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Rhinoceros Hornbill. © Shavez Cheema

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MABULA GROUND HORNBILL PROJECT

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Hornbill Specialist Group

Dear HSG members,

Wow! What a year it has been. As Volume 1(2) was being released and we were advertising for contributions to Volume 2, who could have imagined what lay ahead. To date, Covid-19 has infected more than 160 million people worldwide and resulted in more than 3.3 million deaths. For HSG field biologists and zoo staff, the impact of steps taken to limit the spread of Covid-19, including lockdowns, stay at home orders, curfews, and social distancing, has been huge. Most of us had to suspend field programs, often resulting in loss of jobs for HSG members and local staff. Zoos and conservancies closed, losing fortunes. And, most of us have been touched by the deaths of family, friends and colleagues.

The COVID-19 pandemic has changed the world. We are now more aware than ever of the risks we impose upon ourselves due to the current unsustainable ways in which we manage and use nature. As we have experienced over the course of the COVID-19 pandemic, these risks are not just related to our health, but also have deep repercussions for global economies, local livelihoods and society in general. Much has been written about the rise of pathogens - especially in regard to rapidly changing environments. Global warming, deforestation and habitat fragmentation have intensified proximity and rate of interaction between humans, their livestock and nature, increasing exposure risk. Legal international wildlife trade has risen 400% since 2005, and illegal and unregulated trade have also increased over time. Consumption of wildlife, especially birds and mammals, is believed to pose a great risk of disease emergence.

The rise of emerging diseases of zoonotic origin has understandably caused widespread concern and underscores the need to prevent future spillovers and potential pandemics. Wildlife trade bans and closing of all markets selling live wildlife have been proposed, but such approaches are considered impractical by many and would not solve the problem. Domestic animals, for example, account for 96% of mammalian biomass on Earth and the vast majority of meat traded and consumed is from domestic rather than wild animals. When considering these differences in scale of production and consumption, the risk of contracting a food-borne illness from domestic animals in trade has been estimated to be ~3,000 times greater than from wild animals in trade. However, it should be noted that wildlife health is not monitored and managed with the same diligence as domestic animal health, which is very uneven globally.

While not all emerging infectious disease events have occurred within the context of the wildlife trade, SARS, Ebola, and monkeypox, are examples of spillover events with their origins most probably - although not conclusively - linked to wildlife consumption, wildlife farms, and/or markets selling live wildlife. The SARS Cov-2 virus that causes the COVID-19 disease is suspected to have originated in horseshoe bats and entered humans via an intermediary animal associated with the wildlife trade. However, no intermediary, wild or domestic, has been unambiguously identified so we still have significant gaps in our knowledge as to exactly how and when these diseases emerge.

What we do know for certain is that one spillover is one too many. Every pandemic begins with a single infection event and while infection events may occur frequently around the world, most infections are unable to spread. In the unlikely event that an infection spreads into an urban human community (coupled with airborne transmission), pandemics can result. As Andy Dobson and colleagues (including HSG member Margaret Kinnaird) point out, the costs of preventing a pandemic can be measured in hundreds of billions of dollars while the economic and social costs of dealing with a pandemic (e.g. Covid-19) are measured in tens of trillions of dollars. If prevention is the best medicine, then we clearly need to change our relationship with nature, and wildlife, if we hope to head off the next pandemic.

Stay well and stay safe.

~Tim O’Brien and Margaret Kinnaird

Observations of Hornbills in Tawau Hills Park, Sabah, Malaysia

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Abstract

Hornbills (Family: Bucerotidae) are one of the iconic animal groups in Borneo, forest-dependent and playing a significant role in the tropical rainforest ecosystem. Here, we aim to explore the hornbill species present in the rainforests of Tawau Hills Park (THP), Sabah. We performed two months of field survey using existing trails as survey transects. Detected hornbills were identified and recorded. We recorded all eight Bornean hornbill species. THP together with the adjoining Ulu Kalumpang Forest Reserve to the north provide nearly 800 square kilometers of forest habitat, representing an important hornbill conservation area. Of the eight species, three are classified as Critically Endangered or Endangered in the IUCN Red List. We sighted White-crowned Hornbills Aceros comatus *and Black* Hornbills Anthracoceros malayanus *frequently flying into the oil palm plantation to the south to feed on oil palm fruits. Finally, we note the need to identify and restore wildlife corridors in the plantation-forest landscapes of Borneo.*

Keywords: Bucerotidae, dipterocarp forest, seed disperser, Borneo

Introduction

Hornbills are classified under the Order Bucerotiformes and Family Bucerotidae. They belong to a group of bird species that are characterized by their distinctive long, large down-curved and pointed beak, commonly called the "bill". Some possess a casque located on the upper mandible of the bill, which is coated with a thin keratin sheath known as rhamphotheca. The function of the casque is debated (Kemp, 1969; Alexander *et al.*, 1994), and there may be more than one, including: in aerial jousting contests (Kinnaird *et al.*, 2003); to provide acoustic resonance and enhance the distinctive call of some species (Alexander *et al.*, 1994); and to reinforce the upper mandible, enhancing the maximum force at the tip of the bill (Naish, 2015). There are 62 species of hornbills in the Old World, occurring across tropical Africa, Asia, Australasia (Poonswad *et al.*, 2013).

Borneo, the third-largest island in the world, is home to eight species of hornbills: White-crowned Hornbill (*Berenicornis comatus*), Wrinkled Hornbill (*Rhabdotorrhinus corrugatus*), Bushy-crested Hornbill (*Anorrhinus galeritus*), Oriental Pied Hornbill (*Anthracoceros albirostris*), Black Hornbill, Rhinoceros Hornbill

(*Buceros rhinoceros*), Helmeted Hornbill (*Rhinoplax vigil*), and Wreathed Hornbill (*Rhyticeros undulatus*) (Bennett *et al.*, 1997; Phillipps and Phillipps, 2016; Yeap and Perumal, 2017). Recent research on hornbills includes their taxonomy (Fitriana *et al.*, 2020), natural history and ecology (Kitamura, 2011; Rahayuningsih *et al.*, 2017), distribution (Mohd-Azlan *et al.*, 2016), traditional ecological knowledge (Franco and Minggu, 2019), as well as their responses towards human disturbance and conservation effort (Beastall *et al.*, 2016; Yeap *et al.*, 2016; Budiman *et al.*, 2017). Hornbills are important not only to the tropical forest ecosystem as seed dispersers, but may also contribute significant benefits to socio-economy (Franco and Minggu, 2019). Here, we aim to identify the hornbill species present at Tawau Hills Park, Sabah, a Protected Area little-known outside Malaysia.

Methods

Study Site

Tawau Hills Park (4°22’33 N, 117°59’02 E) is a Protected Area of mainly old-growth tropical rainforest legislated before the concept of biological diversity conservation was prominent in Sabah, in 1979, to protect catchments for the supply of water to Tawau town and the Semporna Peninsula located in south-eastern Sabah, Malaysia (Fig. 1). The park comprises 27,972 ha of evergreen dipterocarp forest with some lower montane forest, and is located 24 kilometres from the Tawau town. In the north, it connects to Ulu Kalumpang Forest Reserve (50,736 ha), and the entire forest block is surrounded by plantations, mainly of oil palm (Phillipps and Phillipps, 2016; Tawau Hills Park, 2018). Three main mountain peaks are sit-

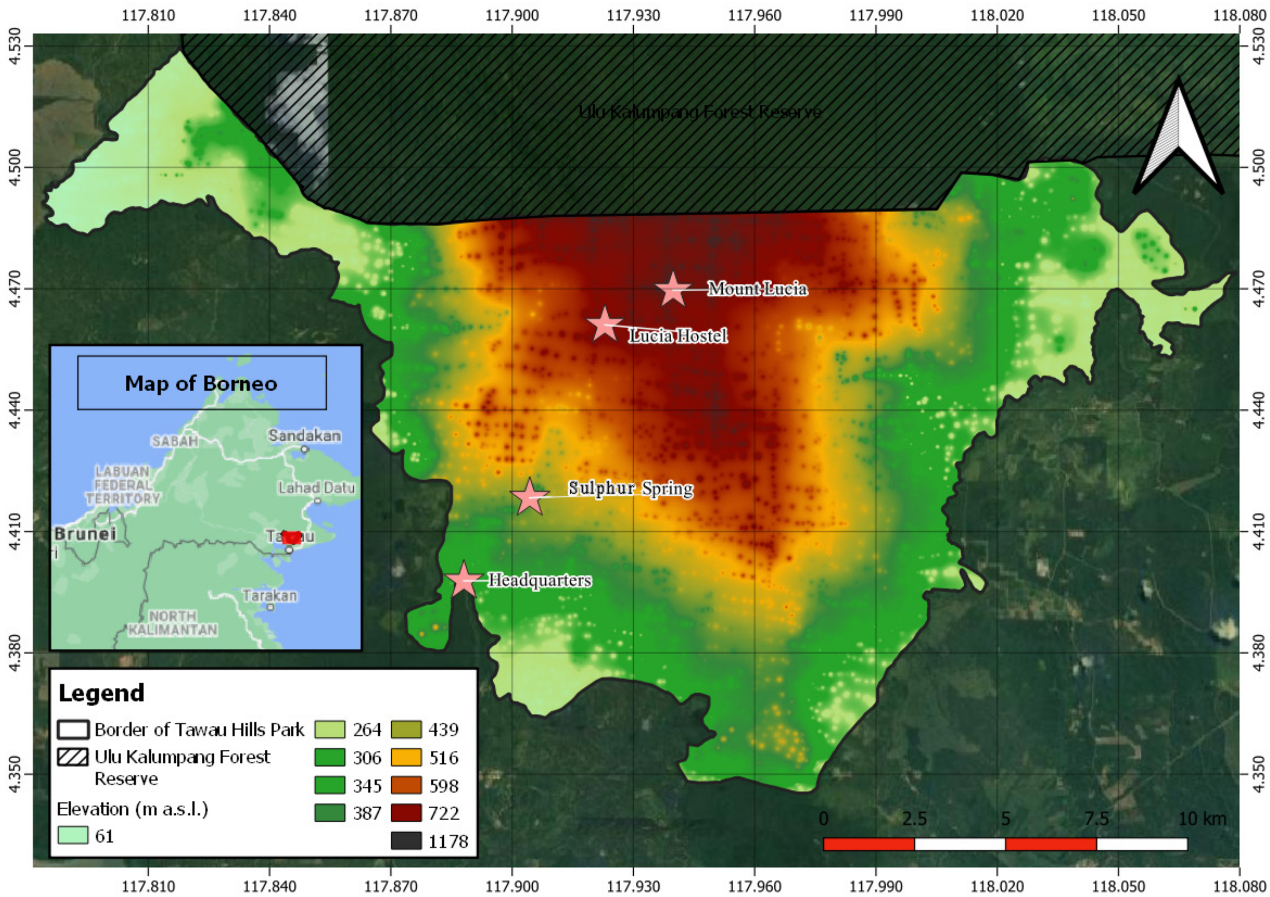

Fig. 1. Map of Tawau Hills Park located at south-eastern part of Sabah, Malaysia. (Map created in QGIS version 3.16).

uated in the park: Mount Magdalena (1312 m), Mount Lucia (1202 m), and Mount Maria (1083 m). The Park not only fulfils its original intended role, but is also a favourite recreation destination, especially for local residents, and supports a rich diversity of native plants and animals.

Field Survey

The survey was mainly focused in lowland forest (i.e., near the Park headquarters) and on Mount Lucia (10.55 km away from the headquarters). We conducted the surveys for five days per week and three weeks each month (from June 2020 to August 2020; Table 1). Three existing trails in the lowland forests were used as survey transects, and two on Mount Lucia. Using existing trails produces data unsuitable for statistical analysis (Bibby *et al.*, 1998; Hiby and Krishna, 2001) but our aim was to simply document hornbill occurrence.

Hornbill searching was carried out by a team of three, starting from 06:30 to roughly 11:00 and again from evening 16:00 to 18:00 (Table 1). The same team members carried out all surveys. We performed the surveys by continuously walking along the trails (trail length 900 m to 3.3 km; Table 2). Opportunistic sightings away from the survey trails were also recorded.

Binoculars were used as an aid to detect and identify the birds. Photographs of hornbills were

Table 1. Hornbill survey sampling effort in the lowland forests and Mount Lucia of Tawau Hills Park, Sabah.

