*. 2013). Where species come into competition for nesting space, there are several possible outcomes. One is destruction of eggs and takeover of a nesting site, which can be reduced through defence of nesting territories or by increasing the presence on the nest, for example by starting incubation in the early stages of laying. Another is brood-parasitism, either by conspecifics (intraspecific) or by another species (interspecific) (Beissinger *et al*. 1998). Interspecific brood-parasitism is thought to occur in ~1% of all bird species, including obligate brood-parasites such as cuckoos (Payne 1977), cowbirds and ploceid finches (Cockburn 2006). Facultative interspecific brood-parasitism, where a female of a non-brood-parasitic species adds eggs to another species' nest, has been reported in avian taxa including Passeriformes, Anseriformes and Galliformes (Barrientos *et al*. 2015). However, to our knowledge there are no reports of interspecific brood-parasitism occurring in the parrot order (Psittaciformes) and only two records of intraspecific brood-parasitism (Masello *et al*. 2002; Martínez *et al*. 2013).

Although more than 300 animal species in Australia depend on nesting cavities for breeding, the majority of research on cavity competition in birds has been carried out in the Northern Hemisphere (Grarock *et al*. 2013). The Crimson Rosella *Platycercus elegans* and Eastern Rosella *P. eximius* are closely related Australian parrots that nest in cavities (Joseph *et al*. 2008; Shipham *et al*. 2015), have similar breeding biology, occupy similar habitats and can hybridise (Courtney 1967; Higgins 1999; Forshaw & Cooper 2002). Clutch-size varies from three–eight eggs (mean 5.23) in the former and three–nine (mean 5.60) in the latter (Krebs 1998; Higgins 1999; Larson *et al.* 2015). Crimson Rosellas are known to compete aggressively for cavities during the breeding season and to destroy clutches of other conspecific pairs by pecking holes in eggshells; in one study, more than a quarter of all clutches were destroyed by conspecifics (Krebs 1998).

We have been carrying out a long-term study of the ecology (Eastwood *et al*. 2014, 2015; Larson *et al*. 2015), behaviour (Ribot *et al*. 2011, 2013; Mihailova *et al*. 2014), physiology (Knott *et al*. 2010, 2017; Carvalho *et al*. 2011) and genetics (Joseph *et al*. 2008; Ribot *et al*. 2012; Knott *et al*. 2013) of Crimson Rosellas in south-eastern Australia. Breeding Crimson Rosellas have been studied in woodland and farmland at five field sites using artificial nest-boxes placed 4–5 m above ground-level and spaced at least 50 m apart (Larson *et al*. 2015). Here we report the probable occurrence of interspecific brood-parasitism, where a Crimson Rosella nestling was reared and fledged in an Eastern Rosella nest, during the 2016 breeding season.

Observations

Table 1 shows our observations during ten checks, in September–November 2016, of a nest-box at Bellbrae, Victoria (38°19′S, 144°11′E). This nest-box is one of 12 boxes in a small patch (~270 m x 670 m) of *Eucalyptus* trees surrounded by paddocks. On the first check (27 September), we saw an Eastern Rosella leaving the nest-box and found one egg inside the box. Thirteen days later, we again saw an Eastern Rosella leaving the nest-box and this time found eight eggs. One week later

Table 1. Observations on rosellas at a nest-box at Bellbrae, Victoria, September–November 2016. Dates are given as day, month.

Date	*Observation*
27.09	Eastern Rosella left nest-box, 1 egg present.
10.10	Eastern Rosella left nest-box, 8 eggs present.
17.10	Eastern Rosella left nest-box, 8 eggs present (2 with indented shells).
30.10	3 nestlings, 2 broken eggs (collected). Remaining unhatched eggs not visible.
03.11	3 nestlings, 1 broken egg (collected).
10.11	3 nestlings.
11.11	3 nestlings, 1 broken egg (collected).
17.11	3 nestlings, 1 broken egg (collected).
25.11	3 nestlings.
28.11	Nest-box empty.

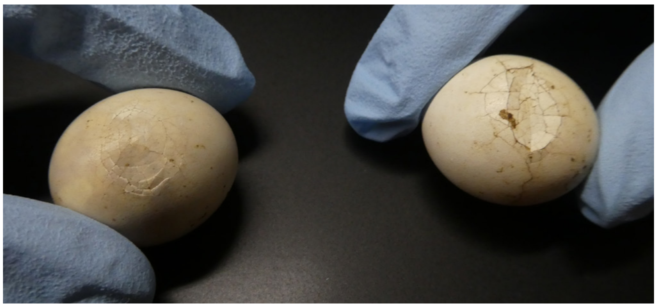

Figure 1. Two of the indented Eastern Rosella eggs retrieved from the nest-box. Photo: Johanne M. Martens

(17 October), two eggs had small indentations in the shells (Figure 1).

