SHORT COMMUNICATION

Bat boxes are not a silver bullet conservation tool

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ABSTRACT

Nest boxes are often promoted as substitute structures for hollow-dependent fauna, but are they generally effective? In a long-term bat-box monitoring project in southeastern Australia, box occupancy was dominated by one common and widespread urban-adapted species, Gould's wattled bat *Chalinolobus gouldii*. In contrast, the 13 other bat species in the area made little or no use of the boxes. Policymakers, land managers and conservation professionals working in the field of biodiversity offsets should be aware that bat boxes are unlikely to compensate adequately for the broadscale loss of tree hollows caused by various forms of human disturbance.

INTRODUCTION

Worldwide, tree hollows provide vital refuges for a broad range of fauna (Lindenmayer et al. 2017). Nest or roost boxes are often incorporated into biodiversity offset programs to compensate for the loss of natural tree hollows caused by various forms of human disturbance (Le Roux et al. 2016). Bat boxes have proved successful in conservation efforts focused on individual species of hollow-roosting insectivorous bats (Chiroptera), such as *Pipistrellus pygmaeus* (Flaquer et al. 2005) and *Myotis bechsteinii* (Kerth & Van Schaik 2012). However, the efficacy of bat-box programs in providing supplementary roosts for bats at the community level remains unclear (Mering & Chambers 2014, Rueegger 2016). While they are negatively impacted by urbanisation, compared to other mammals, bats are relatively diverse and abundant in these highly modified landscapes (van der Ree & McCarthy 2005) where bat-box programs are frequently undertaken (López-Baucells et al. 2017). However, surprisingly little attention has been paid to the question of whether bat-box programs have achieved explicit goals, such as supporting viable, diverse communities of bats, and particularly for species of conservation concern (Mering & Chambers 2014, Rueegger 2016).

Here, we summarise the key findings from a long-term bat-box monitoring project in Melbourne, southeastern Australia. Bat boxes were installed at four sites with the *a priori* objective of providing supplementary roosts for the community of hollow-roosting insectivorous bats that persist throughout Greater Melbourne (Table 1). Our primary aim was to determine whether the bat boxes have been an effective conservation tool and fulfilled this objective.

METHODS

This study was conducted within the greater metropolitan area of Melbourne (37°48' S, 144°55' E) in the state of Victoria, southeastern Australia. A total of 126 bat boxes, comprising nine designs based on those typically used in the Northern Hemisphere, were installed at four sites of regenerating forest to compensate for the limited number of naturally occurring tree hollows. The four sites were: Organ Pipes National Park (OPNP, 40 boxes), Gresswell Nature Conservation Reserve (GNCR, 29 boxes), Wilson Reserve (WR, 20 boxes), and the La Trobe University Wildlife Sanctuary (LTUWS, 37 boxes; Appendices S1 and S1). The boxes were installed on trees at heights ranging from 4–6 m above ground level.

All boxes at each site were manually checked during the day for the presence of bats; the frequency of these checks varied at each site, but they were typically conducted monthly or bi-monthly. Surveys were conducted from 1994–2016 at OPNP, 2005–2016 at WR, 2005–2015 at GNCR, and 2010–2015 at LTUWS, resulting in a total of 444 surveys at the four sites (Appendix S3). During surveys, all bats found roosting in boxes were collected, identified, and a range of biometric data were recorded for each individual. From 2012–2016 all bats found roosting in boxes were permanently marked either with a metal-alloy bat band (Australasian Bird and Bat Banding Authority) or with a microchip (Trovan ID100 Passive Implantable Transponder).

We used a G-test to compare the observed frequency of box use by different bat species (at all four sites combined for the entire survey period) with expected frequencies of use generated from species occurrence records throughout Greater Melbourne for the period 1990–2016 (data source: 'Victorian Biodiversity Atlas', The State of Victoria, Department of Environment, Land, Water and Planning, December 2016; Table 1).

