Project Completion Report

on

Population Status and Diets of Sympatric Hornbills in Jomotsangkha Wildlife Sanctuary (JWS), Bhutan

Submitted by;

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ABSTRACT

This study was carried out in Jomotsangkha Wildlife Sanctuary (JWS), a newly established PA in Bhutan, located in the south-eastern part of the country bordering India (Assam State to the south and Arunachal Pradesh to the east). The population status of hornbills in the area was assessed through systematic trail walks that covered a total distance of 205 km. Four hornbill species were recorded during the study that included the Great Hornbill (GH) *Buceros bicornis*, Oriental Pied Hornbill (OPH) *Anthracoceros albirostris*, Wreathed Hornbill (WH) *Aceros undulatus* and Rufous-necked Hornbill (RNH) *Aceros nipalensis*. Great Hornbill had the highest encounter rate (ER = 0.8), followed by Oriental Pied Hornbill (ER = 0.2), while Wreathed Hornbill and Rufous-necked Hornbill were encountered the least (ER = 0.1). For studying diet of the hornbills opportunistic observations on foraging during trail walks were made. Observations on diet were also made from regurgitated seeds in middens below roost and nest sites. A total of 46 food species belonging to sixteen plant families and four animal families were recorded consumed by hornbills in JWS. The fruits of Meliaceae and Moraceae family were observed to be primarily consumed by hornbill in the area.

A total of 13 nests, GH (n = 7), followed by WH (n = 3), two nests of OPH and one nest of RNH were located in the area during the study. From the total, 9 nests were recorded in *Tetramales nudiflora* and one each in *Ficus* sp., *Altingia excelsa*, *Terminalia* sp. and unknown species. Roosting sites were also searched during the study. A total of 9 roosting sites, GH (n=7) and one each for OPH and WH were located in the area. Roosting sites were recorded on *Tetramales nudiflora* (n=5), and one each on *Bombax ceiba*, *Quercus* sp. *Albezia procera* and *Tectona grandis*. At the roost sites, GH flocks range from 2-42 individuals, whereas OPH and WH flocks were counted with 27 and 25 individuals respectively.

Key words: Population status, sympatric hornbills, hornbill diets, nesting sites, roosting sites, Jomotsangkha Wildlife Sanctuary and Bhutan hornbills.

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ACRONYM

BC	- Biological Corridor
CFO	- Chief Forestry Officer
DBH	- Diameter at Breast Height
DNH	- Diameter at Nest Height
DoFPS	- Department of Forest and Park Services
E	-East
ER	- Encounter rate
FNCRR	- Forest and Nature Conservation Rules and Regulation
GBH	- Girth at Breast Height
GH	- Great Hornbill
GPS	- Global Positioning system
IBAs	-Important Bird and Biodiversity Areas
IUCN	- International Union for Conservation of Nature
JWS	- Jomotsangkha Wildlife Sanctuary
KYNP	- Khao Yai National Park
LC	- Least Concern
N	- North
NE	- Northeast
NW	- Northwest
NTFP/NTWP	- Non Timber Forest Products
NT	-Near Threatened
OPH	-Oriental Pied Hornbill
PAs	- Protected Areas
PNP	- Phrumsengla National Park
RNH	- Rufous-necked Hornbill
S	- South
SE	- Southeast
Sp	- Species
SW	- Southwest
Sq.Km	-Square Kilometer

T1-T15	- Trail number 1 to 15
TWFC	- Tenesserim Western Forest Complex Corridor
UWICER	- Ugyen Wangchuck Institute for Conservation and Environmental Research
VU	- Vulnerable
W	- West
WH	- Wreathed hornbill
WWF	-World Wide Fund for Nature

CHAPTER 1 – INTRODUCTION

1.1 An over view of hornbill

Hornbills are large, conspicuous and distinctive birds under two families (Bucorvidae and Bucerotidae) of order Bucerotiformes. They are charismatic birds, found only in tropical forest of Asia and Sub-Saharan Africa. Characteristically they have spectacular appearance with large bill surmounted with casque, long and powerful wings, brightly coloured body and make loud calls. The species are so called because of its remarkable bill. Hornbills primarily feed on fruits but they are also found feeding on insects and small mammals. Due to predominantly frugivorous in diet, they are considered important agents of seed dispersal in the tropical forest. This dietary mechanism of hornbills, foraging and seed dispersal benefit forest ecosystem and they are called 'farmers of the forest' (Naish, 2011).

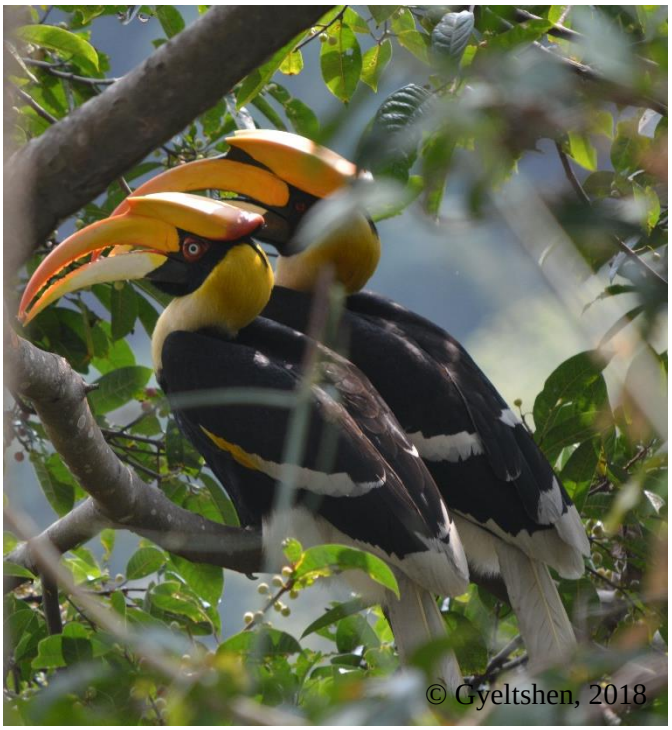
Under 15 genera, total of 57 species and 75 sub-species of hornbills are recognized globally. Out of this, 25 species are in Africa and 32 in Asia (Poonswad *et al.*, 2013). South-east Asian forest have the greatest diversity of hornbills within Asia (Datta, 2001). Indonesia and Thailand are hornbill richest country with 14 and 13 species respectively. Malaysia have only 9 species though is famed for its rainforest. India has 9 species with two endemic and northeast India with greatest diversity among other parts of the country with 5 species. The number of hornbills reported from other countries of South-east Asia such as Myanmar, Cambodia, Laos, Vietnam and southeast China ranges from 4 to 6 species. Four species of hornbills are recorded in Bhutan.

Hornbills require large geographical area to fly over in search of or to track food resources. They are unique about specialized requirement of old-growth forest (Raman, 2009). Hornbills are secondary cavity-nesters since they are unable to excavate their own nest cavity and instead use natural cavities of large softwood trees, crevices in rock faces and holes in mud banks (Datta, 2001; Poonswad, 2010). During breeding season, female remains incarcerated inside nest cavity, seals hole and keep only a slit opening through which food is passed by the male to female and the chicks.

Hornbills are usually monogamous because of the consequences that male has to feed female and chicks during breeding season and inability of the male to provision two or more females simultaneously (Datta, 2001). The cooperative breeding behavior is also seen in hornbill, especially in brown hornbills where non-reproductive members of social groups provides aid to the offspring of other individuals (Juan-Carlos & Gonzalez, 2013).

1.2 Distinguishing characters of four hornbill species recorded in Bhutan

1.2.1 Great Hornbill (GH)



Large (95-120cm length) and150-178cm wing span. Has massive hollow casque on curved bill. Body, head and wings are primarily black, abdomen and neck are white, and tail is white with sub terminal black band. Tinted oil from preen gland is spread over while grooming which gives yellow to red coloration over bill, neck, casque, tail and wing feathers. It has prominent eye lashes. Male and female are similar except male has red irises while those of females are white and body, casque and bill of male are slightly larger than female.

Figure 1. Great Hornbill male (right) and female (left).

1.2.2 Oriental Pied Hornbill (OPH)

Oriental pied hornbill is smallest Asian hornbill (55-60 cm) length with 23-36 cm wing span. They weigh between 600g-1,050 g. The plumage of the head, neck, back, wings and upper breast is black with a greenish gloss. The tail is black with white tips on side feathers. The plumage of lower breast, belly, thighs, under-wing and all the tips of the wings is white. Males and females are similar in coloration. Males can be distinguished from females by their larger body size, yellow bill which has black base and bright red eyes.