	No. of survey days x hours/day	Total sampling
Lowland Forest (around the headquarters and the boundary of the park)	25 days x 6.5 h (June – mid-July 2020)	162.5 hours
Mount Lucia (900 m a.s.l and 10.55 km away from the headquarters)	20 days x 6.5 h (mid-July – August 2020)	130 hours
Total		**292.5 hours**

Table 2. Trails used for hornbill survey and total length of each surveyed trail in Tawau Hills Park, Sabah.

Site/Trails	Length of trail (km)
Lowland Forest	
Tallest Tree Trail	0.9
Sulphur Spring Trail	3.2
Canopy Walkway Trail	1.2
Mount Lucia	
Peak of Mount Lucia	3.3
Argus Dancing Ground Trail	1.5

taken using digital single-lens reflex (DSLR) cameras. We followed the "Birds of Borneo", a standard field guidebook by Phillipps and Phillipps (2016) to identify the birds. All team members were able to identify hornbills to species level from their calls.

Results and Discussion

All eight species of hornbills known to occur in Borneo were sighted in THP (Fig. 2). Of the eight species, three are classified by IUCN as Critically Endangered or Endangered under IUCN Red List. (Table 3). Oriental Pied and Wrinkled hornbills were uncommon (*i.e.*, rarely heard or seen) whereas the remaining six species (*i.e.*, Black, Bushy-crested, Rhinoceros, Helmeted, Wreathed, and White-crowned hornbills) were commonly seen, heard, or both. Three species (Rhinoceros, Helmeted and Wreathed) were common on Mount Lucia, while White-crowned and Bushy-crested Hornbills were less common in the hilly region of THP. Oriental Pied Hornbills are a riverine forest and forest edge adapted species (Davies and Payne, 1982) and have now even adapted to moderately man-modified environments or semi-urban areas (Banwell and Lim, 2009) but the other seven species are forest-dependent (Naish, 2015).

The availability of suitable nesting sites and key food sources are the key limiting factors to the breeding population size of hornbills (Poonswad, 1995; Anggraini *et al.*, 2000; Naniwadekar *et al.*, 2015). Large forest blocks are necessary to provide sufficient habitat to sustain breeding populations of forest dependent-species (Kemp, 1995; Sitom-

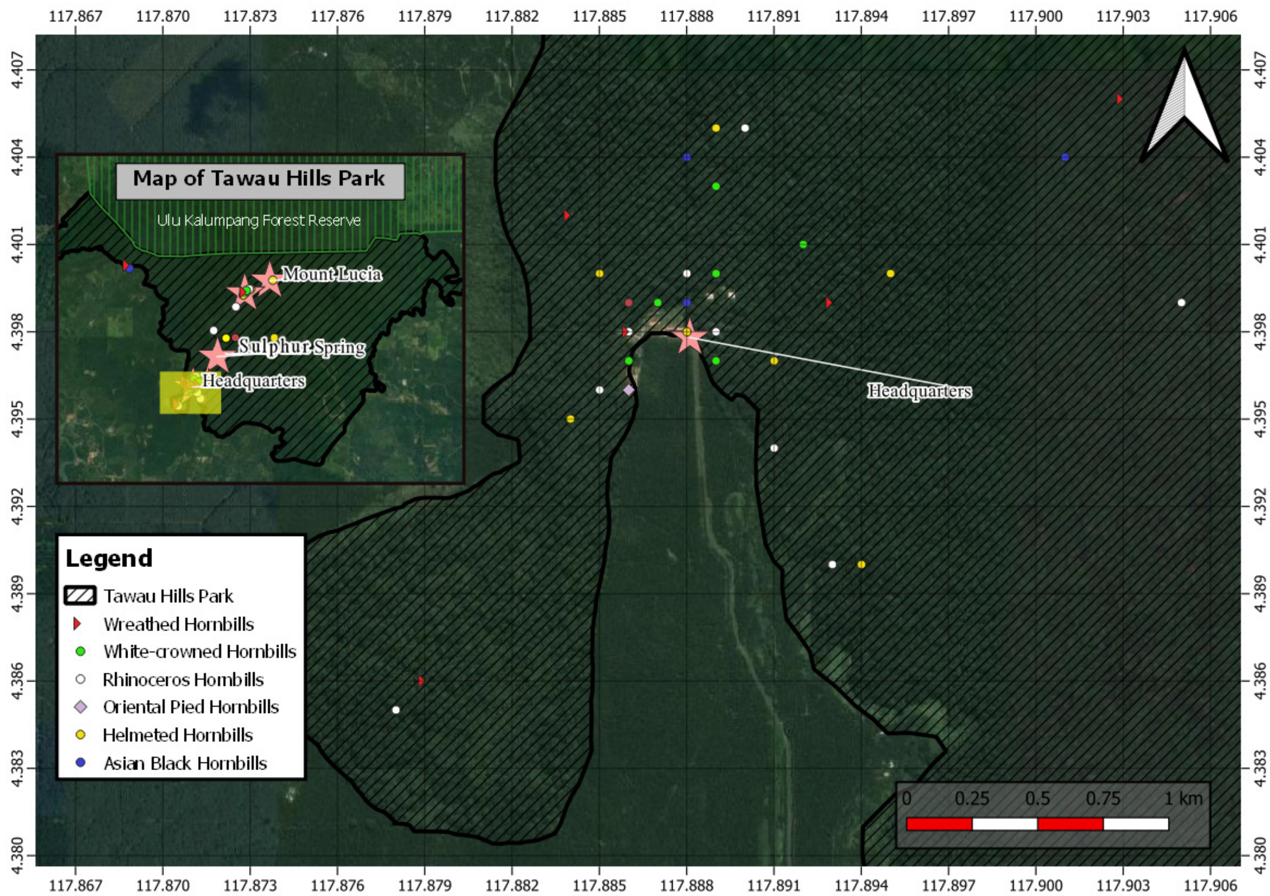

Fig. 2. Example of location on the independent occurrence of sighted hornbill species situated at south-west of the Tawau Hills Park. (Map created in QGIS version 3.16).

Table 3. Checklist of hornbill species found in Tawau Hills Park from June to August 2020.

Hornbill Species	IUCN	Abundance
Helmeted Hornbill *Rhinoplax vigil*	CR	Commonly heard, rarely seen
Wrinkled Hornbill *Rhabdotorrhinus corrugatus*	EN	Rarely heard or seen
White-crowned Hornbill *Berenicornis comatus*	EN	Commonly heard and seen
Bushy-crested Hornbill *Anorrhinus galeritus*	NT	Commonly heard and seen
Black Hornbill *Anthracoceros malayanus*	VU	Commonly heard and seen
Rhinoceros Hornbill *Buceros rhinoceros*	VU	Commonly heard and seen
Wreathed Hornbill *Rhyticeros undulatus*	VU	Rarely heard but commonly seen
Oriental Pied Hornbill *Anthracoceros albirostris*	LC	Rarely heard or seen

CR = Critically Endangered, EN = Endangered, VU = Vulnerable, NT = Near Threatened, LC = Least Concern

pul *et al.,* 2004; Naish, 2015). Leighton (1982) estimated that at least 38,500 ha of forest is needed for a minimum viable population of 50 pairs of the large-bodied Helmeted Hornbill. Together THP and Ulu Kalumpang Forest Reserve represent a single forest block of nearly 80,000 ha. The fragmentation and shrinking of natural forests in Borneo in recent decades have resulted in blocks of habitat that may be insufficient to sustain hornbill breeding populations, due to both insufficient food sources and large standing trees as nesting sites for these cavity-nesters (Lambert and Collar, 2002). Hornbills are very selective in terms of choosing their nesting sites. For example, studies have reported that the characteristic of nest entrances (e.g., shape and size), nest tree species, and the height of the tree cavities do influence the recruitment of hornbill assemblages in an area (Poonswad, 1995; Datta and Rawat, 2004; Rahayuningsih *et al.,* 2017; Utoyo *et al.,* 2017).

Figs (*Ficus* species, family Moraceae) represent an important food source for hornbills. Common fig species are important in hornbill diet and their abundance has shown to have a positive correlation with the percent contribution in hornbill diet (Datta, 2003). Sitompul *et al.* (2004) pointed out that there is a correlation between the density of Sumba hornbills (*Rhyticeros everetti*) in Indonesia and the abundance of ripe figs, provided that the forest is large. Three fig species (*Ficus subcordata, Ficus cucurbitina,* and *Ficus villosa*) were noted to be common in THP. We sighted Helmeted, Rhinoceros, Wreathed, and Black Hornbills feeding on the fruits of *F. subcordata* and *F. cucurbitana.* According to Phillipps (2020), a total of 25 fig species have been recorded within and around the boundary of THP. We suggest that hornbill diversity and abundance in THP may be in part due to *Ficus* diversity and abundance there.

White-crowned and Black Hornbills were seen almost daily; and occasionally Rhinoceros Hornbill, flying from the THP forest into adjacent oil palm plantation to feed on oil palm fruits (*Elaeis guinensis*). Previous studies have demonstrated that Asian hornbills have wide diet breadth (Datta, 2003). Moreover, they generally prefer red, yellow-orange, purple, or black fruits that are easily visible and accessible in the canopy (Datta, 2003; Kitamura *et al.,* 2004; Kitamura *et al.,* 2011). However, to what degree oil palm fruits contribute to the dietary requirement of the birds in THP is unknown, and further evaluation is needed.

Continuing tropical forest fragmentation and loss of old-growth forests, both within and outside protected areas represents a major concern for species survival; the priority mitigation measure is to reconnect forest blocks through restoration projects (Hansen *et al.,* 2020). In the context of hornbill conservation in THP and Ulu Kalumpang Forest Reserve, we recommend restoration projects that would specifically favour hornbills in the long term. One advantage is that the hornbills, and other frugivorous bird species, will tend to enhance the restoration effort by bringing additional seeds of additional species into the restoration zone. A long-term vision and effort is necessary. Sabah Softwood Berhad, an agroforestry company has already initiated implementation of such a project through developing a 13.89 km wildlife corridor, with width ranging from 400 m to 800 m, between Ulu Kalumpang Forest Reserve amd Ulu Segama Forest Reserve further to the north (Nathan *et al.,* 2020).

Conservation actions

One of the priority actions needed to protect the hornbill species in Borneo is the enforcement of laws and legislations, both local and international. The relevant authorities, such as rangers, customs, wildlife officers, or police should perform their duties full of responsibilities. This includes investigation of violation cases, apprehending violators and issues fines, collaboration with other law enforcement agencies, and patrol assigned areas regularly. This is important to combat crimes like illegal logging and wildlife trade.

Apart from managing the existing protected area, the state governments should also focus on the forested landscape outside of the protected range. High Conservation Value (HCV) assessments need to be performed on various landscape ecosystems to identify priority areas that need to be managed and monitored, and thereby minimizing the impact of human activities such as land-use conversion (Jain *et al.,* 2018). Besides, more wildlife corridors and reforestation projects need to take place where the trees replanted are figs and in particular, hornbill favourite foods like the *F. racemosa, F. cucurbitina, F. benjamina* and *F. subcordata.*

Workshops involving relevant stakeholders (e.g. government agencies, NGOs, landowners) from different fields should be carried out to deliberate about the current issues faced by hornbills and measures needed to save them from extinction. For example, illegal trading elimination, protecting hornbill population and their habitat, and providing information (i.e. collect, analyse, update and share) to maintain a healthy viable population are three main actions suggested in "Recommendations from the Helmeted Hornbill Conservation Strategy and Action Planning Workshop" that was held in Kubah National Park, Sarawak (Jain *et al.,* 2018).

A shortage of good nesting tree cavities could be overcome by creating and placing artificial hornbill nests in the forest. Pasuwan *et al.,* (2011) demonstrated that a pair of breeding Great Hornbills (*Buceros bicornis*) used the artificial nest after a year it had been installed in Budo Mountain, Southern Thailand, and the number of hornbills utilizing the nest boxes has increased steadily. Meanwhile, in Borneo, a pair of Rhinoceros Hornbill has been reported using a nest box in Kinabatangan and a fledged chick was observed (Imrich, 2020). 1StopBorneo Wildlife, an NGO, also installed a few nest boxes in Sukau and found that one of the boxes was used by Oriental Pied Hornbills. Moreover, many artificial nests have been put up and Oriental Pied Hornbills are recorded to be nesting in people's houses in Panaga Brunei. Thus, artificial nests do provide additional nesting opportunities for the hornbills, and potentially increase viable population in the wild (James *et al.,* 2011; Pasuwan *et al.,* 2011).