RESULTS

Three of the 14 species of hollow-roosting bats that occur in the Greater Melbourne area used the bat boxes with some regularity, while another five species used boxes occasionally. However, occupancy records from all four sites for the entire survey period were dominated by one species, Gould's wattled bat *Chalinolobus gouldii* (Table 2). *Chalinolobus gouldii* was the only species that had a greater than expected proportion of box use ($G = 79447.7$, d.f. = 7, $P < 0.001$), accounting for 72% more box occupancy records than expected given its documented occurrence throughout Greater Melbourne (Fig. 1). *Chalinolobus gouldii* was the only species that formed maternity groups at all four sites during the spring/summer reproductive season (groups of pregnant females in early spring, followed by groups of lactating females with dependent non-volant young, Table 2). The other seven species made limited use of the boxes; four species bred in them but only in low numbers (Table 2). Box use was highest during summer, autumn and spring, with reduced use during the winter months (Fig. 2).

DISCUSSION

Bat boxes are widely considered a beneficial tool for the conservation of hollow-roosting bats (Mering & Chambers 2014). However, there is no empirical evidence showing that they provide effective supplementary artificial roosts for bat communities. The majority of studies worldwide show that bat boxes are typically used by 1–3 species, which are usually common, abundant species of minimal conservation concern (Mering & Chambers 2014, Rueegger 2016). Our findings further support this pattern: long-term box use at all four sites was dominated by one common and widespread urban-adapted species, *Chalinolobus* *gouldii* (Threlfall et al. 2012). Further research is needed to determine the factors driving the dominant use of bat boxes by common species (such as *Chalinolobus gouldii*) in order to increase the conservation value of bat-box programs in human-modified landscapes (Evans & Lumsden 2011). Furthermore, a greater understanding is needed of the potential impacts that localised apparent increases in populations of common species (facilitated by bat boxes) may have on competition and community composition (Evans & Lumsden 2011, Mering & Chambers 2014, Rueegger 2016). Policymakers, land managers and conservation professionals working in the field of biodiversity offsets should be aware that there is a growing body of evidence that bat-box programs employing traditional box designs (i.e., boxes made from wood, plywood, or a mixture of concrete and sawdust) do not generate significant positive conservation outcomes for bat biodiversity, and therefore do not effectively compensate for the broadscale loss of tree hollows caused by various forms of human disturbance. This provides further evidence for the importance of retaining natural hollow-bearing trees (Le Roux et al. 2016, Lindenmayer et al. 2017).

Alternative designs for the provision of artificial hollows need to be developed and empirically tested, in an effort to provide supplementary habitat suitable for species that, to date, have not used traditional bat-box designs, particularly species of conservation concern (Mering & Chambers 2014, Rueegger 2016). For example, using chainsaws to cut into trees or felled logs to create artificial roost habitats that more closely resemble the structural and thermal characteristics of natural hollows (Griffiths et al. 2017). Roosts constructed from materials such as resin or wood shingles that are designed to mimic exfoliating bark should also be trialed, particularly in regions where they have not typically been used (Mering & Chambers 2014, Rueegger 2016).

Over a monitoring period spanning more than two decades, our project's primary conservation objective (to provide supplementary roost habitat for a range of bat species) was not achieved. However, bat boxes were extremely effective in providing supplementary artificial roosts for *Chalinolobus gouldii*. While common species using boxes may provide important ecosystem services, such as reducing localised abundance of pest invertebrates (Boyles et al. 2011), the extent to which this occurs in urban and peri-urban landscapes warrants further investigation. Our long-term project has provided valuable opportunities for community engagement and education, as well as yielding insights into the ecology of the species that primarily occupy the boxes (Godinho et al. 2015). However, our findings show that the assumption that deploying traditional bat-box designs is an effective habitat offset tool for maintaining bat diversity in human-modified environments needs to be re-examined.

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FIGURE CAPTIONS

Figure 1. Difference in the observed versus expected proportion of box use by the eight species that occupied boxes at the four sites over the entire survey period (1994–2016). Expected proportions of box use were derived from species occurrence records throughout Greater Melbourne, sourced from the Victorian Biodiversity Atlas for the period 1990–2016 (see Table 1). Species abbreviations: Cg, Chalinolobus gouldii; Cm, Chalinolobus morio; So, Scotorepens orion; Vd, Vespadelus darlingtoni; Vr, Vespadelus regulus; Vv, Vespadelus vulturnus; Aa, Austronomus australis; Mp, Mormopterus planiceps.

