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Breeding success and its correlates in native versus invasive secondary cavity-nesting birds

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ABSTRACT

Australian cavity-nesting birds in urban habitats can encounter strong competition for nesting cavities. This results from the shortage of old large hollow-bearing trees in urban areas and because cities often host a suite of alien birds, including cavity-nesters. However, it is unclear whether some behavioural differences are involved with access to nesting cavities. We aimed to examine parental nest attendance, nest disturbance and breeding success in native parrots and the most common invasive urban bird in Australia, the Common Myna, *Acridotheres tristis*. We installed 78 experimental nest boxes in Newcastle, the second largest city in New South Wales, Australia, to compare native parrots and Mynas. We found that despite occupying nest boxes equally, native parrots had significantly lower breeding success, lost more clutches to hatch failure, exhibited lower levels of parental nest attendance, and encountered higher levels of nest disturbance than the alien Myna. These findings provide important insight into the breeding success of native and alien secondary cavity-nesting birds in cities. Evaluating the effectiveness of urban nest boxes will help guide future research and management aimed at optimising nest box design for maintaining native cavity breeders.

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Introduction

Cavity-nesting birds are impacted by large cavity-tree removal as they rely on tree cavities to breed (van der Hoek *et al.* 2017). In urban Australia, tree cavities are an increasingly rare resource, not only because of rampant deforestation, but also because Australia does not have any native cavity-excavating birds like the Woodpeckers (Lindenmayer *et al.* 2014). Cavity formation, therefore, relies upon lengthy invertebrate- and fungal-assisted decay processes that occur mostly in large old trees. Consequently, planting young trees does not compensate for the time lag of decades before resources form once old-growth forests are cleared (Gibbons *et al.* 2002, 2008). The compounding effects of cavity loss and low rates of replacement might contribute to explaining why Australasia has the highest proportion of threatened cavity-nesting birds in the world (17%) (van der Hoek *et al.* 2017).

As natural habitats shrink and urban habitats expand, some native birds move into built-up environments (Marzluff 2001, 2017; Møller 2009). For the cavity-nesting birds that are now found in cities, securing access to nest cavities might be just as challenging as in natural habitats, if not more (Harper *et al.* 2005a). First, nest cavities are likely to be rare because urban vegetation is recent, and where old-growth tree-hollow bearing trees do occur, they are

being removed for safety concerns (Harper *et al.* 2005a; Morton 2013). Second, levels of nest disturbance might be high because urban avian populations can reach densities that far surpass those of natural environments (Møller *et al.* 2012). Third, levels of competition might be high because urban areas present a sharp increase in the relative proportion of synanthropic alien avian invaders, some of which are also cavity-nesters (Marzluff 2001; McKinney 2006; Kark *et al.* 2007; Sol *et al.* 2012). These factors might affect the reproductive success of native cavity-nesting birds disproportionately relative to synanthropic alien avian invaders. Indeed, the latter have a much longer evolutionary history of urban colonisation and might therefore be better equipped behaviourally to cope with high competition and nest disturbance (Shochat *et al.* 2010).

Some patterns of parental care, specifically those that maximise defence and protection of cavities and clutches, might be adaptive under highly competitive conditions. There is increasing evidence that heightened territorial aggression forms part of an 'urban syndrome' (Cilento and Jones 1999; Evans *et al.* 2010; Sol *et al.* 2012; Minias and Tregenza 2015; Davies and Sewall 2016), but it is not known whether cavity defence is similarly enhanced. While aggressive nest defence is the most visible aspect of parental care, other subtler behaviours, which deter intruders

without overt aggression and reduce disturbance, namely parental nest attendance, might also provide an advantage. One might predict that such behaviours should be prevalent in synanthropic avian invaders which have a long evolutionary history of urban colonisation but less prevalent in native cavity-nesting birds which have only colonised urban habitats recently.

We aimed to compare the breeding success of native cavity-nesting Australian parrots with that of an invasive, alien secondary cavity-nesting bird, the Common (Indian) Myna, *Acridotheres tristis*, in urban habitats and further investigate whether differences in patterns of parental nest attendance and nest disturbance might contribute to differences in breeding success.

Methods

Nest box locations and design

We installed 78 nest boxes in the Newcastle area (NSW, Australia). We used vertical nest boxes made of plywood (400 (H) x 170 (W) x 170 (D) mm) with an entry hole diameter of 65 mm (Nest Boxes Australia, Loganholme 4129 Australia). The nest box design was informed by former successful nest box studies examining interactions between Mynas and native parrots (Orchan *et al.* 2012; Grarock *et al.* 2013). Each box was fitted with a 75 cm external perch located 3 cm under the entrance and an internal ladder was carved out of the internal wall allowing easier access for the parrots.

