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Review Article

The Use of Nest Boxes in Malaysia: Design and the Potential for Research and *In-situ* Conservation of Birds

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ABSTRACT

Nest boxes have been used as artificial cavities for decades to attract cavity-nesting birds that rely on such structures to roost and breed. Nest boxes aid research efforts to understand the biology and behaviour of birds and may increase breeding success, thereby contributing to the conservation of a species. The type and dimension of nest boxes and the survey design used in the tropics vary, depending on the targeted species. This paper reviewed 30 published *in-situ* works using nest boxes and their survey design in Malaysia. Most studies were done on Barn Owls (*Tyto alba javanica*) (25), followed by hornbills (5), where they were conducted in oil palm plantations (50%), rice fields (20%), forest habitats (16.7%), urban landscapes (10%), and different habitat matrices (3.3%). Attempts to enhance/manage the local populations were the main research purpose. Unlike studies from other tropical countries, studies involving nest boxes in Malaysia are still in their infancy. This review suggests future research focus on forest species, especially those requiring immediate conservation attention, and delineate parameters highlighted in published works to counter literature inconsistency. Such research involving nest boxes may also be further expanded to the study and/or conserve other interconnected fauna species.

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INTRODUCTION

Secondary cavity-nesting birds often rely on tree cavities that are naturally available or are excavated by primary cavity-nesting birds (e.g., woodpeckers) and mammals (e.g., sun bears *Helarctos malayanus*) to roost and breed. As tree cavities are often competed for, especially those of good quality as nest cavities, such structures may serve as a limiting factor for the breeding population of a species (Newton, 1994) and researchers' efforts in understanding the birds' biology and behaviour. To either achieve the goal of population expansion or improve the research of these birds, nest boxes have been used to act as artificial nest cavities to attract these birds (Lambrechts et al., 2012). These secondary cavity-nesting birds may range from certain passerines (Cooper & Bonter, 2008; Gelter & Tegelström, 1992; Hanmer et al., 2017; Hudin et al., 2017; Miller, 2002; Riyahi et al., 2022; Zhang et al., 2021) and non-passerines especially raptors (Calabrese et al., 2020; Geduhn et al., 2016; Liébana & Sarasola, 2013; Raid, 2012; Rejt, 2001; Richards et al., 2004; Zárybnická et al., 2016), parrots (Olah et al., 2014; Ortiz-Catedral & Brunton, 2009; Wimberger et al., 2017), hornbills (Cremades et al., 2011; Pasuwan et al., 2011), and waterfowls (Davis et al., 2007; Gong et al., 2018).

The use of nest boxes has contributed to a wide range of research topics varying from breeding ecology (Arct et al., 2022; Beasley & Parrish, 2009; Davis et al., 2007; Hanmer et al., 2017; Mainwaring et al., 2015; Palko et al., 2011), feeding ecology (Balčiauskienė et al., 2005; Hudin et al., 2017; Rejt, 2001), nest site preference (Cooper & Bonter, 2008; Hanmer et al., 2017; Miller, 2002; Olah et al., 2014; Ortiz-Catedral & Brunton, 2009), conspecific and heterospecific interactions (Gong et al., 2018; Zárybnická et al., 2016), as well as occupancy rate (Liébana & Sarasola, 2013; Sudarmaji et al., 2021; Zhang et al., 2021). Additionally, some studies retrieved nestlings, breeding pairs, or even nest materials from nest boxes to assess the presence of ectoparasites (Hanmer et al., 2017; Proudfoot et al., 2006; Soltész et al., 2018) and the effect of rodenticide exposure (Richards et al., 2004; Geduhn et al., 2016), as well as for population genetic studies (Gelter & Tegelström, 1992; Riyahi et al., 2022). Otherwise, nest boxes may be solely deployed for conservation purposes to increase local bird populations (Calabrese et al., 2020; Cremades & Ng, 2012; Pasuwan et al., 2011).