Figure 2. Summary of seasonal patterns of box use at (a) Organ Pipes National Park (OPNP) and (b) Wilson Reserve (WR) from 2005–2016. Forty boxes were checked at OPNP monthly from 2005–2007, and then every second month from 2008–2016; at WR 20 boxes were checked monthly. Mean (±SE) number of bats using boxes in each season was calculated for species that accounted for ≥ 1% of total box use records: Cg, Chalinolobus gouldii; Cm, Chalinolobus morio; So, Scotorepens orion; Vd, Vespadelus darlingtoni; Aa, Austronomus australis (see Table 2).

TABLES

Table 1. List of hollow-roosting insectivorous bat species in the Greater Melbourne region. Species occurrence records are sourced from the Victorian Biodiversity Atlas (VBA) for the period 1990–2016. The VBA database incorporates records from a range of survey types: harp trapping, mist netting, bat detectors, incidentals, and roost observations.

Species name	**Common name**	**VBA records (% of total)**	**Status in greater Melbourne**
Vespertilionidae			
Chalinolobus gouldii	Gould's wattled bat	163 (16.2%)	Common
Chalinolobus morio	chocolate wattled bat	77 (7.7%)	Common
Myotis macropus	large-footed myotis	4 (0.4%)	Rare and restricted to riparian areas
Nyctophilus geoffroyi	lesser long-eared bat	135 (13.4%)	Common
Nyctophilus gouldi	Gould's long-eared bat	4 (0.4%)	Rare, mostly in outer suburbs with high tree cover
Scotorepens balstoni	inland broad-nosed bat	10 (1.0%)	Rare
Scotorepens orion	eastern broad-nosed bat	20 (2.0%)	Uncommon
Vespadelus darlingtoni	large forest bat	97 (9.6%)	Common
Vespadelus regulus	southern forest bat	47 (4.7%)	Uncommon

Vespadelus vulturnus	little forest bat	178 (17.7%)	Common
Molossidae			
Austronomus australis	white-striped free-tailed bat	241 (24.0%)	Common
Mormopterus planiceps	southern free-tailed bat	19 (1.9%)	Uncommon
Mormopterus ridei	eastern free-tailed bat	7 (0.7%)	Rare
Emballonuridae			
Saccolaimus flaviventris	yellow-bellied sheath-tailed bat	4 (0.4%)	Rare, potential vagrant

Table 2. Summary of long-term bat box use over the entire survey period at four sites in Melbourne, Australia: OPNP, Organ Pipes National Park; WR, Wilson Reserve; GNCR, Gresswell Nature Conservation Reserve; LTUWS, La Trobe University Wildlife Sanctuary. Breeding activity is summarised for the period when all bats using boxes at all four sites were permanently marked with a bat-band or microchip (2012–2016). Breeding females include pregnant and lactating bats (with dependent young) that used boxes during spring/summer.

	Site			
	OPNP	WR	GNCR	LTUWS
Project summary				
Survey period	1994–2016	2005–2016	2005–2015	2010–2015
Number of times all boxes at each site were manually checked	213	141	61	29
Total number of bat captures (all species combined)	22,121	4,669	2,815	1,711
Records of each species' box use (% of total captures)				
Chalinolobus gouldii	19929 (90.9%)	4432 (94.9%)	2477 (88.0%)	1663 (96.6%)
Chalinolobus morio	39 (0.2%)	46 (1.0%)	8 (0.3%)	1 (0.1%)
Scotorepens orion	0	76 (1.6%)	0	1 (0.1%)
Vespadelus darlingtoni	1,430 (6.5%)	27 (0.6%)	9 (0.3%)	3 (0.2%)
Vespadelus regulus	61 (0.3%)	0	0	0
Vespadelus vulturnus	1 (0.005%)	0	0	0
Austronomus australis	656 (3.0%)	88 (1.9%)	321 (11.4%)	53 (3.1%)
Mormopterus planiceps	5 (0.02%)	0	0	0
Breeding activity: 2012–2016				
Number of box checks conducted during spring/summer	17	31	10	10
Number of (permanently-marked) breeding females that used boxes				
Chalinolobus gouldii	303	57	113	144
Scotorepens orion	0	5	0	0

Vespadelus darlingtoni	53	1	0	0
Vespadelus regulus	1	0	0	0
Austronomus australis	26	0	2	4

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article at the publisher's web-site.

Appendix S1. Description of the four field sites.
Appendix S2. Examples of the nine different bat-box designs.
Appendix S3. Summary of bat-box survey effort.