Finally, nature conservation tourism can have a positive impact on hornbills in Borneo. Not only economically to the park or nature reserve, nature tourism can also help in conserving and raising awareness on hornbills in local ecosystems. Many wildlife tourists are attracted by these large majestic birds and are willing to spend days looking for and watching them. Thus, tourists can act as eco-rangers indirectly, "patrolling" the park during wildlife watching.

Acknowledgements

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Photo 1. A Rhinoceros Hornbill on a fruiting *Caryota* no, a palm species endemic to Borneo.

Photo 2. A male Oriental Pied Hornbill perched at the entrance of the nest cavity.

Photo 3. A male Wrinkled Hornbill on the branch of a fig tree.

Photo 4. A female Bushy-crested Hornbill feeding on the fruit of *Ficus cucurbitina*.

Photo 5. A male Helmeted Hornbill perched at the entrance of nest cavity with food in its bill.

Photo 6. A White-crowned Hornbill was spotted at the boundary of Tawau Hills Park.

Photo 7. Fruits of *Ficus subcordata* found in Tawau Hills Park.

Photo 8. Fruits of *Ficus cucurbitina* found in Tawau Hills Park.

Observations of nesting strategies of three African hornbill species

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Abstract

Rainfall is known to be a determining factor for the onset of avian breeding in semi-arid regions due to its positive effect on food availability. The effect of rainfall as a cue for timing of breeding as well as the nesting success (clutch size, hatching rate and number of successful fledglings) was investigated among three sympatric hornbill species: African Grey Hornbill (AGH) Lophoceros nasutus, *Southern Red-billed Hornbill (SRH)* Tockus rufirostris, *and Southern Yellow-billed Hornbill (SYH)* T. leucomelas *breeding in nest boxes in a private nature reserve in a semi-arid region of South Africa. The first ecologically relevant rainfall (>10 mm) preceded the initiation of breeding in all three species. The AGH and SYH were the first species to start breeding, followed by the SRH. We monitored 28 nesting attempts by hornbills during the breeding season of 2019/2020. All three species showed hatching rates higher than 70% with the SYH having the highest (85%). All nesting attempts of the AGH (n = 6) and SYH (n = 7) were successful resulting in at least one successfully fledged chick, while seven of the 15 nesting attempts by SRH failed. Rainfall and subsequent food availability were proximate factors associated with the onset of breeding and nesting success of all three hornbill species. The effects of changes in temporal and spatial patterns of rainfall linked to climate change on breeding initiation and nesting success of birds should be closely monitored to identify potential negative effects on population persistence.*

Keywords: hornbill breeding, nesting success, hatching rate, nest boxes, climate change

Introduction

Found in Africa and southeast Asia, hornbills are well known and studied for their unique breeding strategy (Kemp, 1995; Datta and Rawat, 2004). All hornbills (Family Bucerotidae) are hollow-dependent and make use of natural cavities as nesting sites (Kemp, 1995). However, with the exception of ground-hornbills (*Bucorvus* spp.), their nesting strategy is unique in the sense that the female seals herself inside the nesting cavity, only leaving a narrow vertical slit through which the male can feed her and the chicks (Kemp, 1995).

Hornbills are secondary tree cavity users, and the availability of nesting cavities is crucial for breeding and ultimately nesting success (Datta and Rawat, 2004; Poonswad *et al.*, 2013). Considering the alarming rate of deforestation in parts of the hornbills' distribution range (Amrutarane and Datta, 2015; Cooper *et al.*, 2017; Wickramasinghe *et al.*, 2018), tree cavity scarcity accompanied with habitat loss have been recognised as major causes in the decline of various African hornbills (Trail, 2007) such as the Yellow-casqued *Ceratogymna elata* and Brown-cheeked *Bycanistes cylindricus* Hornbills in Ghana (Holbech *et al.*, 2018). Apart from plantation expansion and the development and urbanisation of natural habitats, the high demand for fuelwood in South Africa contributes to habitat loss as millions of tonnes of fuelwood is removed annually from natural areas (Shackleton and Shackleton, 2004; Munyati and Kabanda, 2009; Wessels *et al.*, 2013). With cavity availability reduced, inter-and intraspecific competition for nesting cavities could affect species interactions, population structures as well as life-history strategies (Williams and Shackleton, 2002; Cornelius *et al.*, 2008).

Although finding a suitable nesting site is crucial (Latif *et al.*, 2012), the timing of avian breeding is considered one of the determining factors of nesting success (Barrientos *et al.*, 2007) and it is commonly triggered by the lengthening of daylight (Barrientos *et al.*, 2007). However, in semi-arid regions, rainfall is more likely to be the determining factor to trigger breeding due to its positive effect on primary productivity and food availability (Kemp, 1974; Poulin *et al.*, 1992; Boyer *et al.*, 2003; Illera and Diaz, 2006). In recent years however, the start of the wet season has become more unpredictable, rainfall is more erratic and extreme events such as droughts and extreme precipitation are more common (Easterling *et al.*, 2000; Jennings and Magrath, 2009). The reproductive effort and output of several avian species have been associated with changes in seasonal rainfall (Bolger *et al.* 2005, Mares *et al.* 2017). Climatic changes could possibly affect the nesting success of hornbills, since their breeding is triggered by rainfall and a mismatch between food availability and chick rearing could ultimately affect the nesting success (Van de Ven, 2017). The objective of this study was to compare the nesting strategies of three sympatric hornbill species by (1) examining the effect of rainfall as a cue for breeding initiation and (2) recording the nesting success in terms of clutch size, hatching rate and number of fledglings. We predicted that the first ecological relevant rain (>10 mm) of the wet season would trigger the onset of breeding in the three hornbill species as observed by an increase in nest box occupancy. Belonging to the same family and having similar breeding strategies, we expected similarities in clutch size, hatching rate and number of fledglings between the three hornbill species.

Methods

Study area

This study took place at the Mogalakwena River Reserve (MRR), a 1500 ha private nature reserve located in the Limpopo Province of South Africa at an altitude of 700 m above sea level (22°44’S, 28°47’E). The region is semi-arid with a mean annual precipitation of 370 mm (range: 180−730 mm) throughout the austral summer season (October to April, data obtained from Mogalakwena Research Centre between 2013–2019). During the summer months of the study period (October to April) the MRR had a mean daily minimum temperature of 21 °C (range: 12–33 °C) and a mean daily maximum temperature of 34 °C (range: 23–44 °C) (data obtained from Mogalakwena Research Centre between 1 October 2019 to 30 April 2020). In 2015, 81 vertical, plywood (1.5 cm) nest boxes (48 x 25 x 25 cm) with a circular entrance of 6 cm wide were installed at various heights (range: 1.5–4 m) throughout the reserve to serve as artificial tree cavities as part of a study investigating inter-specific competition for tree cavities (Engelbrecht *et al.*, 2017). The study site is inhabited by three cav-

Fig. 1. Three African Grey Hornbill nestlings removed from the nest box in order to fit them with unique metal rings (SAFRING) and to collect morphometric data.

ity nesting hornbill species: African Grey Hornbill (AGH) *Lophoceros nasutus*, Southern Yellow-billed Hornbill (SYH) *Tockus leucomelas* and Southern Red-billed Hornbill (SRH) *T. rufirostris* which readily make use of the nest boxes for breeding.

Data collection

After the first significant downpour of the summer season, all nest boxes were inspected once a week to detect the presence of sealed entrances. At every sealed nest box, the hornbill species and the number of eggs and hatchlings were recorded weekly until the last chick of every occupied nest box fledged. Morphometrical measurements were taken when either the female or chicks were fitted with a unique SAFRING metal ring (Fig. 1). These measurements included body mass to the nearest gram taken with a weighing scale, tarsus length and width, head and culmen length to the nearest millimetre taken with a calliper and wing and tail length to the nearest millimetre using a ruler. A nesting attempt was defined as a female present in a nest box with a sealed entrance for a minimum of 24 hours and considered successful if at least one nestling fledged successfully. The hatching rate was defined as the probability of an egg producing a live hatchling and was calculated by dividing the number of hatchlings by the number of eggs laid (Mayfield, 1975). A substantial downpour was defined as rainfall exceeding 10 mm within 24 hours (Finnie, 2012).

Results

Of the 81 nest boxes, 28 nest boxes were occupied by hornbills during the 2019/2020 breeding season which spanned the period from November 2019 to May 2020 (Table 1). The total rainfall in the 2019/2020 summer season was 294 mm and the first substantial rain (15 mm) was recorded on 8 November 2019 (Fig. 2). Nesting attempts of both the AGH and SYH were first recorded on 5 December 2019, after the area had received a total of 86 mm of rain since the beginning of the rainy season. The first nesting attempt by a SRH female was observed two weeks later on 19 December 2019 after the area received a total of 134 mm rain since the beginning of the rainy season. There was a sharp increase in nesting attempts by SRH after a rain shower (34 mm) on 9 January 2020 (Fig. 2).

Twenty-one of the 28 hornbill pairs breeding in the nest boxes in the 2019/20 breeding season managed to fledge at least one chick. All the nesting attempts of AGH and SYH were successful (Table 1). The SRH initiated 15 nesting attempts of which five were abandoned before egg-laying. By the end of March 2020, the chicks of two SRH nests were predated on, presumably by a monitor lizard (*Varanus* spp.) resulting in eight successful nesting attempts (Table 1).

The mean clutch sizes were similar across the three species with the AGH having the largest mean clutch size of the three species (Table 1). The hatching rate of all three species were similar with the SYB having the highest hatching rate of 0.85 (85%) (Table 1). The AGH breeding pairs successfully fledged a total of 10 chicks (Fig. 4), while the SYH and SRH breeding pairs successfully fledged

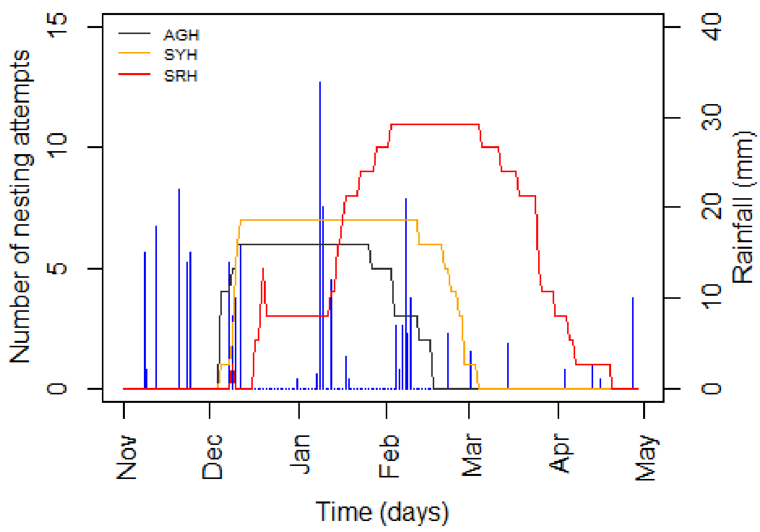

Fig. 2. The number of nesting attempts per species (left y-axis) and rainfall (mm; right y-axis) between 1 November 2019 and 1 May 2020 at the Mogalakwena River Reserve. The grey (AGH: African Grey Hornbill), yellow (SYH: Southern Yellow-billed Hornbill) and red (SRH: Southern Red-billed Hornbill) lines represent the daily total number of nesting attempts per hornbill species and the blue lines indicate daily rainfall events.

a total of 11 and 20 chicks, respectively (Table 1). This is expressed as fledged young per pair (overall).

Discussion

The three sympatric hornbill species found on the MRR all started breeding approximately a month after the area received more than 10 mm of rain in a single shower. All nesting attempts by AGH and SYH were successful whereas seven of the 15 nesting attempts by SRH failed. Various factors such as rainfall, food availability, breeding density, hormones as well as photoperiod have all been identified as proximate factors influencing the onset of avian breeding and there is great variation between species, geographic regions and breeding seasons (Dunn and Winkler, 2010). In semi-arid regions the climatic parameter, rainfall, is considered an important trigger for the start of avian breeding, mainly due to an increase in prey availability (Illera and Diaz, 2006; Barrientos *et al.*, 2007). Ideally, breeding individuals should gain sufficient pre-breeding body condition (Kemp, 1974; Van de Ven, 2017) and the peak in food availability should coincide with energetic de-

Fig. 3. A Southern Red-billed Hornbill, with two eggs visible, nesting in one of the nest boxes at Mogalakwena River Reserve. Note the absence of the tail feathers due to moult.