The type and dimension of nest boxes and the method in nest box provisioning are variable depending on the targeted species. Nest boxes are often carefully designed to facilitate access to the nest cavities and their contents (Lambrechts et al., 2012; Olah et al., 2014). For a particular species, those designs and methods may differ across habitats and countries as well (Lambrechts et al., 2010) with attempts to control the biotic (Davis et al., 2007) and abiotic factors (Arct et al., 2022; Pasuwan et al., 2011) that serve as explanatory variables of species ecology. A few studies have supplemented details on nest box dimensions (Arct et al., 2022; Cooper & Bonter, 2008; Maziarz et al., 2017; Zhang et al., 2021) and illustrations (Olah et al., 2014; Pasuwan et al., 2011; Stanback, 2020; Wimberger et al., 2017) as reference for future studies of species. While most nest boxes were built with a single chamber, some studies may include additional chambers apart from the nest chamber to place monitoring equipment [e.g., camera surveillance system or camera traps; see Surmacki and Podkowa (2022) and Zárybnická et al. (2016)]. Most nest boxes were constructed from wood material (Arct et al., 2022; Miller, 2002; Palko et al., 2011; Zhang et al., 2021), while others were from other non-wood materials (Beasley & Parrish, 2009; Olah et al., 2014).

Depending on the study sites, the nest boxes' distribution may be placed randomly (Davis et al., 2007) or with a specific distance between the nest boxes (Arct et al., 2022; Palko et al., 2011; Zhang et al., 2021). Some studies may consider surveying targeted species' breeding or home range before nest box provisioning (Calabrese et al., 2020; Mainwaring et al., 2015; Richards et al., 2004). These nest boxes were either nailed or tied to trees (Arct et al., 2022; Maziarz et al., 2017; Olah et al., 2014; Ortiz-Catedral & Brunton, 2009; Palko et al., 2011) or else placed on man-made structures (Beasley & Parrish, 2009; Hudin et al., 2017). While many studies may not report the orientation of the nest boxes, some studies from the temperate and subtropical regions have highlighted the preferred position of the entrance facing the east to the southeast direction (Miller, 2002; Zhang et al., 2021). The height at which the nest boxes were placed is different across species from those that can easily be accessed (Arct et al., 2022; Lambrechts et al., 2010; Miller, 2002; Ortiz-Catedral & Brunton, 2009; Palko et al., 2011) otherwise higher into the canopy (Pasuwan et al., 2011).

For decades, studies using nest boxes were frequently done in the temperate region (Arct et al., 2022; Calabrese et al., 2020; Cooper & Bonter, 2008; Gelter & Tegelström, 1992; Gong et al., 2018; Hudin et al., 2017; Liébana & Sarasola, 2013; Ortiz-Catedral & Brunton, 2009; Raid, 2012; Rejt, 2001; Riyahi et al., 2022; Soltész et al., 2018; Zhang et al., 2021), with fewer studies conducted in the subtropic (Miller, 2002; Davis et al., 2007; Wimberger et al., 2017) and tropical regions (Cremades et al., 2011; Palko et al., 2011; Pasuwan et al., 2011; Olah et al., 2014; Sudarmaji et al., 2021). The implementation of nest boxes in the Southeast Asian region is still relatively new, apart from provisioning nest boxes for barn owls (*Tyto alba javanica*) to encourage the local population to breed and control the rodents in agricultural areas (Adidharma, 2002; Sipayung, 1992).

APPLICATION OF NEST BOXES IN MALAYSIA

Unlike studies from other tropical countries, *in-situ* studies involving nest boxes in Malaysia are still in their early stages, although they have been implemented since the late 1970s (Lenton, 1983). From a total of 30 published works, it is found that most studies involving nest boxes were done on barn owls (25), followed by hornbills (5), of which the works were conducted in oil palm plantations (50%), rice fields (20%), forest habitat (16.7%), urban landscapes (10%), and different habitat matrices (3.3%). The main research topics covered by these studies comprised methods in enhancing/

managing local populations (43.3%), prey selection (16.7%), breeding behaviour (13%), home range (10%), growth performance (6.7%), sex identification (6.7%), and egg measurement (3.3%). A summary of the studies using nest boxes, nest box dimensions, and respective survey designs is presented in Table 1.