Figure 2. Oriental Pied Hornbill (male).

1.2.3 Wreathed Hornbill (WH)

It is large (75 to 85 cm in length). They have black wings and short white tail. They have prominent corrugated bill and casque with ridges. The bill colored creamy. They show sexual dimorphism. The male has rufous brown forehead, crown and nape. The sides of the head, fore neck and upper breast are whitish. There is yellow gular pouch with dark bar. The irises are red. The female has black head and neck. The gular pouch is colored blue. The iris are brown. The male is slightly larger.

Figure 3. Wreathed Hornbill male (right) and female (left).

1.2.4 Rufous-necked Hornbill (RNH)

The Rufous-necked Hornbill is large (90 to 117 cm in length). Body is black with long tail having basal half black and the distal half white. The bill is pale yellow and has a row of vertical dark ridges on the upper mandible. The casque is almost absent. They shows sexual dimorphism. The male slightly larger has reddish brown head, neck and underparts. The upper parts are black and the black wing has white-tipped outer primaries. The female has black head, neck and underparts. There is red gular skin. The irises are brownish red and orbital skin is pale blue.

Figure 4. Rufous-necked Hornbill male.

1.3 Problem statement

One-fifth of the world's bird species occurs in Asia (Ornithology, 2016), including many species that are currently assessed as threatened (Sherub, 2017). Habitat loss and fragmentation is identified as the main threat to 85% of threatened or endangered species in the red list by International Union for Conservation of Nature (IUCN) (WWF, WWF Global, 2017). Overexploitation and the growing hunting crisis threatens forest species of Asia, Africa and south-America (Robin *et al*, 2018). It becomes serious threat to those species which requires specialized habitat especially like hornbills.

Hornbills have specialized requirement with regards to large tracts of old-growth primary forest habitat, frugivorous diet and the consequent dependence on resources which may be patchy in time and specialized nesting requirement (Tsuji, 1994). The special requirement has made hornbill sensitive to multi-anthropogenic disturbances and their conservation has become global concern. On the other hand, hornbills have not received much conservation attention like charismatic mega-fauna such as tiger (*Panthera tigris*) and elephant (*Elephas maximus*). In northern Western Ghats of India, habitat alteration by logging has reported leading to local extinction of hornbill (Raman, 2009). On addition to habitat destruction, in North-east India, hornbills are vulnerable due to the traditional values of their feathers, beaks, casque, flesh and supposed medicinal value of their fats and in central Africa hornbills are hunted and consumed (Robin *et al*, 2018).

Bhutan has four species of hornbill; Great Hornbill (GH), Oriental Pied Hornbill (OPH), Wreathed Hornbill (WH) and Rufous-necked Hornbill (RNH) but their conservation status is largely uncertain. The two species of the 4 are categorized as globally threatened in the red list of threatened species by IUCN. Rufous-necked Hornbill is red listed Vulnerable (V) and it is totally protected species under schedule-I of Forest and Nature Conservation Rules and Regulation (FNCRR) of Bhutan, 2017. The species is known in few pockets of broadleaf forest in world. Almost nothing is known from many of its habitat in Bhutan. Great Hornbill is reported decreasing its population trend and listed Near Threatened (NT) by IUCN. Wreathed Hornbill and Oriental Pied Hornbill are Least Concern (LC) species in the world and correspondingly not much conservation attention is being paid for these species. In Bhutan these species lack conservation focus due to limited research and dearth of comprehensive information.

The study about hornbills in Bhutan is scanty and most of the studies conducted have focused on a single species and very few on sympatric species. This thesis is amongst the few attempts

to understand resource partitioning in the sympatric hornbills assemblage. On other hand, this is the first attempt to study hornbill in Jomotsangkha Wildlife Sanctuary. Despite the sanctuary is one of the hornbill rich (presence of all four hornbill species that is reported in the country) area in the country, no study on hornbill is carried in the area hitherto. Including ecology, many aspects about the hornbills of JWS is not known other than hornbills are reported present in the area.

1.4 Scope and contribution of the study

Bhutan having maximum part with forest coverage is rich in biodiversity. However there lacks an effective protection and monitoring of many species due to absence of scientific data. Hornbill is the one among many which is studied less in the country. JWS, in southern foothills of Bhutan with broadleaved forest harbors 4 species of hornbills. This thesis study is the only hornbill study in the area so far. It opens the need of conservation aspects of hornbills in the area. This study tells about the various hornbills found in JWS along with their relative abundance (population status by encounter rate), availability of diets fruits that the hornbills consume in the area and the nesting and roosting site preferred by hornbills within the area.

JWS is one of the biodiversity hotspot within the country. The sanctuary is an important habitat for many species including some of the globally threatened species. Addition to the charismatic hornbills, the area is home for many keystone species such as 23 mammal species including Critically Endangered (CR) Pygmy hog (*Porcula salvania*) and Chinese Pangolin (*Manis pentadactyla*), Endangered (EN) Bengal Tiger (*Panther tigris tigris*), Asiatic elephants (*Elephas maximus*) and Hispid hare (*Caprolagus hispidus*), Vulnerable (VU) Asiatic Black Bear (*Ursus thibetanus*), Gaur (*Bos gaurus*), and Common leopard (*Panthera pardus*). Four types of small cat are found in the area, VU Clouded leopard (*Neofelis nebulosa*), Near Threatened (NT) Asiatic golden cat (*Catopuma temminckii*), and Marbled cat (*Pardofelis marmorata*) and Least Concern (LC) leopard cat (*Prionailurus bengalensis*). The area also have more than 200 recorded bird species. On the other hand, the frugivorous hornbill in the area disperse seed and play vital role in maintaining forest ecosystem that homes many species. Thus any work for the conservation of hornbills is expected to bring direct conservation impacts to all the species in the area.

The hornbills are reported from many parts of the foothills forest in Bhutan. However the species lacks detail study. Many aspects of the species remain not known including its population status. This study, the pilot attempt to assess population status of hornbill species in JWS can be startup to understand the hornbills in Bhutan by carrying similar study in other hornbill habitats in Bhutan. Understanding the status of hornbill can help in long term monitoring of the species and accordingly proper conservation strategy can be adopted.

1.5 Objectives of the study

1) To assess the population status of hornbills in JWS.
2) To study the dietary habits of hornbills in JWS.
3) To study the nesting site and roosting site of hornbills in JWS.
4) To make general public aware about hornbill conservation

CHAPTER 2 – REVIEW OF LITERATURE

2.1 Role of hornbills in the Ecology; Seed dispersal

Seed dispersal is a key process in plant communities and frugivory is very important in vertebrate communities. The vertebrates disperse between 65% and 90% of woody species in tropical and subtropical Asia, with birds dispersing more species than mammals. Hornbills are often the largest frugivores in their habitat and the world largest species of flying frugivores. Hornbills occurring in tropical forest of Asia and Africa, 75-100% of their diet is comprise of fruits (Rohit, 2014) from 748 plant species (163 in Africa and 589 species in Asia) in 242 genera of 79 families (Teampanpong, 2014; Kitamura, 2011) Hornbills were the most important visitors on large-seeded tree species (Datta *et al.*, 2012). It has been emphasized the many primary forest species with capsular dehiscent fruits are solely disperse by large hornbills because of their large gap size and ability to split open husk (Datta, 2001). Their large gap size is associated with specialized frugivory to open capsular fruits that other frugivores cannot. Large-seeded native fruiting trees may depend on hornbills as the remaining disperser of their seeds. Consequently, with the additional loss of hornbills, they may no longer regenerate in the landscape (Teampanpong, 2014).

Animal-mediated seed dispersal is recognized to influence spatial organization of plant communities (Trolliet, 2017). Hornbills consume pulp/aril of fruits and regurgitate or defecate seeds undamaged at far distance from parent trees and they play important role in seed dispersal. The net seed arrival on the forest floor was positively associated with hornbill abundance (Naniwadekar, 2014). It has been hypothesized that the extinction of hornbills would lead to a chain of extinctions of various tree species (Kitamura *et al*., 2004) that are partly or wholly dependent on them (Datta, 2001). Consequently the other animals that highly depend on these plant species will be negatively impacted. It is found that the increasing amount of forest cover in the landscape was associated with an increase in the density of hornbill-dispersed seedlings (Franck, 2017).