Nest box monitoring

Weekly monitoring

We monitored all nest boxes weekly using a gooseneck camera attached to an extendable pole for three successive breeding seasons (August 2014 to April 2017). We collected information on species ownership but also on number of eggs, nestlings and fledglings. We then calculated the egg ratio (number of eggs/clutch) for each box and each species, as well as the number of fledglings per nest under the assumption that each box was occupied by the same pair throughout each season. This is a reasonable assumption given what is known about the biology and nest box behaviour of the species studied here (Counsilman 1974; Eastwood *et al.* 2018). For each box, we recorded the number of breeding attempts and their outcome (success/failure). A breeding attempt was considered each time a pair laid at least one egg in a nesting round. A failure was defined as a breeding case where eggs were laid with no nestlings fledged. A success was counted when at least one active fledgling (ready to fly off) was found during monitoring of the clutch, followed by an empty nest the following week.

Continuous monitoring

During the 2015–2016 breeding season, we monitored 13 occupied nest boxes continuously using movement-triggered cameras (Little Acorn surveillance cameras model LTL-5310x – 5) from the time at which an egg was found to the point in time when all birds had left the nest. Seven boxes were occupied by Eastern Rosellas (*Platycercus eximius*) and six were occupied by Mynas. The cameras were functional 24 h/day and captured an image each time a movement occurred around the nest with a 30-s interval between two activations.

Data analysis

Native parrots were predominantly represented by Eastern Rosellas. A maximum of three boxes per season were occupied by other parrot species (Crimson Rosella, *Platycercus elegans*; Rainbow Lorikeet, *Trichoglossus moluccanus*). Therefore, we compiled data from different parrot species under the label native parrots for all analyses except that of egg ratios (number of eggs per clutch) where a visual inspection of data suggested a large difference between Rainbow Lorikeets and Rosellas.

Due to small sample size within each breeding season, all breeding data were pooled across the three successive breeding seasons and then compared across Mynas and parrots. We compared the number of nest boxes occupied by Mynas and parrots using a Chi-Square Test. Then, the total number of fledglings per box, the mean number of eggs/clutch and the mean number of attempts/year were compared using non-parametric Independent Mann-Whitney tests. Finally, for Mynas and parrots separately, we compared the number of clutches that failed due to hatch failure with the number of clutches that failed due to chick death using binomial tests.

All images revealing the presence of animals were sorted into four categories depending on which animal was sighted: (1) parents (all conspecifics), (2) predators, (3) competitors (heterospecific cavity-nesters), and (4) intruders (heterospecific non-cavity nesters). We assumed that all conspecifics were parents because birds were not banded, so it was not possible to distinguish parents from non-parents. In most cases, it was clear from their behaviour that visiting conspecifics were parenting the clutch rather than intruding (rapidly entering and/or exiting the box after landing on the roof or the perch at the nest entrance).

For each nest box and each image category (see above), we divided the total number of images captured by the number of days the box was observed (i.e. the camera was functional) to estimate the level of parental nest attendance, as well as visitation levels by intruders, competitors and predators. It is possible

and even likely that images resampled the same individual visitor repeatedly, but this was not a concern because we were interested in overall disturbance levels. So, for example, even if a nest was visited by one individual cat five times or by five different individual cats once each, we considered the level of disturbance to be the same. We used non-parametric Independent Mann-Whitney tests to compare levels of nest attendance and disturbance among Mynas and parrots. Finally, we examined whether higher nest attendance was associated with lower levels of nest disturbance using a Pearson correlation. All statistical analyses were carried out using SPSS 24 (SPSS Inc., Chicago, IL, USA) and R v3.4.3 (2017)

Results

Over the three breeding seasons, Mynas occupied 14.33 ± 2.03 nest boxes and native parrots occupied 15.67 ± 3.38 nest boxes among the 78 installed on the area. Both species displayed the same level of occupancy: X^2 ($df = 1$, $N = 89$) = 0.101, $P = 0.75$, across three breeding seasons (August 2014–April 2017). However, parrots fledged significantly fewer fledglings/individual than Mynas (Mann-Whitney: $n_{\text{mynas}} = 43$, $n_{\text{parrots}} = 46$, $U = 681$, $P = 0.008$, Figure 1). The comparatively lower breeding success was despite parrots laying significantly more eggs/clutch than Mynas; parrots (excluding Rainbow Lorikeets): 4.4 ± 0.2 ; Mynas: 4.1 ± 0.1 ; Mann-Whitney: $n_{\text{mynas}} = 43$, $n_{\text{parrots}} = 42$, $U = 1,1.5$, $P = 0.03$. Native parrots also made significantly fewer breeding attempts/year than Mynas (Mann-Whitney: $n_{\text{mynas}} = 43$, $n_{\text{parrots}} = 46$, $U = 738$, $P = 0.006$).

