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Oriental Pied Hornbill *Anthracoceros albirostris* © Lee Kai Chong

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MABULA GROUND HORNBILL PROJECT

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Hornbills in Zoos in Thailand: Species, Numbers, and their Welfare

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Abstract

Hornbills (Family Bucerotidae) are a popular group of species with zoo visitors in Thailand, but there is no central registry of the total number of these birds held across all zoos throughout the country. Populations in the wild have declined in recent years due to habitat loss and wildlife trade, part of which may be driven by the demand to supply zoos. Welfare conditions of hornbills kept in Thai zoos have not been recorded. We surveyed Thai zoos to record the number of hornbills on public display, species, and sex between 2020 and 2022. We then conducted assessments of hornbill exhibits using twelve environmental parameters to evaluate the conditions in which these birds are kept. We observed 228 hornbills, all adults, in twenty-three zoos comprising eight native and three non-native species. We found that the overall welfare concern relates to the absence of a complex captive environment, with many exhibits not providing adequate vegetation or nest boxes. Our findings highlight the need for increased attention to the welfare of hornbills kept in Thai zoos and the urgent need for improved animal welfare legislation and zoo licensing requirements in Thailand.

Keywords: animal welfare, Bucerotidae, captive wildlife, conservation, exhibit design

Introduction

Hornbills (Family Bucerotidae) are the largest avian frugivores in Southeast Asia and play a significant role in forest ecology through the dispersal of seeds (Kitamura *et al.*, 2005; Kinnaird and O'Brien, 2007; Poonswad *et al.*, 2013). However, hornbill populations have declined significantly in the region due to increased threats from habitat loss, poaching and the commercial trade for live birds, parts and derivatives (Poonswad *et al.*, 2013; Trisurat *et al.*, 2013, Beastall *et al.*, 2016). In addition, there is a report that hornbills have been taken from the wild to supply zoos in Thailand (Wildlife1.org, 2001). Generally, concerns exist over the illegal wildlife trade within Thai zoos (Dasgupta, 2016; Wipatayotin, 2020). Indeed, the issue of animal acquisitions for zoological collections has been recently highlighted as an issue of importance for zoo management and legislators (Nijman, 2021).

Hornbills are notoriously difficult to breed *ex-situ*, primarily due to their specific nesting requirements and importance to mate selection (Kinnaird and O'Brien, 2007; Chaiyarat *et al.*, 2012; Pawar *et al.*, 2018). According to the Zoological Information Management System (ZIMS) (a database of wild animals under human care, including over 1100 member institutions), there are currently 2318 living hornbills registered within these institutions worldwide, as of 07 June 2022. ZIMS data does not help determine the legality and origin of listed species. Still, it does provide information on individual identification, parentage and health records providing a useful source for animal management and sharing data between institutions. However, most zoos in Thailand do not subscribe to ZIMS and there is a need for monitoring to promote open and transparent data on animal acquisitions. In addition, monitoring should include the evaluation of the welfare of captive hornbills in Thai zoos, as this has not yet been structurally assessed.

Animal welfare can be measured on a sliding continuum from very poor to very good (Broom, 1999). The Five Domain Model provides a useful framework to assess animal welfare by measuring nutrition, environment, health, behaviour and mental state (Mellor *et al.*, 2020). There are different approaches to measuring animal welfare, including the natural living approach, which focuses on the degree to which an animal has the opportunity to express natural behaviours (Rollin, 1992; Fraser and Matthews, 1997; Appleby, 1999); evaluating animal's subjective experiences including emotions and preferences (Dawkins, 1988; Fraser, 2008); and the biological functioning approach which considers physiological measures (Broom, 1986). Incorporating all approaches in the assessment of welfare is ideal (Hosey *et al.*, 2009; Brando and Buchanan-Smith, 2018); however, this may not be feasible in some situations. For example, in Thailand, some facilities housing captive wildlife may be unwilling to allow assessors to collect comprehensive data utilizing the above approaches due to fear of criticism of poor welfare, as many have been criticized in the past (Cohen, 2009; Schmidt-Burbach *et al.*, 2015). Thus, we needed to use a method that would enable us to assess welfare without having access to off-exhibit areas or the need to obtain information on the life histories of individual birds. Therefore, we developed an assessment based on environmental parameters (e.g., enclosure design and the resources contained within an exhibit) that allow us to evaluate how these conditions affect animal welfare.

Providing good welfare requires a well-informed and species-specific enclosure design that provides environmental complexity (Bracke and Hopster, 2006; Ross *et al.*, 2009; Tan *et al.*, 2013). Exhibits should also allow the animal to have choice and control within its environment, such as, whether to sunbathe or shelter from wind and rain or retreat from conspecifics or visitors. Behavioural restriction from a barren environment can cause a multitude of welfare problems, including abnormal repetitive behaviours (Morgan and Tromberg, 2006; Hosey *et al.*, 2009; Tan *et al.*, 2013). Therefore, considering the species' natural history and behavioural ecology is essential for the housing and husbandry of captive species (Bacon, 2018).

Although the literature on captive hornbill welfare is relatively limited, there is extensive literature on other social, intelligent, and long-lived avian species, such as parrots (Psittaciformes), that shows the impact a captive environment has on a bird's physical and mental wellbeing (Speer, 2014; Mellor *et al.*, 2021; Peng and Broom, 2021). Nevertheless, as hornbill species are predominantly arboreal, elevated nest boxes and perches of varying heights and suitable materials such as wood are required (Galama *et al.*, 2002). Perches, such as those made from metal or hard plastic contribute to pododermatitis (bumblefoot) in perching birds and should be avoided (Global Federation of Animal Sanctuaries, 2019). Food bowls should be elevated as bowls placed on the floor induce unnatural behaviour as hornbills are then forced to descend to the floor to eat. Moreover, food on the floor is easily accessible to rodents and increases the risk of disease transfer (Galama *et al.*, 2002). Leftover food and faeces should be frequently cleaned, and substrates changed when necessary to ensure cleanliness and prevent pathogen spread.

Some hornbill species can cover large home ranges; for example, the Great Hornbill (*Buceros bicornis*) has a home range of approximately 30 km^2 and may travel 15 km in a day (Poonswad *et al.*, 2013). Providing a big enough enclosure to reflect a species' natural home range is always a challenge (Clubb and Mason, 2003); thus, the quality of a captive environment is important and not just the size (Hediger, 1950). For captive arboreal birds, enclosures should allow room for flight for better animal welfare (Peng *et al.*, 2013; Klausen, 2014). Hornbills are also social animals found seasonally in flocks and form strong social bonds with their mates (Kinnaird and O'Brien, 2007). Housing social bird species alone is discouraged, with isosexual pairing preferable to being housed alone (Meehan *et al.*, 2003)

The primary objective of this study was to document conditions for captive hornbill in Thai zoos by producing a simple assessment framework that could be used to rapidly evaluate hornbill exhibits from the public view. Information gained from this assessment could be used to recommend welfare improvements where necessary and facilitate future assessments to measure progress. We also wanted to evaluate the number of hornbills and the diversity of hornbill species in Thailand's zoos to understand how widely represented they are within collections.

Methods

We initially surveyed 55 zoos in Thailand from July to December 2020 to record which zoos kept hornbills within their collections and conducted assessments of exhibits with hornbills. Since Fourage *et al.*, 2022 (*in prep.*), we subsequently re-visited zoos that kept hornbills to repeat the assessment between April 2021 to April 2022 and found hornbills in an additional four facilities that had previously been closed due to the covid-19 pandemic. We categorized zoos by management types: 1. government-subsidized zoos, including open zoos run by the Department of National Parks, Wildlife and Plant Conservation (DNP), which serve as wildlife rescue and breeding centres and are open to the public; 2. zoos accredited by the World Association of Zoos and Aquariums and the Southeast Asian Zoo Association; 3. private zoos which charge an entrance fee to the public and are typically for-profit businesses. We recorded hornbill species (we did not record sub-species, e.g. *Buceros rhinoceros rhinoceros*), numbers, age (adult or juvenile), and sex (male, female, unknown).

We consulted the Hornbill Husbandry and Management Guidelines by the European Association of Zoos and Aquariums (EAZA) (Galama *et al.*, 2002), which served as an important guide for developing our assessment. We also drew heavily from the Global Federation of Animal Sanctuaries (2019) guidelines for perching and arboreal birds. We refined the assessment criteria based on a literature review of hornbill natural history and selected 12 measures; each scored from zero (poor, low, absent) to two (excellent) (Table 1). When scoring the provision of water, we simply scored a zero for absent and a two for present without evaluating the cleanliness of water as in many cases it was not possible to accurately assess

Table 1. Table detailing criteria used for exhibit assessment.

	Score		
Measure	**0**	**1**	**2**
Exhibit size	Less than 4 wingspans in length and/or less than 3.0m high	4 wingspans in length and 3.0m high	More than 4 wingspans in length and 3.0m or higher
Exhibit Boundary	Boundary material is not secure and can cause escape or serious injury to the bird	Barrier safely prevents escape. A larger mesh aperture size enables a portion of the bird's beak to pass through and easier access for pests	The barrier is secure, and a smaller mesh aperture prevents the bird from fitting its beak through and better protects from pests
Shelter and light	Direct exposure to the weather without shade or a totally covered area that does not allow enough sunlight	Some shelter from the weather and some exposure to natural light but not optimum	Optimum provision of shade/shelter and light that provides the right balance of protection and access to the elements
Substrate	Unnatural surfaces only - e.g. concrete, tile	A mix of natural and unnatural substrate	Predominantly natural – e.g. dirt, wood bark, sand (not compacted)
Provision of drinking water	No	N/A	Yes
Provision of perches	No perches or one perch at a low height and / or made of metal	Two or more perches made of natural or wooden materials	Multiple, stable natural or wooden perches at varying heights in suitable locations, including a forked perch
Provision of vegetation	None – the exhibit is devoid of plants and shrubs	Some species-appropriate plants and shrubs in one or two locations	A variety of plants and shrubs/trees in multiple locations throughout the exhibit
Cleanliness	Unhygienic exhibit – discarded food, faeces and litter pose health risks. Food and water placed under perch or on the floor	Moderately clean exhibit – no litter, but some discarded food and faeces build-up. Food is elevated, and the water source is not located under perch	Clean exhibit - Food is elevated, and the water source is not located under the perch
Ventilation	Poor ventilation – lack of airflow causes stale air/ odours and affects air exchange and distribution	Adequate ventilation but exhibit design restricts but not within all areas of the exhibit	Good air exchange and distribution

	Score		
Measure	**0**	**1**	**2**
Environmental noise	Immediate vicinity to loud noise (e.g. electronic noise from shows, PA system)	Moderate electronic noise but not in the immediate vicinity	Electronic noise cannot be heard over natural sounds
Privacy	Bird is fully exposed to visitors in all areas of its exhibit without a place to hide (excluding nest box)	Partial concealment from view due to exhibit design but not fully hidden	Multiple options of places to fully hide within the exhibit
Appropriate social grouping	Over-crowding of hornbills for the size of the exhibit. Housing different species of male and female hornbills together or singly housed birds	N/A	No over-crowding, with birds(s) of the same species.

from afar. While we would have liked to have assessed more criteria that can significantly impact welfare, we refrained from assessing measures that could not be made reliably. One such measure is the provision of enrichment, an essential component in providing good welfare for captive wildlife (Shepherdson *et al.*, 1998). However, due to the difficult nature of assessing the presence or absence of enrichment made in observations at a set point in time, it is quite possible that we could have not witnessed enrichment and thus scored incorrectly. For example, mealworms may be provided as a feeding enrichment but not observed when we conducted the assessments.