Thirteen days later (30 October), there were three nestlings (estimated to be *c*. 1 week old by their size) as well as the two indented eggs noted on the previous check. We removed the two unhatched eggs and weighed the nestlings: one was much heavier than the others (49 g, 36 g, 27 g). The remaining eggs from the clutch were not seen during this check. During subsequent checks, we found three further unhatched eggs (all of which were indented) and removed them and froze them on the same day (Table 1). None showed signs typical of egg destruction by other rosellas, as they did not have distinctive parrot-bill-shaped holes in the shell (Krebs 1998). We compared all indented eggs with Crimson Rosella eggs from the same breeding season in Victoria, and found that all five unhatched eggs were smaller than Crimson Rosella eggs, and were consistent with the egg sizes reported in the literature for Eastern Rosellas but not Crimson Rosellas (Table 2). During a check on 17 November, we again found a marked size difference between the three nestlings; the largest weighed 146 g, and the two smaller ones weighed 113 g and 108 g. During a check shortly before fledging (25 November), when the nestlings were fully feathered, we observed from the plumage patterns and size differences that the biggest nestling was a Crimson Rosella, whereas the two smaller ones were Eastern Rosellas (Figure 2). The nest-box was empty on 28 November, suggesting that all three nestlings had fledged.

We observed the nest-box from a distance of ~30 m on 3 days (3, 10 and 11 November) for a total of *c*. 9 h in the course of catching the adults. During this time, we caught both adult Eastern Rosellas when they went into the nest-box to feed the nestlings, and saw the female go inside the box on several occasions before we caught the male. We observed adult Crimson Rosellas in the nest-tree and <1 m from the entrance of the box, but never going inside.

Figure 2. Crimson Rosella nestling (on left), sharing the nest with two Eastern Rosella nestlings (on right), Bellbrae, Victoria. It is distinguishable by the differences in plumage patterns on the back and wings, as well as by its blue cheek-patches, which are white in Eastern Rosellas. Photo: Helena S. Stokes

Discussion

During the 2016 breeding season, we found a mixed brood of two Eastern Rosella nestlings and one Crimson Rosella nestling in the same nest-box. We also found damaged eggs with indented shells in this box, which we compared with Eastern and Crimson Rosella eggs. Based on these measurements, we are confident that the damaged eggs from the mixed-brood nest-box were all Eastern Rosella eggs. In 14 years of study on Crimson Rosellas with >700 nest-boxes, this is the first time that a mixed-species brood has been observed, and we know of no reports of this in the literature, suggesting that it occurs very rarely. There are at least three potential explanations for this observation, which we now summarise.

One explanation may be accidental placement of an egg by a Crimson Rosella in an existing Eastern Rosella nest. The Crimson Rosella female that we observed might have lost her clutch in another nest-hollow (for example from predation or displacement by another species) and tried to continue laying in this new nest-box. This is likely, as Common Ringtail Possums *Pseudocheirus peregrinus* (which prey on rosella eggs and nestlings) are often found in nest-boxes at this field site (Mihailova *et al*. 2018). A similar case has been reported by Jorm (1993), who saw an adult Eastern Rosella occasionally feeding Crimson Rosella nestlings in a nest-box in his garden, possibly after it had lost its own nest. Another case occurred in our

Table 2. Measurements (mean and range, mm) of eggs of (a) the clutch reported in this study, (b) five randomly selected Crimson Rosella clutches from the same study site, and data from the literature for (c) the Eastern Rosella *Platycercus eximius eximius* and (d) Crimson Rosella *P. elegans elegans*; *n* = number of eggs; NSW = New South Wales.

	Length	*Breadth*
(a) Mixed-species clutcht (*n* = 5)	25.8 (25.4–26.1)	22.1 (21.7–22.4)
(b) Crimson Rosella, this study site (*n* = 13, from 5 nests)	28.2 (25.7–29.7)	23.8 (21.9–25.7)
(c) Eastern Rosella, NSW (Forshaw 2002; *n* = 7)	26.9 (25.7–28.1)	21.7 (21.3–22.1)
(d) Crimson Rosella (Higgins 1999; *n* = 16)	29.1 (27.9–30.0)	23.5 (22.4–24.6)