Hornbills are the only landscape-level species that can fly over fragmented landscape as known for their long-distance movements. Some hornbill species shows nomadic behavior during lean fruiting period. Hornbills help in regeneration of degraded or disturbed forests by carrying genetic materials (viable seeds) from primary forest and maintains forest ecosystem (Anggraini, 2000). For maintaining healthy forest, restoring ecological resilience and biodiversity in the degraded forest of southern Tenesserim Western Forest Complex Corridor

(TWFC), Hornbills are known as potential agents and can be flagship species. They are designated as landscape species for conservation in TWFC (Teampanpong, 2014).

2.2 Dietary habits of Asian hornbills

Asian Hornbills are primarily frugivorous (Kitamura *et al*., 2004), however they are also found feeding on insects and small mammals and thus considered as omnivorous. Proportion of animal food in the diet may vary by species and perhaps by season (Poonswad *et al*., 1998). In Arunachal Pradesh, study on diet of hornbills during non-breeding period found fruits comprise >95% of its diet and only GH is found consuming insects other than fruits (Rawat., 2003). However, more than 70 small animals are recorded from the diet of hornbills in Thailand (Teampanpong, 2014). Fig species are asserted as keystone resource for the hornbills as well as other frugivorous that they search for and utilized even when other fruits are available (Mudappa, 2000; O'Brien, 2007). There are more than 750 species of figs of which over 500 species are found within Asian hornbill realm (O'Brien, 2007). Hornbills predominantly feed on figs, lipid-rich berries/drupes and capsular fruits in tropical forest. They have diverse diet but found feeding primarily on fruits from five families; Annonaceae, Lauraceae, Miliaceae, Moraceae and Myristicaceae (Corlett, 2017).

Hornbills use different foraging methods such as cracking tree bark, probing, hawking, plucking and snatching. A study by Poonswad *et al* in 1985 found hornbills mostly forage by plucking method (Poonswad *et al*., 1998). Hornbills sometimes carry single fruit in the bill tip but transport fruits mostly in expandable gular pouch, esophagus and stomach (Kitamura, 2011). The volume of fruit they transport vary with body size, from 100 ml in a 1.2 kg *Anorrhinus* species to 300 ml in a 2.5 kg *Aceros*/*Rhyticeros* species that may carry as much as 500 g of fruit at one time (Kitamura, 2011). They are important disperser of seeds greater than 15mm in size (Teampanpong, 2014). In Asian hornbills, gape widths range from 30 to 55 mm and they also consume larger fruits.

Fruits consume by hornbills are generally two types; soft pulp with numerous small seeds which includes all fig fruits and other with stone seeds which include all other non-fig fruits (Poonswad *et al*., 1998). They digest only the fleshy part of fruits that they swallow and regurgitate/defecate the seeds intact (Kitamura, 2011). Smaller seeds are defecated, after retention for equal period as regurgitated seeds (around an hour), although 10 min has been reported as regurgitation time for *Oxyceros griseus* (Ismail *et al*., 2017).

Despite hornbills are efficient in processing and digesting fruits, they consume 60–600 g of fruits per day which is equivalent to 20–33% of their body weight (O'Brien, 2007). As a consequence of fruit-rich diet, it is presumed the hornbills hardly drink water and seem efficient in processing water. Kinnaird and O'Brien (2007) stated this may be linked to bilobed form of hornbill kidneys which is unusual. The hornbill's feaces are drier than tend to be the case of other birds and it is believed due to this efficient water extraction mechanism they possess. Fast flight and large home range coupled with prolonged seed retention could potentially result in many seeds being dispersed long distances, with some possibly carried >10 km by the larger species (Ismail *et al.*, 2017)

Sympatric species may partition resources in order to coexist if resources are limiting (Shumpei *et al*., 2009). They may select different food items, forage in different strata, or differ temporally in use of resources to avoid competition (Rawat., 2003). The study on foraging pattern of three sympatric hornbill species in Arunachal Pradesh found the percentage of feeding records on fig fruit species by GH, WH and OPH were 73%, 35% and 47%. This shows the GH consume fig fruits significantly more than WH and OPH. In other words, non-fig fruits in the diet of WH is more than other two hornbills. The similarity in non-fig fruit consumed by three hornbill species is found very low with 9.5%. Food resource partitioning occur in terms of fruit size and types also. OPH consume small fruits (75%) and mostly on berries and drupes while only 19% of fruits consume by GH is small size and GH and WH mostly consume on capsules and single-seeded drupes (Rawat., 2003). The study also found significant differences in the use of canopy levels; Great Hornbill mostly sighted in the upper canopy, Wreathed Hornbill in the emergent layers, and Oriental Pied Hornbill in the mid- and lower canopy levels; however, if only the foraging height records were considered, the differences in canopy levels used were less pronounced (Rawat., 2003).

During breeding season, the female remains sealed inside nest cavity from before laying eggs till fledging of the chicks. This entire breeding period, male and male assistance in cooperative breeding species are provisioned to carry diets to nest and feed female and chick(s) in the nest (Poonswad *et al*., 2004). Soon after fledging the juvenile and poor body condition of female after prolonged confinement inside nest requires more nutrition. This period is linked with the availability of diet.

2.3 Hornbills; Breeding biology

Hornbills are seasonal breeder. They usually breed annually but in some species found breeding once after every alternate year (Leighton, 1982). The breeding season of hornbills varies based on geographical ranges. The breeding season usually starts in March month and prolong till August, which span around 20-22 weeks. But in Thailand, breeding season of hornbills generally starts in dry season around January and February and ends at the end of dry season or beginning of wet season around May and June (Teampanpong, 2014). Pre-breeding activity of hornbills such as courtship and nest inspection begins from January itself (Datta, 2001). Breeding cycles (period between female imprisonment and fledging of young) are synchronize with food productivity of the forest (Mudappa, 2000; Datta, 2001).

Hornbills are monogamous. The survival of female and chick relies on the male's ability to provide food during her incarceration time. Thus the female hornbills are thought to be very selective when choosing a mate. The strength of the pair's bond is believed to be an important factor for successful reproduction (Corinne *et al*., 2015).

Prior to breeding, the couple perform courtship. During the courtship period, males performed vocalization with great frequency, regurgitation, approach, food offering and nest inspection. The female also perform same behaviors, but at a lower rate. The couple also perform multiple activities such as billing with food, biting, neck biting, nest showing, honking, and allopreening (Corinne *et al.*, 2015). Once the suitable hole is selected and approved by female, the couple plaster the nest entrance hole with sticky materials such as mud, feaces, wood shavings, saliva and sticky fruit pulps (Erik, 2000). Both the birds were engaged in mudding up the aperture, the male working from outside and the female from within (Williams, 1986). However plastering is done more by the female. She enters the nest when she is ready to lay eggs and continue plastering from inside the cavity with mud, fecal matter and fruit pulp. During this period, male is found bringing mud and fruits to female (Wee, 2008). Sealing continue leaving only narrow slit through which male passes food for her and chicks until the nesting period is completed. For further sealing, the female applies them with the flattened sides of the bill, rendering the edges of the slit thicker and thicker. To defecate, the female positions the anus at the slit and squirts her excreta with much force (Kauth *et al.*, 1998) and the entrance remains free from any droppings usually. Female usually create sound by pecking on inside wood wall of nest which is thought to be communicating with male (Kauth, 1998).

Hornbills has specialized nesting behavior whereby they nest in tree cavities. They cannot excavate cavity of their own, thus are secondary cavity nester of naturally formed cavities or those excavated by other birds such as barbets and woodpeckers (Balasubramanian, 2010). They nest in tall and larger trees in the dense forest, open forest or even near human habitation (Paleri, 2007) in certain tree species. In Arunachal Pradesh of India, hornbills are usually found nesting on *Tretamales nudiflora*, *Ailanthus grandis*, *Terminalia myriocarpa* and *Altingia excelsa* (Rawat, 2004). In Thailand, the hornbill nests are reported from tree species such as *Dipterocarpus*, and *Eugenia* sp. (Poonswad P. , 1994). The Great hornbills in southern India are reported nesting on *Alseodaphne semecarpifolia, Terminalia bellerica, Tetrameles nudiflora, Lagerstroemia lanceolata*, *Bombax ceiba* and some other species (Kannan D. A., 2009). Wreathed hornbills in Mount Ungaran, Indonesia are reported to nest in *Dipterocarpu*s, *Eugenia*, *Syzygium glabratum* and *Syzygium antisepticum*, *Ceratoxylon formosum,* and *Ficus* sp. (Margareta, 2017), whereas in lowland rainforest around Way Canguk Research Station, they nest on *Terminalia bellirica* and *Heritiera javanica*. Helmented hornbill nest was reported in *Dipterocarpus humeratus* in the same region. In Bhutan, the hornbills nest are reported in *Tetrameles nudiflora* and *Altingia excels*, *Schima khasiana* and *Toona cilliata* (Sherub, 2017; Dorji, 2017; UWICER, 2017).