We would have also liked to have included the presence and quality of nest boxes within exhibits as a scoring criterion. However, without information from the facility about breeding intentions, we felt that we could not fairly assign a score. We also could not say with certainty whether nest boxes were added or removed periodically. We believe that this is unlikely in a majority of zoos visited. Instead, we decided to still record this information and report it but not include it in the assessment.

Additionally, measuring the compatibility of exhibit mates by assessing distances between birds, allo-feeding etc., would have been ideal, but again, due to the snapshot nature of the assessment, this was not possible. The highest possible total score was 24. We purposely kept the methods simple and straightforward so that they could be replicated in the future for hornbills, or other species, in Thailand's zoos or elsewhere.

Results

Survey

We recorded hornbills in 23 out of 59 zoos visited, comprising six accredited zoos, eight private zoos and nine government zoos, including five zoos that served as DNP Wildlife Rescue and Breeding Centres. We observed 228 hornbills of

11 different species (Table 2). Government zoos displayed 71 hornbills in 43 exhibits, accredited zoos displayed 76 hornbills in 50 exhibits, and private zoos displayed 81 hornbills in 51 exhibits. Eight species were native to Thailand, and three were non-native species *viz.*, one Trumpeter Hornbill (*Bycanistes buccinator*), three Papuan Hornbills (*Rhyticeros plicatus*) and one Southern Ground Hornbill (*Bucorvus leadbeateri*).

From our check on zoo websites, Facebook, and TripAdvisor of facilities still closed as of April 2022 due to covid-19, we saw photographs of five different hornbill species at two closed private zoos. Although we could not confirm the presence of the birds on-site, this suggests that there may be hornbills in at least 11 private zoos in Thailand, and it is probable that there are hornbills in 12 more DNP open zoos that we could not visit. In total, this would amount to 36 zoos with hornbills that are open to the public in Thailand.

Great Hornbills were the most commonly observed hornbills, while the Trumpeter Hornbill, Plain-Pouched Hornbill and Southern Ground Hornbill were the least common. We found that 54% of birds of all species were male, 41% were female, and for 5% of recorded individuals, we could not positively confirm sex (usually due to the bird being in a tree and partially obscured). It is highly likely that some zoos, such as the accredited zoos, have many more hornbills that were not on display. In one accredited zoo, there was an area sealed off to the public, apparently to provide a quiet area where hornbills would not be disturbed during the breeding season. In fact, ZIMS data for accredited zoos in Thailand on 07 June 2022 show 382 hornbills, a substantially higher number of birds than on display.

Table 2. Table showing the species, IUCN Red List status, number of zoos observed holding each species, number of individuals, sex and number of individuals observed per zoo type (G = Government Zoo; A = Accredited Zoo; P = Private Zoo).

Species	IUCN	Zoos N (%)	Total: Male: Female: Unknown	G: A: P
Great Hornbill *Buceros bicornis*	VU	19 (83)	93: 53: 38: 2	20: 35: 38
Rhinoceros Hornbill *Buceros rhinoceros*	VU	16 (67)	45: 24: 21: 0	13: 12: 20
White-crowned Hornbill *Berenicornis comatus*	EN	6 (26)	8: 4: 4: 0	1: 3: 4
Wreathed Hornbill *Rhyticeros undulatus*	VU	14 (61)	17: 9: 8: 0	3: 7: 7
Plain-Pouched Hornbill *Rhyticeros subruficollis*	VU	1 (4)	1: 1: 0: 0	0: 1: 0
Tickell's Brown Hornbill *Anorrhinus tickelli*	NT	2 (9)	2: 2: 0: 0	2: 0: 0
Bushy-crested Hornbill *Anorrhinus galeritus*	NT	3 (13)	3: 2: 1: 0	1:1: 1
Oriental Pied Hornbill *Anthracoceros albirostris*	LC	15 (65)	45: 23: 14: 8	27: 15: 3
Papuan Hornbill *Rhyticeros plicatus*	LC	2 (9)	3: 2: 1: 0	0: 0: 3
Trumpeter Hornbill *Bycanistes buccinator*	LC	1 (4)	1: 0: 0: 1	1: 0: 0
Southern Ground Hornbill *Bucorvus leadbeateri*	VU	1 (4)	1: 1: 0: 0	0: 1: 0
Total			**228: 124: 93: 11**	**71: 76: 81**

We found that 72% of the hornbills we observed are considered threatened on the Red List. We only observed one Endangered species, the White-crowned Hornbill (*Berenicornis comatus*), and we did not see any Helmeted Hornbills, the only Asian hornbill species listed as Critically Endangered.

Exhibit assessment results

The overall mean score per exhibit was 15.91 (*SD* 4.95; maximum score = 24) out of 144 exhibits assessed. The accredited zoos scored highest in all the twelve measurement criteria, with a mean score 20.62 (*SD* 1.96) across exhibits; government zoos scored 15.44 (*SD* 3.22) across exhibits; and finally, private zoos scored the lowest with a mean score of 11.71 (*SD* 4.15).

We recorded a wide range in the quality and complexity of exhibits, ranging from large naturalistic aviaries with extensive vegetation to barren cages (Table 3). Private zoos scored lowest for the provision of vegetation, with 86% (n=44) of exhibits not including any vegetation compared to 12% (n = 6) of exhibits in accredited zoos. Government zoos also scored low for vegetation and poorly for substrate, where 28% (n = 12) of exhibits had concrete floors. This finding contrasts with accredited zoos, which predominantly had natural sub-

Table 3. Table showing the assessment criteria in rank order of highest score by mean overall score per measure for 144 exhibits (maximum score per measure is two); frequency of scores per 0, 1 and 2 by zoo type (G = Government Zoo (total 43 exhibits); A = Accredited Zoo (total 50 exhibits); P = Private Zoo (total 51 exhibits).

Assessment criteria	Mean score per measure across 144 exhibits	% 0 scores	% 1 scores	% 2 scores
		Total: G: A: P	Total: G: A: P	Total: G: A: P
Ventilation	1.88	**1:** 0: 0: 2	**10:** 5: 0: 25	**89:** 95: 100: 73
Exhibit barrier	1.85	**0:** 0: 0: 0	**15:** 21:14: 10	**85:** 79: 86: 90
Provision of water	1.76	**12:** 5: 12: 18	n/a	**88:** 95: 88: 82
Provision of perches	1.44	**11:** 7: 0: 27	**32:** 60: 0 39	**56:** 33: 100: 33
Substrate	1.44	**22:** 28: 4: 35	**12:** 9: 4: 22	**66:** 63: 92: 43
Cleanliness	1.39	**28:** 44: 0: 41	**4:** 19: 0: 0	**67:** 37: 100: 59
Exhibit size	1.36	**27:** 14: 0: 65	**10:** 14: 8: 8	**63:** 72: 92: 27
Environmental noise	1.36	**20:** 0: 0: 57	**24:** 23: 24: 22	**56:** 77: 76: 20
Shade and light	1.26	**10:** 9: 0: 22	**54:** 40: 56: 63	**36:** 51: 44: 16
Appropriate social grouping	0.71	**65:** 53: 23: 73	n/a	**35:** 47:77: 27
Privacy	0.79	**56:** 81: 0: 88	**10:** 9: 14: 4	**35:** 7: 84: 8
Provision of vegetation	0.66	**58:** 77: 12: 86	**18:** 16: 30: 8	**24:** 7: 58: 6

Fig. 1. A. Hornbill exhibit at an accredited zoo (score 24); B. Great Hornbill exhibit at a government zoo and wildlife rescue and breeding centre (score 14); C. Rhinoceros Hornbill exhibit at a private zoo (score 10); D. Large open aviary at a private zoo (score 20) (maximum possible score = 24).

strates such as dirt, sand, and concrete in only 4% (n=2) of their exhibits.

Three private zoos, comprising 29 exhibits, scored zero for environmental noise. In one zoo, repeated loud improvised explosions were part of an entertainment show three times daily, and we witnessed hornbills startled during these incidents. We also found that some birds were subject to continuous background music and announcements played from speakers placed nearby exhibits. In more than half of the assessed exhibits, privacy was an issue, with six out of the eight private zoos obtaining zero scores. The primary reason for these low scores was the barrenness of the exhibit, whereby birds were in full view to visitors without sufficient vegetation to act as a visual barrier or areas within the exhibit to retreat. Additionally, some exhibits were circular where visitors could walk around all sides without the zoo preventing viewing from at least one side or half. However, other circular exhibits included large living trees with dense foliage providing ample choice for the bird to hide if they chose (Figure 1).

Almost three quarters (73%) of total exhibits provided an exhibit size at EAZA minimum standards or above. However, in private zoos, 65% of exhibits were below the size of minimum standards, with most of these exhibits only permitting the bird to fly or hop along a single perch or from one perch to another. We observed three exhibits where cages were so small that it was difficult for the birds to fully extend their wings. One of these cages housed a Wreathed Hornbill (*Rhyticeros undulatus*) with a wingspan of 75–85cm (Kemp and Boesman, 2020) in a cage measuring 100 cm x 70 cm x 100 cm. The most common type of exhibit barrier was wire rope mesh. Few exhibits had an optimum mesh size of 25 mm x 25 mm, which helps minimize beak injuries and keeps out potential predators, such as snakes or pests, such as rats. In addition, a smaller mesh size helps prevent public feeding of the birds and helps prevent visitor injuries caused by hornbill bills through the mesh. We frequently observed hornbills with a third of their beaks penetrating mesh barriers with 50 mm x 50 mm apertures (Figure 2). We also witnessed, on several occasions, birds in adjacent enclosures fighting conspecifics/congenerics through the mesh.

Ventilation scored the highest of all measures as all but one of the exhibits was located outside, and a majority of exhibits used wire rope mesh instead of concrete walls, which permitted better airflow. However, in other aspects, this could be problematic in terms of providing protection from high winds and would be especially concerning if the exhibit did not provide suitable shelter. The most common issues relating to shelter and light were inadequate roof coverage, exposure of the hornbill to wind, rain, and too much sun, or the exhibit was too covered and, although providing shelter from the elements, did not provide sufficient sunlight. Although many exhibits appeared to be cleaned regularly, some exhibits in private zoos had substantial food and faeces build-up on the floor. In government zoos, the primary cause for poor cleanliness scores was food and water bowls placed under perches or food bowls placed directly on the floor.

