Diversity and relative abundance of hornbills in selectively-logged production forests in Central Sarawak, Malaysian Borneo

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Summary. Rapid point surveys and opportunistic records were used to assess the relative abundance of hornbills in three selectively logged production forests (Forest Management Units: FMUs) in the interior of Sarawak. Each FMU contained coupes of different logging histories: recently logged (1-2 years ago), future logging (logged 5-30 years ago), and currently logged (logged 20-30 years ago). Point surveys were conducted while driving along a 30 km-transect, sampling one or two coupes representing each logging category, over two days in three months (August, April, and July) in each of the three FMU areas. Opportunistic records were obtained during boundary patrols, regular wildlife monitoring surveys, and forest operations. Of eight hornbill species occurring in Borneo, only one species (Wrinkled Hornbill) was not detected. The most frequently recorded species was the Rhinoceros Hornbill (36%), followed by the critically endangered Helmeted Hornbill (18%) and White-crowned Hornbill (16%). There were no significant differences between the three logging categories in the frequency of detection of hornbills during point surveys, but hornbills were detected at more points (67%) in future logging coupes than in currently logged (42%) or recently logged forest (44%) coupes. The occurrence of seven hornbill species in a production forest complex suggests that selectively logged forest provides suitable habitat for these species if managed sustainably, especially if nest and fruiting trees are actively protected.

Ringkasan. Survei singkat dan pencatatan oportunistik digunakan untuk menilai kelimpahan relatif rangkong di tiga hutan produksi tebang pilih (Forest Management Units: FMU) di pedalaman Sarawak. Setiap FMU mempunyai penebangan dengan sejarah yang berbeda: belum lama ditebang (1-2 tahun yang lalu), penebangan yang akan datang (pernah ditebang 5-30 tahun yang lalu), dan yang saat ini ditebang (pernah ditebang 20-30 tahun yang lalu). Survei singkat dilakukan saat berkendara di sepanjang transek 30 km, dengan pengambilan sampel di satu atau dua blok yang mewakili setiap kategori penebangan, selama dua hari dalam tiga bulan (Agustus, April dan Juli) di masing-masing dari tiga hutan produksi tersebut. Catatan oportunistik diperoleh selama patroli perbatasan, survei pemantauan satwa liar dan operasi hutan. Dari delapan jenis rangkong yang terdapat di Kalimantan, hanya satu jenis (Julang jambul-hitam) yang tidak terdeteksi. Jenis yang paling sering tercatat adalah Rangkong badak (36%), diikuti oleh Rangkong gading (18%) dan Enggang jambul (16%). Tidak ada perbedaan yang signifikan antara ketiga kategori penebangan dalam frekuensi deteksi rangkong dengan survei singkat, tetapi rangkong terdeteksi di lebih banyak titik survei di blok kelompok penebangan di masa depan (67%) daripada di hutan yang saat ini ditebang (42%) atau hutan yang belum lama ditebang (44%). Keberadaan tujuh jenis rangkong di kompleks hutan produksi menunjukkan bahwa hutan tebang pilih menyediakan habitat yang cocok bagi spesies ini jika dikelola secara lestari, terutama jika pohon sarang dan pohon buah dilindungi secara aktif.

Introduction

The tropical rainforest of Sarawak has been largely destroyed due to conversion to agriculture, logging activities and hydroelectric projects (Blandoi *et al*. 2020). This has resulted in forest fragmentation and isolation, which in turn has affected many bird species of conservation importance, such as hornbills (Naniwadekar *et al*. 2015a, 2015b). Despite the loss of primary forest and ongoing human activities, however, many species have adapted to the modified environment including secondary forest and commercial plantations (Mohd-Azlan 2006; Pawar *et al*. 2018).

The survival of Southeast Asian hornbill populations is highly dependent on the availability of food resources (Kinnaird *et al*. 1996; Anggraini *et al*. 2000; Budiman *et al*. 2017). Given their large body size, hornbills require habitat that consists of large forest patches with mature trees for feeding and nesting. Hornbills are considered important ecological indicators of the success of forest regeneration and preservation of tree species diversity (Meijaard *et al*. 2005) and are known to play an important ecological role as seed dispersers throughout Southeast Asia, where their decline has affected the recruitment of many large-seeded tree species (Chaisuriyanun *et al*. 2011; Kitamura 2011; Kitamura *et al*. 2009, 2011). Hornbills are also regarded as important from socio-cultural and socio-political perspectives in many parts of Sarawak, Western Borneo (Bennett *et al*. 1997).