Fig. 4. Accessing the contents of nest box #81. This was one of the first boxes to be occupied and the African Grey Hornbill breeding pair successfully fledged two chicks.

mands of the growing chicks in the nest (Dunn and Winkler, 2010). In the current study, the AGH, followed by the SYH, were the first species to attempt breeding in early December, possibly taking advantage of the peak in food availability after the rain in November. Although a few SRH females initiated breeding mid-December and early January, the majority waited until early February. Although food availability was not determined in the current study, all three hornbill species entered the nest boxes after the MRR received a substantial downpour (>10 mm within 24 hours). This could indicate that rainfall is used as a predictor for food availability for the coming breeding period (Illera and Diaz, 2006). Therefore, rainfall could be considered as a factor influencing the onset of breeding in the three sympatric hornbill species. However, it is important to note that rainfall is not the only climatic variable to affect food availability in semi-arid regions. Temperature affects invertebrate activity and the germination of plants (Barrientos *et al.*, 2006), which in turn affects herbivorous invertebrates (Sanz *et al.*, 2003) and thus food availability. Even though rainfall preceded the onset of breeding in the three sympatric hornbill species in the current study, further studies combining multiple breeding seasons and including the effects of rainfall, temperature and food availability are needed to test alternative hypotheses.

The difference in feeding behaviours of the three hornbill species could possibly explain the delayed breeding of SRH in contrast to

Table 1. Summary of nesting success by three hornbill species (AGH: African Grey Hornbill, SYH: Southern Yellow-billed Hornbill and SRH: Southern Red-billed Hornbill), including the ranges for the mean clutch size, hatching rate and mean number of fledglings per nest at the Mogalakwena River Reserve in the 2019/2020 summer breeding season.

Species	AGH	SYH	SRH
Nesting attempts	6	7	15
Successful nests	6	7	8
Mean clutch size	4.0 (3-5)	3.7 (3-4)	3.6 (3-5)
Hatching rate	0.75 (0.25-1)	0.85 (0.5-1)	0.78 (0.33-1)
Mean no. fledglings/nesting attempt	1.7 (1-3)	1.6 (1-2)	1.3 (0-3)
Total number of fledglings	10	11	20

the AGH and SYH. The AGH is principally an arboreal feeder and SRH essentially obtain all their food on the ground, whereas SYH are the least specialized and feed opportunistically using hawking, gleaning and digging methods (Kemp, 1995). Kemp (1974) noticed that a flush of new leaves before the onset of the wet season allowed arboreal feeding hornbills to exploit arboreal invertebrates feeding on the fresh leaves, hence offering a potential explanation for the earlier occupation of nest boxes by AGH and SYH. Kemp (1974) also observed that the sprouting of new grass after the first rain coincided with SRH breeding initiation, possibly due to the increased availability of invertebrates to be gleaned off vegetation at or near ground level (Kemp, 1995). Thus, the difference in foraging strategy may allow the AGH and SYH to attain pre-breeding body conditions before SRH do and therefore start breeding earlier in the season.

Interspecific competition is another factor that could possibly explain the delayed breeding of the SRH. Being the smallest in wing length and body mass of the three sympatric species (Kemp, 1995), the SRH could possibly be less dominant and therefore be forced to wait for cavities to become available. Further studies focusing on interspecific competition for nesting cavities between the three sympatric species, as well as other cavity dependent species, is needed to confirm this. Following a few rain showers in November and early December, several SRH pairs attempted breeding. However, this was followed by a very hot and dry December and early January, when there were no follow-up rains, which resulted in the abandonment of these nesting attempts by SRH. The number of nesting attempts by SRH increased following a big rain shower in early January (34 mm).

The SRH had the highest number of nesting attempts in nest boxes, followed by the SYH and the AGH. It is important to keep in mind that the number of nesting attempts monitored in this study are only those of nest boxes and not natural tree cavities. It could be that the AGH and the SYH prefer nesting in natural tree cavities rather than nest boxes. Since the SRH started to breed later compared to the other two species, suitable natural tree cavities may have already been occupied and SRH resorted to using nest boxes for breeding. However, this would need to be investigated further since there are many factors at play when choosing a suitable nesting site (Latif *et al.*, 2012) and the total number of breeding pairs per species at MRR is unknown.

All nesting attempts of both the AGH and SYH were successful compared to the SRH which only had eight successful nesting attempts from fifteen initial nesting attempts. A possible explanation for the five SRH females abandoning the nest boxes, might be that hornbills are long-lived species and adhere to the life-history theory which states that adults will choose their own survival over that of their offspring (Mills *et al.*, 2005). Since the MRR experienced a hot and dry December 2019 and January 2020, climatic conditions may have become unsuitable in the nest cavity or male provisioning may have been insufficient, forcing the females to abandon their nests to ensure their own survival. Another two failed nesting attempts of the SRH were the result of predation.

The clutch sizes of the three study species were very similar and ranged between three to five eggs compared to a study on the same three species in South Africa in which clutch sizes ranged from two to five eggs (Kemp, 1976). Although all three species had hatching rates higher than 70% (AGH: 0.75; SYH: 0.85; SRH: 0.78), the hatching rate of the SYH was the highest at 85%. Kemp (1976) found higher hatching rates for AGH and SRH (AGH: 0.84; SRH: 0.81), with a lower hatching rate for the SYH (0.73) compared to the current study. Observed hatching rates may have differed due to different methods used to observe nest contents. In his study, Kemp (1976) recorded nest contents from natural nesting sites in tree cavities by inserting a little mirror through the nest opening, whereas the current study assessed nest contents by opening up the nest boxes. Kemp's study (1976) was conducted in the Kruger National Park, South Africa, which has a different habitat and climate than the MRR, which could also contribute to the different results. The study by Kemp (1976) was also conducted over four consecutive breeding seasons, in comparison to the current study which only takes into account one breeding season. Hatching rate can however be influenced by different factors including poor to no development of the embryo due to temperature extremes and inadequate gas exchange (Lourens et. al., 2006; Mortola 2009; Du and Shine, 2015), maternal hormones provided to the embryo (Schwabl *et al.*, 2007), genetic makeup of the breeding pair as well as the embryo itself (Cordero *et al.*, 2004; Hasson and Stone, 2009). Cannibalism of eggs has also been observed in some hornbill species, such as the SYH, which is considered a result of insufficient food provisioning by the male (Finnie, 2012; Van de Ven, 2017). Hatching rates vary naturally between species as well as between individuals within the same species (Stewart and Westneat, 2012). Further studies investigating differences in hatching rate should include environmental and ecological variables as well as genetic and behavioural data of the breeding pair across various breeding seasons (Stewart and Westneat, 2012).

The mean number of fledglings per nesting attempt was similar across the species (AGH: 1.7; SYH: 1.6; SRH: 1.3) and corresponded with the SYH and SRH mean fledgling numbers of the study conducted by Kemp (1976) (AGH: 2.4; SYH: 1.4; SRH: 1.5). The AGH showed a much lower mean number of fledglings in the current study (1.7) compared to the estimate of 2.4 obtained by Kemp (1976). Conditions, such as rain and food availability, might have been better in the breeding season for the AGH in the study conducted by Kemp (1976), which possibly resulted in a higher mean number of fledglings compared to the other two species. Brood reduction in hornbills is a common phenomenon observed when conditions become suboptimal (Finnie, 2012). Females have been observed to selectively feed only the oldest chick when male provisioning is insufficient to ensure the survival of at least one chick (Davis *et al.*, 1999; Chan *et al.*, 2007). Infanticide cannibalism has also been recorded in some hornbill species (Chan et al, 2007; Ng *et al.*, 2011) including the SYH (Finnie, 2012; Engelbrecht, 2013). The lower mean number of fledglings of the SYH and SRH in the study of Kemp (1976) might have been a result of unfavourable conditions and insufficient male provisioning, forcing the females to cannibalise. It is important to note that the method used to inspect nest contents in this study differed from those by Kemp (1976), which may result in different findings. Further studies including multiple seasons are recommended to conclude if any of the three study species has a more successful breeding strategy than the others and what factors influence the nesting success of AGH, SYH and SRH.

Although the results of this study comprise one season only, they support the importance of rain and subsequent food availability on the initiation of breeding by the three sympatric hornbill species (Kemp, 1974; Dunn, 2004; Dunn and Winkler, 2010). It is suggested that in years with low rainfall, food availability will be lower, and this may have repercussions for the start of the breeding season, clutch sizes, the physical condition of the breeding pairs and nestlings, as well as the number of fledglings (Van de Ven, 2017; Van de Ven *et al*., 2020). We predict that nesting success could possibly also be affected if the wet season becomes shorter, if the start of the wet season becomes more unpredictable, and if the annual rainfall becomes more erratic, which are all phenomena associated with climate change (Simmons *et al*., 2004; Jennings and Magrath, 2009; Dunn and Winkler, 2010; Skagen and Adams, 2012). It is therefore important that regular monitoring of the nesting strategies of the three sympatric hornbill species as well as other cavity nesting birds be conducted to identify the impact of climate change on the breeding success of these species.

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Notes from the field

CCTV monitoring system: a novel approach in hornbill research and conservation

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Nest monitoring provides valuable information to study hornbill biology and conservation. In Asia, hornbill nesting studies were generally conducted by direct observations with the aid of field gears (e.g. binocular/telescope) from hides (Poonswad *et al.*, 1998; Kinnaird and O'Brien, 1999; Kaur *et al.*, 2015; Pawar *et al.*, 2018). The application of closed-circuit television (CCTV) camera in hornbill nest monitoring is still little-explored, except for the study of Oriental Pied Hornbill *Anthracoceros albirostris* in Singapore (Ng *et al.*, 2011) and a study on Indian Grey Hornbill *Ocyceros birostris* (Gadikar, 2017; Barve *et al.*, 2020).

Yunnan Tongbiguan Nature Reserve (TBG) sits along the Sino-Burmese border (23°54'-25°20'N, 97°31-98°06'E, altitude range: 210-3400 m), and is the only place in China with extensive *Shorea* dipterocarp forest where four hornbill species (Rufous-necked Hornbill *Aceros nipalensis*, Great Hornbill *Buceros bicornis*, Wreathed Hornbill *Rhyticeros undulatus* and Oriental Pied Hornbill) still co-occur (Zheng *et*

Fig. 1. Wildlife CCTV monitoring stations in Yunnan Tongbiguan Nature Reserve, China.

Fig. 2. CCTV system provides 24-hour monitoring of hornbill nesting behaviours in Yunnan Tongbiguan Nature Reserve, China (a. Oriental Pied Hornbill *Anthracoceros albirostris*, b. Wreathed Hornbill *Rhyticeros undulatus*, c. Great Hornbill *Buceros bicornis*).

al., 2020); (http://en.people.cn/n3/2021/0312/c90000-9828532.html).

The hornbill monitoring programme in TBG was initiated in 2015, and successful breeding of three hornbill species (Great, Wreathed and Oriental Pied Hornbills) have been recorded every year until today (authors, unpubl. data.). To investigate the feasibility of CCTV system in monitoring key species in TBG (e.g. hornbills, Gaoligong Hoolock Gibbon *Hoolock tianxing* and Phayre's Leaf-monkey *Trachypithecus phayrei*), ten CCTV monitoring stations were set up in 2018 (Fig. 1). These CCTV monitoring stations were installed at wildlife hotspots, each mounted with two CCTV cameras (one for close-up shot, one for wide-angle shot). The cameras were China-made and equipped with two million pixels lens providing full HD (1080p) resolution video at 30 fps. Video footage was then transmitted by long-distance wireless communication system to the headquarters of TBG. Electricity from nearby villages was used as power supply for six of the CCTV stations, and solar panels were installed in four remote stations too distant from the electrical grid. The construction cost for each unit varied according to the different terrains, but one unit averaged $13,000 USD; together with the cost for the control centre, total cost of the CCTV monitoring network was around $146,000 USD. Fees for network service and equipment maintenance have been included in the warranty period of three years. Warranty extension will be negotiated with the contractor later, the running cost of the whole network is expected to be 10,000 to 12,000 USD annually after the warranty expires.

Three CCTV stations were set up to monitor hornbill nests discovered in previous monitoring programmes; two of which were solar-powered. To minimise disturbance to the breeding hornbills, CCTV stations were constructed 80 to 200 meters away from the nest trees. With the advantage of CCTV monitoring system, TBG staff were able to monitor nest sites live without physical presence and respond immediately should any illegal activities or situations have arisen at these nests. The 24-hour monitoring regime generated a large volume of video footage, and those with hornbill activities were stored in a separate hard drive. In an attempt to study nesting ecology of the three breeding hornbill species, a total of 1,977 hornbill footages lasting ca. 7,300 minutes have been collected during our pilot study between March and July 2020 (Fig. 2).