In terms of appropriate social grouping, we found that 65% (n = 93) exhibits housed a single hornbill and 32% (n =46) exhibits housed two hornbills together, of which 35 exhibits housed a male and female pair. Only 3% (n = 5) exhibits housed more than two hornbills; the maximum number observed was ten in a very large walk-through aviary. Four

Fig. 2. A. Great Hornbill with beak protruding through mesh fence at a government zoo (score 15); B. Oriental Pied hornbill at an accredited zoo (score 19); C. Wreathed Hornbill in a small cage at a private zoo (score 5); D. Great Hornbill with covered and elevated food tray at an accredited zoo (score 22) (maximum possible score = 24).

of these exhibits housed different hornbill species together, and in three exhibits, we observed males and females of different hornbill species. We only recorded one very large mixed-species exhibit in a government zoo that housed multiple species with the Oriental Pied Hornbill, including the Lesser Adjutant (*Leptoptilos javanicus*), Green Peafowl (*Pavo muticus*) and the Asian Giant Tortoise (*Manouria emys*). We did not score the placement of exhibits to adjacent hornbill exhibits due to the minimal evidence in determining whether a single hornbill, a territorial and social animal, is better housed near other birds than out of visual and auditory contact. However, we found that most exhibits directly adjoined another exhibit.

Finally, although we did not include scores for nest boxes in the exhibit assessment, we found that 47% (n = 67) of exhibits did not include a nest box. Similarly, again we did not score enrichment. Still, we can report that we only spotted one feeding enrichment device, and no other indication of other forms of environmental enrichment was observed during our assessment.

Discussion

Surveys

In our survey of captive hornbill populations in Thai zoos, we found that over a third of surveyed facilities kept hornbills in their collections, showing that this family is well represented within zoo collections in Thailand. Almost all hornbills were native species, and nearly three quarters were considered threatened on the Red List.

The relatively high number of birds raises questions regarding their origin, particularly as we did not record the presence of any juvenile individuals. It is, of course, possible that any hornbill chicks born in zoos may have been removed from their parents in the exhibit to avoid adult male aggression after fledging. However, as hornbills are difficult to breed in captivity, and without publicly available records on the acquisition of individuals within each zoo, there are valid concerns that some birds are wild-caught, as previously reported by Wildlife1.org (2001). The two most commonly observed species, the Great Hornbill and Rhinoceros Hornbill, have seen wild populations steadily decline in recent years, exemplified by the change in the Red List status of both species from a Near Threatened status in 2017 to Vulnerable in 2018. Although we know that habitat loss is the most significant factor in the reduction of these species, the popularity of hornbill species in zoos may also contribute to the decline of wild populations.

Exhibit Assessments

Our evaluation of hornbill exhibits highlights welfare concerns and shows a significant difference between zoo type and the quality of the exhibit. Out of the 144 exhibits assessed, many lacked sufficient environmental complexity in that they were not designed and furnished to consider species-specific needs. Exhibits in accredited zoos provided better resources that can facilitate enhanced welfare compared to government and private zoos, where many exhibits were small and barren. Therefore, we can infer that many of these hornbills in these exhibits likely experience challenges in attaining a positive welfare state.

Our finding that 71% of exhibits in private zoos did not meet minimum EAZA horizontal and vertical space requirements is alarming as flight is a fundamental component of a bird's behaviour repertoire. The inability to perform flight, a highly motivated behaviour, can lead to poor physical health and abnormal behaviours (Peng *et al.*, 2013). Research also shows that barren exhibits and the poor utilization of three-dimensional space can compromise welfare, as shown in multiple species, including parrots (Peng *et al.*, 2013) and chimpanzees *(Pan troglodytes)* (Rheinhardt *et al.*, 1996; Ross *et al.*, 2009). Our study recorded some large but not complex exhibits; thus, it is important to recognize that although birds need an exhibit large enough for flight, exhibit size does not necessarily equate to better welfare (Browning and Maple, 2019).

One interesting finding from our research is how more than half of the hornbills were housed alone. Many bird species are highly motivated to interact with conspecifics (Woods *et al.*, 2022), though there are instances where captive managed birds cannot be housed with conspecifics, including breeding undesirability or aggression issues (Van Hoek and ten Cate, 1998). However, the result that many private zoos with multiple individuals of the same species display birds individually in neighbouring exhibits is unusual as accredited zoos and government zoos generally house birds with a conspecific. Although we do not know why some birds were housed alone, one reason could be to increase the number of occupied exhibits within facilities, given the appearance of larger collections.

Another concern found in this study was the number of hornbills subjected to loud noises from entertainment shows. Loud noises are known to create stress in many animal species (Orban *et al.*, 2017; Jakob-Hoff *et al.*, 2019), so it was unsurprising that we saw the startled reactions of hornbills in one zoo responding to loud explosions from an entertainment show within that zoo. However, our brief observations of their reactions suggest that the hornbills were not habituated to these noises despite this show occurring multiple times daily. A study of two Great Hornbills in Denver Zoo examining the effect of seasonal zoo events with increased exposure to artificial lights and visitor noise did not reveal indications of increased stress in the birds (Readyhough *et al.*, 2022). However, it is unlikely that the birds in that study experienced the abrupt and intense changes in noise levels that the hornbills in our study experienced.

A further issue contributing to the low scores of some exhibits is privacy. Studies have shown that a lack of hiding spaces and retreat options in avian species is a significant cause of abnormal behaviours (De Almeida *et al.*, 2018; Peng and Broom, 2021). Privacy was the worst in private zoos, possibly because these zoos prioritize the need for animals to be visible and on-show over animal welfare. However, privacy was also very poor in government zoos, likely due to exhibits not purpose-built for the species housed as many government zoos receive rescued and confiscated wildlife.

The issue of visibility of animals on exhibit presents a dilemma for many zoos on how to satisfy the visitor experience but also provide optimum welfare and has led to the development of methods to reduce the visibility of visitors to animals, such as camouflage netting (Blaney and Wells, 2004; Hosey *et al.*, 2009). According to one study of two Black-casqued Hornbills (*Ceratogymna atrata*) at a UK zoo, the visitor effect did not appear to impact hornbill behaviour (Rose *et al.*, 2020). It is not possible to compare this study to our research in Thailand primarily due to the very different conditions that the birds were kept in. For example, many birds in our study had minimal distance separating them from visitors and were observable on three to four sides of the enclosure with little to no privacy.

In contrast, the hornbills in their study had a much larger enclosure, and the birds had an option to be on or off exhibit, whereas the hornbill occupants of the exhibits we assessed may experience decreased welfare due to the lack of privacy and retreat options. Given the barrenness of many exhibits and the absence of nest boxes in many enclosures, a sheltered and private space such as a nest box could be beneficial in providing greater environmental complexity and choice.

The lack of vegetation in many exhibits also contributes to the barrenness of enclosure environments. This issue is a concern found in our study, particularly in most exhibits in private and government zoos. Birds could not use the vegetation as enrichment, shelter or shade or to reduce the direct sight of visitors or animals in nearby exhibits. Furthermore, hornbills like to use vegetation such as branches with leaves to distance themselves from an aggressive partner or shake leaves, clean their bills and use moisture on the leaves to "shower". An additional contributing factor to exhibit barrenness was the prevalence of concrete as a substrate in many exhibits. Concrete is not suitable as it prevents foraging, dustbathing and using substrate materials for nesting (Galama *et al.*, 2002). Our findings that government exhibits predominantly had concrete substrates are likely due to the fact that some government zoos serve as wildlife rescue centres. The use of a concrete substrate may be defended due to the ease of cleaning and disinfecting, particularly when incoming animals may be carrying diseases.

Financing exhibit upgrades in government zoos are unlikely for the foreseeable future due to recent significant budget cuts. At the beginning of 2022, the Department of National Parks, Wildlife and Plant Conservation had its funding cut by 70%, leading to concerns over basic costs such as animal feed and staff wages (Thai PBS World, 2022). Private zoos have also seen a substantial income reduction caused by the drastic decrease in visitors due to the covid-19 pandemic (Daly, 2021). However, this likely has little impact on exhibit conditions, as the way that most exhibits have been designed shows little consideration towards animal welfare. In contrast, accredited zoos generally provide well-designed species-specific exhibits. There are additional issues that help to explain the poor conditions in some exhibits. Vague animal welfare standards (Dorloh, 2017; World Animal Protection, 2020) and Thai zoo licensing requirements do not define captive wild animals' husbandry and housing requirements. Consequently, this weakens the obligation of zoos to provide good welfare. Additional contributing factors may include poor animal welfare knowledge among animal caretakers and their managers and a general lack of animal awareness in Thailand (Cohen, 2013; Sinclair and Phillips, 2019).

We conclude that the overall poor environments within many exhibits recorded in this study are highly concerning. Many hornbills will spend their lives in barren and unstimulating exhibits that do not consider their basic needs. In addition, many zoos have dated exhibits, and while we recognize that constructing new exhibits can be prohibitive in terms of cost and space, even making simple and relatively inexpensive improvements such as providing more perches, nest boxes, vegetation, and a natural substrate can significantly improve a bird's quality of life. In reality, creating the necessary changes is challenging. A change in animal welfare legislation, zoo licensing and zoo standards is needed to force zoos to improve conditions; however, enforcing such changes is not without difficulty. Collaboration with zoos and zoo accreditation organizations such as the World Association of Zoos and Aquariums and the Southeast Asian Zoo Association may help organise and encourage participation in training workshops and welfare inspections to facilitate improvements. Finally, improved monitoring of zoological collections is also needed to help reduce the potential of trade in hornbills, a critical step in the conservation and welfare of these birds.

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Nest monitoring and nesting status of sympatric hornbills in the Anamalai Hills, Western Ghats, India

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Abstract

As secondary cavity nesters, exhibiting strong nest-site fidelity, hornbills may be limited by the availability of nesting sites and monitoring nest occupancy is important in understanding their breeding populations. In this study, we aimed to assess the current status of nest occupancy of two sympatric hornbill species (MGH: Malabar Grey Hornbill Ocyceros griseus *and GH: Great Hornbill* Buceros bicornis*), in the southern Western Ghats. We quantified nest tree characteristics, nesting status and occupancy in 2018 and identified its correlates for 116 GH and MGH nests first located between 1991 and 2016. Nest tree characteristics for GH and MGH were similar to earlier research findings, except that smaller dimensions observed of currently active GH nest trees suggests a loss of very large trees in the study area. Overall nesting status for GH was 57% (N= 50), and 61% for MGH (N= 66). GH nest occupancy in 2018 was positively related to the apparent age of the nest, negatively to wood density, and positively to plantation habitat. MGH nest occupancy was negatively associated with apparent age of nest. Nest trees were found to be in use even after 27 years (GH, 5 nests) and 25 years (MGH, 1 nest), indicating the importance of individual nest trees for hornbills. Nest occupancy monitoring provides baseline information and enhances the understanding of population ecology for threatened hornbills in the Western Ghats.*

Keywords: breeding, Bucerotidae, long-term monitoring, tree cavities

Introduction

Among Asian avifauna, up to 40% of large-bodied (body mass >2 kg) bird species are threatened with extinction due to drivers of global change particularly land use and climate change (Tilman *et al.*, 2017; Campo-Celada *et al.*, 2022). Ecological constraints coupled with changing climatic conditions are increasingly affecting the nesting phenology in birds; for instance, about 30% of species showed earlier nesting in the USA over the last century (Bates *et al.*, 2022). Long-lived and large-bodied species such as hornbills are even more vulnerable due to their life-history traits. They are slow-reproducing birds with small clutch size (usually 1 – 4 eggs) and breeding once per year or at longer intervals (Poonswad *et al.*, 2013), being mostly dependent on larger forest tracts with suitable nest trees and year-round fruit resources (Kinnaird and O'Brien, 2007). Forest loss (Sheth *et al.*, 2020), habitat fragmentation

(Suttidate, 2022), land use alteration (Pawar *et al.*, 2021), climate change (Datta, 2022; Pattinson *et al.*, 2022), and illegal trade (Phassaraudomsak *et al.*, 2019) threaten many species of Asian hornbills whose populations are in decline across their distribution ranges. Asian hornbills are secondary cavity-nesting birds that rely on naturally-formed tree cavities or cavities excavated by primary cavity-nesting birds. Availability of suitable cavities for nesting is thought to be a major limiting factor for large-bodied birds like hornbills (Poonswad, 1995). Hence hornbills are known to utilise remnant nest trees even in sub-optimal habitat with lower density of nest tree species (Datta, 1998; Datta and Rawat, 2004). Wide variation in hornbill life-history traits such as body size (0.2 to 4 kg), nesting duration (80 to 140 days), and habitat associations is related to differences in nest selection by sympatric species based on body size, shape of cavity entrance, surrounding habitat, and availability of fruit resources at the nesting sites (Shukla *et al.*, 2015; Utoyo *et al.*, 2017). As hornbills are also known to exhibit nest-site fidelity, nest monitoring is therefore an important aspect of hornbill population ecology and conservation and a metric to identify critical hornbill habitats.

