RESEARCH REPORT

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Nest box contentions: Are nest boxes used by the species they target?

By Ross L. Goldingay, David Rohweder and Brendan D. Taylor

Ross L. Goldingay is an associate professor in the School of Environment, Science and Engineering, Southern Cross University (PO Box 157, Lismore, NSW 2480, Australia; Email: ross.goldingay@scu.edu.au). David Rohweder is the managing director of Sandpiper Ecological Surveys Pty Ltd (PO Box 401, Alstonville, NSW 2477, Australia; Email: david@sandpipereco.com.au). Brendan D. Taylor is a senior ecologist with Sandpiper Ecological Surveys Pty Ltd (PO Box 401, Alstonville, NSW 2477, Australia; Email: brendan@sandpipereco.com.au). This study is part of a broader investigation that uses nest boxes to understand the ecological requirements of hollow-dependent wildlife.

Summary Nest boxes have grown in popularity as a habitat management tool in Australia during the last decade. This management use remains contentious because some studies suggest nest boxes are ineffective. There are three recent contentions: (i) nest boxes mostly benefit common species, (ii) exotic species may be dominant users of nest boxes, and (iii) species of conservation concern use nest boxes infrequently. We address these contentions using data from 1865 nest boxes involving eight nest box designs. These nest boxes were installed predominantly <200 m from a road in association with highway duplication and re-alignment across 16 projects in New South Wales. The Common Brushtail Possum (*Trichosurus vulpecula*) is the species of most relevance to contention 1. It used 9% of boxes overall including 26% of '*possum*' designated boxes. The most frequent nest box users were small petaurid gliders (mostly Sugar Gliders, *Petaurus breviceps*) which used 63% of '*small glider*' designated boxes. This nest box and another suited to the Sugar Glider comprised 40% of all boxes installed, so it is not surprising that this species might be a common user. Exotic species were uncommon users of the nest boxes enabling contention 2 to be rejected. Active hives of Feral Honeybees (*Apis mellifera*) occupied just 1% of boxes, and another 1% of boxes were used by introduced rodents and birds. The Squirrel Glider (*Petaurus norfolcensis*) is the species most relevant to contention 3. It was seen in 80 boxes across 11 projects, representing 7% of the three types most frequently used. These observations are not consistent with the third contention. Nest boxes can provide many important insights about the requirements and interactions of hollow-dependent fauna. However, they are not intended as an alternative to retaining hollow-bearing trees.

Key words: *artificial cavity, cavity-dependent mammals, highway mitigation.*

Implications to Managers

Recent concerns that nest boxes disproportionately favour common or introduced species are misguided.Nest box entrance size determines species use. Installation of a large number of nest boxes suited to common species will lead to frequent use by these species but this may be desirable in some projects.There is growing evidence that threatened species will frequently use nest boxes. Nonetheless, nest boxes should not be viewed as an alternative to retaining hollow-bearing trees.

Introduction

Nest boxes and bat boxes have long been installed throughout Europe and the USA as research and conservation tools (Robertson & Rendell 2001; Goodenough *et al.* 2008; Corrigan *et al.* 2011; Schölin & Källander 2011; Shutler *et al.* 2012; Williams *et al.* 2013; Burgess 2014; Rueegger 2016). In a research context, nest boxes have been most frequently used to investigate breeding ecology. In Australia, the most common research focus has been on investigating the influence of nest box variables such as entrance size, volume and height above the ground on use (Menkhorst 1984a; Lindenmayer *et al.* 2003; Goldingay *et al.* 2007, 2015; Le Roux *et al.* 2016).

Nest boxes may play a role in providing substitute shelter and breeding sites in Australia where hollows are absent or in low abundance (Menkhorst 1984b; Brazill-Boast *et al.* 2013; Goldingay *et al.* 2015). A recent trend in New South Wales has been to instal nest boxes to support species displaced from hollows as a consequence of habitat clearing. This has mostly occurred in the context of clearing for highway duplication and re-alignment, and for coal mining. This management application has outpaced research knowledge of factors that may enable success. Indeed, a recent evaluation by Lindenmayer *et al.* (2017) of one such road project highlighted a lack of knowledge of the local abundance of the target species and therefore what a threshold level of use of nest boxes should be applied to measure effectiveness. That project was deemed a failure due to a paucity of nest box use by the target species. An evaluation of a bat box project at a mine site by Rueegger *et al.* (2019) also highlighted a lack of research knowledge that has hindered evaluation and prospects of a successful outcome.

