

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 hu-

man 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 km² 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 iso-sexual 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.

Measure	Score		
	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 <i>Buceros bicornis</i>	VU	19 (83)	93: 53: 38: 2	20: 35: 38
Rhinoceros Hornbill <i>Buceros rhinoceros</i>	VU	16 (67)	45: 24: 21: 0	13: 12: 20
White-crowned Hornbill <i>Berenicornis comatus</i>	EN	6 (26)	8: 4: 4: 0	1: 3: 4
Wreathed Hornbill <i>Rhyticeros undulatus</i>	VU	14 (61)	17: 9: 8: 0	3: 7: 7
Plain-Pouched Hornbill <i>Rhyticeros subruficollis</i>	VU	1 (4)	1: 1: 0: 0	0: 1: 0
Tickell's Brown Hornbill <i>Anorrhinus tickelli</i>	NT	2 (9)	2: 2: 0: 0	2: 0: 0
Bushy-crested Hornbill <i>Anorrhinus galeritus</i>	NT	3 (13)	3: 2: 1: 0	1: 1: 1
Oriental Pied Hornbill <i>Anthracoceros albirostris</i>	LC	15 (65)	45: 23: 14: 8	27: 15: 3
Papuan Hornbill <i>Rhyticeros plicatus</i>	LC	2 (9)	3: 2: 1: 0	0: 0: 3
Trumpeter Hornbill <i>Bycanistes buccinator</i>	LC	1 (4)	1: 0: 0: 1	1: 0: 0
Southern Ground Hornbill <i>Bucorvus leadbeateri</i>	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

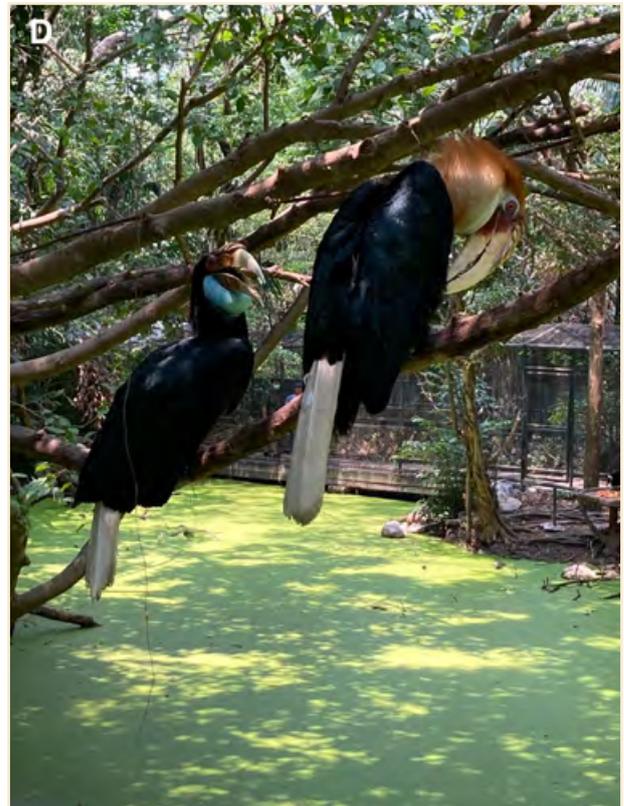


Fig. 1. A. Hornbill exhibit at an accredited zoo (score 24); B. Great Hornbill exhibit at a government zoo and wildlife rescue and breeding centre (score 14); C. Rhinoceros Hornbill exhibit at a private zoo (score 10); D. Large open aviary at a private zoo (score 20) (maximum possible score = 24).