In Asia, nest monitoring and augmenting nesting success by protecting and restoring existing nest cavities have become a critical aspect of hornbill conservation (Poonswad *et al.*, 2005; Rane and Datta, 2015). In the Western Ghats of India, previous research has focused mainly on nest and nesting habitat characterisation (Mudappa and Kannan, 1997; James and Kannan, 2009; Girikaran *et al.*, 2019), and breeding incidence in relation to habitat (Pawar *et al.*, 2021), but little is known of patterns of nest reuse in successive years (Mudappa, 2005; Bachan *et al.*, 2011). Given hornbill nest-tree fidelity, nests may be active in succeeding years if tree cavities remain suitable, or become inactive due to overgrowth of nest cavity opening or change in cavity dimensions due to growth of the tree along with wood decomposition within the cavity. Nests may even become defunct

Male Malabar Grey Hornbill, Western Ghats, India (Photo: Rohit Naniwadekar).

Male Great Hornbill, Western Ghats, India (Photo: TRS Raman).

if the trees or branches break off or become transformed to such an extent as to become unusable (Mudappa, 2005). Tree growth and wood decomposition rates may be related to tree size or age and wood density, with hardwoods tending to have slower growth and decomposition than softwoods (Cornwell *et al.*, 2009; Zheng *et al.*, 2016), which in turn could influence nest cavity suitability and use over time. Whether nests remain active after a period may therefore depend on habitat or tree attributes such as size or wood density.

In this study, we assessed the current nesting status of sympatric hornbill species in a protected area and adjoining plantation landscape in the Anamalai Hills of the Western Ghats, India. The objectives of our study were: (a) quantification of the present nest occupancy of Great Hornbill (*Buceros bicornis*, GH) and Malabar Grey Hornbill (*Ocyceros griseus*, MGH), (b) characterization of nest trees and, (c) identification of correlates of the nesting status of sympatric species in relation to habitat and tree attributes. As the final aspect was exploratory in nature, we present our results along with potential explanations and hypotheses to stimulate research on these relatively unexplored aspects of hornbill biology.

Methods

Hornbill nest search surveys and monitoring were carried out in the Anamalai Hills between January 2017 and May 2018. The following protected areas (PA) sites were covered: Anamalai Tiger Reserve (958 km², 10°12′ to 10°35′ N, 76°49′ to 77°24′ E), Parambikulam Tiger Reserve and Vazhachal Reserved Forest (842 km², 10°31′ N to 10°33′ N, 76°70′ E to 76°81′ E). We also surveyed the plantation landscape (Plantation) of the Valparai Plateau (220 km², 10°15′ N to 10°22′ N, 76°52′ E to 77°01′ E). Details of the study areas are available in Mudappa and Raman, 2007; Pawar *et al.*, 2018; 2021. To document and monitor the nesting status of hornbills, besides nests located during the study, we visited nests historically known from previous studies in the same region (Mudappa and Kannan, 1997; Mudappa, 2000; 2005; James and Kannan, 2009; Bachan *et al.*, 2011; Pawar *et al.*, 2018). These nests were monitored during the hornbill breeding season (Dec 2017 to May 2018). Additionally, new nests found during the surveys were documented and monitored.

On locating a hornbill nest, the following nest tree characteristics were recorded: tree species, height of nest tree, height of nest cavity from the ground, girth at breast height (GBH; measured at 1.3 m from the base of the tree, or above in the presence of buttress), location (main trunk, primary branch, secondary branch), and orientation (compass bearing in degrees) of the cavity opening (Mudappa and Kannan, 1997; Datta and Rawat, 2004; James and Kannan, 2009). Tree and nest height were measured using a Bushnell laser rangefinder and GBH was measured using a measuring tape. For each nest, we calculated the apparent age of the nest as the number of years since it has been known by local people and/or researchers. Estimates of the apparent nest age are likely to be accurate as they were documented in earlier research and were surveyed during this study accompanied by the same field assistants as in the previous studies. Nest trees were categorized into emergent, top canopy, and mid-canopy trees based on the canopy height. We also noted if the nest tree was alive or dead. The hornbill species occupying active nests were identified based on direct observation at the nest, but for inactive and defunct nests, we relied on information from earlier surveys on previously known occupants and nest location corroborated against earlier GPS location.

Each nest was observed at least one to nine times (average number of visits = 2) during nesting seasons from 2016 to 2018. The status of each nest was recorded following Mudappa, 2005:

a. Active: if the nesting was in progress (*i.e.*, occupied), the nest entrance was sealed, and/or the midden had fresh droppings
b. Inactive: if no nesting had commenced and there was no sign of fresh defecation in the midden
c. Defunct: when the tree and/or nest cavity itself had become unusable. Unusable nests were mainly identified by observing the complete or partial closure or enlargement of the cavity entrance, if the nest-cavity bearing branch or the tree were found to have fallen.
d. Uncertain: uncertain about the nesting status due to a lack of clear visibility of the nest or the midden.

We examined differences in nest characteristics of GH and MGH using summary statistics, t-tests, and chi-square tests. Directionality in nest orientation for each species was assessed using Rao's spacing test of uniformity, while differences between species were assessed using Watson's two-sample test of homogeneity. For each hornbill species, we used generalised linear models (GLM), assuming binomial errors and logit link functions, to examine if the probability that a nest was active in the recent season (2017–18) was related to the following independent variables: age of nest (integer variable), mean (± SE) GBH and nest height (continuous variables), nest tree species and habitat (categorical variable: PA and Plantation).

The statistical analyses were executed using R software (R Core Team, 2021). We used packages 'Circular' (Agostinelli and Lund, 2022, 'effects' (Fox and Weisberg, 2019) and 'ggplot2' (Wickham, 2016) for analyses and visualisation of results.

Results

We revisited and monitored 116 hornbill nests from the Anamalai Hills (101 of which were known from the past surveys): 50 Great Hornbill (GH) and 66 of Malabar Grey Hornbill (MGH). Of these, 91 nests (78%) were located and monitored in the PA, while 25 hornbill nests (22%) were in Plantations.

Nest characteristics

GH nests were observed on 23 tree species and MGH nests on 24 tree species. The smaller MGH nested in native trees (89.3%) and also in non-native trees (10.6%) like silver oak *Grevillea robusta*, African tulip *Spathodea campanulata*, and *Eucalyptus* sp. The larger

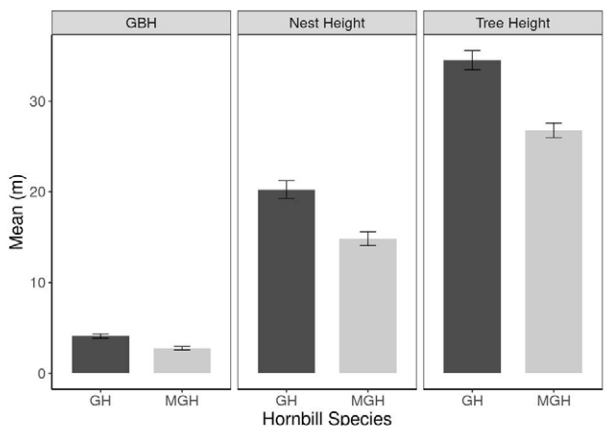

Fig. 1. Nest characteristics of Great Hornbill (GH) and Malabar Grey Hornbill (MGH) nests in the Anamalai Hills. GBH, nest height, and tree height measurements are based on n = 45, 44, and 42 nests, respectively, for GH and n = 59 nests for MGH.

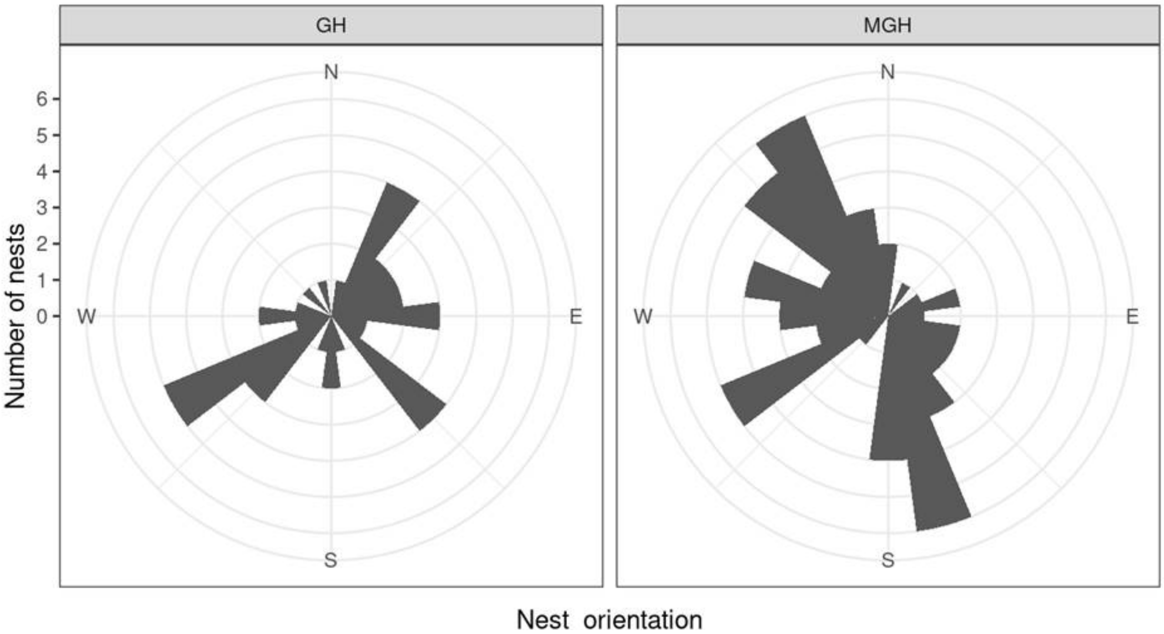

Fig. 2. Pattern of orientation of Great Hornbill and Malabar Grey Hornbill nests in the Anamalai Hills, India.