A prevailing view from recent nest box studies in Australia (Le Roux *et al.* 2016; Lindenmayer *et al.* 2016, 2017) is that nest boxes mostly benefit common species, that exotic species may be dominant users of nest boxes, and that species of conservation concern only use nest boxes infrequently. We refer to these three view points as nest box contentions. A further concern that has been noted for some time (Lindenmayer *et al.* 2009) is that nest boxes may degrade or collapse far too quickly to satisfy the role for which they were intended. In this study, we address the three recent contentions that question the value of nest box installations. We do not address the concern about nest box attrition due to the short duration of our study, but note there is evidence (Goldingay *et al.* 2015; Goldingay *et al.* 2018) that challenges the notion that nest boxes incur high maintenance and loss within 10 years of installation.

In this study, we investigate the use of 1865 nest boxes installed across 16 major road projects conducted by the New South Wales Roads and Maritime Services (RMS). Bat boxes were also installed, but we do not evaluate their use. The objective of the box installations, as described in various consultant reports (RMS, unpublished reports), was mostly to provide shelter sites for animals displaced during clearing. Our study does not review the merit of this management policy, which is more complex than it appears due to a lack of knowledge of animal populations in the nest box installation areas and the variable density of tree hollows in those areas.

The aim of our study was to test the three contentions that: (i) common species were the most frequent users, (ii) exotic species were dominant users, and (iii) threatened species rarely used nest boxes. We use data collected from the 16 nest box projects that featured eight different nest box designs. The common species that gave rise to the first contention were the Common Brushtail Possum (*Trichosurus vulpecula*), the Eastern Rosella (*Platycercus eximus*), Crimson Rosella (*P. elegans*), Common Ringtail Possum (*Pseudocheirus peregrinus*) and Yellow-footed Antechinus (*Antechinus flavipes*) (see Le Roux *et al.* 2016; Lindenmayer *et al.* 2016, 2017), so we investigated how frequently these species used nest boxes in these 16 projects. We also investigate the specificity of the nest box designs for particular species. This is fundamental to determining whether common species are more frequent users than expected and threatened species less frequent than expected. Some designs may favour common species, and installing large numbers of those designs will predictably produce a high frequency of records of common species.

Methods

Study design

Nest boxes were installed across 16 landscapes adjoining new sections of highway across a broad area of New South Wales (Fig. 1). Highway sections measured 6.5–32.0 km in length. Habitat at individual sites consisted of woodland, or wet or dry sclerophyll forest. Nest boxes were mostly installed in habitat areas within 200 m of the highway but occasionally in patches of habitat 200–500 m away. Nest boxes were installed in areas where the density of hollow-bearing trees was <6 per ha, except in one case, it was 11 per ha. The number and type of nest boxes installed varied across projects based on the number of hollow-bearing trees and the size distribution of hollows contained within the clearing footprint of the highway. Nest boxes were attached to trees, predominantly using fencing wire with a concertinaed section to allow for tree growth, at a height of 4–10 m above the ground. Boxes were installed in clusters of 2–4 different types on different trees 5–30 m apart. All nest boxes reported on were made of plywood. Boxes made from hollow logs (n = 21) or aluminium (n = 67) across four projects were excluded.

A wide variety of different box types were installed and conformed to eight basic types (Table 1). All boxes had front entries except 38 of the small glider boxes which had rear entrances but there were too few to analyse as a separate design. Other boxes (n = 17) that did not conform to these designs were omitted.

Nest box data

The three contentions were addressed by reference to the frequency of use by different species. Data on the contents of nest boxes were obtained from consultants' reports provided by RMS. Projects were at different stages of completion and varied in the timing and frequency of when nest boxes were inspected. The first inspection in most (67%) projects occurred 1 year after installation and boxes received an average of three inspections (range 1–6) over an average of 2 years (range 1–6) (69% covered ≥2 years). This period of monitoring and number of checks should be sufficient to establish broad patterns of use and preference (Lindenmayer *et al.* 2009; Goldingay *et al.* 2015). We collated data representing a cumulative record of use of each nest box over the period of available data. That is, a given nest box produced a single record for any species but could produce records of multiple species. Records of box used by some species were indicated by the direct observation of an animal or indirectly by a record of a characteristic nest. Where both occurred in different visits, the animal record took precedence.