Barn Owls

Barn owls, formerly a vagrant in Peninsular Malaysia, became a common resident species when they were introduced in agricultural areas to provide biological control of pests (i.e., rodents) as a complementary or alternative approach to rodenticide treatment (Puan et al., 2020). As the availability of nest sites was the limiting factor of barn owl numbers, nest boxes were provisioned to increase their population in oil palm plantations (Duckett, 1991; Lenton, 1983). The success in elevating the population had helped control the rat populations in some cases, lessening the dependency on anticoagulant rodenticide since the late 1970s (Duckett, 1991; FFTC, 2002; Lenton, 1983). Additionally, the cost of maintaining nest boxes was relatively cheaper than the costs of rodenticide and labour, which had been shown to reduce the overall cost spent by the plantation owners (Abidin et al., 2021). Other than in plantations with immature (Naim et al., 2010) or mature oil palms (Salim et al., 2014, 2015, 2016), nest boxes had also been provided in rice fields [(Amzah et al., 2014; FFTC, 2002; Hafidzi et al., 2003, 2007; Hafidzi & Na'im, 2003a, 2003b), urban landscapes, e.g., urban garden; see Saufi et al. (2020a, 2020b), and different habitat matrices, e.g., cocoa-coconut farmland; see Lee (1997)].

Before the 2000s, studies that involved provisioning nest boxes focused mainly on the methods to enhance/manage the local population (Duckett, 1991; Lee, 1997; Lenton, 1983), with few studies investigating their ecology (Lim et al., 1993). However, recent studies not only focused on upgrading previous methods (Abidin et al., 2021; Amzah et al., 2014; FFTC, 2002; Hafidzi et al., 2007; Hafidzi & Na'im, 2003b; Saufi et al., 2020b) but had expanded into their biology and ecology including breeding behaviour (Abidin et al., 2022; Naim et al., 2011; Salim et al., 2014), growth performance (Naim et al., 2010; Salim et al., 2016), egg measurement (Salim et al., 2015), home range (Hafidzi et al., 2003; Naim et al., 2012; Saufi et al., 2019), prey selection (Hafidzi & Na'im, 2003a; Puan et al., 2011, 2012; Saufi et al., 2020a), and sex identification (Ravindran et al., 2018, 2019). In addition, some studies retrieved eggs, nestlings, and even adults from nest boxes to assess the level of anticoagulant rodenticide exposure and the associated effects towards their growth and behaviour (Naim et al., 2012; Salim et al., 2014, 2015, 2016).

In the past, nest boxes were constructed from wood with zinc sheet roofs placed on top of telegraph or hardwood poles (Duckett, 1991; FFTC, 2002; Lenton, 1983; Naim et al., 2010, 2011). Studies from the past two decades may also use wood material (Amzah et al., 2014) as well as fibreglass

Table 1
Summary of the nest box dimension and survey designs in Malaysian bird studies

Species	Reference	Main study focus	Study site	Number of nest boxes provisioned	Material	Dimension (width × length × height; cm)	Distribution	Provisioned height and structure	Other methods
Barn owl	Lenton (1983)	A review of biology and study design to introduce population	Oil palm plantation	-	Wood	50 × 50 × 100	-	Placed on top of telegraph poles	-
Barn owl	Duckett (1991)	Joint barn owl Project from stakeholders to introduce population	Oil palm plantation in Negeri Sembilan	200	Weatherproof plywood (6mm thickness) with zinc sheet roof (28 gauge)	Follows Lenton (1980) with adjustments [see Lenton (1983) instead], i.e., 46 × 122 × 51 with the entrance of 15 cm width by 20 cm height; 19 cm width by 20 cm height door placed at the long side of the box secured by rubber tyre as hinges; partition placed half of nest box width on the same side as the entrance door	1 box per 5 ha	At least 4.5 m above ground using a minimum of 10 cm × 10 cm hardwood pole and buried at least 1.2 m deep; hole prepared with tractor-mounted auger (0.5 to 0.6 m diameter); pole placed centrally and filled with rubber then cement mix	Nest boxes were provisioned under the shade of a canopy tree; for exposed nest boxes, roof insulation and ventilation were made; a metal cowl was placed on a pole; two mild steel bars were placed as struts; ventilation holes of 2.5 cm diameter on the nest box ceiling
Barn owl	Lim et al. (1993)	Prey selection	Oil palm plantation in Johor	182 (pre-established by plantation owner)	-	-	1 nest box per 10.9 ha	-	-