research project in the Adelaide Hills, South Australia, in 2006, where a female Crimson Rosella and a male Eastern Rosella were seen feeding Crimson Rosella nestlings together (MLB pers. obs.). Another possible explanation is that the Crimson Rosella female might have used this box in previous years and tried to breed in the same box again. Our previous recapture data show that overall nest-site fidelity is high in this species: although 84% of breeding individuals change nest-boxes between breeding seasons at least once, the distance that Crimson Rosellas move between nest-boxes is small (mean 0.17 ± standard error 0.03 km: Eastwood *et al*. 2018). This supports observations that although they may use different nest-boxes in subsequent years, Crimson Rosellas remain in the same area (Krebs 1998). Another possible explanation for an accidentally shared nest could have been the Crimson Rosella having the urge to nest but having no available suitable, empty nesting cavity. However, this is unlikely, as there seemed to be other natural tree-cavities available in addition to many empty artificial nest-boxes; the uptake rate by rosellas for nest-boxes (proportion of nest-boxes where eggs hatched) at our five field sites was only 19% in the study year (16% uptake by Crimson Rosellas and 3% by Eastern Rosellas: unpubl. data).

Another explanation for our observation may be a failed attempt at intraspecific brood-parasitism, where the 'wrong' nest was chosen by the Crimson Rosella female, namely an Eastern Rosella instead of a Crimson Rosella nest. High rates of intraspecific brood-parasitism are more likely to be observed in species with life histories that include high fecundity rates, low parental care, high adult mortality (Arnold & Owens 2002) and precocial offspring (Yom-Tov 2001). Intraspecific brood-parasitism is therefore expected to be low in most parrots, which are long-lived and show high parental investment in altricial offspring (Higgins 1999; Brouwer *et al*. 2000; Yom-Tov 2001). However, there are cases of possible intraspecific brood-parasitism in Crimson Rosellas. One was observed at our study site during a genetic analysis of 42 pairs of Crimson Rosellas and their offspring: one nestling in a brood showed genetic dissimilarity with both of its putative social parents (Eastwood *et al*. 2018). There is evidence for intraspecific brood-parasitism in other parrot species: it has been found in 3% of the nests of the colonial breeding Monk Parakeet *Myiopsitta monachus* in a study using a microsatellite-based genotyping method to determine relatedness between nestlings and between nestlings and adults (Martínez *et al*. 2013). Masello *et al*. (2002) found two cases of intraspecific brood-parasitism in 49 families of the colonial Burrowing Parrot *Cyanoliseus patagonus* using DNA fingerprinting. Intraspecific brood-parasitism, therefore, does seem to occur in the Psittaciformes, but at very low levels.

Finally, it is possible that our observation represents facultative interspecific brood-parasitism by the Crimson Rosella. Brood-parasitism might have evolved because of clutch destruction in the laying phase, where another completed nest would then provide the best opportunity for laying; for this, most bird species would usually choose nests of conspecifics, especially in colonial species (Hamilton & Orians 1965). However, facultative interspecific brood-parasitism, where a female of a non-parasitic species adds eggs to another species' nest, also occurs in some species and has been linked to shortages of nest-cavities (Barrientos *et al*. 2015). As Crimson Rosellas and Eastern Rosellas only initiate incubation after laying several eggs, and continue to make short foraging trips during incubation (Krebs 1998; Higgins 1999; Krebs *et al*. 2002), there are multiple opportunities for interspecific brood-parasitism. A failed attempt at egg destruction by territorial Crimson Rosellas seems to be unlikely, as the broken eggs found in the nest-box in our study did not have the distinctively shaped holes in their shells that usually result from egg destruction by Crimson Rosellas (Krebs 1998), but looked indented as if squashed.

We conclude that the shared nest is most likely evidence of brood-parasitism, as we observed only the Eastern Rosellas rearing the nestlings, with no observed parental care by the Crimson Rosellas. We suggest that this occurred either by accident, or as a result of failed intraspecific brood-parasitism, as this form of brood-parasitism is known to occur on rare occasions in Crimson Rosellas, and interspecific brood-parasitism has not, to our knowledge, been reported before in Crimson and Eastern Rosellas. Our observation does, however, provide only limited data, which precludes a definite explanation. Our observations raise the possibility that interspecific brood-parasitism can occasionally occur in parrots, and that it may be more widespread across avian taxa than previously thought. As nest-hollow availability is likely to decrease in the future as habitats are further modified by humans (Grarock *et al*. 2013), cases of multiple species attempting to use the same nest may occur more often (Barrientos *et al*. 2015). Possible adverse impacts from such occurrences could include reduced breeding success or enhanced disease transmission, which could be of particular importance for endangered species.

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