Sarawak is home to eight hornbill species, comprising the Rhinoceros Hornbill *Buceros rhinoceros*, Helmeted Hornbill *Rhinoplax vigil*, Black Hornbill *Anthracoceros malayanus*, Bushy-crested Hornbill *Anorrhinus galeritus*, White-crowned Hornbill *Berenicornis comatus*, Wrinkled Hornbill *Rhabdotorrhinus corrugatus*, Wreathed hornbill *Rhyticeros undulatus*, and Oriental Pied Hornbill *Anthracoceros albirostris*. All hornbill species in Sarawak are protected under the Sarawak Wildlife Protection Ordinance (SWLPO) 1998. An offence relating to the killing or capturing of these species in Sarawak may result in a fine of up to RM 25,000 and two years of jail (WLPO 1998). On a global scale, many of these species are considered of conservation importance by the International Union for Conservation of Nature (IUCN), which lists the Helmeted Hornbill as Critically Endangered (CR), Wrinkled and White-crowned Hornbills as Endangered (EN), Rhinoceros and Wreathed Hornbills as Vulnerable (VU). Black and Bushy-crested Hornbills are considered Near Threatened (NT) and Oriental Pied Hornbill as Least Concern (LC) (BirdLife International 2020).

Habitat fragmentation created by logging activities in combination with illegal hunting of hornbills for feathers and meat may have caused major declines for some species in this region (Bennett *et al*. 1997; Poonswad *et al*. 2005). Logging destroys high canopy trees, which in turn reduces foraging substrates and perches for hornbills (Johns 1987). Tropical timber is a demanding market and therefore the sustainable management of forests in Sarawak is crucial for the survival of hornbills. In view of this, surveys of the hornbill species in production forests may provide important information on their distribution and persistence. This study aims to describe the diversity and distribution of hornbills in three Forest Management Units (FMUs) in interior Sarawak that are certified and undergoing regular certification auditing as required under the Malaysian Timber Certification Scheme (MTCS 2012).

Methods

This study was carried out in three selectively-logged production forests in FMUs that are managed by Ta Ann Holdings Berhad and located in the interior parts of Kapit Division Kapit FMU, Raplex FMU, and Pasin FMU are accessible by a combination of public and logging roads. The first two are south of the towns of Kapit and Song, respectively, while Pasin FMU is located in Song district. The three production forests mainly comprise hill mixed dipterocarp forest with elevations ranging from 30 m to 1254 m asl.

Under the Sustainable Forest Management (SFM) prescriptions, each FMU is allowed to harvest in one coupe per year with an approximate area of 3.2% of the total area, on a 25-year rotational basis. The 25-year rotation period was determined by the Forest Department of Sarawak by assessing various parameters regarding timber stock and forest condition, which were then analysed through the individual-based vegetation modeling software "FORMIND". All FMUs within Ta Ann (Kapit, Raplex and Pasin) were established in 2016 with approval by the State Government of Sarawak for Sustainable Forest Management Certification.

Kapit FMU has a total area of 1,498 km2 and retains approximately 297 km2 (c. 20%) of its total area as High Conservation Value Areas (HCVA), solely for the conservation of biodiversity. Raplex FMU, covering an area of 640 km2, has approximately 190 km2 of HCVA (c. 29%), while Pasin FMU, covering an area of 1,324 km2 has approximately 430 km2 (c. 32%) of HCVA. The HCVAs are legally protected from logging in perpetuity. The forests in the study sites have a history of logging, human settlements and agricultural activities. The nearest totally protected areas (TPA) from these production forests are Lanjak-Entimau Wildlife Sanctuary (1,687 km2) to the west of Pasin FMU and Betung Kerihun National Park (8,000 km2), in West Kalimantan, Indonesia, on the southern limits of Kapit FMU (Fig. 1).