The current CCTV system configuration still had certain limitations. The low resolution of video footage combined with the distance of the camera to the nest hole limited our ability to species-level identification of most food items. In future studies, we will set up collecting nets below hornbill nests, and items identified in the debris could complement the CCTV monitoring data and improve the classification of food items (Poonswad *et al.*, 2004). The cost-benefit of higher-resolution video cameras is also being explored.

Another challenge encountered was the heavy rainfall during the hornbill breeding season. The annual precipitation of TBG reaches about 2,300 mm, with 89% received during May to October (Yang and Du, 2006). The hornbill breeding season in TBG is from February to July, and the persistent rain in July caused malfunction in one of the CCTV stations, at a critical time towards the end of nesting confinement in the breeding season. Rain cover and other water-proofing upgrades of the CCTV monitoring stations will be installed before the next wet season to extend service life of the system. Contrary to our presumption, the adverse weather did not significantly affect the lifespan of the solar-charged CCTV stations, and these solar-powered stations were able to maintain 24-hour operation time even on rainy days.

While the initial cost of monitoring hornbill nests by CCTV is high, and the technical specifications still have room for improvements, it greatly minimizes manpower investment for extended fieldwork time, which can be both logistically and financially costly, and minimizes disturbances to breeding hornbills. The performance of solar-powered CCTV stations in our pilot study also demonstrated the versatility of the technique. CCTV monitoring therefore presents a new opportunity for hornbill study and conservation in areas not too remote for the transportation of constructing similar devices.

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Plant4Tawau: hornbill conservation by the replanting of *Ficus* in forest tracts of Tawau, South East Sabah

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Our project

Plant4Tawau is our latest conservation initiative in Sabah and this preliminary article outlines the background to the project and our key aims and objectives. The importance of frugivorous birds and mammals in the maintenance of biodiversity in the rainforests of Borneo is increasingly understood; for example, fruit-eating hornbills are known to disperse fig seeds over large distances. A loss of fruit trees will, of course, result in a decline in species dependent on their fruit. In this project, we plan to plant new fig trees in selected parts of threatened rainforest in the Tawau District of Sabah and then monitor the impact of the resulting increased fruit availability on the hornbill population.

It is a visionary, long term project that aims to reconnect fragmented areas of rainforest in Sabah; some of these are identified in Fig. 1, which represents their locations in the district of Tawau in southeast Sabah. For example, reconnections are planned between Tawau Hills Park, an area of 29,000 hectares, with the much smaller areas of Bukit Gemok and Tajong Forest. The project is planned to begin with Bukit Gemok, a reserve known to contain important populations of hornbills and primates. In particular, this project is dedicated to the conservation of the Hornbills of Borneo. It is hoped that the resulting forest regeneration will re-establish the diversity of native fauna and flora. Hornbills have been chosen as key indicator bird species for the monitoring of the impact of our project on rainforest biodiversity. These reforestation sites will be replanted with selected *Ficus* (fig) species. We intend that the project lifespan will be a minimum of 20 years and be guided by the timeline in Table 1, which necessarily can only be provisional because of COVID19 restrictions.

The stages in the roll out of the project are outlined below:

- Cultivation of fig seedlings
- Determine planting strategy based on local habitat and terrain
- Fig planting using a number of different methods, but mainly line planting, random planting, seed sowing or planting on host trees
- Surveys to establish appropriate sites, and positions within sites, for camera trapping
- Camera trapping to determine 'baseline' wildlife abundance and diversity, then at regular intervals during the project to monitor changes in abundance and diversity of frugivorous species
- Engagement with local communities
- Development of wildlife tourism

Seven educational institutions have so far committed to annual visits from May 2021: SMK Balung, Universiti Malaysia Sabah, SMK UmasUmas, Vision International School, SM Ursulas

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Table 1. Provisional project timeline, beginning January 2021.

Stage	Beginning	Comment
Ficus propagation	January 2021	In progress Engagement with local communities
Soft Launch of planting initiative	March 2021	Successful
Sapling planting	April 2021	In progress Engagement with local communities
Continued propagation of *Ficus*	May to October 2021	Engagement with local communities
Monthly planting activities with educational institutions	May to December 2021	See list of institutions below
Engagement of overseas tourists and volunteer groups with project	From August 2021	Subject to pandemic restrictions
Launch of Plant4Tawau	March 2022	This will be one year after the Soft Launch

The timeline is provisional but it can be seen that the early stages have already begun. Only the stages planned for 2021 have been closely planned.

Convent, SMK JambatanPutih, and Jesselton International School. It is anticipated that more institutions, particularly schools, will be recruited from the Tawau District.

This sequence has been developed to enable the replanting and protection of the figs and the subsequent monitoring of their impact on biodiversity after they have begun to fruit. The project has the broader objectives of creating jobs for local communities and the development of tourism through safaris to view hornbills and other species attracted to these forested areas. Through our previously established Plant4BorneoElephants initiative (Can Elephants and Plantations co-exist to a mutual benefit — 1StopBorneo Wildlife), we have demonstrated that this new project can also benefit from 'tourist engagement' by encouraging visitors to participate in fig planting during their safari.

Some background on figs

For many European people, however, the fig remains a single species cultivated for its distinctive edible fruit: how little they know!

Fig. 2 shows fruit of *Ficus carica* (*F. carica*), the 'common fig' tree, which is thought to have originated in West Asia; it is likely to have been

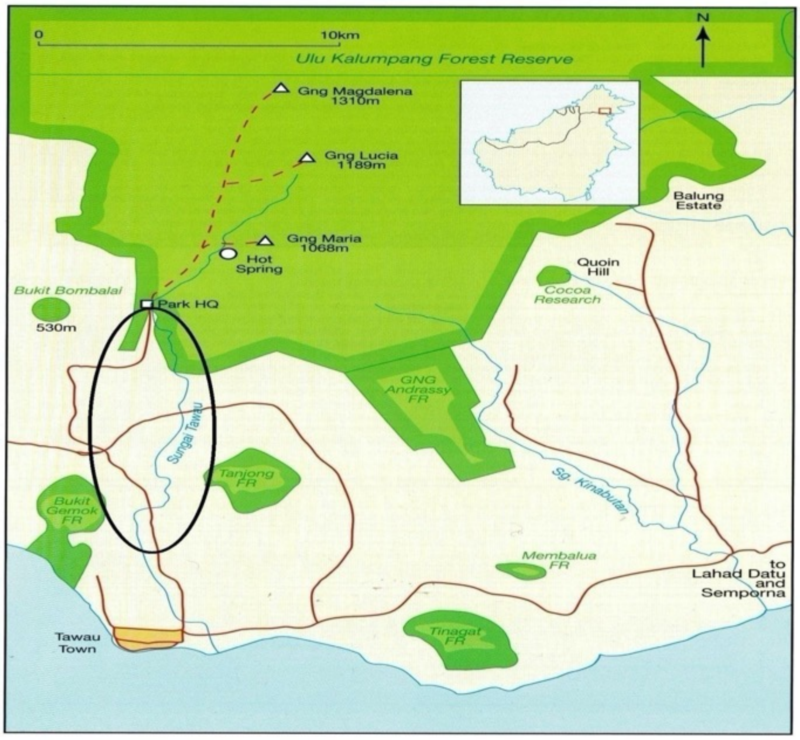

Fig. 1. Forest fragments in Tawau identified for re-plantation of *Ficus* species; Park HQ refers to Tawau Hills Park headquarters. Map: Quentin Phillipps.

first associated with early human settlements around the Mediterranean from where it has been introduced to many regions of the world, including northern Europe and parts of the USA. Commercial cultivation today is dominated by Turkey that together with other countries such as Algeria, Egypt and Morocco contribute about two thirds of the world trade in these 'figs'. There is little here to link *F. carica* to tropical rainforests. The fruit displayed in Fig. 2 is highly valued for its flavour and has also been in remedies, such as for constipation, for example in the form of traditional 'syrup of figs'.

However, the genus *Ficus* is far bigger, containing well over 800 species, many of which are tropical; as described by Phillipps (2020), there are over 500 species recorded in Asia and Australasia with 132 of these found in Papua New Guinea and a higher number, at least, 150, in Borneo. Species may differ from the typical small tree of *F. carica:* they may be large trees, shrubs, vines and even epiphytes. A feature that many species share is the production of a fruit that is an important food source for a wide range of animals; this is certainly true in the rainforests of Borneo and is the basis of our project.

Humans have also used products of some species for medicinal purposes; for example, *F. maxima*, widely distributed in Central and South America, has been used by indigenous people for treatments ranging from an antidote for snake bites (it's leaves) to treatment for gastrointestinal parasites (it's sap from branches or the trunk). This suggests that *Ficus* species are likely to be part of the huge reservoir of plants and their compounds that still await discovery in the world's forests; yet another argument for urgent rainforest protection. Many homes in the UK have a 'rubber plant' as a decorative, indoor plant. This is *F. elastica*, a native of South and South-East Asia, where in the wild it grows to sizes way beyond the requirement of a household plant! It has nothing to do with commercial

Fig. 2. Fruit of *Ficus* carica. One fruit has been cut open to reveal the fleshy compound fruit containing many seeds. (Source: Agnieszka Kwiecień, Nova, CC-BY-SA 3.0, via Wikimedia Commons).

rubber production which is based upon a tree in a quite separate genus. In Asia, *F. elastica* may not be a very popular houseplant but the 'Chinese Banyan' (*F. microcarpa*) is widely cultivated both as an indoor bonsai plant and also grown in parks as a large tree for shade. *F. religiosa*, known as the sacred fig, is widely distributed around the tropics, where it has been often introduced for religious purposes. It is seen as a holy symbol and has been planted in temples by both Buddhists and Hindus.

Fig diversity, resilience and adaptability

As we have seen, figs have been exploited by humans in a number of ways, showing them to be highly adaptable and resilient. Strangler figs are among the most adaptable members of the *Ficus* genus, having the ability to grow in almost any terrestrial habitat, including in those without direct access to soil for their roots. Typically, they begin life as a sapling that germinates from a seed dropped in the faeces of an animal disperser; these seeds preferably germinate on host trees as epiphytes but can also grow on other substrates like rocks and building walls. As they mature, their roots grow long and thick, slowly covering the substrate on which they grow. Once the roots reach the ground, the fig will quickly spread as it gains more nutrients, and eventually strangles its host tree (Fig. 3).

The strangler fig plant will slowly outgrow their host and fully envelop it with its roots, hence effectively "strangling" it. In some cases, after the host tree has long died, the fig tree remains standing and becomes a separate tree, with a hollow interior left behind by the decayed host.

Strangler figs that thrive in urban areas may grow on roadsides and buildings (Fig. 4), which can cause damage to pavements and walls. In some abandoned buildings, trees may grow out of control and envelop the entire building; some strangler figs have been known to increase the appeal of old buildings and become tourist attractions; Ta Prohm Temple in Cambodia is well known for its beauty which has in part been created by the excessive fig growth covering the

Fig. 3. Strangler fig tree in a palm oil plantation. The fig's roots are clearly seen growing around the host tree trunk and will eventually strangle it. Photo: Wong Chun Xing.

Fig. 4. A small strangler fig tree colonising a wall. This is a young tree with roots that have yet to reach the ground. Photo: Wong Chun Xing.

temple with roots.

Perhaps the most dramatic strangler fig species have been described in the Indian subcontinent, where *F. benghalensis* became known as the banyan tree, as illustrated in Fig. 5.

The name derives from Baniyas, Hindi for a community of traders, that colonising Europeans often observed trading in the shade of these dramatic trees. One individual tree in India, which has an incredible circumference of 486 m and covers an area of 1.89 hectares, originated from a single tree that has died; amazingly the tree structure remains standing since it is supported by the roots of a 'clonal colony' which have grown from the surviving branches and roots of the original parent tree. These striking trees may be thought of as part of the natural architecture of towns and cities where they occur in Asia; however, compared with forest figs, they are of considerably less importance in their contribution to biodiversity.