Table 1 *(continue)*

Species	Reference	Main study focus	Study site	Number of nest boxes provisioned	Material	Dimension (width × length × height; cm)	Distribution	Provisioned height and structure	Other methods
Barn owl	Lee (1997)	Study design to introduce population	Oil palm plantation and cocoa-coconut farmland in Perak	24 (12 nest boxes in each site)	-	-	Set between third and fourth oil palm rows at 500 m apart for oil palm plantation, in 2 rows within an old coconut field	-	-
Barn owl	Food and Fertilizer Technology Center (FFTC) (2002)	Study design to enhance population	Rice field	20	Plywood painted with white paint	Detailed dimensions were provided in the figure but were visually unclear	1 nest box per 40 ha	Using a 55 m length pole buried 10 m deep	Place broken bark, pine needles, and leaves as nesting materials; deposits or pellets do not need to be cleaned out
Barn owl	Hafidzi and Na'im (2003a)	Prey selection	Rice field in Selangor	-	-	-	-	-	-
Barn owl	Hafidzi and Na'im (2003b)	Evaluate rice damage by rice field rats concerning barn owl provisioning	Rice field in Selangor	15	-	-	5 nest boxes each in 5, 10, and 20 ha	-	-
Barn owl	Hafidzi et al. (2003)	Home range	Rice field in Selangor	79	-	-	-	-	-

Table 1 *(continue)*

Species	Reference	Main study focus	Study site	Number of nest boxes provisioned	Material	Dimension (width × length × height; cm)	Distribution	Provisioned height and structure	Other methods
Barn owl	Hafidzi et al. (2007)	Influence of wet and dry seasons on breeding individuals and relation to rat damage	Rice field in Selangor	33 (18 and 15 nest boxes in the first and second sites, respectively)	-	Follows Duckett (1976)	1 nest box per 45 ha in the first site; 5 nest boxes each in 5, 10, and 20 ha in the second site	-	-
Barn owl	Naim et al. (2010)	Growth performance of nestling in rat baiting area	Immature oil palm plantation in Perak	22	Wood	-	1 nest box per 25 ha	-	-
Barn owl	Naim et al. (2011)	Breeding performance	Oil palm plantation in Perak	22	Wood	-	1 nest box per 25 ha	-	-
Barn owl	Puan et al. (2011)	Prey selection	Oil palm plantation in Negeri Sembilan	Pre-established by plantation owner	-	-	1 nest box per 10 ha	-	-
Barn owl	Naim et al. (2012)	Home range concerning rodenticide	Oil palm plantation in Perak	24	-	-	Average of 1 nest box per 25 ha	-	-
Barn owl	Puan et al. (2012)	Prey selection and predatory behaviour	Oil palm plantation in Negeri Sembilan	Pre-established by plantation owner	-	-	1 nest box per 10 ha	-	-