GH nested in native rainforest tree species, except for a single nest found in a silver oak tree in a coffee plantation.

As expected, GBH, tree height, and nest height were significantly higher for the larger GH than small MGH (Fig. 1, Welch two sample t-tests, $t > 4.36$, $df > 83$, $p < 0.05$). The mean (± SE) GBH and height of nest trees of GH was 1.5 times and 1.3 times greater than that of MGH nest trees (GBH: 4.11 ± 0.24 m, $n = 45$ *vs* 2.78 ± 0.19 m, $n = 59$ and height: 34.5 ± 1.05 m, $n = 44$ *vs* 26.8 ± 0.8 m, $n = 59$), respectively. GH nest mean (± SE) height averaged 1.4 times higher (20.26 ± 0.97, $n = 42$) than that of MGH (14.9 ± 0.76 m, $n = 59$).

For GH, 73.8% of the nest cavities were located on the main trunk and the remainder (26.2%) on primary branches. For MGH, 69.5% of the nest cavities were located on the main trunk, 23.7% on primary branches, and 0.1% on secondary branches. Orientation of GH nests did not depart significantly from a uniform distribution (U = 139.4, $p > 0.05$), while MGH nests showed a significant departure from uniform distribution as more nests were oriented towards the south-east and north-west (U = 163.6, $p < 0.05$; Fig. 2).

Nesting status

In PA, 56.1% of GH nests were active, 22% were inactive, 19.5% were defunct, while the status of 2.4% nests was uncertain. In plantations, 55.6%, 33.3% and 11.1% of GH nests were active, inactive, and defunct, respectively (Fig. 3, Table 1). Out of 50 GH nests monitored, 5 of the 6 nests located in 1991 by previous researchers were active even in 2018 and 8 of 15 nests located between 1991 and 2000 were active in 2018. In PA, 54% of MGH nests were active, 34% were inactive, and 12% were defunct. In plantations, the proportion of active, inactive, and defunct MGH nests was 62.5%, 6.3%, and 6.3%, respectively. Nesting status of 25% of MGH nests in plantations was unknown as we could not check the nest occupancy during the study (Fig. 3, Table 1). The oldest MGH nest active in 2018 was first identified 25 years ago in 1993 (10 of 27 nests

Table 1. Summary of nesting status of monitored hornbill nests during 2017 – 2018 in the Anamalai Hills, Western Ghats. (GH- Great Hornbill; MGH- Malabar Grey Hornbill)

Status	Anamalai Tiger Reserve		Parambikulam Tiger Reserve		Vazhachal Reserved Forest		Valparai Plateau (Plantation)	
	GH	MGH	GH	MGH	GH	MGH	GH	MGH
Active (%)	62.5	59.3	70	37.5	47.8	71.4	55.6	62.5
Inactive (%)	25	40.7	20	25	21.8	28.6	33.3	6.25
Defunct (%)	12.5	-	10	37.5	26.1	-	11.1	6.25
Uncertain (%)	-	-	-	-	4.34	-	-	25
N	8	27	10	16	23	7	9	16

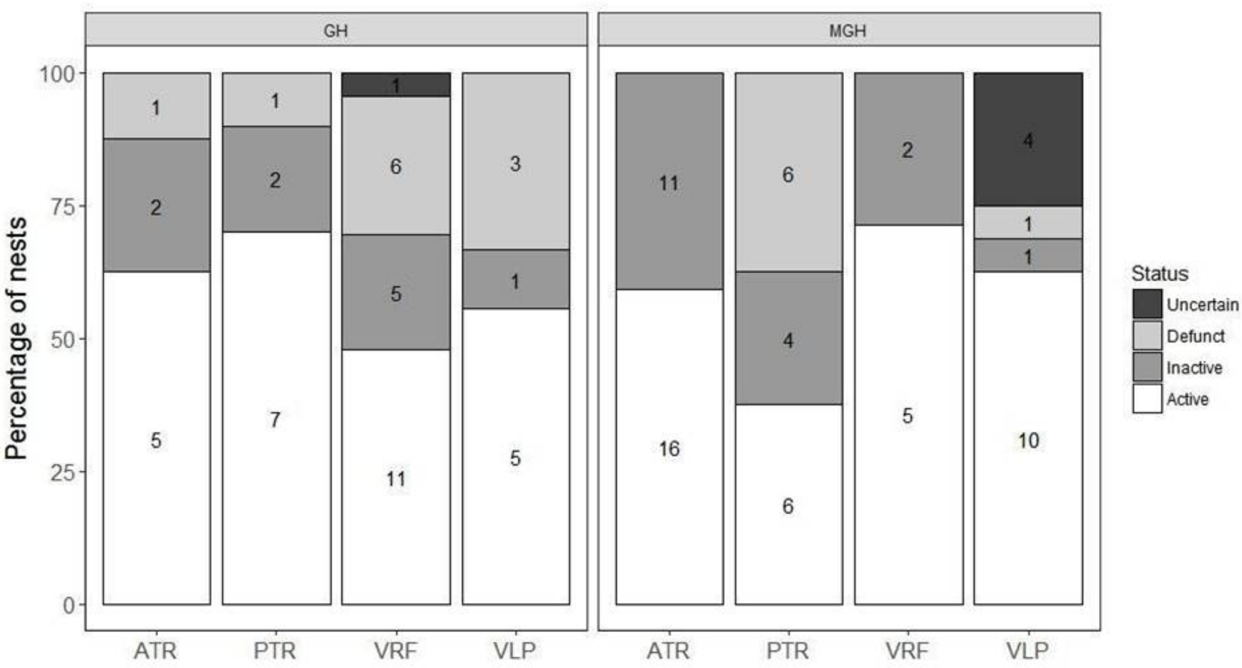

Fig. 3. Status of Great Hornbill (GH) and Malabar Grey Hornbill (MGH) nests in the Anamalai Hills. Numbers indicate count of nests. ATR – Anamalai Tiger Reserve; PTR – Parambikulam Tiger Reserve; VRF – Vazhachal Reserved Forest; VLP – Valparai Plateau

located during 1993 – 2000 were active in 2018). GLM analyses indicated different influences on nesting status for the two hornbill species (Table 2). The probability of an active GH nest was positively related to the apparent age of the nest, negatively related to wood density of the nest trees, and positively associated with Plantation habitat (Table 2, Fig. 4). In contrast, MGH nesting status was negatively related to the apparent age of the nest (Table 2, Fig. 5).

Table 2. Correlates of hornbill nest occupancy—summary results of the best generalized linear models (GLM) and model parameter estimates (± SE).

Details	Great Hornbill	Malabar Grey Hornbill
Best selected model	~ age of nest + wood density + habitat	~ age of nest
Intercept	4.29* (1.72)	1.75** (0.54)
Age of nest	0.128^{+} (0.07)	-0.097** (0.03)
Wood density	-9.94** (3.5)	-
Habitat (Plantation)	2.79* (1.31)	-
AIC	57.31	75.43
R^2	0.22	0.15

***$P < 0.001$; **$P < 0.01$; *$P < 0.05$, +$P < 0.10$

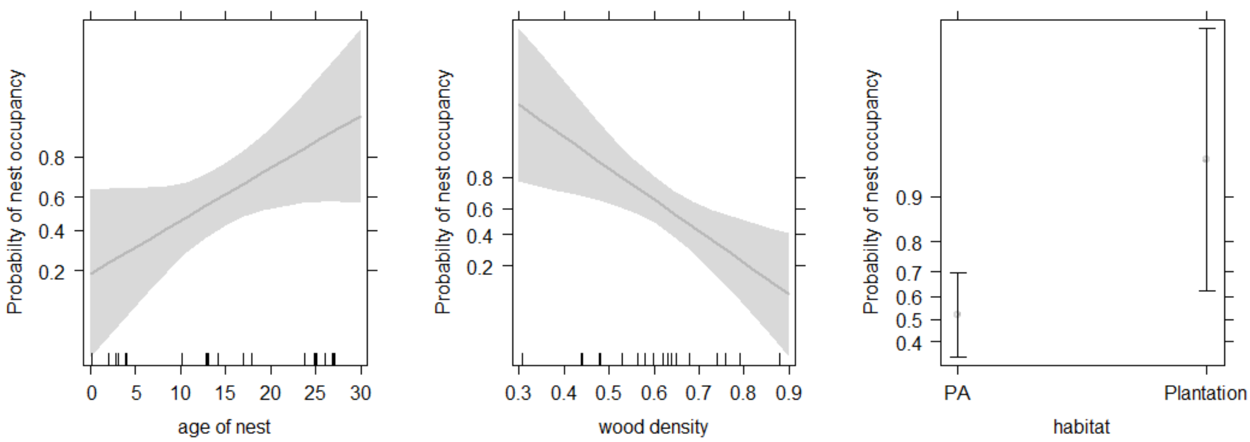

Fig. 4. Great Hornbill nesting status in relation to apparent age of nest, wood density of nest tree species and habitat (PA – protected area, plantation) where the nest is located. Effects are shown as lines with 95% confidence interval bands (shaded) or mean parameter estimates and error bars based on GLM.

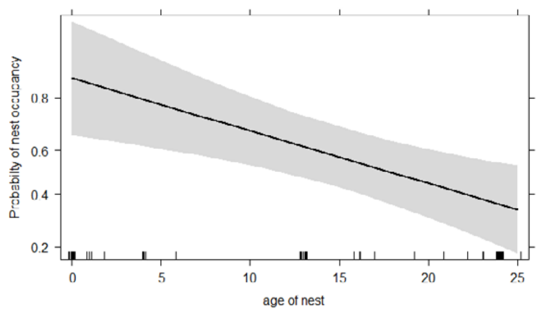

Fig. 5. Malabar Grey Hornbill nesting status in relation to apparent age of nest. Effects are shown as lines with 95% confidence interval bands (shaded) or mean parameter estimates and error bars based on GLM.

Discussion

The present study was the most comprehensive hornbill nest monitoring effort in India, covering 116 hornbill nests in a single breeding season. As most of these nests were first recorded between 1991 and 2008, the evidence that a large proportion of nests were still used during 2018, and individual nests were still in use after 27 years (GH) or 25 years (MGH), highlights the importance of individual/particular nest trees for hornbills. Clear differences were documented between MGH and GH*, with the latter using larger trees for nesting as expected based on body size differences and earlier research (Mudappa and Kannan, 1997; James and Kannan, 2009). Active nests were found in both protected areas (79% of nests) and plantations (21%), indicating use of human-modified habitats by breeding hornbills. Tree and habitat correlates of reuse of old nests were documented for both species for the first time.