Hornbills often show high nest-site fidelity, returning to the same nest cavity year after year. Female enters the nest when she is ready to lay her eggs, and close the remaining opening prior to egg-laying, leaving only a narrow slit. Female enters the nest usually in mid-late March, but the length of nesting cycle varies between species. The nesting cycle of Great Hornbill range from 110-129 days, Wreathed Hornbill from 120-140 days, 93-97 days in Oriental Pied Hornbill (Datta, 2001), 55-58days in Visayan Tarictic Hornbill (Erik, 2000), average of 88 days for Malabar Grey Hornbill and average of 120 days for Rufous-necked Hornbill (Sherub, 2017; Kinley, 2016). A period of 55– 68 days for the North Sulawesi Hornbill is reported by O'Brien (1997). The female remains in the nest for the entire incubation period and for about 1 month following hatching of the chick. While incubation, she undergoes a complete molt in the nest shedding the feathers of the wings and tail. She and her offspring are entirely dependent on her mate for food during this period (HRF, 2017). Probably all the hornbill species have similar breeding habits; use of tree holes and plastering of entrance hole except Bucorvus, the Ground Hornbill (Morea, 1937).

The clutch size of hornbills are usually up to 4 (Chan *et al*, 2007). Hatching dates differ across species ranging from 28-46 days. The female remains with chicks inside nest even after

hatching. Only towards the end of the nesting period, female and the young simultaneously break out of the nest (Mudappa D. , 2000). She unloaded the soil, mud and sealed materials so the gap became wider (Margareta, 2017). The female comes out prior to nestling in some case and nestling inside reseal the cavity. In such case, both male and female then feed the nestling for few days until they are capable to come out and fly. But sometime the chick emerge following female on same day. The average fledging success are usually 1 or 2 per nest and sometimes fails (Wee, 2008; Datta, 2001; Datta, 2004).

2.4 Hornbills in Bhutan; Growth of Hornbill knowledge and threats to conservation

Bhutan with 23 Important Bird and Biodiversity Areas (IBAs), eight eco-regions, diverse ecosystems and eco-floristic zones have made country home to a wide array of flora and fauna (International, 2016). The country is rich in biodiversity and many species are yet to explore at ecological level. The 4 species of Hornbills in Bhutan are present only in certain parts and they are known very limited. Few studies are carried on hornbills but are focused on single species and very limited attempt to know at ecology level. At management level, it lacks specific policy to conserve hornbills due to lack of research data. Only Rufous-necked Hornbill, red listed as Vulnerable by IUCN is listed in the schedule-I of the Forest and Nature Conservation Rules and Regulation of Bhutan, 2017 as totally protected bird (Ra-online, 2000) and also it is the hornbill species of principle focus by conservation researchers in the country. Almost nothing is known about other 3 species of hornbill; GH. WH and OPH. Many people in Bhutan are unaware of ecological role of hornbills in the forest. A study in Phrumsengla National Park (PNP) found out 51.7% of inhabitants haven't seen RNH that exist in their locality (Kinley, 2016).

However to those to whom hornbills are known, they respect and honour hornbills. Hornbills are considered sacred and noble birds. They are believed to have simple life, monogamous nature of relationship, displaying faithfulness with their partners. The hornbills are said to be displaying majestic characteristics when they eat, flock, roost, etc... People love hornbills as they doesn't destroy agricultural crops (UWICER, 2017).

Many research has shown hornbills being large bodied birds with specialized requirement are severely impacted by the threats of habitat loss and fragmentation. For the survival of hornbills, they require large nesting tree with cavities and food resources which are chiefly associated in old-growth and undisturbed primary forest. However with expansion in human population, agriculture for food security and socio-economic development has caused encroachment into

hornbill's habitat. This has led to habitat fragmentation posing multi-conservation threats to the hornbills.

Bhutan with 69% of farming population, their dependent on forest is immediate to substantiate their livelihood. Dependence on forest resource with lack of conservation education becomes serious threat to hornbills in Bhutan. Timber extraction for the purpose of Forest Management Unit or timber felling for the demand of local public which sometimes coincides with the feeding and nesting tree species, as both hornbill and public prefer large size tree with clean bole are threats to the hornbills (Kinley, 2016; Cheki, 2017). Policy to provide subsidized timber resource has encouraged people to use more timber resource resulting maximum felling. Construction of road in the forest and clearing forest for electric transmission line has detrimental effects on fragmenting of viable hornbill habitat. Age old cattle herding practice by local communities where the cattle are graze in forest or the trees are lopped for fodder, setting temporary camp in the forest, wild fruits collection for consumption and for sell to generate income, cutting trees for handicraft making and NTFP collection for herbal medicine purposes poses habitat degradation and resource competition threats. Setting forest on fire carelessly, shifting cultivation and expansion of agriculture field degrade hornbill habitat. So far no report of hunting or poaching for Rufous-necked hornbills in Bhutan but status of other three species are unknown due to lack of research (WWF, 2009; UWICER, 2017; Sherub, 2017).

On addition to multi-anthropogenic threats, the hornbill also faces severable natural threats from both biotic and abiotic factors. Hornbill faces competition threats for nest cavity and food resources from other frugivores, dying of nest tree, rotting of nest cavities and preying from predators. Not only that, the country being in the Himalayan ranges, it experience spectrum of climatic conditions which are sometimes harsh and become threats to hornbills. Two Rufous-necked hornbill nest at Namling Yungma and Paimey la are badly destroyed by landslide in 2014. The tragic loss of three hornbills (female along with two fledglings) happened in Dochur, Lhuentse when nesting tree was broke down by strong storm. One female Rufous-necked Hornbill was crushed to death from felling of death tree at Lingmethang (UWICER, 2017).

CHAPTER 3 - STUDY AREA

3.1 Location of the study area

The study was carried in Jomotsangkha Wildlife Sanctuary (JWS) in Bhutan. The Sanctuary was notified as Khaling Wildlife Sanctuary in 1993. However the Sanctuary was under the jurisdiction of Samdrup Jongkhar Territorial Division until 2017 when it was separated as Jomotsangkha Wildlife Sanctuary with two range office; Jomotsangkha Range and Samdrupcholing Range Office. The Sanctuary has an area of 334.73 Sq.Km. It is located in the extreme southeastern part of the country, under Samdrup Jongkhar district. The sanctuary covers administrative blocks of five Gewogs namely Langchenphug, Serthig, Samrang, Pemathang and Phuntshothang Gewog. The area lies at the transboundary zone with India whereby it is bordered by Assam state to the south, Arunachal Pradesh to the east, Serthig geog to the north and Nyera Amachhu River to the west. The area lies between 26º48'N and 26º 60'N (Northing) and 91º42'E and 92º08'E (easting).