Table 1 *(continue)*

Species	Reference	Main study focus	Study site	Number of nest boxes provisioned	Material	Dimension (width × length × height; cm)	Distribution	Provisioned height and structure	Other methods
Barn owl	Amzah et al. (2014)	Study design to enhance population	Rice field in Penang	20	Plywood painted with white paint	37.5 × 67.5 × 42.5	-	4.5–6.0 m above ground, attached to a random coconut tree	-
Barn owl	Salim et al. (2014)	Breeding performance concerning rodenticide	Mature oil palm plantation in Pahang	42 (pre-establish by plantation owner)	High durable fibreglass	50 × 115 × 61	1 box per 15 ha	7 m above the ground	-
Barn owl	Salim et al. (2015)	Effect of rodenticide deposited in eggs	Mature oil palm plantation in Pahang	-	-	-	-	-	-
Barn owl	Salim et al. (2016)	Nestling growth concerning rodenticide	Mature oil palm plantation in Pahang	42	High durable fibreglass	50 × 115 × 61	1 box per 15 ha	7 m above the ground	-
Barn owl	Ravindran et al. (2018)	Sex identification based on morphology and molecular-based methods	Oil palm plantation in Pahang	-	-	-	-	-	-
Barn owl	Ravindran et al. (2019)	Molecular sexing using blood and feather	Oil palm plantation in Pahang	-	-	-	-	-	-

Table 1 *(continue)*

Species	Reference	Main study focus	Study site	Number of nest boxes provisioned	Material	Dimension (width × length × height; cm)	Distribution	Provisioned height and structure	Other methods
Barn owl	Saufi et al. (2019)	Homing instinct of female individual	University campus in Penang	1	-	-	-	-	-
Barn owl	Saufi et al. (2020a)	Prey selection	Urban garden in Penang	14	Wooden and fibreglass	-	-	-	-
Barn owl	Saufi et al. (2020b)	Release method	Urban garden in Penang	14	Fibreglass	63 × 72 × 28	1 box per 15 ha	5 m above ground on metal poles buried one meter deep and secured with concrete	Entrance faced North to Northeast
Barn owl	Abidin et al. (2021)	Effectiveness of introducing population to control the rat population	Oil palm plantation in Sabah	16	-	-	-	-	-
Barn owl	Abidin et al. (2022)	Breeding of translocated individuals	Oil palm plantation in Sabah	16	-	-	16 nest boxes per 25 ha and at least 36 m from the nearest road	5.3 m above ground on smooth poles	Placed two weeks prior to the study, the entrance faced the East or North
Hornbill	Kaur and Ancrenaz (2016)	Study design to enhance population	Forest in Sabah	5 [including 4 plastic drums from HUTAN (2018) and a	Recycled plastic for rectangular nest box; plastic drum	64 × 67 × 120; diamond-shaped entrance hole about 10 cm wide and 29 cm length	-	-	Camera traps were placed near the nest box, while a data logger

Table 1 *(continue)*

Species	Reference	Main study focus	Study site	Number of nest boxes provisioned	Material	Dimension (width × length × height; cm)	Distribution	Provisioned height and structure	Other methods
				rectangular nest box]	nest box wrapped with styrofoam, a wire mesh, and a layer of cement and sand for cylindrical	at 30 cm from the bottom			was placed inside the nest box
Hornbill	HUTAN (2018)	Study design to enhance population	Forest in Sabah	4	Plastic drum insulated with a layer of polystyrene covered with another plastic drum and a coating of cement	210 x 90 (diameter × height); entrance hole at 30 cm from the bottom	-	15–25 m above ground attached to trees with adequate cover using rot-proof webbing	A perch was constructed at the lower part of the entrance hole; the base was covered with soil and sawdust
Hornbill	Gaia (2019)	Study design to enhance population	Forest in Sabah	20 (including from Kaur and Ancrenaz (2016))	-	-	-	Installed 30 m high on 50 m tall tree next to Helmeted Hornbill (*Rhinoplax vigil*) dying nest tree	-
Hornbill	Kaur (2019)	Study design to enhance population	Forest in Sabah	-	Follows Kemp (1995)	-	-	-	-
Hornbill	Vercoe et al. (2021)	Study design to enhance population	Forest in Sabah	25 [including from Gaia (2019)]	Wood, fibreglass, and plastic barrel	-	-	-	Lichens were allowed to grow on the nest box surface