Studies on other Asian hornbills have found the preponderant use of particular tree species for nesting, such as *Dipterocarpus* in Thailand (>40% of nests) and *Tetrameles nudiflora* in Arunachal Pradesh (>80%) and Narcondam island (>30%) (Datta and Rawat, 2004; Naniwadekar *et al.*, 2020). In the Anamalai Hills, GH and MGH did not indicate preponderant use of particular tree species for nesting, with each species using about two dozen tree species. An important finding of this study is that 20% of nest trees were located in plantations, including in a few large non-native trees retained as shade trees, and most nests were active even a decade after they were first recorded. Although the overall proportion of active nests is comparable in the PA and plantations, the latter habitat has fewer hornbills, lower breeding incidence (Pawar *et al.*, 2021) and fewer nests, likely due to lower tree density and fewer large trees available in the tea and coffee plantations.

The nest tree dimensions recorded in this study were smaller than those reported earlier in the case of GH, but not for MGH. As the earlier studies (Mudappa and Kannan, 1997; James and Kannan, 2009) had measured nests in the Top Slip, Karian Shola, and Karimala areas within the Anamalai hills, we selected nests that were active during either 2016 – 17 and/or 2017 – 18 from the same areas for comparison. For GH, in comparison to James and Kannan (2009, n = 24 nests), all parameters were on average smaller in the present study (n = 14 nests), including diameter at breast height of nest tree (1.05 m *vs* 1.33 m earlier), nest tree height (31.07 m *vs* 43.75 m), and nest height (18.9 m *vs* 22.0 m; range 11 – 25 m in the present study *vs* 11.2 – 40 m earlier). With the exception of a single *Palaquium ellipticum* nest tree of 45 m height, all other nest trees measured from this area in the present study were shorter than the average height (43.75 m) reported earlier (James and Kannan, 2009). This suggests that large nest trees of GH are disproportionately fewer in recent years. Although no data are available on tree mortality from the study area, this may mirror patterns of decline of large trees, especially those with cavities, in other parts of the world (Lindenmayer *et al.*, 2012; Lindenmayer and Laurance, 2017). For MGH, in comparison with Mudappa and Kannan (1997, n = 27 nests), parameters were similar in the present study (n = 24 nests), including diameter at breast height of nest tree (0.85 m *vs* 0.75 m earlier), nest tree height (25.6 m *vs* 27.7 m), and nest height (13.8 m *vs* 16.5 m). The lack of similar differences in the case of MGH suggests that the differences observed for GH are unlikely to be due to observer effects.

Earlier research on nest orientation of GH indicated that 8 of 24 nests were oriented in the east-south-easterly direction (James and Kannan, 2009), but our results suggest no specific directionality (Fig. 2). In contrast, nest orientation departed significantly from a uniform distribution for MGH, with more nests with north-west, south and southeast, and southwest directions. Earlier research on MGH had recorded about 41% nests oriented towards the northeast and 22% each towards the southwest and southeast (Mudappa and Kannan, 1997), which roughly accords with our findings except that more nests were found oriented towards the northwest rather than the northeast in the present study. The causes for directionality and this variation from earlier research remains unknown and may depend on the pattern of branch breakage and cavity formation in relation to direction of prevailing winds and monsoon storms.

The only long-term nest occupancy monitoring data from the Western Ghats is of Malabar Grey Hornbill between 1993 and 2000 (Mudappa, 2005), which found a decline in the proportion of active nests over the study period. These were presumably replaced by new nests over the years, although no data are available on either availability or formation rates of suitable nest cavities in the study area as such, this is an area for future research. The proportion of nests that became unsuitable due to deformities remained low, similar to observations from the present study. Aspects that influenced whether a nest tree discovered in earlier years remained in use in 2018 differed between GH and MGH. In the case of GH, the probability that a nest was still active was positively related to the apparent age of the nest, negatively related to wood density of the nest trees, and positively associated with plantation habitat. As GH mainly nested in large, slow-growing trees, the apparent age of the nest signified years of additional growth during which the nest cavity might have remained conducive to occupation by GH. We speculate that the negative relationship with wood density may be related to the fact that change in dimensions of the cavity or nest opening in hardwood trees may make it difficult for GH to physically modify or occupy the nest. The positive relationship with plantation habitat may be related to the fact that nest trees are scarce in plantations and whatever remnant trees remain tend to be occupied and re-used. In contrast, MGH nesting status was only negatively related to the apparent age of the nest, suggesting that growth of MGH nest trees over the years may increase their size and cavity dimensions to an extent where they become unsuitable for occupation by this smaller-bodied species. As smaller trees usually grow at faster rates (Bec *et al.*, 2015), they may show higher rate of deformation of cavities, which may lead to partial or complete closure of the cavity opening, rendering them unsuitable for hornbills.

Long-term hornbill population monitoring and periodic nest monitoring would yield important information on nest tree dynamics, nesting status, and breeding of hornbills, which are critical in assessing impacts of rapid environmental changes on hornbill populations and predicting future trends. Climatic change such as a rise in the temperature has been reported to lead to dramatic declines in the nesting success in the Southern Yellow-billed Hornbills (*Tockus leucomelas*) in African desert landscapes (Pattinson *et al.*, 2022). In the north-eastern parts of India, fluctuation in hornbill nesting over years may be related to untimely rainfall, rises in temperature, and shifts in peak fruit availability (Datta, 2022). Studies of the relationship between climatic variables and nesting of hornbills across multiple sites will help in teasing apart the causal processes and mechanisms. Such research is also useful to identify future conservation strategies, including restoration of unused nest cavities in the Western Ghats.

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***Erratum: "GH and MGH" was corrected to "MGH and GH" on page 24 on 09 Aug 2022**

A Note on Oriental Pied Hornbill reintroduction in Singapore and its dispersal from 2010–2021

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Background

Three species of hornbill have been recorded in Singapore: Oriental Pied Hornbill *Anthracoceros albirostris*, Rhinoceros Hornbill *Buceros bicornis* (locally extinct), and Black Hornbill *Athracoceros malayanus* (recent record). The Helmeted Hornbill *Rhinoplax vigil* historical record in Singapore is considered doubtful (Poonswad *et al.*, 2013). Other species of hornbills recorded such as Bushy-crested, Great, Narcondam, Northern Red-billed, Trumpeter, Southern Ground, Wreathed and the White-crowned are considered escapees from captivity.

The Oriental Pied Hornbill (OPH) ranges from northern India, south Nepal, Bhutan, south-east Tibet to south China, and across Southeast Asia to Java and Bali. The OPH is a forest edge species occurring from coastal lowlands up to 700 m in elevation. This species is found in parks, plantations, wooded areas and near mangroves. Considered as medium size, the male is about 70–85 cm (700–900 g) and the female 60–65 cm (500–800 g) in length, with the male having a larger casque (Poonswad *et al.*, 2013).

The renowned naturalist, Alfred R. Wallace, recorded this species in Singapore in 1855 and it was probably still in Singapore in the 1920s; however, there are no breeding records. Gibson-Hill mentioned that there was no record of hornbills in Singapore in the 1950s (Gibson-Hill, 1950). A small population recorded on the main island of Singapore in the late 1960s to late 1970s are presumed escapees. Some individuals were recorded in Pulau Ubin since 13 March 1994; they were believed to be visitors from Malaysia and the first local breeding was observed at Pulau Ubin on 26 April 1997 (Wang and Hails, 2007; Lim, 2009).

The breeding season of the OPH in Singapore generally starts from December and ends in March or April. Each clutch consists of one to four eggs, but usually only one to three chicks will fledge successfully (Teo, 2012). A paper (Ng *et al.*, 2011) presented at the 5th International Hornbill Conference, held in Singapore from 22nd to 25th March 2009, documented camera surveys of five nests of wild Oriental Pied Hornbills in Pulau Ubin over four breeding seasons between 2005 and 2009, and one nest in the southern part of Bukit Timah Nature Reserve from 2008 to 2009 of a captive pair taken from Jurong Bird Park. The nests in Pulau Ubin were in natural cavities of *Durio zibethinus* trees and in artificial nest boxes, and 14 breeding cycles were recorded over four years. In the southern part of Bukit Timah Nature Reserve, two breeding cycles were observed. Out of the 16 cycles, a total of 51 chicks hatched. The observations showed that the mean number of eggs laid in the wild was 3.3 and number of chicks fledged was 1.8 giving an average fledging success of 55%. Most of the chicks that were lost were due to cannibalism and infanticide.

In order to encourage wild hornbills to breed, more than 20 artificial nest boxes were installed all over Singapore from Pulau Ubin in the east to Sungei Buloh Wetland Reserve in the west (Cremades and Ng, 2012). The population has subsequently increased significantly throughout Singapore. In 2012, the population of OPH in Singapore was estimated to be between 75-100 individuals, with 19 nesting pairs recorded, of which 10 pairs were nesting in Pulau Ubin (east), two in Changi (east), two in the Istana (central), and one each in Turf City (central), Sungei Buloh (west), Seletar (north), MacRithchie (central), and Pasir Ris (east). The number of progeny in 2012 was estimated to be between 35 and 60 (Cremades and Ng, 2012).

Methods

In order to find out more about the current distribution of the OPH in Singapore, the first author downloaded eBird (https://ebird.org), iNaturalist (https://inaturalist.org) and other records from the Global Biodiversity Information Facility (GBIF) portal (GBIF.org 2022). There were 5177 occurrence records of OPH from Singapore in GBIF, of which 4533 are from eBird and 569 are research-grade observations on iNaturalist. As sightings prior to 2010 were considered to be very sparse, 4901 records ranging from 2010 to 2021 (including 4311 eBird and 518 iNaturalist records) were chosen for analysis. The sighting records were segregated into a selection of time periods and a kernel density filter was applied to each to create a series of sighting density maps that illustrate the dispersal of the Oriental Pied Hornbills from 2010 to 2021. Seven sighting density maps were generated for the periods 2010-2015 inclusive and one for each year from 2016 to 2021 (Figure 1).

Results and Discussion

The maps (Figures 1) show how the OPH has spread in Singapore over the past 12 years and that the dispersal of the hornbills are in areas near the reintroduction sites, with more sightings in the eastern part of Singapore. A pair of captive OPH from Jurong Bird Park was chosen to be bred in an artificial nest box in the southern part of Bukit Timah Nature Reserve for two breeding cycles in 2009, resulting in three chicks fledging (Cremades *et al.*, 2011). It is of particular interest to note that subsequent sighting records from 2010 to 2021 did not show any OPH in the forests, and no hornbills were reported in the Central Catchment Nature Reserve and Bukit Timah Nature Reserve. Poonswad *et al.* (2013) indicated that the preferred habitats of this species are forest edges, open woodlands, coastal and riverine scrub and cultivation. We can speculate that this species may disperse further in the future, if their survival and dispersal in Singapore is encouraged by planting of food plants in various parks and gardens.