Oil palm plantations, which are tree monocultures, are often described as being low in biodiversity and disastrous for the ecosystem. This is partly true, but such plantations do have some 'fig diversity' since some *Ficus* may thrive in plantations where they can exploit the limited space available that inhibits the growth of less adaptable plants. Many epiphytic figs have made palm oil trees their host, providing compelling evidence that our reforestation can work in existing plantations, even without cutting down existing palm trees. We can directly plant fig saplings onto palm trees, which can then become beneficial to reforestation projects. It is worth remembering that oil palm trees already support a limited range of wildlife even without 'fig planting'. The palm oil trees that will be used as hosts for our figs will be selected from older trees in a plantation, aged 25 years or more; by selecting these, which will be past their years of maximum palm nut yield, and so not being regularly harvested, we will ensure that plantation palm oil yields are unaffected.

Reforestation using other *Ficus* species can also useful on cleared land, especially after it has

Fig. 5. *Ficus benghalensis*: This is an ancient tree with an extensive root system; the original host tree is completely enveloped by the strangler fig's root system. (Source: T. R. Shankar Raman, CC-BY-SA 3.0, via Wikimedia Commons.)

been logged or burned, since they are known to be important pioneer species, rapidly colonising empty, barren land. In fact, in contrast to strangler figs, these fig species grow best on cleared land where there is plenty of space for rapid growth. Consequently, there may be more large fig trees found in mature secondary forests than primary rainforest. In preliminary work, we have recorded a sapling of *Ficus nota*, a noted pioneer species of open land, as growing to 5 m in height in only 2 years after planting.

The rapid, regenerative properties of *Ficus* species contribute to their resilience: roots can grow from wounds on a tree and separated parts of a tree can even form a new, independent tree; even a small, severed stem may survive and slowly develop into a new tree. This property of figs can be exploited for conservation since it enables the propagation of large numbers of saplings using both cuttings and a procedure known as marcotting or air layering, where an aerial stem is cut and the wound held open to enable a growth medium to be applied directly to the exposed tissue. In time, new roots will grow from the stem into the medium so that when the stem is cut below the original wound, it can be planted to produce a new sapling.

Ficus pollination

Ficus species do not produce 'external flowers' that are positioned to readily attract pollinators or be wind pollinated; instead, they possess a specialised structure called the syconium, within which multiple, small flowers (florets) develop, each one requiring pollination for seed production. The mature syconium, which is the familiar 'fig fruit' as shown in Fig. 2, is, in fact, a compound structure that may be made up of many small fruits, the exact number depending on the *Ficus* species.

Pollination must occur within the syconium and is achieved when tiny female wasps belonging to the family Agaonidae enter via a narrow opening in order to lay their eggs. If these females are also inadvertently carrying *Ficus* pollen from another plant, they will also pollinate florets of the syconium. Afterwards, the egg-laying and pollinating female wasps die; next, there is simultaneous maturation of fig seeds and completion of the wasp life cycle to produce the next generation of adult wasps. The newly emerging male wasps fertilise new females before boring their way out of the syconium before dying. The females are able to leave via the males' exit route before flying to detect an immature 'fig fruit' in which to lay her eggs.

The wasp and the fig are entirely dependent on one another for production of their next generation in a relationship described as mutualism, which has developed through co-evolution of wasp and fig. This dependency means that the loss, for example, of the wasp from an area of forest would mean that the fig will not produce ripe fruit. But it might mean more than this, since the possible reduction in availability of fruit for hornbills and many other species may also impact their populations.

The above description of mutualism between wasp and fig is much simplified; there are many fig and wasp species. In some cases, for example, a species of fig may be entirely dependent on a single species of wasp, whilst in others, pollination can be by a number of wasp species. There are many more ways in which this mutualism is made more complex but, for our purposes, the message is clear: fig ecology, and therefore the interaction between hornbill species and the figs they feed on, may be dependent on a range of factors.
Ecosystems are complex and any conservation intervention must plan for this. There are numerous examples of how an understanding

plant/insect interaction can be important both commercially and in conservation. The palm oil industry of Malaysia and Indonesia, for example, received an enormous boost in the 1980s when an insect pollinator, a weevil, *Elaeidobiusk amerunicus,* was introduced from West Africa. This eliminated the need for the slow, 'hand pollination' of palm oil trees that had previously been required in Malaysia. More recently, however, it seems that weevil pollination is declining, perhaps illustrating the danger of introducing 'non-native' species into an ecosystem. Such dangers should not be ignored during conservation projects: upsetting an ecosystem may have unforeseen consequences.

Why are figs so important in the rainforest?

Phillipps, in his *Field Guide to the Mammals of Borneo* (2016, p. 77*)* characterises the genus *Ficus* as containing 'keystone species' in the tropical forests of Borneo. He is referring here to their importance as the major food for a range of mammals, from gibbons to fruit bats, but it is also true for many birds, including green pigeons, partridges, pheasants and hornbills. Their 'keystone' role in the forest is further enhanced because they bear fruit asynchronously, providing a 'continuous background' of fruit; other fruit-eating (frugivorous) animals, for example the orang utan and many squirrels, rats and tree shrews, rely more heavily on fig fruit as 'fall back' food to compensate when other plants, seeds and fruits are not available.

It is not surprising, therefore, that we have observed that whenever a fig tree fruits, a 'wildlife frenzy' in the canopy can occur; during the day, many birds and mammals may be seen actively feeding. At night, too, fruit bats as well as civets, such as the binturong and masked palm civet, may be eating the figs, and, below a fig tree, there may be oriental bay owls and other owl species patiently waiting for rats coming to eat the figs.

This is not all, since we have also recorded Sumatran and Borneo Keeled pit vipers waiting for frugivorous prey, and fallen figs may be eaten by Bulwer's pheasants, crested firebacks, bearded pigs: and the list goes on. It has even been claimed that some turtle species may supplement their diet with fallen figs.

A programme of *Ficus* planting

It should be obvious by now that controlled planting of specifically chosen fig trees could contribute enormously to forest biodiversity.

In this project, up to 25 species of rainforest *Ficus* will be planted with a special focus on identified key species, including those listed in Table 2 below, which all also provides links for background information on these species. All these figs have been recorded within the forests of the Tawau district (Cheema *et al*. unpublished data). Many are also known to be important for hornbills: Phillipps, for example, offers compelling evidence of the importance of *Ficus* fruits in the diet of the endangered helmeted hornbill (https://borneoficus.info/2018/05/26/fig-ecology-helmeted-hornbill/).

The hornbills of Sabah

Sabah is blessed with 8 of the world's species of hornbill, conspicuous birds with large bills, loud calls and sometimes audible wing beats. Often hornbills possess an extension from the upper part of the bill known as a casque; our Rhinoceros hornbill gains its name because its bill and casque are large and brightly coloured. The biggest of them, the Helmeted hornbill, is sadly critically endangered after extensive hunting for its ivory casque.

All the hornbills are important seed dispersers for a variety of rainforest trees, feeding mainly on their fruits that contain seeds. Often, all of a fruit is ingested but only its flesh is digested, leaving the seeds to pass out undamaged in a bird's faeces. It is, of course, why fruit trees such as figs have evolved edible fruits: to attract animals such as hornbills to disperse their seeds across the forest after flying from the 'feeding tree'. For this reason, hornbills have been called 'farmers of the forest', reflecting their importance in primary and 'old growth' secondary forest where they are most likely to be found. Some birds, for example Rhinoceros and Bushy-crested Hornbills, may travel several kilometres after feeding, so that they may actually spread seeds not only within a rainforest but also between isolated forested areas. The larger species, such as the Helmeted, Wreathed and Rhinoceros, need large territories and forest destruction often has a serious impact on their numbers. Smaller species, for example the Oriental Pied and Black Hornbills, may tolerate humans better and so may even be seen breeding and feeding in plantations.

Hornbills sometimes feed on a variety of smaller animals, including insects, snakes, small birds and bats. However, their main food source is fruit, especially the numerous figs of Borneo.

The Helmeted Hornbill, *Rhinoplax vigil*, is mentioned here because it so critically endangered; the importance of the figs it feeds on to its survival is extensively logged at https://borneoficus.info/2018/05/26/fig-ecology-helmeted-hornbill/. Fig. 5 shows *R. vigil* feeding on *F. dubia* fruit in Sabah; the same fruiting tree also attracted the Rhinoceros Hornbill (*Buceros rhi-*

Table 2. *Ficus* species identified for planting; the species list will be broadened to include other species. (All information has been obtained from https://borneoficus.info, accessed 10/12/2020 and 16/05/2021. This site is regularly updated and serves as an excellent source of information on some of Borneo's important *Ficus* species.)

Species	Favouring animal species	Source
Ficus subcordata	Hornbills	https://borneoficus.info/2017/03/14/ficus-subcordata-introduction/
Ficus cucurbitina	Hornbills, Civets and Orang utans	https://borneoficus.info/2017/03/14/ficus-cucurbitina-introduction/ https://borneoficus.info/2020/08/07/ficus-cucurbitina-the-spiny-fig/ https://borneoficus.info/2020/09/13/ficus-cucurbitina-tawau-hills-park-2/
Ficus benjamina	A wide variety of birds	https://borneoficus.info/2020/10/16/ficuzs-benjamina-growing-in-oil-palm-tawau-sabah/
Ficus racemosa	Orang utans, Civets, Binturong and Hornbills	https://borneoficus.info/2017/02/12/ficus-racemosa-ecology/ https://borneoficus.info/2019/12/30/ficus-racemosa-propagation-for-reforestation-projects/
Ficus dubia	Binturong, Hornbills and other birds	https://borneoficus.info/2021/05/13/ficus-dubia-seed-predators-and-dispersers-at-maliau/

noceros), shown in Fig. 6 below and the Large Green-Pigeon (*Treron capellei*).

It is clear the balance between strangler figs and their seed dispersers such as the helmeted hornbill is delicate: a decline in one population can result in a linked decline of the other. It is the intention of this project to demonstrate that the opposite can occur: an increase in fig numbers can lead to a resulting increase in seed disperser numbers. The crisis threatening helmeted hornbill populations is well documented. Initiatives like the one outlined by Birdlife (The Helmeted Hornbill crisis and BirdLife's conservation efforts | Birdlife, accessed 01/12/2020) clearly show this.

However, it is important to realise that different hornbill species may feed on fruits of different *Ficus* species or may prefer fruiting trees of different heights or in different locations within a forest. In Borneo, the eight hornbill species may coexist by displaying niche segregation, that is different species avoid competition for food by selecting to feed in different parts of the forest and on different fruits. Clearly, our project will be influenced by this, in particular by which

Fig. 6. Female Rhinoceros Hornbill feeding on fruiting *Ficus dubia*. Photo: Shavez Cheema.

Fig. 6. Female Helmeted Hornbill feeding on fruiting *Ficus dubia*. Photo: Shavez Cheema.

Ficus species are selected for cultivation and subsequently where saplings are planted. For example, it has been reported that Helmeted and Wreathed Hornbills prefer to forage in the upper canopy whereas Bushy-crested and Rhinoceros species tend to feed in the middle canopy below. This, of course, provides some explanation for why the latter two species are easier to spot within the rainforest.

Selection of different fruit types has also been described: Helmeted and Rhinoceros Hornbills feeding preferentially on fruits, including figs, with higher sugar content compared with smaller hornbills, such as the Bushy-crested, that show a preference for a higher fat content. Koid Qian-Qun *et al.* (unpublished 2021) have provided a more detailed review of the ecology of hornbill species of Borneo.

Since we aim through this project to contribute to the conservation of hornbill species, such understanding of hornbill ecology should prove vital in our approach to fig cultivation. Observations on hornbill feeding and seed dispersal are by no means complete, however, and this is unsurprising given the distance hornbills may fly and the inaccessibility of many areas of a rainforest. There are other aspects of hornbill-fig ecology, for example the indirect impact of hornbill feeding where fruits drop onto the forest floor providing food for a variety of ground-dwelling animals, which illustrate how hornbill feeding is part of a much more complex food cycle in the forest.

It is, therefore, an important aim in itself to protect these fascinating and attractive birds; however, by choosing them as indicator species for our forest fig replanting project, we are illustrating how vital they can be, not just as tourist attractions, but more importantly as models for the monitoring of rainforest conservation. Fig-hornbill conservation should contribute to reforestation and wildlife corridor creation but is just one of many actions needed in order to minimise the impact of human activities on rainforest ecosystems.