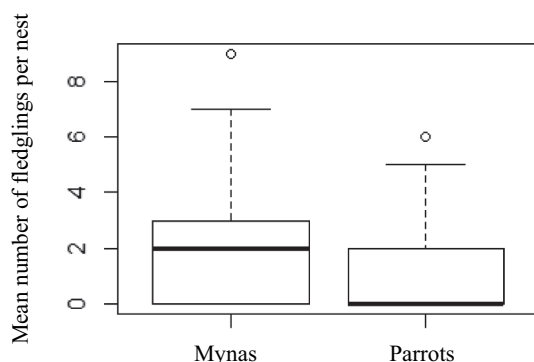


Figure 1. Boxplots comparing the mean number of fledglings per individual in Mynas and native parrots over three successive breeding seasons. The line within each box represents the median, while the upper and lower borders of each box depict the 25th and 75th percentiles, the lower and upper bars the 10th and 90th percentiles, and the circles the outliers. $N_{\text{parrots}} = 46$; $N_{\text{mynas}} = 42$

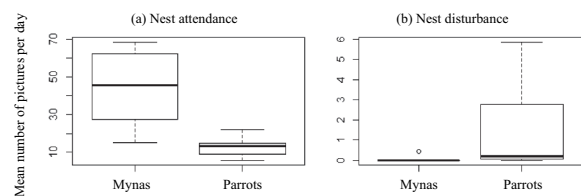


Figure 2. Nest attendance (a) and nest disturbance (b) in Mynas and native parrots measured as mean number of images per day captured by trigger cameras. Nest attendance was calculated using images of conspecifics, which were classified as ‘parents’ based on their behaviour (see text for more details). Nest disturbance was calculated using images of all heterospecifics. The line within each box represents the median, while the upper and lower borders of each box depict the 25th and 75th percentiles, the lower and upper bars the 10th and 90th percentiles, and the circles the outliers.

Significantly more parrot clutches (31/46) failed than Myna clutches (25/43) (Chi-square = 8.5, $df = 1$, $P = 0.003$). Native parrots experienced significantly more hatch failures than chick deaths (one sample binomial test; $P < 0.001$) whereas Myna clutches were no more likely to fail from hatch failure than from chick death (one sample binomial test; $P = 0.108$).

Continuous monitoring of nest boxes revealed that Mynas showed a significant higher nest attendance than native parrots (Mann-Whitney: $n_{\text{mynas}} = 6$, $n_{\text{parrots}} = 7$; $U = 1.0$, $P = 0.002$). Additionally, parrot nests were subject to significantly higher levels of disturbance than Myna nests (Mann-Whitney: $n_{\text{mynas}} = 6$, $n_{\text{parrots}} = 7$, $U = 35$, $P = 0.035$). Rates of disturbance by competitors (heterospecific cavity-nesters) were significantly higher at parrot nests than Myna nests (Mann-Whitney, $U = 39$, $P = 0.008$), but did not differ for other visitor categories (intruders, $n_{\text{mynas}} = 6$, $n_{\text{parrots}} = 7$, $U = 23.5$, $P = 0.731$; predators, $n_{\text{mynas}} = 6$, $n_{\text{parrots}} = 7$, $U = 27$, $P = 0.445$; Figure 2). Disturbance at parrot nests was only generated by native heterospecific cavity-nesters never by Mynas.

Based on a small sample size of 13 nests, the relationship between nest attendance and nest disturbance was in the direction expected (higher nest attendance, reduced nest disturbance), but was not significant (Pearson correlation: $R = -0.2$, $P = 0.507$).

Discussion

This study compared the breeding success and the patterns of parental nest attendance and nest disturbance of native Australian parrots with those of the introduced, synanthropic, highly abundant Myna.

Across three breeding seasons, parrots produced fewer fledglings than Mynas despite similar levels of nest box occupancy. Despite laying fewer eggs/clutch, Mynas fledged more chicks. Parrots displayed higher

levels of nest failure, lower levels of nest attendance and higher levels of nest disturbance than Mynas. Although we cannot evaluate life-time reproductive success of native parrots and Mynas comparatively, the present results suggest that reproduction in urban environments might be more challenging for parrots than for Mynas. These results also point to the possibility that parrots' parenting style might be disadvantageous in highly competitive environments.