(Salim et al., 2014, 2016; Saufi et al., 2020b) or both (Saufi et al., 2020a) for box construction. However, only several studies have reported the nest box dimension in brief or detail (Amzah et al., 2014; Duckett, 1991; FFTC, 2002; Lenton, 1983; Salim et al., 2014, 2016; Saufi et al., 2020b). From these studies, dimensions differed from the relatively bigger base (Duckett, 1991; Salim et al., 2014, 2016) to vertically longer nest boxes (Lenton, 1983). In addition, a partition was placed with the width of half the nest box to separate the nest and entrance chamber. It was to prevent the chicks from falling out and darkening the interior nest box (Duckett, 1991). In some cases, white paint may be applied to wooden nest boxes to increase shelf life (Amzah et al., 2014; FFTC, 2002).

Depending on the study's purpose, the nest boxes' distribution may differ across studies, while certain studies used pre-established nest boxes by landowners (Lim et al., 1993; Puan et al., 2011, 2012; Salim et al., 2014). For example, in oil palm plantations, the density of the nest boxes ranged from one box per 5 ha (Duckett, 1991), 10 ha (Puan et al., 2011, 2012), 10.9 ha (Lim et al., 1993), 15 ha (Salim et al., 2014, 2016) to 25 ha (Naim et al., 2010, 2011, 2012). Other studies may provision 16 nest boxes per 25 ha (Abidin et al., 2022) or between two adjacent oil palm rows 500 m apart (Lee, 1997). In rice fields, nest boxes were installed at a density of one box per 40 ha (FFTC, 2002) and 45 ha (Hafidzi et al., 2007); otherwise, 5 nest boxes per 5, 10, and 20 ha (Hafidzi et al., 2007; Hafidzi & Na'im, 2003b). In other landscapes, such as the cocoa-coconut farmland, nest boxes were placed in two rows within the old coconut field (Lee, 1997), and nest boxes in urban gardens were provisioned at a nest box per 15 ha (Saufi et al., 2020b).

The nest boxes were often placed on poles ranging from 4–7 m above ground to deploy nest boxes in designated study sites (Abidin et al., 2022; Duckett, 1991; FFTC, 2002; Salim et al., 2014, 2016; Saufi et al., 2020b) but may also be placed onto trees in landscapes lacking suitable trees [e.g., rice fields; see Amzah et al. (2014)]. Cement mix may be applied into the pole's hole for more support (Duckett, 1991; Saufi et al., 2020b). At the same time, most studies did not specify the time allocated before observation, a study considered provisioning two weeks before a study commenced (Abidin et al., 2022). Certain studies have highlighted specific areas or orientations to which nest boxes should be installed to increase their occupancy rate. For example, nest boxes may either be placed under the shade of a canopy tree (Duckett, 1991) or have their entrance facing towards the north to the northeast direction (Abidin et al., 2022; Saufi et al., 2020b). For nest boxes installed in open habitats, roof insulation and ventilation were built to maintain a relatively cooler nest box interior (Duckett, 1991).

Hornbills

In Malaysia, the early efforts in provisioning nest boxes for hornbill conservation were initiated by a French Non-Government

Organization, HUTAN Kinabatangan Orang-utan Conservation Program (HUTAN/KOCP) and Gaia, a local social enterprise in Sabah (Kaur, 2019) as well as Piasau Camp Miri Nature Park Society (PCMNPS) in Sarawak (Lai, 2021). Complementary to the efforts to survey natural hornbill nests or tree cavities and restore them, nest boxes were also constructed based on recommendations by Kemp (1995) and installed in Lower Kinabatangan Wildlife Sanctuary (LKWS), Sabah (Kaur, 2019). As a result, 25 nest boxes with materials varying from wood, fibreglass, and plastic barrel were provisioned (Vercoe et al., 2021). In addition, a rectangular nest box was built from recycled plastic material, while four cylindrical nest boxes were built from a plastic drum wrapped with styrofoam, a wire mesh, and a layer of cement and sand (Kaur & Ancrenaz, 2016).