Nest boxes were inspected using a combination of direct inspection from a ladder or elevated work platform, or using a pole camera. Animals and nest material in nest boxes were identified. Different observers across projects had different levels of experience in identifying mammal nests. The use of pole cameras in some inspections is also likely to have introduced some ambiguity as to whether a nest was occupied or which species had constructed the nest. For example, some nests consisting of loose leaves may well have contained the ball nests of Feathertail Gliders (*Acrobates* sp.) (a common feature of that species; Beyer & Goldingay 2006) but that could not be ascertained without searching through the leaves by hand. Therefore, nest records were not attributed unless the descriptions were clear. In total, 278 (15%) boxes had evidence of leaf and bark nests, bracken, depressions and scats that could

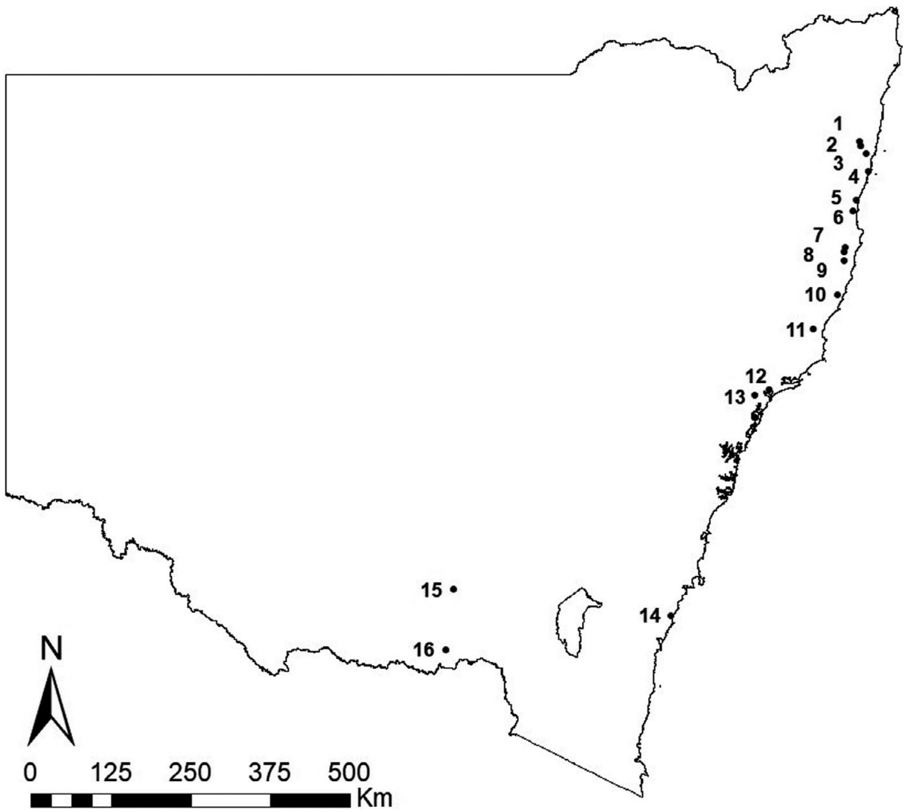

Figure 1. Map of New South Wales showing the numbered locations of the nest box projects. The number of boxes included in our analysis is shown in brackets. 1, Glenugie (44); 2, Halfway Creek to Glenugie (129); 3, Woolgoolga to Halfway Creek (126); 4, Sapphire to Woolgoolga (119); 5, Nambucca Heads to Urunga (202); 6, Warrell Creek to Nambucca Heads (126); 7, Kempsey Bypass (130); 8 Kundabung to Kempsey (186); 9, Oxley Highway to Kundabung (253); 10, Coopernook to Herons Creek (74); 11, Bundacree Creek to Possum Brush (62); 12, Tomago (79); 13, Hunter Expressway (190); 14, Termeil Creek (70); 15, Kapooka (51); 16, Woomargama (24).

Table 1. Eight nest box designs and their dimensions (cm) included in this study

Nest box type	Entrance diameter	Width	Vertical height	Number installed (% of total)
Scansorial mammal	3–4	18 × 18	30	368 (20%)
Small glider	4–5	20 × 20	30	403 (22%)
Small parrot	6.5	20 × 20	40	367 (20%)
Large glider	7–9	25 × 30	40	206 (11%)
Possum	8.5–10	25 × 30	40	341 (18%)
Small owl	10	25 × 30	50	44 (2%)
Large owl	20	55 × 55	80	48 (2%)
Large parrot	20	30 × 40	120	88 (5%)

not be unambiguously attributed to a species. These records were excluded from any of the data compilations.

Data analysis

We used logistic regression implemented in IBM SPSS Statistics 25 (IBM, Armonk, NY, USA) to investigate the influence of box type on whether a box was used or not. Other variables could also influence box use but because we relied on consultants' reports data for other variables were not consistently available. One additional variable that was included in our analysis was broad geographic location. Eleven of the projects were located along the Pacific Motorway on the NSW north coast and might be associated with habitat of higher quality or larger populations of the focal species. Therefore, we categorized boxes as to whether they were located on the north coast or not. Due to the similarity of nest box entrance size, the *possum* and *small owl* boxes were pooled into one group, and the *large parrot* and *large owl* boxes pooled into another group. The analysis of the small glider data only used records where animals were seen in a box during at least one of the inspections (i.e. coded for glider seen within (1) or not seen (0)). Using such data should increase the likelihood of detecting preferences for particular box types. Models with the variables *box-type* and *location* were assessed for model fit using the Hosmer and Lemeshow test (Quinn & Keough 2002).