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Observations of Oriental Pied Hornbills (*Anthracoceros albirostris*) investigating holes in karst limestone walls in Ipoh, Perak, Malaysia

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On 14 July 2020 we observed and filmed two Oriental Pied Hornbills (*Anthracoceros albirostris*) investigating three elongated holes in a karst limestone wall at two sites (Fig. 1) from 10:09:00 to 12:24:03 in the city of Ipoh, Perak, Malaysia. Possibilities for this behavior include hornbills nesting, scouting for a new nest, or raiding nests of other birds. Times of observations are delineated as follows: 10:09:00 to 10:35:07 and 11:47:12 to 12:00:13 at Hole Site 1, and 12:15:10 to 12:24:03 at Hole Site 2.

Hole Site 1

At Hole Site 1, a tree growing out of a crack in the limestone wall a few meters away from two elongated holes in the limestone wall serves as a perch ("perching tree 1"). White excrement coming out of and below each hole is caked on the wall. Two Oriental Pied Hornbills investigated the holes as follows:

10:09:00 A single Oriental Pied Hornbill on perching tree 1 is joined by another at 10:15:17. Forty seconds later (10:15:57) one of the hornbills flies to the upper hole and perches. At 10:16:25 the hornbill is dive bombed by a Myna bird and the hornbill is startled. The Myna makes a second dive bombing 18 seconds later (10:16:43) and brushes the Oriental Pied Hornbill's wing (Figs. 2, 3). This

Fig. 1. Screen grab showing locations of Sites 1 and 2 on karst limestone wall.

Fig. 2. A Myna dive bombs an Oriental Pied Hornbill perched on lip of upper hole at Site 1 while another hornbill is on perching tree 1. Screen grab.

Fig. 3. Oriental Pied Hornbill perched on lip of upper hole at Site 1 while another hornbill is on perching tree 1. Screen grab.

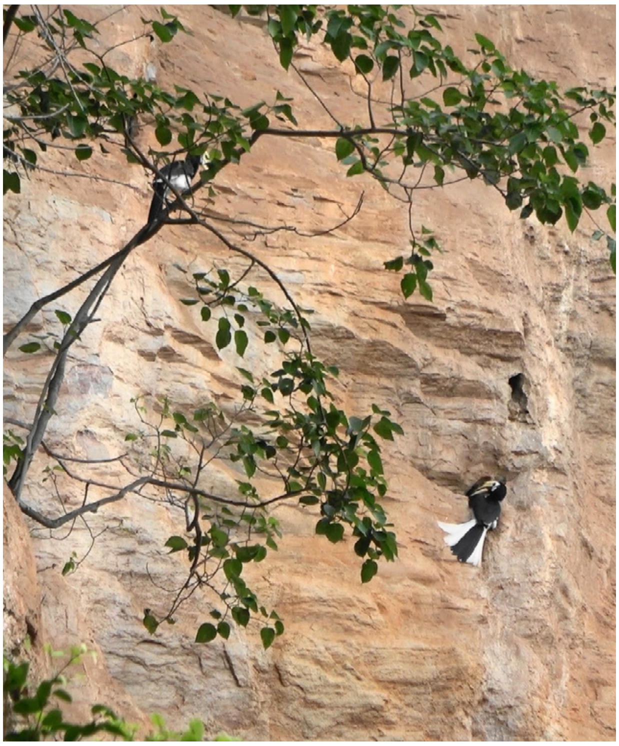

Fig. 4. Oriental Pied Hornbill perched on lip of bottom hole at Site 1 while another hornbill is on perching tree 1. Screen grab.

Fig. 5. An Oriental Pied Hornbill flies past hole at Site 2 to join another hornbill on perching tree 2. Screen grab.

Fig. 6. An Oriental Pied Hornbill removes detritus from hole at Site 2. Screen grab.

time the hornbill does not react but a few seconds later, at 10:16:56, the hornbill struggles to maintain its balance and flies away from the hole at 10:17:02 (Baylis & Fletcher, 2020, Video 101750). Meanwhile, the other hornbill is grooming on perching tree 1.

A hornbill flies to the bottom hole at 10:27:33 to look briefly inside then flies to perching tree 1 at 10:27:38 (Baylis & Fletcher, 2020, Video 102720). This same hornbill returns at 10:28:58 to the bottom hole (Fig. 4), looks inside, then flies back to perching tree 1 at 10:30:10 (Baylis & Fletcher, 2020, Video 102833).

A hornbill flies to the upper hole at 10:33:49 and inserts his head and upper body deep inside the hole to peck around then flies off at 10:34:48 (Baylis & Fletcher, 2020, Video 103508).

During this morning session, the hornbills sometimes struggle to maintain a foothold on the limestone lip of the hole. At 10:35:07 we ended observations with one hornbill still on perching tree 1.

From 11:47:12 to 12:00:13 we observed no hornbills at Hole Site 1 but there was one Myna on perching tree 1.

Hole Site 2

Hole Site 2 is just above denser forest several meters away from Hole Site 1 with only one elongated hole, but this hole is richer in white excrement caked on the lip and on the wall below the hole. A tree growing from a ledge on the limestone wall ("perching tree 2") has one leafy branch only a few meters from the single hole. Two Oriental Pied Hornbills investigated the hole as follows:

12:15:10 A single Oriental Pied Hornbill on perching tree 2 is joined by another at 12:15:27 (Fig. 5). The first hornbill hopped down to the leafy branch at 12:20:30 to be eye level with the hole and at 12:21:21 flew to the hole and inserted beak and head to remove detritus, including leaves (Fig. 6), after which it pecked inside the hole and ate something too small to identify. At 12:24:03 the hornbill dropped from the hole and flew off (Baylis & Fletcher, 2020, Video 122411).

Follow-up

We went back to Hole Sites 1 and 2 on 24 July 2020 to monitor activities. There were no Oriental Pied Hornbills at either site but two to three Mynas were flying in and out of the holes at Site 1. Whether they were nesting or just resting in the holes was not clear.

Conclusions

Based on these observations, we conclude that the Oriental Pied Hornbills were not nesting in any of the holes. We are unsure, however, whether they were scouting a location for a new nest or raiding Myna nests but suspect the latter.

Acknowledgements

We wish to thank Yeap Chin Aik from Malaysian Nature Society, Kuala Lumpur, for his spirited communications and encouragement on this project.

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Donna Mae Baylis

W. K. Fletcher

First Release of Visayan Tarictic Hornbill *Penelopides panini* at the Danapa Nature Reserve, Negros Oriental, Philippines

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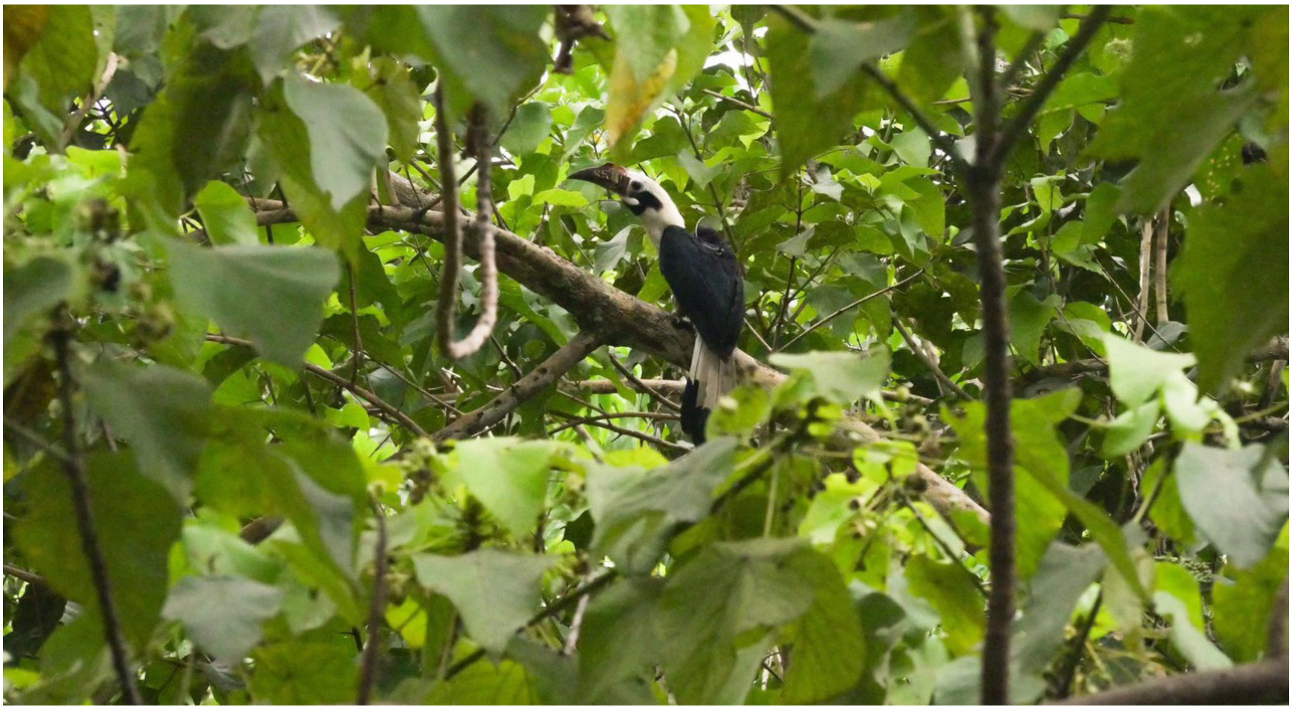
On 8 June 2021, we at the Talarak Foundation Inc., Negros Island, Philippines, conducted our first release of captive bred Visayan Tarictic Hornbills *Penelopides panini* into the wild of the Danapa Nature Reserve. Having previously been found across the Negros, Panay and other West Visayan islands, *P. panini* has now been restricted to forest patches on just the Negros and Panay. Listed as Endangered in the IUCN *Red List of Threatened Taxa* but Critically Endangered in the Philippine Red List, this species is still seen in illegal markets and evidence continues to be found of its poaching in the wild. Negros island has a few areas, including the Balinsasayao Twin Lakes Natural Park and North Negros Natural Park, where the species is seen frequently and appears to have a healthy population. But the connectivity between these areas and the smaller unprotected forests on the island are unknown, with anecdotal suggestions that the species has been extirpated from much of this range. Our foundation has been successfully breeding *P. panini* for over 5 years and with an increasing captive population, we identified the present time as opportune for a scientifically planned release to reintroduce the species back into the wild following the IUCN guidelines on reintroduction. We released four dispersal-aged birds (between 2-3yrs old) into a 300 ha protected reserve called the Danapa Nature Reserve (located in Bayawan city, Southwest Negros) that we are managing along with the city government. The hornbills were previously located within the forests around this site but were extirpated in the last 10 years from local hunting and removal of the nesting trees for timber and agroforestry.

All the birds we intended for release are offspring from our successful captive breeding efforts within our conservation centres in Bacolod City and Ka-

bankalan City on Negros. In December 2020, we moved a mixed group of 15 (8 males, 7 females) Visayan Hornbills to soft-release flight aviaries on site at the Danapa Nature Reserve. These animals were between 8 months and 3 years old and kept in two mixed aviaries of 7 – 8 individuals each, where they were fed a combination of wild foods and the previously used captive food items (including root vegetables, fruits and invertebrate animal protein). Our preliminary assessments of the site had identified that there was substantial food availability in the forest reserve with a high diversity of other native bird, invertebrate and mammalian fauna, which indicated abundant niches and viable habitat. We kept the birds in the soft-release aviaries until they had settled into eating most of the natural foods, had reduced signs of stress towards the local environment and sounds of native wildlife, and our pre-release preparations related to community outreach and monitoring strategies were completed to satisfaction.

For our monitoring strategy for these hornbills, we planned to use GPS tags to monitor the locations and movement patterns of our released individuals. With an average body mass of 490 g, we required tags that weighed less than 15 g and suitable for harness mounting and remote GPS data download. We elected to use the 14 g Bird Solar 15 from eObs (https://e-obs.de/products.html) and the 12 g Milsar Radio Tag GSM S9 (https://milsar.com/products/gsm-radio-tag-s9.html). As this is one of the first releases of *P. panini*, and the first for an area with no extant population or known locations for congregation, we do not know whether the species will remain within the Reserve or leave its boundaries. We estimated that the birds will remain in the Reserve as the surrounding areas do not have suitable habitats or food supplies, and our use of nest boxes and artificial feeding stations should be attractive to the released individuals. With this air of the unknown, we decided to go with two different tagging options; one tag (eObs) provides radio download of GPS data while also using UHF beacons for radio tracking and observation, and one tag (Milsar) also provides radio download of GPS data in addition to GSM cellular data download using 3G/4G networks if the bird flies outside the bounds of the reserve and beyond the survey area of the research team.