Kapit FMU was recently certified under the Malaysian Timber Certification Scheme (MTCS 2012) in June 2018 while Raplex FMU was certified in June 2019 and Pasin in March 2020. These FMUs adopt Reduced Impact Logging (RIL) that combines environmental, biological and engineering principles in forest harvesting techniques that attempt to reduce the level of damage to biodiversity. The establishment of HCVFs, stream buffers and other protection measures during pre-harvest planning, such as marking foraging areas and nest trees for species of conservation importance, may reduce the impacts of timber extraction.

Kapit and Raplex FMU are surrounded by 79 villages with several rivers intersecting and surrounding them, such as Sungai (Sg) Kapit, Sg Yong, Sg Sut, Sg Gaat, Sg Pila, Sg Rajang and Batang Baleh. There are 111 villages around Pasin FMU, and the main rivers around the FMU are Sg Bangkit, Sg Tekalit and Sg Katibas. The local communities are mainly dependent on a combination of shifting cultivation, small scale farming, non-timber resource harvesting, and hunting. The local communities are not allowed to hunt protected species but do hunt certain game animals for subsistence (e.g.: Sus barbatus, Rusa unicolor, Muntiacus spp., Tragulus spp.) and collect non-timber forest resources such as ferns, rattans, fuelwoods and medicinal plants.

Survey and Analysis

Hornbills were surveyed using point surveys and opportunistic records in FMU coupes with known logging histories. At the time of our hornbill surveys, FMU coupes consisted of three treatments: currently logged forest, recently logged forest (≤ 2 years) and future logging forest, which had been logged 5-30 years ago and comprised a mosaic of abandoned, overgrown roads, regenerating secondary forest patches and old forest, especially on the steeper slopes. Currently logged forest coupes were areas of active logging, but due to their large size (60 km^2), it was possible to avoid areas of high activity during sampling.

Point surveys were conducted while driving along a transect of approximately 30 km over two days in each of the three FMU areas (15-16 August 2018, 24-25 April 2019 and 16-19 July 2019) in early mornings (07:00–11:00 hrs) and evenings (15:00–19:00 hrs). Ten points were sampled in each FMU (Fig. 1; Table 1). Each point was surveyed for 10 min, resulting in a sample of 100 min per FMU or 300 min in total for all FMUs.