Results

Contention 1: use of nest boxes by common species and the influence of nest box design

The Common Brushtail Possum is the species widely cited as one that dominates nest boxes (see Le Roux *et al.* 2016;

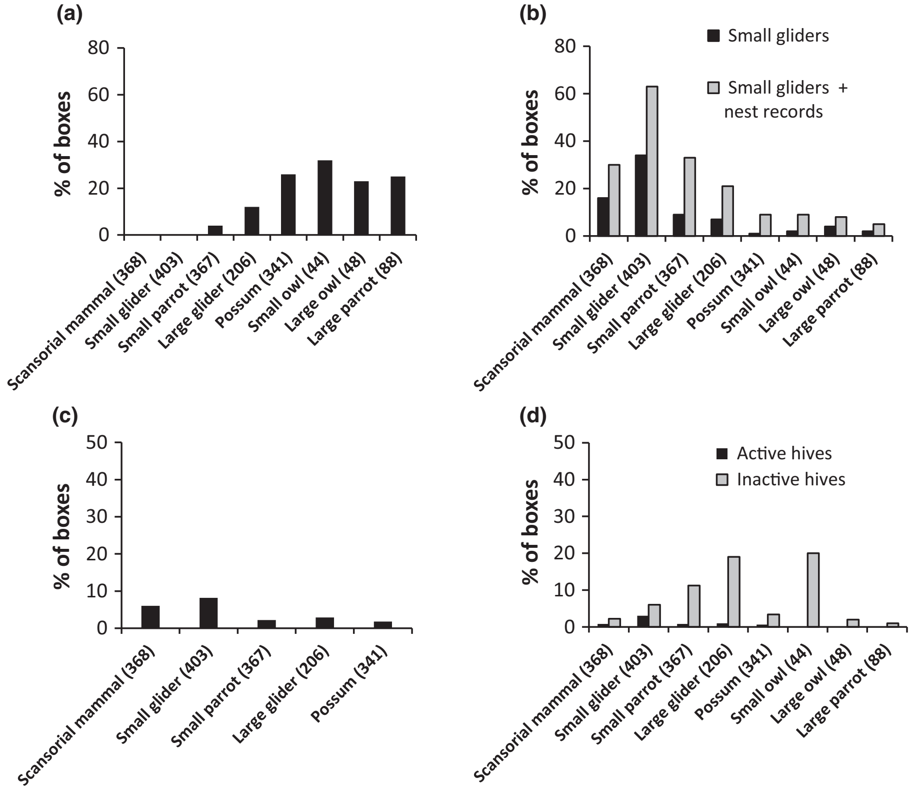

Figure 2. Percentage of nest boxes of each type (sample size in brackets) used by different species. (a) Use of boxes where Brushtail Possums were seen. (b) Pooled data for Sugar Gliders and Squirrel Gliders representing boxes where gliders were seen as well as boxes containing either gliders or their unoccupied nests. (c) Boxes used by Antechinuses including unoccupied nests. (d) Boxes used by Feral Honeybees. Use includes active hives (n = 18) and inactive or remnant hives (n = 139).

Lindenmayer *et al.* 2016, 2017). We detected this species as well as another Bushtail Possum (*T. caninus* but not *T. cunninghami*), which often could not be distinguished, in 9% of all boxes, with a predominance of records in the *possum* (26%) and *small owl* (32%) boxes (Fig. 2a). These two box types accounted for 20% of all boxes installed (Table 1). The *scansorial mammal* and *small glider* boxes were omitted from the analysis because the small entrance size (3.5–5 cm diameter) should have excluded Brushtail Possums. The model that included *box-type* and *location* failed the Hosmer and Lemeshow test (χ^2 = 15.8, df = 4, P < 0.01) indicating a poor fit to the data. This was resolved when *location* was removed. The analysis revealed that box type significantly explained Brushtail Possum detection in nest boxes (χ^2 = 91.3, df = 3, P < 0.001). The *small parrot* box was used as a reference because it had the smallest entrance size and lower use. The other three box types were significantly (P < 0.001) more likely to be used compared with the *small parrot* box. Compared with the *small parrot* box, possums were 9.1 times (odds ratio) more likely to use the *possum* box, 8.1 times more likely to use the *large parrot* box and 3.4 times more likely to use the *large glider* box.