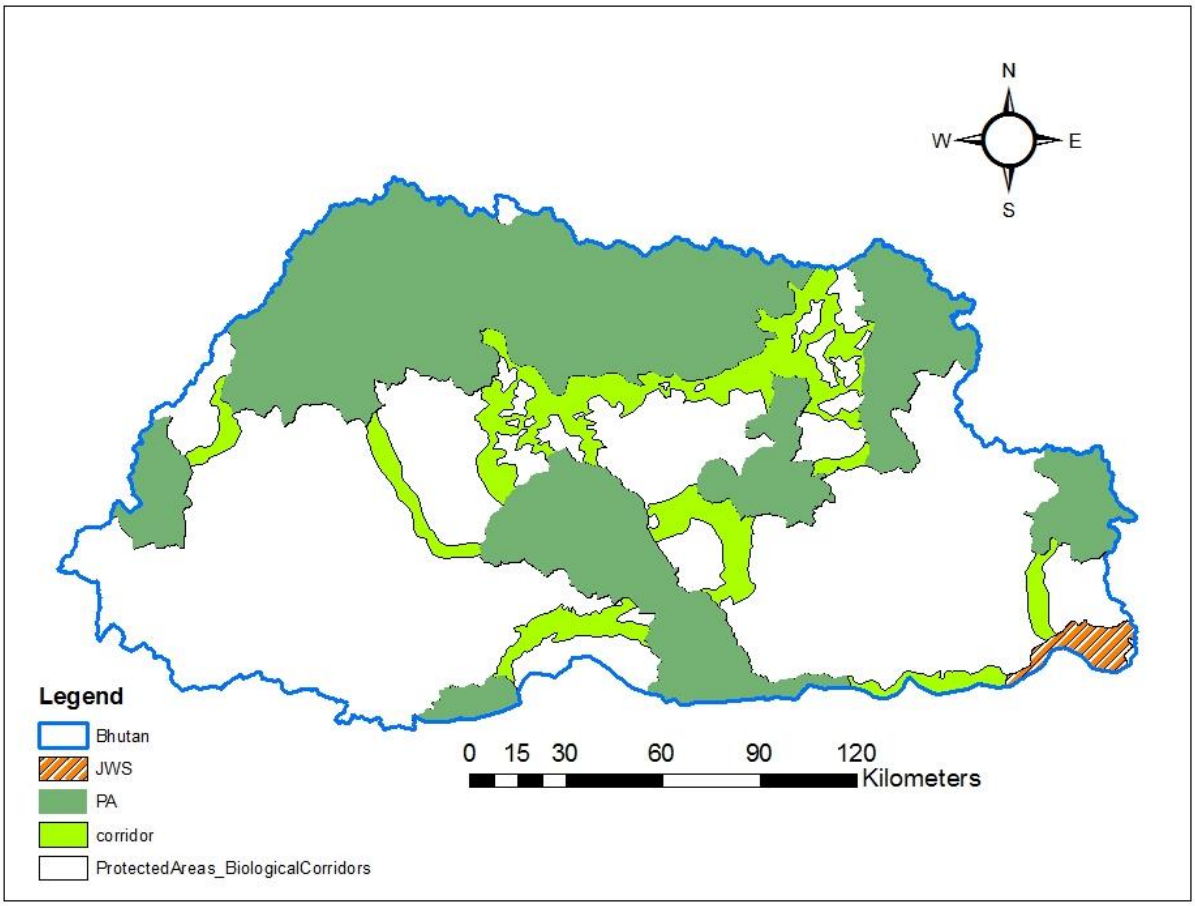


Figure 5. Bhutan map showing study area (JWS) and all the protected areas with connecting biological corridors (BC).

The area is hilly with undulating terrain. The altitude of the sanctuary ranges from 174m to 2300m. The area has many river systems and the river size fluctuate seasonally (becomes larger in monsoon season). Some of the major river system in the area are Jomori River and Chhukarpo River in the east, Samrang River and Kalanadi River in central and Nyera Amachhu and Nonai River in the west. The sanctuary consist of dense sub-tropical forest with both cool and warm broadleaved forest. It also has few grass land fringing along the southern bordering areas. The primary broadleaved forest with thick canopy and less disturbed in the area is an important habitat for many wildlife species therein.

3.2 Jomotsangkha Wildlife Sanctuary and People

The sanctuary lies in the Indo-Malayan realm and it is one of the biodiversity hotspot in the country. The sanctuary is habitat for diversity of flora and fauna including many globally threatened animals and keystone species of conservation focus. The endangered Asiatic elephants (*Elephas maximus*) and vulnerable Gaur (*Bos gaurus*) are the two megafauna known to everybody in the area owing to their large size and life threatening experiences of people. Critically Endangered Pygmy hog (*Porcula salvania*) and Chinese Pangolin (*Manis pentadactyla*) are reported in the sanctuary but no latest record of Pygmy hog due to lack of survey. Presence of Endangered Bengal Tiger (*Panthera tigris tigris*) was confirmed by camera trapping in 2015. In addition, the information received from camera trap also include presence of Hispid hare (*Caprolagus hispidus*), Asiatic Black Bear (*Ursus thibetanus*), Common leopard (*Panthera pardus*), four types of small cat [VU Clouded leopard (*Neofelis nebulosa*), NT Asiatic golden cat (*Catopuma temminckii*), and Marbled cat (*Pardofelis marmorata*) and LC leopard cat (*Prionailurus bengalensis*)], the total of 23 mammal species in the sanctuary. More than 200 species of birds are recorded in the sanctuary including four species of charismatic hornbills. The sanctuary is also home for diversity of herpetofauna, butterfly, orchids and many biodiversity upon which the survey is still going on to formulate management plan for this newly established sanctuary.

Similar to many of the protected areas (PAs) in the country, the Jomotsangkha Wildlife Sanctuary (JWS) also have people living within it. More than 500 households lives in the area. The people living within are primarily farmers. They depends on agriculture and forest for their livelihood. The people cultivate paddy and maize as their main stable food. They herd cattle and goat and is an integral part of their farming life. Addition to milk and butter, the manure for agriculture field are the main reason for rearing cattle.

3.3 Intensive study site within Jomotsangkha Wildlife Sanctuary

It was not possible to survey whole area of the sanctuary intensively due to terrain and thick forest. Therefore, the area is narrowed down to approximately 90 Sq.Km, within which the intensive survey was done. The intensive study area lies within the jurisdiction of Langchenphu goeg, which is also the geog that covers maximum part of JWS. The intensive study area falls under Jomotsangkha range in the eastern side. Within this area, the survey was carried around the forest of four main villages;

1. **Jampani village;** the village is located 4.35km away towards north from Jomotsangkha main town. It is in the extreme eastern part of the sanctuary. Geographically the area is located at 26º55.426' N and 92º06.146' E. more than 30 household lives in the area. The forest around Jampani village is a good habitat for hornbills. The tree species mainly found in the area of hornbill importance either for perching, roosting or nesting are *Ficus* sp., *Tretameles nudiflora*, *Daubanga grandiflora*, and *Terminalia* sp.

2. **Tokaphu village;** the village is on the way towards Menjiwoong from Jomotsangkha main town. It is located at the distance of 11.23km from Jomotsangkha towards North West direction. Comparatively very few people lives there with only 5 households. Three trails were walked in the forest near to Tokaphu village. Geographically the area is located at 26º57.051'N and 92º04.156'E at the elevation of 400m. Apparently the forest around this village are more continuous and less disturb. Hornbills dwells around this area mainly feeding on *Blechimedia* sp., *Ficus* sp. and *Aglia* sp. on addition to many others.

3. **Agurthang village;** the Agurthang village is located up on the hill at the elevation range of 520m to 733m towards North West direction from Jomotsangkha town measuring 5.35km along the footpath from Jomotsangkha. The area is located at 26º54.276'N and 92º04.021'E. Two trails were walked in the nearby forest of Agurthang village, one trail towards Agurthang village from Jomotsangkha village and other moving up towards Ani Uni Mountain from Agurthang. Not more than 30 household lives in the area. The people grow maize as a stable food in this area. They herd cattle that are freely graze in the vicinity forest most of the time.