We note, however, that the increased dispersal of OPH denoted on the maps may be partly due to increased reporting and records by observers on eBird and iNaturalist in recent years, and this needs to be studied and corrected for observer effort in different areas in future studies. To find out more about the dispersal and estimate the current population of the OPH in Singapore, a citizen science project was started in February 2022 in collaboration with Nature Society (Singapore),

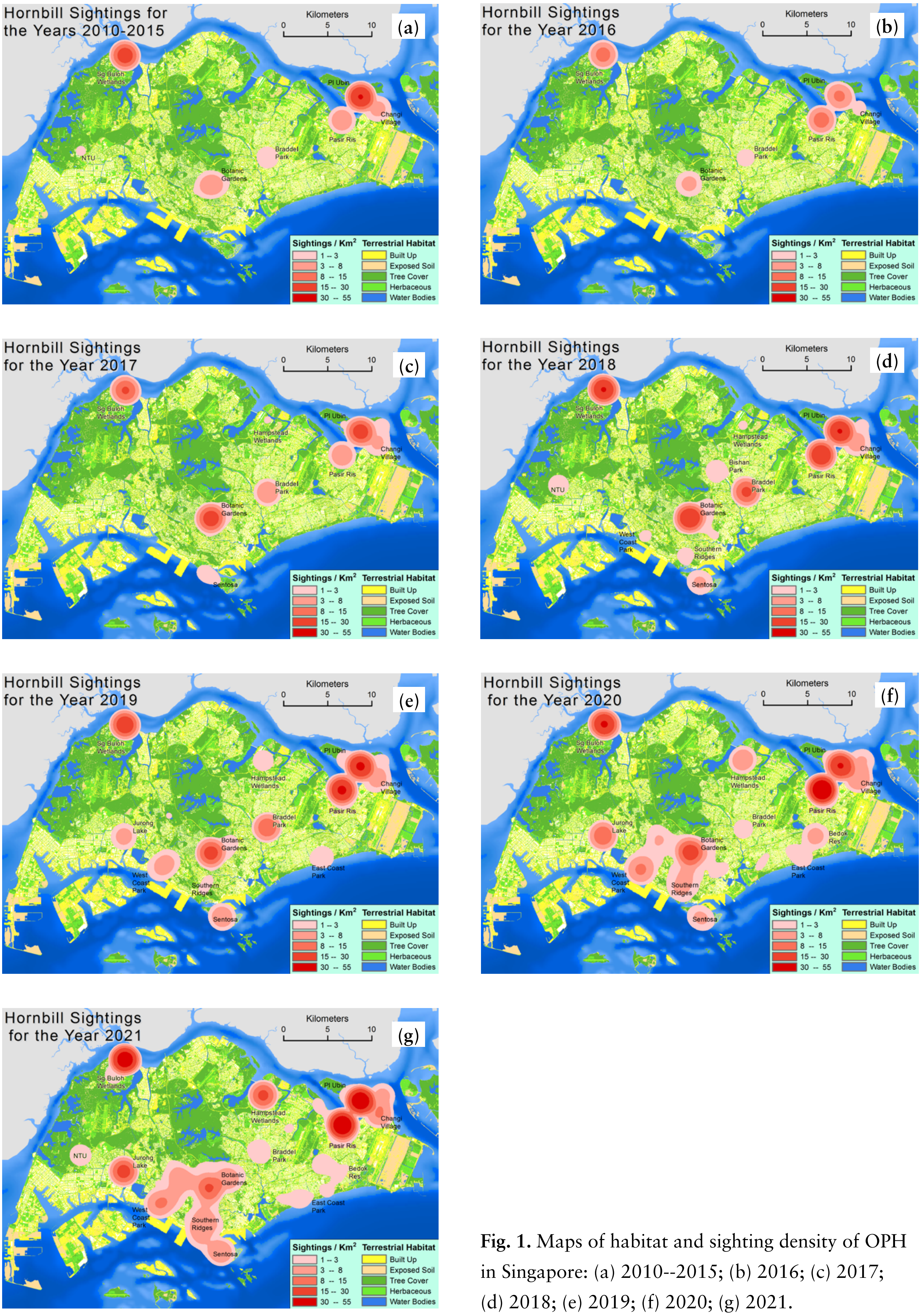

Fig. 1. Maps of habitat and sighting density of OPH in Singapore: (a) 2010--2015; (b) 2016; (c) 2017; (d) 2018; (e) 2019; (f) 2020; (g) 2021.

for which a part-time researcher was hired. Dr. Yong Ding Li of the Nature Society (Singapore), Dr. Rohit Naniwadekar of the Nature Conservation Foundation (India), and Assoc. Prof. Dr. George Gale of the King Mongkut's University of Technology Thonburi (Thailand) provided advice about survey methodology and information to collect. The survey is underway and will help better understand hornbill distribution and abundance in Singapore.

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First photographic evidence of Indian Grey Hornbill (*Ocyceros birostris*) from Navsari Agricultural University, Gujarat, India

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The Indian Grey Hornbill is the only species of hornbill found in Gujarat state in western India. It is an arboreal species, which prefers open deciduous forests and lightly wooded areas, old orchards, roadside avenues, the neighbourhood of cultivation and habitation with *Ficus benghalensis* (banyan) and *Ficus religiosa* (peepal) trees (Ali, 1941; Ali & Ripley, 1987; Whistler, 1949). Syconia or figs of the different *Ficus* species is considered the most important food of Indian Grey Hornbills (Kasambe, 2011). Hornbills are considered as "birds of the forest" but 44% records of the Indian Grey Hornbill have been from around city park areas in India (Datta *et al.*, 2018).

In Gujarat, the Indian Grey Hornbill is recorded from forested areas of south and central Gujarat, and Gir forests (Ganpule, 2016). In the Navsari district in south Gujarat the species is very common and can be frequently sighted at Vansda National Park and surrounding forest areas (Jambu and Patel, 2021). However, it has not been recorded previously in the urban Navsari landscape, which is about 55 km away from the known locations of the Indian Grey Hornbill.

Navsari Agricultural University (NAU) has a 400 hectare campus and harbours wooded landscape far away from natural forested areas. It is located on the historical "Dandi marg" road in Navsari district. The bird was first sighted in 2019 by Dr. Surendra Gohil (pers. comm.) near the college of forestry arboretum but it was an unconfirmed sighting as there was no photographic evidence. The staff of the Forestry College also reported frequent sightings of new 'big bird' near the arboretum between December 2021 to February 2022. During January 2022, Jayesh and Jayanti, two staff of the Forestry college, reported the same 'big bird'. Google images and calls were used to confirm the bird. During the visit to the college of forestry arboretum on 6th January 2022, the call of hornbill caught our attention and after thorough scanning through binoculars, a pair of Indian Grey Hornbills was sighted and photographed for the first time in NAU Campus, Navsari. Hornbills were located with the help of local staff in the NAU campus. First, record photographs of the species were taken and species were identified and confirmed using standard field guides (Grimmett *et al.*, 2011; Rasmussen and Anderton, 2012). The periodic observations were collected through direct sightings using binoculars and calls of the birds.

Subsequently from total 22 visits to the farm area of the university campus between 6 Jan-

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uary to 31 March 2022, the hornbill pair was sighted a total of 26 times at different locations in the campus. Of the total 26 sightings, 12 were recorded from the arboretum, seven from block plantation, five from banana pseudo-stem unit, one from orchard and one from the library. Hornbills were sighted on Arjuna tree (*Terminalia arjuna*), Red sander (*Pterocarpus santalinus*), Kaim tree (*Mitragyna parvifolia*), and Saru trees (*Casuarina equisetifolia*). A pair was also observed eating figs of *Ficus religiosa* and *Ficus benghalensis* trees despite there being 15 different fig species and other fruiting tree species available in university campus. Online citizen science project data also shows that the Navsari agricultural university has no Indian Grey Hornbill sightings before 16 February 2022 and this species was not reported previously from the area (eBird, 2022). This record will extend the geographic distribution of Indian Grey Hornbill in Navsari district of South Gujarat region.

Fig. 1. A. Fruits of *Ficus benghalensis* (Photo: Minal Patel); B. Fruits of *F. religiosa* (Photo: Minal Patel); C. Pair of Indian Grey Hornbill (Photo: Minal Patel); D. Indian Grey Hornbill (Photo: Soufil Malek)

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Unusual nesting events for Von der Decken's and Northern Red-billed Hornbills in Laikipia County, Kenya

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Tockus hornbills are widespread throughout East Africa and Southern Africa (Kemp, 1995). In highly seasonal environments, Tockus hornbill breeding seasons coincide with rainfall, usually beginning after the first heavy rains of the season (Kemp, 1972; 1995). In Kenya, there are typically two rainy seasons: the long rains occur from April (sometimes late March) through May, and the short rains occur from late October to December. However, rainfall patterns are becoming less predictable with climate change and are strongly influenced by El Niño Southern Oscillation events (ENSO).

We studied the breeding cycle of the Von der Decken's Hornbill (*Tockus deckeni)* and the Northern Red-billed Hornbill (*Tockus erythrorhynchus*) on Mpala Ranch, a 20,000 ha cattle ranch and wildlife conservancy in Laikipia County, Kenya, in 2013 and 2014. Annual average rainfall between 1998 and 2021 was 630 mm (range 324 mm to 1016 mm). In 2013, Von der Decken's Hornbills (n = 8) began nesting in the first week of April following a wet March and was completed by early July (Figure 1). The nesting cycle, based on seven successful nests, averaged 81 days (SD = 8.4 days). The Northern Red-billed Hornbills initiated nesting in the second week of April (n = 3) and fledged young by the end of June. The nesting cycle averaged 71 days (SD = 7.0). The cumulative rainfall for the nesting season was 396.5 mm, and considered abnormally wet.

Male Northern Red-billed Hornbill.

Male Von der Decken's Hornbill.

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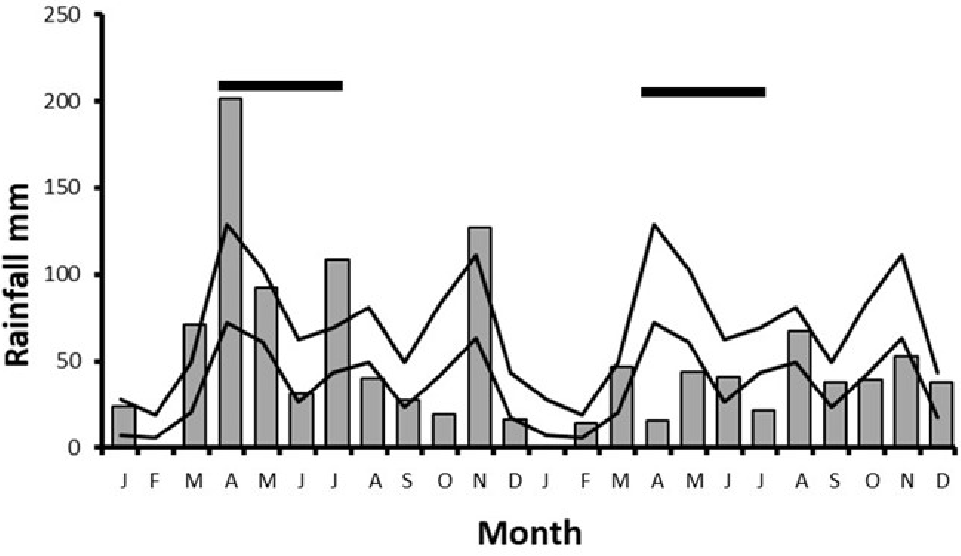

Fig. 1. Monthly rainfall (Bars) for 2013 and 2014 at Mpala Research Center, Laikipia County, Kenya with 95% confidence interval (thin black lines) for average monthly rainfall. Thick black lines indicate breeding season for Von der Decken's and Northern Red-billed Hornbills in 2013 and 2014.