Records of Sugar Gliders and Squirrel Gliders (Fig. 3) were pooled for analysis and referred to as small gliders because they can be difficult to distinguish by inexperienced personnel or if covered by a leaf nest, particularly when viewed with a pole camera. Small gliders were detected in every project, occupying 14% of all boxes, including 34% of the *small glider* boxes (Fig. 2b). If empty nests are included small gliders used 31% of all boxes, but 63% of the *small glider* boxes. The logistic regression revealed that the variables significantly explained glider presence in the nest boxes (χ^2 = 230.4, df = 6, P < 0.001). This model satisfied the Hosmer and Lemeshow test. The variable *location* did not have a significant influence (P = 0.07) whereas *box-type* did (χ^2 = 153.7, df = 5, P < 0.001). The different box types were compared with the *possum* box. The *large parrot* box and the *possum* box did not differ (P = 0.12) but all other box types differed significantly (P = 0.001) in predicting glider presence. Compared with the *possum* box, gliders were 51.9 times (odds ratio) more likely to use the *small glider* box, 18.0 times more likely to use the *scansorial mammal* box, 10.5 times more likely to use the *small parrot* box and 6.9 times more likely to use the *large glider* box.

Across all projects, Antechinuses (*A. stuartii* and *A. flavipes*; one *A. agilis*) were detected in 4% of all boxes, with higher use of the *small glider* (8%) and *scansorial mammal* (6%) boxes (Fig. 2c). Only one record was obtained in a small or large owl box, so these were excluded from the analysis. The logistic regression revealed that the variables significantly explained Antechinus detection in the nest boxes (χ^2 = 26.9, df = 5, P < 0.001). This model satisfied the Hosmer and Lemeshow test. The variable *location* did not have a significant influence (P = 0.69) whereas *box-type* did (χ^2 = 23.3, df = 4, P < 0.001). The *possum* box was used as a reference because it had the lower use. The *small parrot* (P = 0.73) and the *large glider* (P = 0.38) boxes did not differ in use to that of the *possum* box. Use of the *scansorial mammal* box (P = 0.01) and the *small glider* box (P = 0.01) differed significantly to that of the *possum* box. These boxes were 3.6 and 4.9 times (odds ratio), respectively, more likely to be used compared with the *possum* box.

A number of other native species that might be considered common species were detected in the nest boxes (Table 2) (Fig. 4). The most frequent of these was the Common Ringtail Possum. There were just 10 records (feathers or broken egg shells) of small common

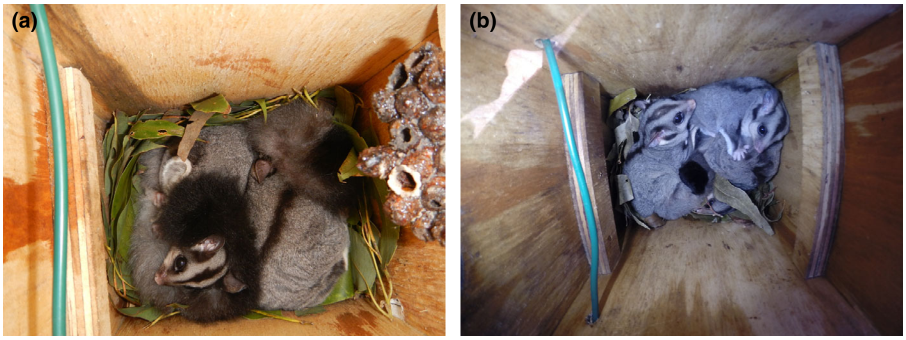

Figure 3. Squirrel Gliders in nest boxes (a, b). Images: Sandpiper Ecological.

parrots (Rainbow Lorikeets (*Trichoglossus haematodus*), Scaly-breasted Lorikeets (*T. chlorolepidotus*), Eastern or Crimson Rosellas).