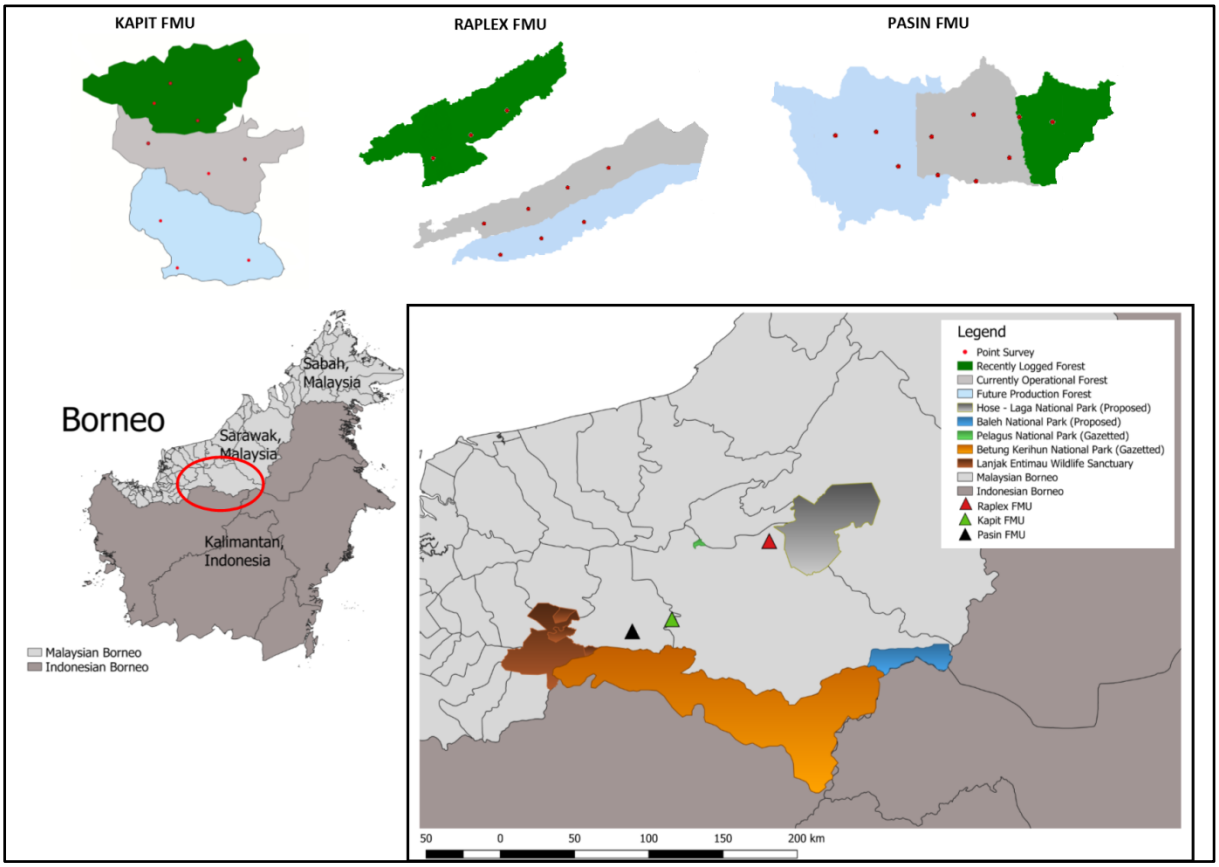

Figure 1. Maps of three FMUs showing hornbill point count survey sites from August 2018 to July 2019 in three different forest operation types. Insert shows locality of these sites in relation to the closest Protected Area (Betung Kerihun National Park, Indonesia).

Table 1. Point sampling design for this study, showing coupes in each of the three FMUs, their production forest types, logging histories, and number of points.

FMU	Coupe	Last logged (years)	Logging category	No. points	Total points
Kapit	24	2	Recent	4	10
	25	20-30	Current	3	
	1	30	Future	3	
Raplex	19	1	Recent	3	10
	20	1	Recent		
	1	20-30	Current	4	
	13	5	Future	3	
	14	5	Future		
Pasin	15	2	Recent	2	10
	1	20-30	Current	5	
	2	14	Future	3	

Opportunistic records of hornbills were obtained during boundary patrols, regular wildlife monitoring surveys and forest operations by the Sustainable Forest Management (SFM) Department of the FMU from 2016 to 2019. Wildlife monitoring surveys were carried out on 22 non-consecutive days at Kapit FMU, 29 days at Pasin FMU and 14 days at Raplex FMU, by FMU staff that were trained in identifying all potential species of hornbills through calls and observations. Boundary patrols were carried after boundary risk assessments, during which boundaries that were potentially susceptible to encroachments were investigated. Most hornbill species were expected to move between coupes in Kapit and Pasin FMU on a regular basis considering the short distance between these FMUs.

The diversity of hornbills during both point and opportunistic surveys was calculated using Hill's N2 index, which is the reciprocal of Simpson's index on species dominance, where a low dominance means higher diversity (Hill 1973; Greenstreet & Hall 1996). Hornbill diversity in the three forest treatments was compared using the Kruskal-Wallis rank sum test. All statistical tests were performed with R software using the package "vegan" (Oksanen *et al.* 2015).

Results

Seven of the eight hornbill species found in Borneo were detected during the study (Table 2; Plate 1). Combining point surveys and opportunistic observations, the most frequently recorded species was the Rhinoceros Hornbill (36%), followed by the Helmeted Hornbill (18%) and White-crowned Hornbill (16%). Two species (Oriental Pied and Wreathed Hornbills) were not detected during point surveys. White-crowned Hornbills were detected significantly more often during point surveys than opportunistic observations, whereas the reverse was true for Bushy-crested Hornbills (Chi-square with Yate's correction factor = 7.90, df = 1, $p < 0.01$). However, there were no significant differences between the proportions of detections from opportunistic observations and point surveys for the remaining three species (Chi-square = 0.55, df = 2, $p > 0.05$).

Table 2. Point survey and opportunistic records of hornbills in forest coupes with three different logging histories, Sarawak. Method: OR, opportunistic records; PS, point surveys. Detection mode: H, heard only; S, seen.