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

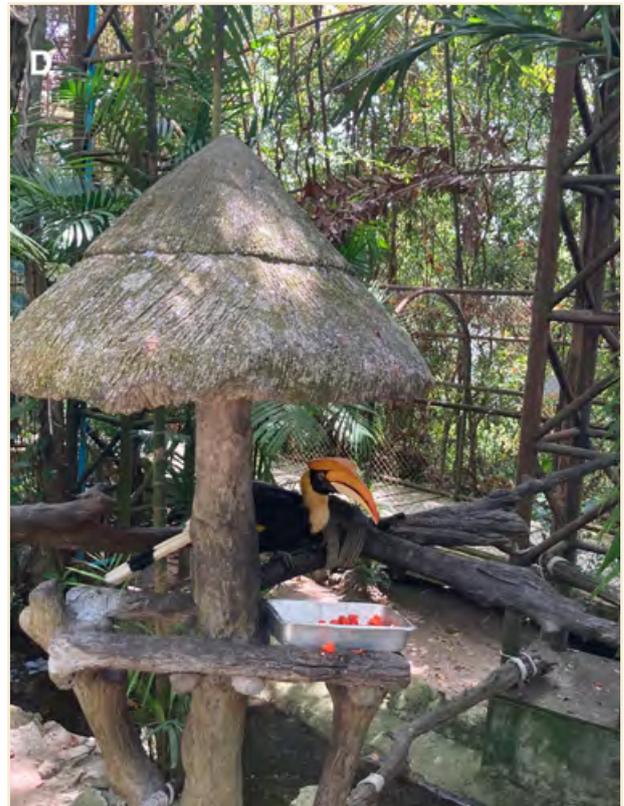
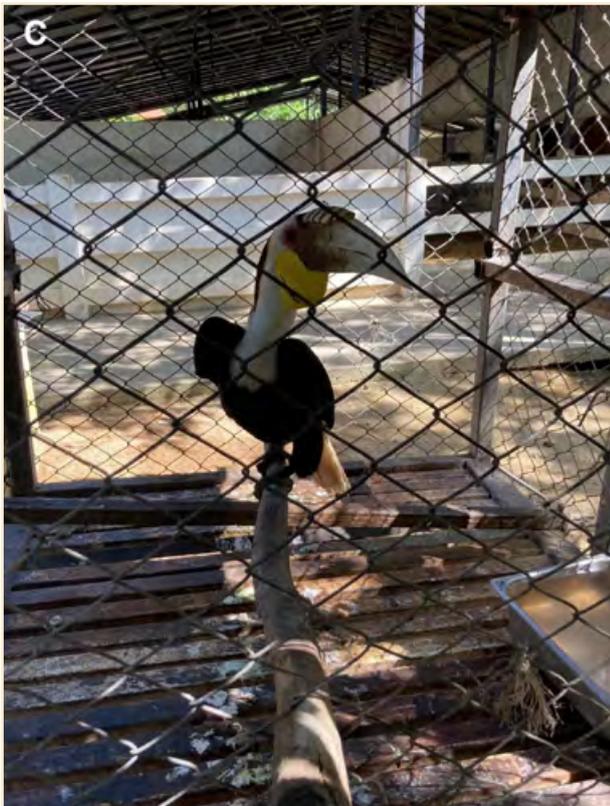
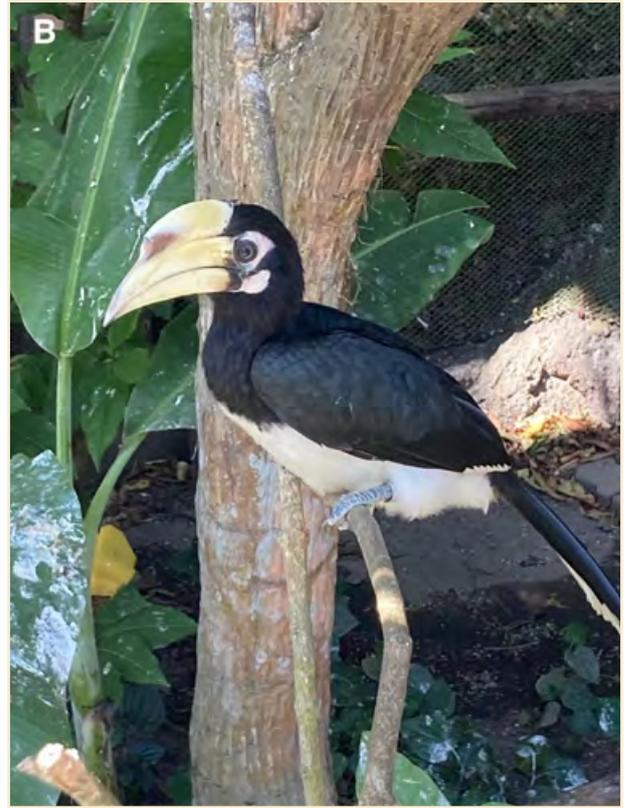


Fig. 2. A. Great Hornbill with beak protruding through mesh fence at a government zoo (score 15); B. Oriental Pied hornbill at an accredited zoo (score 19); C. Wreathed Hornbill in a small cage at a private zoo (score 5); D. Great Hornbill with covered and elevated food tray at an accredited zoo (score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

ample, 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 nec-

ecessary 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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