Contention 2: use of nest boxes by exotic species

Across all projects, there were 157 records of Feral Honeybee hives in boxes, with a greater percentage of records (20%) in the *large glider* and *small owl* boxes (Fig. 2d). Only 18 (12%) of these Honeybee hive records were of active hives. That is, the active hives were present in just 1% of all boxes. Most of the records were of disused honeycomb or its remains (Fig. 5). In analysing these data, the *large parrot/large owl* boxes were omitted due to almost no use. In the earlier analyses, the *possum* and *small owl* boxes were pooled. However, Honeybee use of these two box types differed, largely due to a high use of the *small owl* box in one project (Oxley Hwy to Kundabung), where across all boxes, there were 46 remnant hives and one active hive. Due to the small number of *small owl* boxes relative to the possum boxes, these boxes were omitted from the analysis. The logistic regression revealed that the variables significantly explained bee hive presence in the nest boxes ($\chi^2 = 63.7$, $df = 5$, $P < 0.001$). This model satisfied the Hosmer and Lemeshow test. The variable *location* did not have a significant influence ($P = 0.21$) whereas *box-type* did ($\chi^2 = 54.3$, $df = 4$, $P < 0.001$). There was no difference in use of the *possum* box ($P = 0.53$) compared with the *scansorial mammal* box. All other box types were significantly more likely to be used ($P = 0.001$) compared with the *scansorial mammal* box. Honeybees were 3.6 times (odds ratio) more likely to use the *small glider* box, 4.8 times more likely to use the *small parrot* box and 8.1 times more likely to use the *large glider* box.

Common Mynas (*Acridotheres tristis*) were detected in 10 nest boxes across two projects (2 *possum* boxes, 1 *small glider*, 4 *small parrot*, 1 *small owl*, 2 *large owl*), and Common Starlings (*Sturnus vulgaris*) were detected in three boxes in one project (1 *small glider*, 2 *small parrot*). One box was occupied by the Black Rat (*Rattus rattus*) in each of four projects (2 *small glider*, 2 *small parrot*). Thus, these exotic birds and mammal were detected in just 1% of all boxes.

Contention 3: use of nest boxes by threatened species

Four different threatened species were detected in the nest boxes. The squirrel glider was detected unambiguously in 80 boxes across 11 projects but identification difficulties precluded full enumeration. The Brush-tailed Phascogale (*Phascogale tapoatafa*) used 31 boxes across five projects. The Federally listed Greater Glider (*Petauroides volans*) (Fig. 6) was detected in three nest boxes across two projects, and the Yellow-bellied Glider (*Petaurus australis*) was detected in one box.

Table 2. The number of boxes (projects) in which other vertebrate species were recorded across 1865 nest boxes

Species	No. of boxes
Mammals	
Brush-tailed Phascogale (*Phascogale tapoatafa*)†	31 (5)
Greater Glider (*Petauroides volans*)†	3 (2)
Yellow-bellied Glider (*Petaurus australis*)†	1 (1)
Feathertail Glider (*Acrobates* sp.)	28 (10)
Common Ringtail Possum (*Pseudocheirus peregrinus*)	53 (7)
Black Rat (*Rattus rattus*)‡	4 (4)
Microbats	5 (2)
Birds	
Australian Owlet-nightjar (*Aegotheles cristatus*)	18 (8)
Small Parrots (feathers/eggshells, lorikeets & rosellas)	10 (5)
White-throated Treecreeper (*Cormobates leucophaea*)	7 (4)
Galah (*Eolophus roseicapilla*)	17 (1)
Australian Wood Duck (*Chenonetta jubata*)	4 (2)
Common Myna (*Acridotheres tristis*)‡	11 (2)
Common Starling (*Sturnus vulgaris*)‡	3 (1)
Reptiles	
Lace Monitor (*Varanus varius*)	33 (8)
Carpet Python (*Morelia spilota*)	3 (2)
Green Tree Snake (*Dendrelaphis punctulatus*)	2 (2)
Brown Tree Snake (*Boiga irregularis*)	1 (2)
Frogs	
Peron's Tree Frog (*Litoria peronii*)	14 (4)
Bleating Tree Frog (*Litoria dentata*)	2 (1)

†Threatened species. ‡Introduced species.

Discussion

Contention 1: are common species dominant users of nest boxes?

This contention arose largely from the high use of nest boxes by the Common Brushtail Possum in the studies raising this concern.

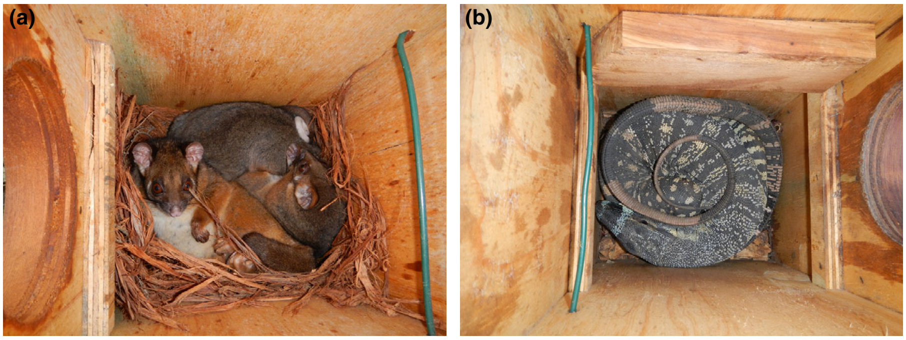

Figure 4. (a) Common Ringtail Possums. (b) Lace Monitor. Images: Sandpiper Ecological.