Treatment	**Future Logging**				**Currently Logged**				**Recently Logged**			
Method	OR		PS		OR		PS		OR		PS	
Detection mode	S	H	S	H	S	H	S	H	S	H	S	H
Rhinoceros Hornbill	2	5	4	2	4	5	3	2	1	2	4	2
Helmeted Hornbill	1	2		4	1	1		3	1	3		2
White-crowned Hornbill	2	1		3		1	2	1		1	2	3
Bushy-crested Hornbill	2	2			1	1			2	3		1
Black Hornbill	1	1	1		2		3		1	2		
Oriental Pied Hornbill	1	1			1				1			
Wreathed Hornbill	1				-				2			
No. detections	10	12	5	9	9	8	8	6	8	11	6	8
Total species detected	7	6	2	3	5	4	3	3	6	5	2	4
Species detected per forest type	7				6				7			
Total detections	36				31				33			
Number of points	9				12				9			
Number (%) of points with detections	6 (0.67)				5 (0.42)				4 (0.44)			
Hill's N2 Index	1.46				1.55				1.50			

Although not recorded sufficiently frequently to analyse statistically, the Black and Oriental Pied Hornbills were detected by sight more than by calls, and the Wreathed Hornbill was never detected by calls. In contrast, Helmeted and White-crowned Hornbills were detected more by calls than by sight, the Helmeted significantly more so than any other species (Chi-square = 6.45, df = 1, $p < 0.05$).

There were no significant differences between the forest treatments in the frequency of detection of hornbills during point surveys (Kruskal-Wallis rank sum test = 0.0014, df = 2, $p > 0.05$). Hornbills were detected at more points (67%) in Future Production Forest than in Currently Logged (42%) and Recently Logged Forest (44%) coupes. The Hill's N2 index values were very similar between treatments, ranging from 1.46 to 1.55, but the significance of this difference could not be tested (Table 2) due to the inherent requirements of available tests of significance.

Discussion

Numerous studies have examined the effects of logging on wildlife in the tropics. Species richness and abundance invariably decrease with logging, especially for forest specialists (Wilson & Wilson 1975; Marsden 1998; Felton *et al*. 2008; Velho *et al.* 2012). In East Kalimantan, Indonesian Borneo, Wilson & Johns (1982) found that faunal species richness in 3- to 5-year-old logged forest was similar to nearby unlogged forest, but that densities were considerably less in the former. Among birds, the large Helmeted and Rhinoceros Hornbills decreased markedly in their densities in logged forest, while densities of the smaller Oriental Pied and Bushy-crested Hornbills did not change significantly. Wilson & Johns (1982) believed that these smaller, more social species were more tolerant of differences in fruit ripeness and availability, and physically better able to move around in the more scrubby regenerating forest vegetation (Wilson & Johns 1982). The present study cannot be directly compared with the latter study as none of the coupes were unlogged and our data are limited to detections, not counts of birds. However, our findings are consistent in indicating that hornbill species richness and diversity in recently logged forest was similar to that in older regenerating forests.

The implementation of harvesting protocols may mitigate some of the adverse impacts of logging on hornbills. Under inclusion of criterion 6.2 of the Malaysian Criteria and Indicators for Forest Management Certification (Natural Forest), figs and other fruiting trees, and trees with nest-holes, should not be harvested. Fig trees (*Ficus* spp.) constitute the most important food resource for hornbills in production forests (Johns 1987). Moreover, hornbills are dependent on large, old trees with pre-existing hollows in which to nest (Kemp 2001; Utoyo *et al.* 2017).

The Wrinkled Hornbill was neither reported nor detected during this study, suggesting that is absent or occurs at very low densities in the study region, as reported elsewhere (Poonswad *et al*. 2013). Wrinkled Hornbills are relatively small and move mainly through the lower canopy of the forest within a small territory, feeding on primarily small fruit crops (Leighton 1982; Kinnaird & O'Brien 2007). This species is known to have soft and indistinct vocalizations, making it less detectable than Rhinoceros Hornbills and Helmeted Hornbills which have easily heard and recognisable calls (Poonswad *et al*. 2013; Burivalova *et al*. 2019). The point surveys in this study were conducted along logging roads which are mostly engineered along ridges, making it more likely to detect the large-bodied species, such as the Rhinoceros Hornbill and Helmeted Hornbill, which frequently fly across valleys and between conspicuous emergent trees. Consequently, hornbills foraging in the understory may have gone undetected. Future studies should consider establishing observation points inside logged and unlogged forest far from the road network.