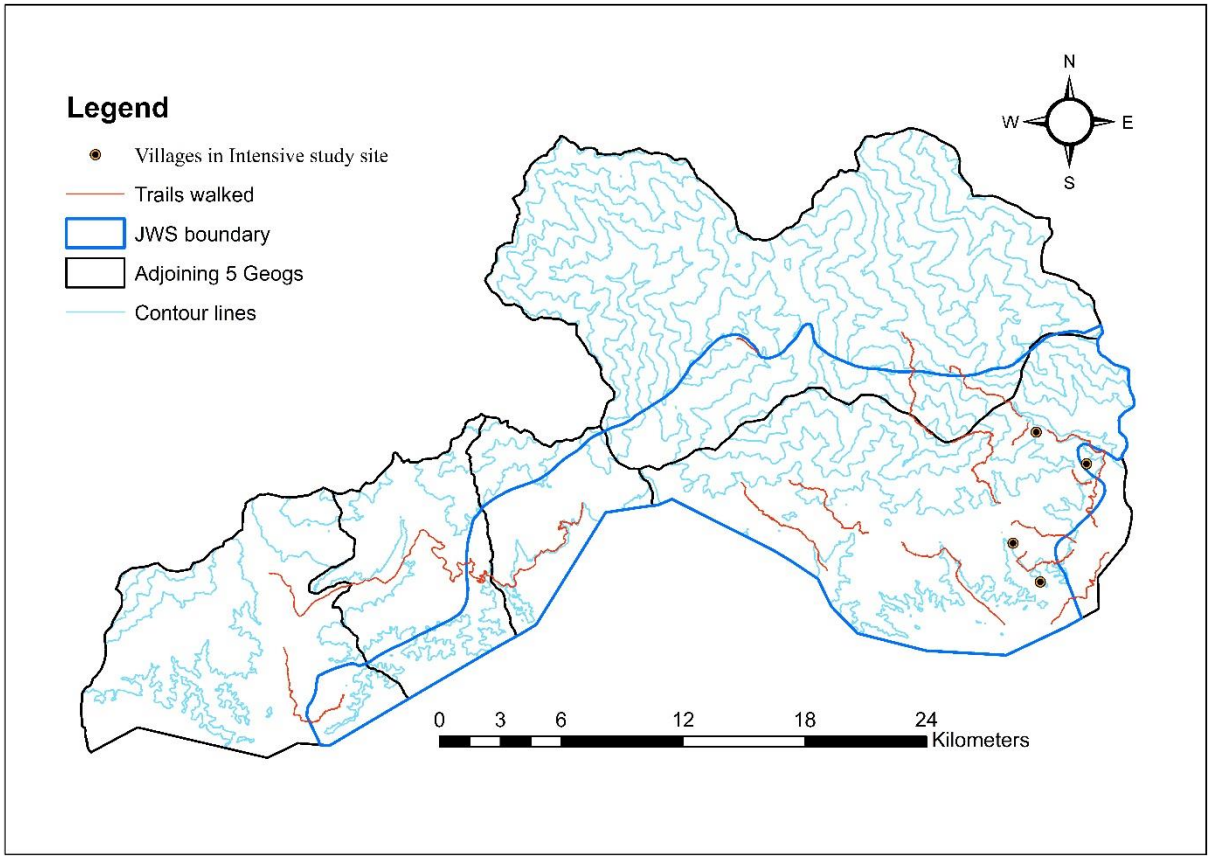


Figure 6. Map of Jomotsangkha Wildlife Sanctuary with five adjoining geogs showing trails walked in it.

4. **Namchazor village;** the Namchazor village is located towards South of Agurthang and towards West from Jomotsangkha village, measuring 5.17 km away from latter. The village is at elevation of 378m. Geographical location of the village is 26º53.184'N and 92º03.973'E. Three trails were walked in the forest around Namchazor village. Around 20 household live in the area and people grows paddy as stable food in this village.

CHAPTER 4 – MATERIALS AND METHOD

4.1 Methods

4.1.1 Research design

Prior to the field visit, visualization of the study area was done using ArcMAP10.3 and Google Earth. By this, the landscape and topography of the area along with forest cover and forest types, drainage, road map, settlement, rivers, habitat type and various altitudinal range were visualized. By these visualization, the geographical landscape of the area appeared undulating terrain and hilly, densely covered with broadleaved forest in which the transect method will be difficult or impossible. Therefore the trail walk method was adopted wherever it was possible by selecting the sampling area randomly.

4.1.2 Consultation and preliminary survey

Having done visualization of the area, then visited to the field for preliminary survey. At field, initially had a brief conversation with Chief Forestry Officer and forestry staffs of JWS. Local people were interviewed whenever encountered and gathered information about area and species. Based on the information gathered from local people, forestry officials and the terrains in the area, the trails to walk for data collection were identified. The trails identified were usually along the foot paths, farm roads and animal trails in the forest. During trail location, the precautions were taken not to locate two trails much closer and the trails were distributed proportionately to the area. Based on the information and preliminary observation, the intensive study area was chosen to carry intensive study.

4.1.3 Study on Population status of sympatric hornbills

A research team comprised of three members had walked along the identified trails. The trails were of variable length ranging from 2km to 27km. The team took a trail walk between 7:00 to 10:00 in the morning and 3:00 to 5:00 in the evening, except one trail along the border was walked for whole day because of insurgency reason and it was the longest trail walked. All the trails were walked once but 9 trails in the intensive study area were walked 3 times. The trails were walked at the rate of 2km/hrs. Sampling timing, and starting and ending point of the trails in the intensive area were reversed on alternative survey to avoid biases associated with time of the day.

During the trail walk (survey) the data were recorded upon both ocular sighting and hearing call. Observation of flying species were recorded but were not counted in population status to avoid repeated counting. The observers had recorded (1) focal species (and sex when possible), (2) number of individuals (male, female and juvenile), (3) flock size, (4) detection cue/activity (visual, vocal or flying), (5) location (lat., lon. and elevation), (6) direction and estimated distance between the focal species and observers (7) other relevant information, for example the tree upon which the species was sighted and height, DBH and canopy cover of it.

4.1.3a Analysis

The number of individuals sighted were analyzed with respect to altitudinal range because it was not possible to analysis at habitat type level since all the trails walked were in similar forest type. The population status was analyzed based on encounter rate (ER). The encounter rate were calculated in two categories; trail wise and species wise.

4.1.4 Dietary study of sympatric hornbills

The determination of diet of hornbills were relied intensively on observation on foraging, regurgitated seeds and middens below the nest and roosting site and by nest watches (by observing on the fruit species the male deliver to female in the nest after female incarceration). The fruit species on which hornbills forage was recorded whenever the hornbills were observed foraging (during trail walk or by opportunistic survey). Regurgitated seeds and middens below roosting, perching and nests were collected and identified. Fruits recorded consuming were noted ripe or unripe.

4.1.4a Analysis:

The total food items of all the hornbill species during pre-breeding season in Jomotsangkha wildlife sanctuary were recorded as fig fruits, non-fig fruits and animal matters and were analyzed.

4.1.5 Study of nesting site of hornbills

Nests were located by local people information, following lone male after initiation of breeding season and by intensive searches in the area by inspecting potential nest trees with cavities for middens (piles of regurgitated seeds and fecal matter) indicating active nest. After the location of nest, several nest tree and nesting habitat parameters were recorded. The following nest site variables were recorded; nest tree species, DBH of nest tree, height of the nest tree, height of nest cavity, height of first branch of nest tree, emergence of nest tree, and distance to human

habitation, road and river. The canopy cover, altitude at ground level of the nest tree, position of nest hole in the forest strata, the location of nest on nest tree, cavity orientation and shape of the nest holes were also recorded. The diameter of tree trunk at nest cavity and the dimension of the nest hole (length and width of cavity hole) were visually estimated. In addition, by taking nest tree as a center, all the tree species with DBH ≥ 30 cm within the radius of 15m were measured and enumerated to determine the characteristics of nesting habitat used by the hornbills.

4.1.6 Study of roosting site of hornbills

Roost site of the hornbill were located based on local people information, by following hornbills in the direction in which they fly in the evening between 15:30 to 18:00, looking for roosting sign (piles of regurgitated seeds) under potential roost trees and by searching in similar site habitats. At the roost site, the structural characteristics of roost tree; roosting tree species, tree DBH, tree height, canopy width, height of first branch, roosting height, distance to human settlement, road and river were recorded. To understand the roosting site habitat, the site parameters such as tree species with DBH ≥ 30 cm within the circular plot of 15 m radius by keeping roosting tree as center were recorded. In the roost area, observers have recorded time of arrival, hornbill species, number (and sex when possible), flock size and direction from where they arrived.

CHAPTER 5: RESULT

5.1 Population status of sympatric hornbills

A total of 15 trails spanning a total of 205 km were walked for 105 hr. The length of the trail ranged from 2 km to 27 km and traversed through different elevation ranges. Nine trails walked were below 1000m, 4 trails below 500m and one trail each above 1000m and 2000m. During the survey, four species of hornbills; Great Hornbill (GH), Oriental Pied Hornbill (OPH), Wreathed Hornbill (WH) and Rufous-necked Hornbill (RNH) were sighted. In all 94 sightings were made during the entire survey, of which great hornbills was sighted more with 60 sightings, the details are given in the Table 1.

Table 1. Number of sightings of four hornbill species along 15 trails.