Figure 5. Abandoned Honeybee hives. (a) Empty honeycomb. (b) Remnants of honeycomb in a nest box with a small glider nest. Images: Sandpiper Ecological.

Figure 6. Greater Glider. Image: Sandpiper Ecological.

This species used 58% (Le Roux *et al.* 2016), 36% (Lindenmayer *et al.* 2016) and 53% (Lindenmayer *et al.* 2017) of boxes it could enter indicating the species was relatively abundant. The perception of this species dominating in those studies also arose because boxes that were suited to it accounted for 50%, 60% and 39% of all nest boxes, respectively. These boxes should not be installed or installed with a lower frequency if this species is not a target of projects. In the present study, Brushtail Possums were less dominant because, whilst they frequently used the *possum* boxes, these boxes accounted for only 18% of all boxes. However, additional box types (*small owl*, *large owl* and *large parrot*; 23–32% were used) were also suitable which highlights an issue with a lack of specificity that encourages frequent use by a common species.

Other common species that gave rise to this contention (Eastern and Crimson Rosellas, Common Ringtail Possum and Yellow-footed Antechinus) were infrequent users in the present study. Small parrots used <1% of boxes in our study compared with 9% (Le Roux *et al.* 2016), 35% (Lindenmayer *et al.* 2016) and 1% (Lindenmayer *et al.* 2017) of boxes elsewhere. Common Ringtail Possums used 3% of boxes in our study compared with 0% (Le Roux *et al.* 2016), 16% (Lindenmayer *et al.* 2016) and 5% (Lindenmayer *et al.* 2017) of boxes elsewhere. Antechinuses used 4% of boxes in our study compared with 0% (Le Roux *et al.* 2016), 6% (Lindenmayer *et al.* 2016) and 13% (Lindenmayer *et al.* 2017) of boxes elsewhere. Thus, overall the other common nest box users were not particularly common users in our study.

The one species group that were common users were the small gliders. The most frequently encountered small glider was the Sugar Glider which is a common and widespread species. However, 40% of installed boxes were suited to the Sugar Glider (i.e. the *small glider* and the *scansorial mammal* boxes). The frequent use of nest boxes by Sugar Gliders likely reflects their local abundance. The studies that were concerned about use by common species (Le Roux *et al.* 2016; Lindenmayer *et al.* 2016, 2017) recorded evidence of Sugar Gliders in only 1% of all installed boxes, in contrast to the 31% of all boxes with evidence of small gliders in our study. Sugar Gliders used 29% of all boxes in north-east NSW (Goldingay *et al.* 2015) and 37% of all boxes near Bendigo (Goldingay *et al.* 2018). This raises the point that some nest box projects will be directed at providing for any local species. The primary objective of the RMS projects we report on here was to provide shelter sites for animals displaced during clearing. Therefore, recording a high rate of use by a species such as the Sugar Glider is consistent with this objective.

Contention 2: are exotic species dominant users of nest boxes?

The studies that expressed concern about exotic species being dominant users of nest boxes (Le Roux *et al.* 2016; Lindenmayer *et al.* 2016, 2017) recorded very high use of suitable nest boxes by feral honey bees (13%; 33%; 19%, respectively) and other exotic species consisting of Black Rats, Common Mynas and Common Starlings (21%; 63%; 28%). In contrast, exotic species were rarely recorded using the 1865 nest boxes in our study. There was evidence of Feral Honeybees in 8% of all boxes but active hives were observed in just 1% of boxes. Another 1% of boxes were used by the other exotic species. The rarity of these species across

16 landscapes in this study allows the contention about exotic species dominating nest box use to be rejected. These contrasting results suggest the south-western slopes and south eastern highlands of NSW, where the above studies were conducted, may be unsuitable bioregions for nest box installation (see below).

Feral Honeybees are the exotic species for which there has been most concern (Lindenmayer *et al.* 2009). In this study, nest boxes with evidence of use by honeybees were subsequently used by native species (see Fig. 5b). It appears that hives were treated between inspections in only one project. First inspections in all projects reported most hives were remnant rather than active. Observations that hives did not persist in nest boxes and were subsequently used by native species are consistent with earlier observations (Goldingay *et al.* 2015).

Contention 3: do species of conservation concern use nest boxes?