While this species is not present within the Reserve currently, they were known to the local community and many people remembered them fondly, alongside the larger Rufous-headed Hornbill *Rhabdotorrhinus waldeni* soaring across the valley landscape of the reserve. The poaching pressure for this species on the island involves either targeted harvesting for pet or medicinal trade or random collection for food. However, the absence of *P. panini* in the area



for at least 10 years had seen this poaching threat severely drop, with the local trade in either wild food or pets and medicine almost completely gone in this area or shifted to other more abundant local species. We had initiated outreach and education efforts in the rural communities around our Reserve in June 2020 and these continue at present. We are aiming to engage and build a sense of pride and desire in the communities to see endemic species, including the Visayan Hornbill, back in the area, living naturally alongside people. We are also looking for feedback on what the drivers of poaching are in the area and how we can assist in mitigating these drivers with alternatives. In February 2021, our education team reached out to the nearby city of Bayawan to continue promoting conservation values, awareness of the Reserve and our joint mission with the city government to protect endemic wildlife, and specifically target the hornbills as emblems of the success of the city's ambition to connect with nature. Using radio shows, Facebook groups and through church and community organisations, we have spread our messages of engagement and city pride for these species across the city and we are already reaping these rewards.

To reduce potential losses and maintain maximum observation and learning potential from this release, we decided to only release a subset of our individuals. Under the advice of our technical experts and partners we selected our four oldest individuals, (3 male, 1 female), all above 2 years old. Further introductions will follow as we test the monitoring methods, and dispersal and survival of the initial group of four.

The four released individuals are fitted with the GPS tags via Teflon harnesses across their mid-back area. We fitted two of these animals with Milsar GSM tags and the other two with eObs UHF tags and opened their aviary on 8th June allowing them to freely leave when they chose to. Within a few hours of opening the aviary, 2 of the 4 hornbills left the aviary and started exploring the nearby trees. Within the first week, we observed the two largest males (Marco and Rudy), fitted with the eObs UHF tags, feeding in fig trees and on small berries within a few hundred meters of the release aviary. The smaller male and female (Panini and Penelope, respectively), with the Milsar tags, took longer to come out but did eventually leave the aviary on June 16. We are still regularly seeing Penelope and some of the male hornbills return to the aviary at night or in times of heavy rain. We are leaving the aviary open for them in case they require sanctuary from the elements during this coming monsoon season. Listening to their calls in the forest, using playback, and by monitoring the GPS tags, we have been able to identify all four hornbills exploring larger areas of the Reserve over the last weeks, with one individual (Panini) being sighted around a nearby village by members of the community after 3 weeks of release. Benefiting from our previous engagement activities, the community members immediately called our staff excitedly to announce they had seen one of our hornbills, which we verified by direct observation with binoculars and using the GPS data. The village Captain also came to see the hornbill perched atop a tree feeding on fig fruits, while the local people were admiring and filming it from below. This is only the start, and these four birds will provide us with valuable data on the survivability, monitoring methods and overall viability of releasing the species in this area. We are thrilled to see them back in the wild inspiring the community to be at one with them and get excited about their endemic species returning to the area.

Although this reintroduction is still in its early stage (4 weeks post release) and we cannot claim success or identify major ecological knowledge learned from the released animals, we are always learning something from them. Using a camera trap placed at the release aviary and through our monitoring and direct observations we have noticed many interesting new behaviours and the adaptability of the hornbills. We have recorded new vocalizations between the individuals in close quarters, especially between the female and males. We have also recorded them feeding on several fruits including different fig species and other native berries, although currently no animal protein. We have also noted that there may be courting behavior in the form of gift giving and body posturing between multiple males and the female, this has not led to aggression or territoriality in the males as yet. The monitoring will continue, and we will be able to adopt our learnings for future releases.

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Crowned Hornbills — the inside story

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The two forest or forest-nesting hornbills in southern Africa are Crowned Hornbill *Lophoceros alboterminatus* and Trumpeter Hornbill *Bycanistes bucinator*. This article explores the nesting habits of Crowned Hornbill, unlike Trumpeter Hornbill, which seldom feed on fruit, but live mainly on animal prey, feeding on both, vertebrates and invertebrates. The photographs were taken over three breeding seasons (December 2018 - 2020) at a nest in Dlinza Forest, Eshowe, KwaZulu-Natal, South Africa (-28.8944° S; 31.4481° E).

Male and female Crowned Hornbills are slightly sexually dimorphic, with differences in their casque sizes. The male (upper) has a longer bill and casque than that of the female (lower).

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Additionally, female Crowned Hornbills usually have conspicuous throat skin patches, but they may be hidden, depending on the angle of the head. It is usually cream coloured, becoming blue-green at the onset of the breeding season. Similar throat skin patches are also present in female Bradfield's Hornbill *Lophoceros bradfieldi*, Monteiro's Hornbill *Tockus monteiri*, and the African Grey Hornbill *L. nasutus*. Males have far less prominent throat skin patches, are dark coloured, and are usually hidden by feathers. The species is also known to regularly feed on chameleons.

The nest observed was a natural hole in a Forest Apple-leaf *Philenoptera sutherlandii* within the Dlinza forest. The dark margins to the edge of the entrance hole is the plaster cast made by the female to narrow the entrance hole as security from predators. Each season, two to three eggs were laid. Nests soon became foul smelling as a result of continual inhabitation and the regular bodily process, so in order to maintain nest hygiene, and perhaps reduce ectoparasites, bits of bark were regularly brought by the male to be added as nest lining. Notice the lack of a throat pouch in these images of the male. The female also continually added to and strengthened the entrance cast by smearing a mix of her own faeces, nest debris, and other matter in order to protect herself and the contents of the nest. These phases and processes are depicted in the following three images.

The newly hatched Crowned Hornbill nestlings are born featherless and blind, emphasising the importance of the enclosed nest entrance.

The chicks develop relatively quickly, as is observed in this four- to five-day old chick, already showing skin and beak changes.

The nestling was estimated to be just under two weeks old at the time these photos were taken. The female always climbed up into the "chimney" of the nest cavity when the nest was approached.

These Crowned Hornbill nestlings, from another season were known to be about 10 days of age and appeared to be at the same developmental stage as the previously photographed chick.

The primary food choice for nesting Trumpeter Hornbills, the other forest nesting species in southern Africa, is fruit. Males, after foraging, are able to return to the nest with crop fills of ripe fruit, regurgitating up to 30 - 40 items sometimes in a single delivery. Because of this, there is slightly less demand on the males, so female Trumpeter Hornbills break out and exit the nest simultaneously with the chicks, when they are ready to fly. This prolonged nesting of the female is one of the major differences between the breeding biology of these two forest nesting hornbills.

The male's role in providing sufficient food when there are nestlings becomes critically important. About half way through the nestling period, the female's flight feathers are sufficiently grown for her to fly again. This is when pressure on the male to keep supplying sufficient food (mainly invertebrates) is at its peak. It's at this stage that the female breaks the entrance cast, exits the nest cavity, and helps the male provide the chicks with food. If the male is killed or injured at any stage before the female's flight feathers are re-grown, she and her chicks will die of starvation, because she'll be incapable of collecting prey.

Here a male delivers various small invertebrates, including Mantids (left), and Cicada (right), to the nest.

Millipedes are generally avoided by most birds as a food source, but hornbills utilize their sticky secretions to help seal their nest entrances. Here, a Red and Black Millipede, *Centrobolus* sp. is delivered to the nest, and was probably crushed for its milky coloured secretions which help strengthen the entrance seal. It is also possible that the foul-smelling millipede liquid secretions could act as a mosquito deterrent, especially with the female having moulted her flight and tail feathers, and her nestlings being mostly featherless in their early stages of development. Studies have shown that Wedge-capped Capuchin monkeys *Cebus olivaceus* in the tropical forests of Venezuela protect themselves against mosquitoes by rubbing their fur with the secretions of millipedes. Also, studies on Monteiro's Hornbill in Namibia show that millipedes are regularly brought to the nest, not only to help plug the entrance hole, but also to help minimize fungal and bacterial growth within the dark nest cavity, suggesting that the hornbills are benefiting from the antibiotic secretions.

Another interesting prey species provided by the male, also strong smelling and noxious, was a Milkweed Locust *Phymateus viridipes*.

The male provides the chicks in the nest with a variety of caterpillar species. Documented below is one of the hawkmoth species; possibly a Measly Hawk-moth *Platysphinx piabilis*.

Even spiky caterpillars are suitable prey items (Wahlberg's Emperor *Imbrasia wahlbergi*) and do not appear to deter Crowned Hornbills.

As mentioned, Crowned Hornbills consume large numbers of chameleons. Those shown here are all Common Flap-necked chameleons *Chamaeleo dilepis*, but they also regularly feed on the smaller geographically restricted, endemic Dwarf chameleons *Bradypodion* spp.

Fruit is less important in the diet of breeding Crowned Hornbill and is utilised more in the non-breeding, winter (May – August) periods. The upper image is of Fluted-milkwood *Chrysophyllum viridifolium*, a sticky fruit sometimes also used to help seal the nest entrance. The lower image is the fruit of one of the Cycad species.

Approximately two thirds of the way through the nestling period, the female's flight feathers are sufficiently well developed for her to fly and gather food for her quickly developing chicks. What appears to be a well beaten African Banana Slug *Elisolimax flavescens* and a Leaf Katydid *Tettigoniidae* spp. are two of her first deliveries to the nest after her approximate two-month incarceration during the laying and incubation phase.

Acknowledgments.

I thank Greg Davies for adding data & improving the first draft, the editorial team of *Hornbill Natural History and Conservation* for editing and inclusion in the bulletin, and finally Steve Woodall for invertebrate identification.

Hornbill News

During the 7th International Hornbill Conference held in Kuching, Sarawak, Malaysia in 2017, Bhutan proposed to host the 8th International Hornbill Conference in 2021. The proposal was approved by the President and the committee members of the Hornbill Research Foundation. However, due to the COVID pandemic, the event is now postponed to 2022.

VENUE

Royal Audit Professional Development Centre (PDC) in Damphu, Kilkhorthang sub-District of Tsirang (District), South-Central Bhutan.

CONFERENCE THEME

The unanimously preferred theme for the conference in Bhutan is "Happy Hornbills, Healthy Forests". Hornbills occurring in the tiny Himalayan kingdom of Bhutan rejoice the harmonious coexistence within its pristine mountainous ecosystem with the Drukpa citizens graciously supported by the profound developmental philosophy of Gross National Happiness (GNH). Environmental conservation is prioritized as one of the four pillars of GNH index aside from equitable socio-economic development while conserving its unique cultural traditions under the good governance system.

Bhutan serves as one of the last refuges of biodiversity conservation within the sacred Himalayan region that includes 4 hornbill species of the 32 found in Asia. Three species are recognized as Vulnerable, while the Oriental Pied Hornbill is thriving amid the ever degrading habitats. The Rufous-necked Hornbill, also called the mountain hornbill breeds successfully at the highest ever recorded elevation in the world.

The awaited conference aims to congregate international experts, youth enthusiasts, and many robust supporters for sustainable hornbill conservation and management practices through presentation of scientific papers, imparting information through posters, and sharing new conservation techniques.

Analogous exhibits and activities on hornbill will also be showcased for general awareness.

Bhutan, one of the few carbon neutral countries of the world and a bio-culturally unique nation welcomes everyone to take this rare opportunity to discuss various conservation issues and challenges faced by the hornbill experts, scientists, and enthusiasts.

CALL FOR ABSTRACTS

Submission of abstracts will soon be announced right after deciding the main thematic areas by the Scientific Committee of the Conference.

KEYNOTE SPEAKERS

Dr. APARAJITA DATTA
Senior Scientist
Nature Conservation Foundation
Mysore, India
Co-Chair (Asia) - IUCN SSC Hornbill Specialist Group

and

Dasho PALJOR J. DORJI
Bhutanese Environmentalist
Ex-Deputy Minister and Special Advisor to National Environment Commission
Founding President of Bhutan Ecological Society
Thimphu, Bhutan

CONFERENCE FEES

Early Bird Discount – USD 100
International Participants (Developed Countries) – USD 800
International Participants (Developing Countries) – USD 550
Note: Fee covers local transportation, venue, food (3 lunches and 3 dinners), tea and snacks for the conference duration, and conference package.

REGISTRATION AND HOTEL

Registration dates will be announced soon. Details including a list of lodging options (ranging from USD 6.89 to USD 63 per night), shall be shared in the next announcement.

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