In 2014, we followed 17 Von der Decken's Hornbill nesting attempts. Nesting began around 10 April, following a normal March rainfall (Figure 1). However, rains failed in April and were below normal in May. Only three nests fledged young in June with an average nesting cycle of 68 days (SD = 3.5), probably a result of the low rainfall. On the other hand, the Northern Red-billed Hornbills did not breed in 2014. Rainfall total for the 2014 breeding season was 147 mm and considered abnormally dry.

We visited Laikipia County briefly in late December 2021 and again in early February 2022. The county had experienced severe drought conditions from November 2020 through July 2021, totaling only 147 mm of rain compared to a long-term average of 466 mm for the same time period. We were therefore surprised to observe evidence of breeding by both species. On the first occasion, we observed a male Northern Red-billed Hornbill delivering food to a sealed nest on 29 December. On 5 February 2022, we observed male Von der Decken's Hornbills feeding fledgling chicks on two separate occasions. The chicks appeared to be ~1 month out of the nest. We estimate that both species initiated nesting sometime in October after some brief unseasonal rains in August and September (64 and 71 mm of rain: Figure 2). Rainfall total for September to December was 154 mm, within the 95% confidence limits of normal rainfall for that time period.

We speculate that, due to the extended drought in 2020 and 2021, both hornbill species either failed to initiate breeding in April 2021, or attempted to breed but failed. A third, but unlikely, possibility is that one or both species attempted to produce two clutches (double clutching) in 2021. Brown et al. (2014) reported successful double clutching for an African Grey Hornbill (*Lophoceros nasutus*) in Namibia. Stanback et al. (2021) reported double clutching in 10 Southern Yellow-billed Hornbills (*Tockus leucomelas*). However, these events were during years of above average rainfall. We followed activities of both Laikipia species between 2012 and 2015 as part of a banding and genetic monogamy study (Kinnaird and O'Brien, 2019) and did not see any evidence of double clutching. As a result of no long rains in 2021, we suspect that both species did not attempt to breed during

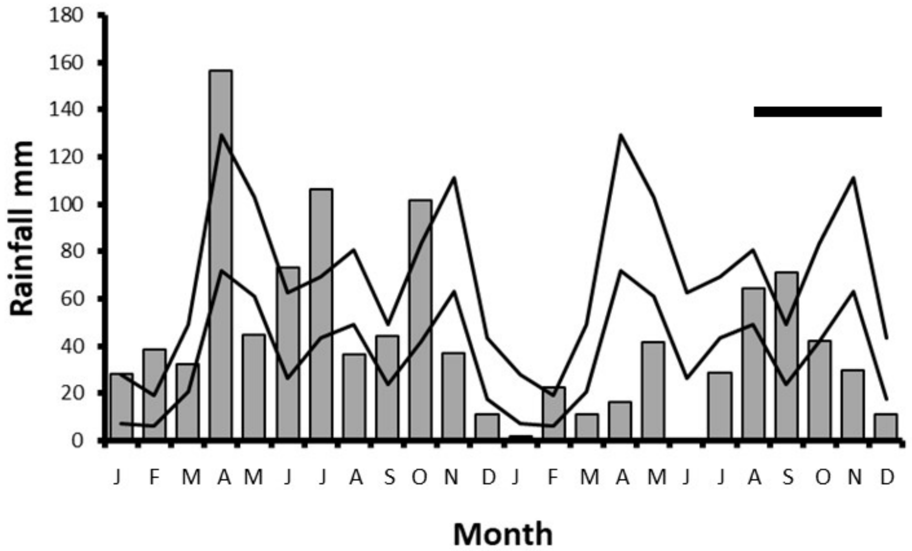

Fig. 2. Monthly rainfall (Bars) for 2020 and 2021 at Mpala Research Center, Laikipia County, Kenya with 95% confidence interval (thin black lines) for average monthly rainfall. Drought conditions present from November 2020 through July 2021. Thick black line indicates 2021 breeding season for Von der Decken's and Northern Red-billed Hornbills.

the normal season. The unseasonal rains in August and September appear to have triggered a late breeding attempt by at least some individuals of both species.

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Fruit exocarp removal: a unique foraging behaviour in Narcondam Hornbills

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Asian hornbills are predominantly frugivorous birds that feed on a diverse array of fruits – from small-seeded figs to large-seeded *Myristica* and *Canarium* (Kinnaird & O'Brien 2007, Poonswad *et al*., 2013). Once on the tree, they carefully search for ripe fruits, which are then deftly plucked and swallowed. Until now, however, there have been no reports of hornbills removing the fruit exocarp before swallowing them.

During our stay on Narcondam Island between December 2019 and February 2020, we regularly found fruit exocarps under fruiting *Caryota mitis* palms. The island has a hyper abundance of rats, and we initially thought the rats were responsible for the fallen fruit exocarps. This was until we saw a flock of ~10 Narcondam Hornbills feeding on *Caryota mitis* fruits. We noticed that the hornbills appeared to be dropping something while feeding on *Caryota* fruits. Further observations during focal palm watches confirmed that it was indeed the hornbill removing the exocarp of the palm fruit before swallowing the pulp and the seed.

Fig. 1. Narcondam Hornbill pair on *Caryota mitis* palm. Art by Sartaj Ghuman.

On visiting a fruiting *Caryota mitis* palm, the birds would carefully pluck a ripe fruit. It has a thick, leathery exocarp and a thin layer of

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pulp on a large seed (mean (SD): seed weight = 2.14 (0.1) g; seed length = 14.0 (0.36) mm; seed width = 15.83 (0.41) mm; n = 5). The fruit is first gently squeezed while being tossed and rotated, an action that probably helps separate the exocarp from the pulp. The fruit is then firmly squeezed, until the exocarp splits and the pulp-coated seed pops out. In that instant, the hornbill lets go of the exocarp and catches the pulp-coated seed. The hornbills were also almost always seen to vigorously shake their head immediately after swallowing the seed (https://youtu.be/tH7KYdhVFB4). This behaviour was not seen when hornbills were feeding on other fruit species (https://www.youtube.com/watch?v=YBNhy9NfwCs).

Handling *Caryota mitis* fruits and especially the fruit pulp when it comes in direct contact with the skin results in a mild to severe itching sensation for humans, a possible reaction to secondary compounds probably meant to protect the fruit from seed predators. Hornbills probably remove the fruit exocarp to avoid the secondary compounds. For example, *Caryota mitis* fruits are also known to have high concentrations of secondary metabolites (El-Akad *et al*., 2021). On the island, we only saw Narcondam Hornbills feeding on the fruits of the *Caryota mitis* palm despite the island being home to *Ducula* pigeons—the Pied and the Green Imperial-pigeon—which are known to feed on medium- and large-seeded plants with relative ease (Naniwadekar *et al*., 2019). In Singapore, diverse frugivores feed on *Caryota mitis* fruits, including the Pied Imperial-pigeons, Green-pigeons, hornbills, civets, macaques and squirrels (Quek *et al*., 2020). Interestingly, none of the groups, except hornbills and Imperial-pigeons occur on Narcondam Island. It would be useful to observe how other animals feed on the fruits of *Caryota mitis* at other sites.

Hornbills often toss fruits in their beaks before swallowing. They also pry open closed dehiscent capsules of fruits belonging to Meliaceae and Mysriticaceae before removing and swallowing the aril (with seed). We did observe the Narcondam Hornbill prying open a closed capsule of *Endocomia macrocomia* (Family: Myristicaceae) and removing the aril. However, we did not come across any other published literature on hornbills that documents the removing of fruit exocarp before ingestion. We also share a video of a Narcondam Hornbill pair feeding on *Caryota mitis* fruits (https://youtu.be/tH7KYdhVFB4).

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Malabar Grey Hornbill *Ocyceros griseus* feeding on Surinam Cherry *Eugina uniflora* from a home garden in Gudalur Taluk of Nilgiris district, India

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The Malabar Grey Hornbill *Ocyceros griseus* is an endemic hornbill species limited to the evergreen and deciduous forests from plains to 1600 m of the Western Ghats, southwest India (Maheswaran and Balasubramanian, 2003). Malabar Grey Hornbill (hereafter MGH) is the smallest of the nine hornbills present in India (Mudappa, 2000). MGH is classified as vulnerable by the IUCN, due to conversion of forest land into monoculture plantations with exotic tree species, for dam construction and other developmental works (Mudappa and Kannan, 1997; Mudappa, 2000). It is also a relatively common hornbill species in the Western Ghats above 600 m elevation, especially where fig trees are present in large numbers, and also extends its ranges into gardens, tea plantations, coffee plantations and tall shade trees in the cardamom plantations (Kemp, 1995). Their diet includes fruits and berries, particularly figs, also insects and lizards; rarely, flowers (Hoyo *et al.* 2001).

On 21 March 2021 at 12:17, I recorded a male MGH (Figure 1) feeding on the fruit, Surinam Cherry *Eugina uniflora* (Family Myrtaceae) in a house garden (11°27′00.3″N 76°28′44.5″E) in Choondy village of O′ Valley town Panchayat in Gudalur taluk in the Tamil Nadu state. This garden was surrounded by the tea & areca nut plantations and a stream. During this observation, this male bird was often coming and feeding on the fruits from this Surinam Cherry tree (Figure 2). Surinam Cherry is native to tropical America, cultivated as hedges in gardens and the fruits are used in jelly, jam and other flavoring items (Flowers of India, 2022). The fruits of Surinam Cherry have the appearance of small pumpkins, are green in colour in an immature state and when ripened, they become orange or red to dark purple colour. The fleshiness of Surinam Cherry is highly variable, with an average of 77% pulp and 33% seed (Franzon *et al.*, 2018). When I inquired with local people about this bird, they said that this bird often comes to their garden to feed on this fruit and it is also not afraid of their presence.

In the earlier study, Pawar *et al.* (2021) have confirmed the year-round use of modified habitats such as plantation by Asian Hornbills. My observation of male MGH feeding on the Surinam Cherry in the house garden is the first report of native hornbill feeding on this invasive fruit. Mudappa and Raman (2020) reported that MGH feeds on at least 19 species of fruits (including *Syzygium* species of the family Myrtaceae), five species of vertebrates and eight types of invertebrates

Fig. 1. A photo of the male Malabar Grey Hornbill found in the home garden. Photo: P. Selvaraj

Fig. 2. A photo of Surinam Cherry. Photo: P. Selvaraj

during the breeding season. Santhoshkumar and Balasubramanian (2014) reported Indian Grey Hornbill consumes fruits belonging to 26 plant species (which includes two species from the Family Myrtaceae namely *Psidium guajava* and *Syzygium cumini*) during their breeding season. Due to specific nesting requirements and diet, hornbills are vulnerable to large scale habitat modification (Pawar *et al.* 2021). As Pawar *et al.* (2018) recommended it is important to increase native hornbill food plants as shade trees in the coffee and tea plantations to be at least half as much as in contiguous forest. Although there have been studies of hornbills feeding on the fruits, no record of MGH feeding on the *E. uniflora* has been reported before this. This field note is the starting point for the future investigations on the impact of endemic MGH feeding on the invasive fruit plants.

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