A perch was placed at the lower part of the diamond-shaped entrance hole, allowing the hornbills to perch close to the nest box (HUTAN, 2018; Kaur & Ancrenaz, 2016). The inner base of the nest box was covered with soil and sawdust (HUTAN, 2018). Some of the nest boxes were attached using rot-proof webbing to trees with adequate cover about 15-25 m high, while others were about 30 m high on a 50 m tall tree next to the hornbill's dying nest tree (Gaia, 2019; HUTAN, 2018). Camera traps were placed facing the nest box entrance, whereas data loggers were placed inside the nest box to monitor the occupants and microclimate within the nest box (Kaur & Ancrenaz, 2016). Lichens were allowed to grow on the nest box surface to create a more natural appearance and provide light energy absorption (i.e., to reduce nest box temperature). Some difficulties in provisioning the nest boxes for birds were addressed, where wooden nest boxes tend to decay rapidly and often take over by stingless bees, civets, ants, and flying squirrels (Vercoe et al., 2021).

CONSIDERATIONS IN IMPLEMENTING NEST BOXES INTO *IN-SITU* STUDIES

As seen in studies conducted throughout the world, provisioning nest boxes may help in understanding the behaviour and ecology of bird species, especially those that are considered vulnerably threatened (Soltész et al., 2018) or rather elusive (Balčiauskienė et al., 2005; Zárybnická et al., 2016). Provisioning nest boxes may also help elevate local bird populations with adequate management planning (Calabrese et al., 2020; Katzner et al., 2005; Mänd et al., 2005). When successfully implemented, this could benefit about 32 obligate secondary cavity-nesting resident species out of the 74 cavity-nesting bird species of 18 families recorded in Malaysia (Puan et al., 2020; van der Hoek et al., 2017). Likewise, about seven vulnerable secondary cavity-nesting species (Black Hornbill *Anthracoceros malayanus*, Great Hornbill *Buceros bicornis*, Plain-pouched Hornbill *Rhyticeros subruficollis*, Rhinoceros Hornbill *Buceros rhinoceros*, Wreathed Hornbill *Rhyticeros undulatus*, White-fronted Scops-owl *Otus sagittatus*, and

Long-tailed Parakeet *Psittacula longicauda*) along with an endangered (Wrinkled Hornbill *Rhabdotorrhinus corrugatus*) and a critically endangered species (Helmeted Hornbill) (Puan et al., 2020; van der Hoek et al., 2017) may also benefit from such implementation. Additionally, nest boxes may also be provisioned for *in-situ* studies involving other fauna, such as mammals (e.g., bats, civets, squirrels), feral bees, and even herpetofaunas that refuge in tree cavities (Goldingay et al., 2020; Griffiths et al., 2020; Vercoe et al., 2021). However, it should be noted that provisioning nest boxes is rather supplementary and not a complete solution to species conservation as some, if not all, rare and threatened species may be unable to use and adapt to the presence of nest boxes. Natural tree cavities are highly encouraged to be maintained and restored (Le Roux et al., 2016).

CONCLUSION

While studies using nest boxes in Malaysia are still in their early stages, this paper suggests that future research or publications should provide as much information as possible concerning parameters highlighted in Lambrechts et al. (2010) and Wesołowski (2011) to counter literature inconsistency. In some cases, a species utilising two different habitats or different nest box sizes may show different outcomes leading to inconclusive results on a species' nest requirements (Lambrechts et al., 2010; Le Roux et al., 2016; Mänd et al., 2005). Detailed information on the monitoring efforts is crucial to provide guidelines for other studies, although often overlooked by many researchers. This review highlighted the lack of studies involving nest boxes and the bias towards species of special interest. For many cavity-nesters in the tropics, locating and reaching their nests in the field may be challenging. Despite being man-made, installing nest boxes is a better alternative to increase research into the feeding and breeding ecology of many little-known tropical birds that use such structures. Therefore, this paper recommends the continued use of nest boxes in this part of the world due to their potential for autecology research and *in-situ* conservation in natural or agroecosystems.

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