The studies that gave rise to this contention had a paucity of records of threatened species in nest boxes. Le Roux *et al.* (2016) and Lindenmayer *et al.* (2016) recorded no species of conservation concern whilst Lindenmayer *et al.* (2017) recorded Squirrel Gliders using an average of 0.4% of all boxes over time and the Brown Treecreeper (*Climacteris picumnus*) 0.1% of boxes, which for both includes boxes of unsuitable design. However, it was not just the Squirrel Glider that was rarely detected by the above studies. Sugar Glider individuals were also rarely detected (1.4%, 1.3%, 0.6% of all boxes, respectively). The stark contrast to our study (31% of all boxes used by small gliders) suggests the landscapes where the other studies were conducted were highly altered, degraded or fragmented and therefore unsuited to the common Sugar Glider and the threatened Squirrel Glider.

In our study, Squirrel Gliders were detected unambiguously (i.e. physically seen and identified) in 80 nest boxes across 11 of 16 projects. The records were from two locations on the south-western slopes of NSW, two locations near Newcastle and seven locations spanning 280 km on the NSW north coast. Three box types (*scansorial mammal*, *small glider* and *small parrot*) accounted for 76 records, representing 7% of these boxes. Based on studies at other locations, there is no avoidance of nest boxes shown by this species. For example, Squirrel Gliders used 100% of suitable nest boxes in Brisbane and in the Sunshine Coast hinterland (Goldingay 2015; Goldingay *et al.* 2015) whereas they occupied 5–9% of nest boxes near Albury (Durant *et al.* 2009). Our findings for the Squirrel Glider reject the third contention.

We also recorded the threatened Brush-tailed Phascogale which used 31 nest boxes across 5 locations. This may appear to be a low level of use, but this species has large home ranges (40–105 ha; Soderquist 1995), tree hollows were at a density of 2–11 per ha at the north coast sites where this species is more likely to occur and our nest boxes were clustered in a linear configuration mostly <200 m from the highway. Other studies have recorded frequent use of nest boxes by Phascogales (Soderquist 1993; Rhind & Bradley 2002; Goldingay *et al.* 2018) demonstrating there is no avoidance of nest boxes by this species. We also recorded a few individuals of the threatened Greater Glider and Yellow-bellied Glider. The infrequent use of nest boxes by these species may reflect their local rarity, or the availability of tree hollows in the surrounding landscape or a lack of specificity of the nest box designs.

Le Roux *et al.* (2016) concluded that nest box locations and designs need to be highly targeted if nest box projects are to be successful in providing population support for threatened species. This is indeed the case. Brazill-Boast *et al.* (2013) found that two years after nest box installation, the number of endangered Gouldian Finch (*Erythrura gouldiae*) breeding pairs using specifically designed nest boxes (~85) was almost double the number that bred in tree hollows (45) prior to nest box installation. Berris *et al.* (2018) reported that >50% of monitored breeding pairs of the endangered Kangaroo Island Glossy Black-cockatoo (*Calyptorhynchus lathami halmaturinus*) nested in artificial hollows, and these hollows contributed to the success of the recovery programme that has seen the population double in size over 20 years. In Western Australia, the endangered Carnaby's Black-cockatoo (*Calyptorhynchus latirostris*) has been documented to nest in 23% of 246 artificial hollows (Groom 2010). This could make a large contribution to conserving this species. More recently, Stojanovic *et al.* (2019) recorded 32 critically endangered Swift Parrot (*Lathamus discolor*) pairs breeding in custom-made nest boxes compared with 43 that bred in tree hollows across three locations. The above studies all demonstrate that targeted nest box designs can be highly successful for threatened species. The contention that threatened species are infrequent users of nest boxes is not supported.

Nest box designs

Nest box design was a good predictor of species presence. This finding is important for future nest box studies as well as others directed at managing tree hollow resources for individual species. The small gliders showed almost twice as much use of the *small glider* box compared with the next most frequently used box. The analysis showed that gliders were 52 times more likely to use the *small glider* box with a 4–5 cm diameter entrance compared with the *possum* box which had a 10 cm entrance. The Antechinuses showed higher use of the two smaller box types compared to boxes with large entrance sizes. These findings reinforce the notion that the smaller species may avoid large entrance boxes where they may encounter or be excluded by larger species (Menkhorst 1984a; Traill & Lill 1997; Goldingay *et al.* 2007). There were too few records of the vulnerable Brush-tailed Phascogale to analyse, but the highest proportion of its records was in the *scansorial mammal* box. Brushtail Possum individuals used 26% of the *possum* and 25% of the *large parrot* boxes. They were 8–9 times more likely to use these boxes than the *small parrot* box from which adults should have been excluded due to the smaller 6.5–7 cm entrance. All the above results confirm that entrance size can be used to target species (Goldingay *et al.* 2015; Le Roux *et al.* 2016).

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