The critically endangered Helmeted Hornbill was observed in all three forest types in this study. Population densities of Helmeted Hornbills in Borneo vary dramatically depending on forest structure and hunting pressure but are generally low due to its specialised diet (Beastall *et al*. 2016; Jain *et al*. 2018). This makes it an excellent umbrella species, under whose protection other hornbill species can also persist. While no detailed study of the species has been conducted in Sarawak, densities in other parts of Borneo range from 0.67-1.0 individuals/km^2 in Brunei (Charles 2005) to 0.7 individuals/km^2 in Barito Ulu, Central Kalimantan (McConkey & Chivers 2004) and 0.3 - 2.5 individuals/km^2 in Ulu Segama, Sabah (Johns 2004). Using the lowest density (0.3) given by Johns (2004), the combination of the entire three FMUs could potentially be home to several viable populations of this species. It is important to consider that local abundance is dependent on food availability and thus varies over time. But even if long-term population densities of Helmeted Hornbills in Central Sarawak were only half of those reported in the literature, the three FMU's could potentially provide habitat for over 500 individuals, thus demonstrating the role that sustainably managed logging concessions could play in tropical conservation efforts.

Although logging activities are known to have adverse impacts on hornbills (Naniwadekar 2015b), most species can persist in selectively logged forest (Johns 1987; Datta 1998). In the present study, hornbills were detected both in forests with a fallow period of at least 30 years and minimal human disturbance, as well as in forests that experienced active and recent logging operations. This might indicate that hornbills are generally quite tolerant of anthropogenic disturbance as long as key habitat structures, such as nesting sites and sufficient food sources remain. Therefore, the importance of well managed secondary forest with old-growth patches for hornbill conservation must not be ignored as the demand for land for agriculture and production forest increases, which may result in additional pressure on the remaining good forest stand for the next logging cycle. Old growth patches should be taken out of consideration for logging indefinitely. Consequently, by understanding the driving factors that contribute to the persistence and assemblage of hornbills in a progressively disturbed habitat, conservation science can inform forest managers on ways to mitigate the adverse effects of logging on these species. For example, the existence of a high conservation value area along the river may provide some relatively pristine habitat within this production forest complex and should be made mandatory to preserve. Assessment on trees that are affected by heart rot is also important. Although trees with heart rot could provide suboptimal quality for pulp, they should be left standing as they provide potential roosting, nesting and food storage sites for many vertebrates, including hornbills (Meijaard *et al*. 2005).

Conclusion

Despite its rapid sampling approach, this study revealed the persistence of seven hornbill species in production forests in Central Sarawak, indicating that these logged forests provide the resources required by these species, and as such need to be protected and managed from further degradation (Cleary *et al*. 2007). Moreover, it shows that incidental records of species of conservation importance encountered during surveys (even if it is not a target survey species) should not be ignored as it may provide baseline information on the distribution and diversity in an area for other researchers. Given the long logging history alongside the large concession area, it is suggested that FMUs are an important habitat for hornbills in the "Heart of Borneo" Forest Complex within Sarawak. However, their long-term persistence in this area in relation to logging activities requires further investigation. Biodiversity management measures in production forest should intensify preserving pockets of large intact forest, connected through river buffers as corridors, which in turn may mitigate some of the adverse effects of logging such as isolation and fragmentation of animal populations. Additionally, reforestation efforts made by concessionaires should not only focus on fast growing species for an eventual harvest, but also consider planting the forest giants of tomorrow to improve habitat quality and provide key structures for hornbills and other wildlife in the future. Since protected areas in Sarawak are notoriously vulnerable to poaching (Harrison 2011), large forest areas such as FMUs, if managed sustainably (including the control of illegal hunting) may, in the long term, supplement nearby protected areas in the conservation of hornbills in Sarawak and Borneo.

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Plate 1. Hornbills photographed during surveys (2017-2019). Clockwise from top right: Black Hornbill (Photo: P. Pengiran), Bushy-crested Hornbill, Wreathed Hornbill and Rhinoceros Hornbill (Photos: L. Robert).