Trail ID	**Total KM walked**	**Number of sightings**			
		GH	OPH	WH	RNH
T1 (Jomo-Tokaphu)	27	8	2	2	2
T2 (Jampani)	6	13	4	5	0
T3 (Chetori)	6	3	0	0	4
T4 (Jomo-Golanti)	18	2	0	0	0
T5 (Agurthang)	12	7	1	3	0
T6 (Namchazor)	15	2	1	0	0
T7 (Toka-M)	18	2	0	0	1
T8 (Ani uni)	21	1	0	1	1
T9 (Howrong)	24	2	2	0	0
T10 (Menji-Ani)	7	1	0	0	0
T11 (Kherkher)	7	1	1	0	0
T12 (Khalingduar)	7	2	0	0	1
T13 (Samrang)	27	8	1	1	0
T14 (Bangtar)	8	8	0	1	0
T15 (Chemari)	2	0	0	0	0
Total	**205**	**60**	**12**	**13**	**9**

Total number of hornbills seen were 245 individuals that included 29 individuals spotted flying. The details on number of individuals of different hornbill species sighted at different altitude range is given in the Table 2. The highest number of hornbills sighted was below 500m, with 140 individuals sighted. Between 500m to 1000m, 103 individuals were sighted. Only two individuals were sighted between 1000-1500m, while none were seen above 1500m.

Table 2. Hornbill individuals sighted at different altitude range

Hornbill Species	Altitude range (m)					Individuals sighted	
	<500	500-1000	1000-1500	1500-2000	Total	Flying	On trees
GH	94	75	2	0	171	23	148
OPH	28	9	0	0	37		37
WH	12	10	0	0	22	5	17
RNH	6	9	0	0	15	1	14
Total	140	103	2	0	245	29	216

5.1.1 Encounter rate (ER)

The population status of the hornbill species in Jomotsangkha wildlife sanctuary was determined based on encounter rate (ER). The encounter rate was calculated under two categories; trail wise and species wise.

5.1.1a Trail wise encounter rate

Among the trails walked, the encounter rate of hornbills range between 0 - 14.7 in the area. The T2 (Jampani) trail was having the highest ER distinctively, despite the fact it is one of the shortest trail walked. However no single individual of RNH was sighted in the trail with highest encounter rate of hornbills. As shown in table 3, no single individual of hornbill is sighted in trail T15 (Chemari).

Table 3. ER of different hornbill species in all the trails walked.

Trail ID	Total KM	No. of individual sighted				Total	ER
		GH	OPH	WH	RNH		
T1 (Jomo-Tokaphu)	27	15	8	3	3	29	1.1
T2 (Jampani)	6	70	9	9	0	88	14.7
T3 (Chetori)	6	4	0	0	7	11	1.8
T4 (Jomo-Golanti)	18	3	0	0	0	3	0.2
T5 (Agurthang)	12	12	4	4	0	20	1.7
T6 (Namchazor)	15	4	5	0	0	9	0.6
T7 (Toka-M)	18	6	0	0	2	8	0.4
T8 (Ani uni)	21	2	0	2	2	6	0.3
T9 (Howrong)	24	8	4	0	0	12	0.5
T10 (Menji-Ani)	7	5	0	0	0	5	0.7
T11 (Kherkher)	7	2	2	0	0	4	0.6
T12 (Khalingduar)	7	3	0	0	1	4	0.6
T13 (Samrang)	27	23	5	2	0	30	1.1
T14 (Bangtar)	8	14	0	2	0	16	2.0
T15 (Chemari)	2	0	0	0	0	0	0.0

5.1.1b Species wise encounter rate (ER)

Among the four hornbill species sighted in the area, the encounter rate is highest in Great Hornbill with 0.8 followed by Oriental Pied Hornbill with 0.2. The Wreathed Hornbill and Rufous-necked Hornbills are having equivalent encounter rate with 0.1 each.

i) Great Hornbill (GH)

The encounter rate of Great Hornbill is highest along T2 (Jampani) trail with 11.7 shown in Figure 7, despite it was one of the shortest trail walked measuring 2 km. Along the other trails, the encounter rate doesn't differ much, ranging between 1.0 and 1.8. Out of 15 trails walked, the Great Hornbills were sighted along all the trails except T15 (Chemari) trail.

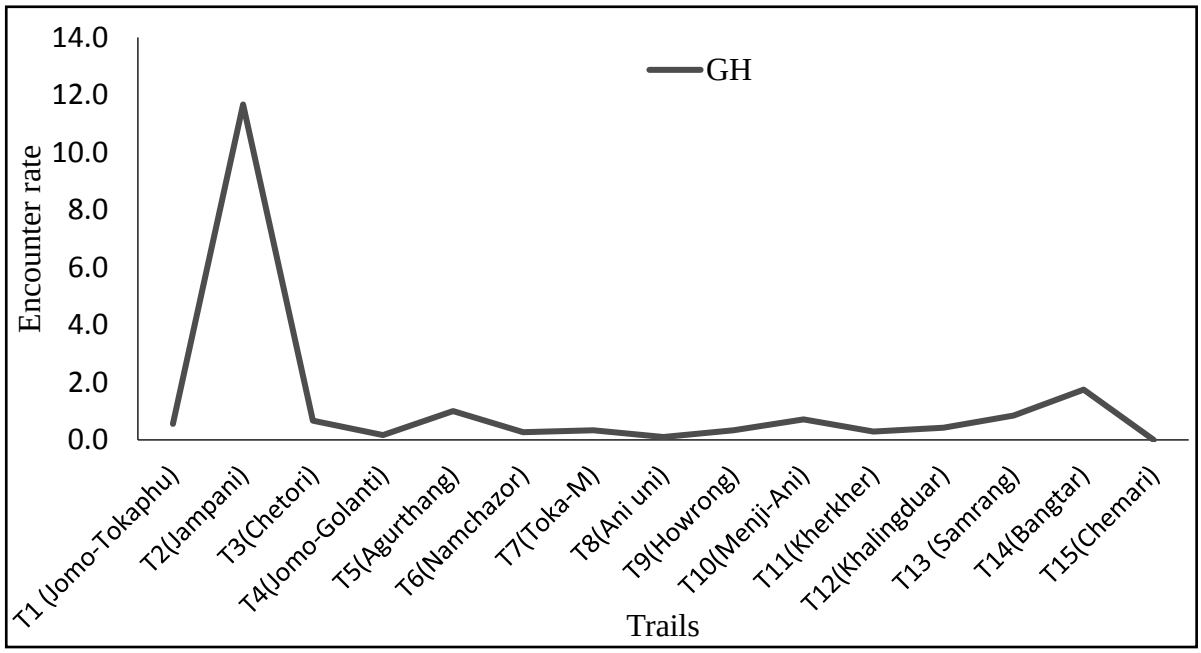


Figure 7. Encounter rate of Great Hornbill (GH)

ii) Oriental Pied Hornbill (OPH), Wreathed Hornbill (WH) and Rufous-necked Hornbills (RNH)

The overall encounter rate of Oriental Pied Hornbill (OPH), Wreathed Hornbill (WH) and Rufous-necked Hornbills (RNH) are much lower than Great Hornbill. The Encounter rate of OPH, WH and RNH ranged between 0.2-1.5, 0.1-1.5 and 0.1-1.2 respectively. The T2 (Jampani) trail was having the highest encounter rate of Oriental Pied Hornbill and Wreathed Hornbill. However, no single individual of Rufous-necked Hornbill was sighted along it. As depicted by Figure 8, the encounter rate of Rufous-necked Hornbill was highest along the trail T3 (Chetori).