Across three breeding seasons, more than half of parrot nests failed, mainly caused by hatch failure. To our knowledge, there has been only one other breeding analysis of parrots and Mynas, and that study found comparative levels of clutch failure in parrots in highly urbanised areas of Canberra as we did here (55% of the clutches did not produce nestlings) (Grarock *et al.* 2013). We currently do not know why so many parrot eggs fail to hatch. We know of no analysis of hatch failure in natural hollows for native parrots, so we cannot exclude that failure might be particularly high in nest boxes. Although breeding success in boxes might differ relative to hollows, nest boxes are increasingly implemented to enhance reproduction of cavity-nesters in urban habitats, so it is important to measure their effectiveness (Goldingay and Stevens 2009; Miller 2012; Norris *et al.* 2018). Knowing how frequently clutches fail and the reasons why provides invaluable information that can improve nest box design (Larson *et al.* 2018). Future research is needed to address this knowledge gap and also explore other ecological factors such as temperature in nest boxes which could show differences from natural hollows (Larson *et al.* 2015; Griffiths *et al.* 2018).

Eastern Rosellas and Mynas differed in the temporal patterning of their parental care. Mynas visited their nests much more frequently and experienced lower levels of disturbance than Eastern Rosellas, especially from hetero-specific cavity-nesting birds. These findings point to a potential causal relationship between increased nest attendance and reduced nest disturbance. Nest attendance is known to reduce predation rate (Hu *et al.* 2017), and thereby increase breeding success (Bukacinska *et al.* 1996). Although the present study did not yield a significant correlation between increased nest attendance and reduced disturbance, this might be because parental attendance only matters when nests are located in areas with high levels of disturbance.

Different evolutionary histories of urban cavity competition could have produced the different levels of nest attendance we detected among Mynas and Eastern Rosellas. Nest visitation rates could also be driven primarily by chick diet, however (Cannon 1981; Moeed 1975). Myna parents typically carry one insect or other food item from the foraging site to the nest and probably do not feed all the chicks/visit (Counsilman 1971). In contrast, a Rosella can forage on many items before returning to the clutch and regurgitating to several chicks per visit (Krebs *et al.* 1999; Krebs and Magrath 2000).

This pattern of chick feeding would produce fewer nest visits per unit of time. Differential feeding rates could explain the lower nest attendance in parrots compared to Mynas, which may then indirectly carry costs of reducing nest guarding in environments where competition for nesting resources is high.

It is a common view amongst urban managers that urban nest boxes are primarily occupied by Mynas and should therefore not be used. Although this view has been upheld by one nest box study in South Australia (Harper *et al.* 2005b) and another one in Israel (Charter *et al.* 2016), the present research shows that in other areas of the Myna's Australian distribution, native birds are equally likely to occupy boxes. Although one might argue that the superior breeding success of Mynas nevertheless supports the view that urban boxes are not a viable option for enhancing native bird reproduction, we tend to disagree. We suggest that our boxes merely provided nesting opportunities for Mynas that would have otherwise bred elsewhere. This is because Mynas tolerate a broad range of breeding substrates including house gutters and lamp posts which are in no way limited. In contrast, our boxes might well have provided breeding opportunities for Eastern Rosellas that would not have otherwise bred elsewhere. Indeed, Eastern Rosellas only nest in cavities and intra-species competition for limited breeding hollows in cities is likely to exclude many individuals from breeding.

In conclusion, future research is needed to confirm the possibility that urban reproduction is challenging for native parrots. Research needs to focus on quantifying reproductive success of parrots in non-urban environments and in natural tree hollows to provide a comparison for urban nest box studies like this one and that of Grarock *et al.* (2013). Another focus needs to be on lifetime success of mynas and parrots in order to determine whether species differences in annual reproductive success found here and in Grarock and colleagues' work is compensated for by longer lifetime reproduction. Finally, research needs to investigate the reasons for low hatch failure in parrots in order to determine whether these can be remedied to boost reproduction of native parrots relative to mynas. It might be useful to consider both proximate factors, such as nest box temperature, and ecological correlates of hatch rates, such as level of urbanisation, which might influence food availability. We hope that our study will encourage mid or long-term nest boxes programmes to evaluate breeding success in native and invasive species with those studies including parental behaviour among other factors.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Author contributions

FL, ASG and SK conceived and designed the experiments. FL and CP performed the experiments. FL and ASG analysed the data. FL and ASG wrote the manuscript. All authors provided comments and edited the paper.

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