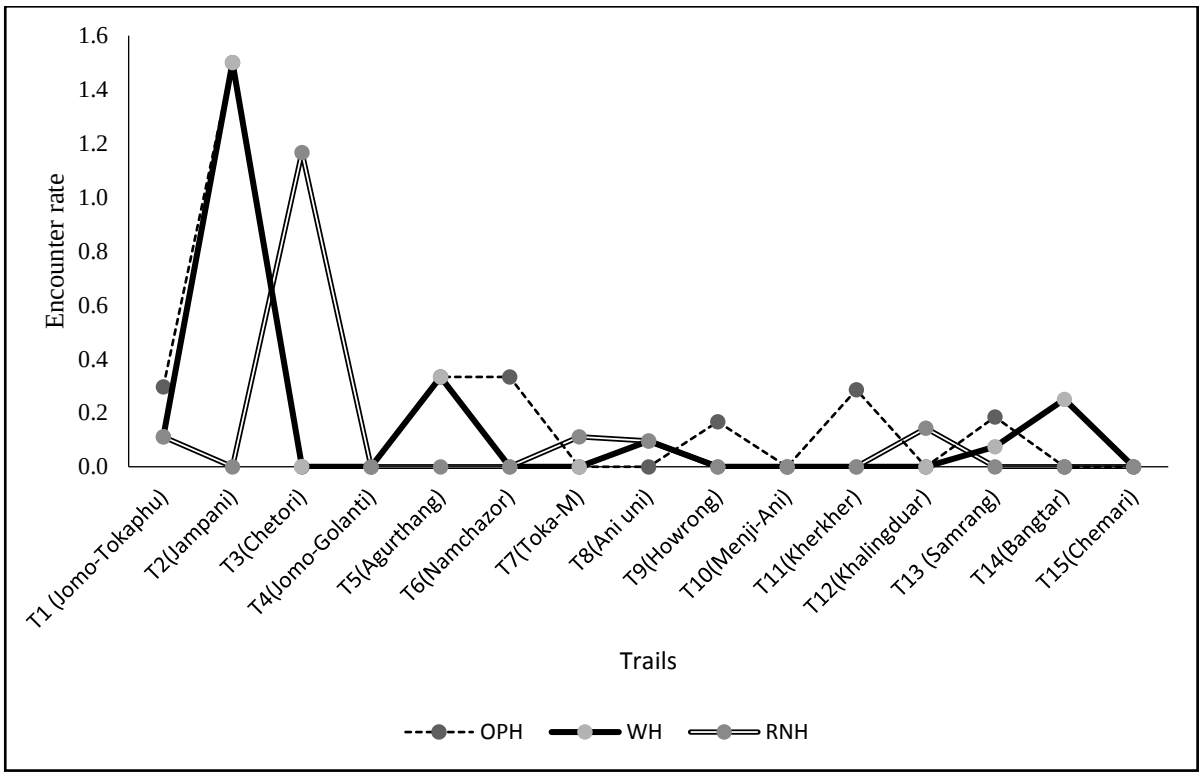


Figure 8. Encounter rate of OPH, WH and RNH along the trails walked.

On the contrary, there was no encounter of OPH, WH and RNH along the trail T4 (Jomotsangkha to Golanti), T10 (Menjiwoong to Ani Uni) and T15 (Chemari). Out of fifteen trails, Oriental Pied Hornbill, Wreathed Hornbill and Rufous-necked Hornbill were sighted only in 7 trails, 6 trails and 5 trails respectively.

5.2 Diet of sympatric hornbills

5.2.1 Food diversity and consumption

The hornbills had a varied diets. A total of 46 food species (3 unidentified) were recorded in the diets. Fruits comprise the largest proportion of the hornbill diets for all four species. Total of 10 fig fruits species, 32 non-fig fruits species and 4 animal species were recorded from the diet. The contribution of different food type differ between the four hornbill species as shown in Figure 9. Ripe fruits comprised 94.3% of food item for Great Hornbill, 89.5% for Oriental Pied Hornbill, 95.8% for Wreathed Hornbill and 92.3% for Rufous-necked Hornbill. The data on number of times a hornbill is feeding on particular food species or carrying to the nest was not collected.

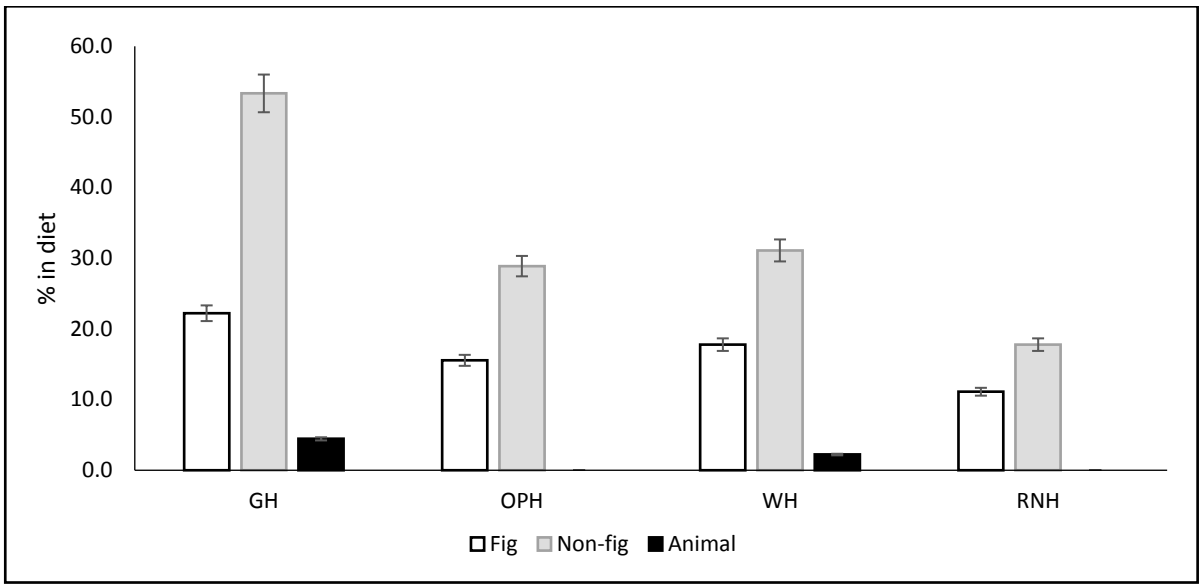


Figure 9. Percentage contribution of different food types in the diet of four hornbill species in the early breeding season.

The variety of diet consumed by hornbills are from sixteen families (Figure 1). The maximum diet species consumed are from Meliaceae and Moraceae accounting 25.6% each of the total diet. The percent of diet consumed from other 14 families range between 2.56% - 7.69%.

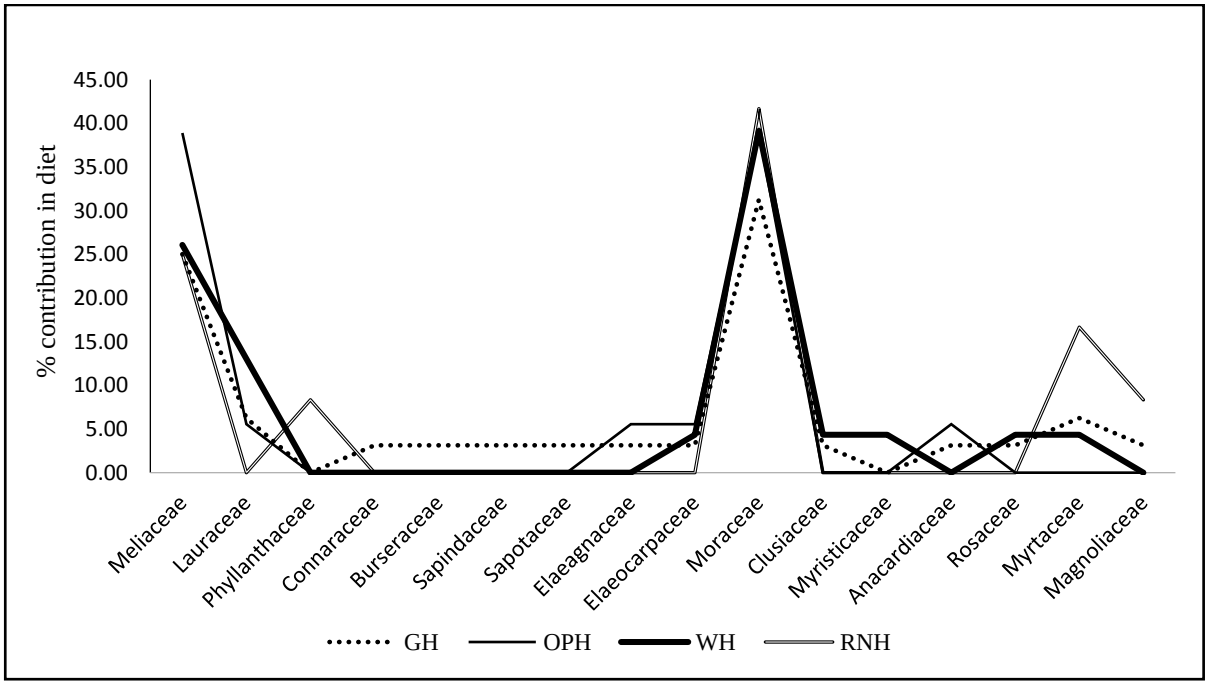


Figure 10. The percent contribution into the diet of four hornbill species by sixteen families of diet species.

The animal species recorded in the hornbill diet; chicks of Bulbul were carrying by male hornbill to its nest, two species of Coleoptera bettle and one species of Crab consumed by hornbills were considered separately from plant families in determining diet contribution. Among the fruit species recorded in the diet, the hornbills hardly feeds on fruit belonging to families other than Meliaceae and Moraceae, as depicted in Figure 10.

5.3 Nesting of hornbills

5.3.1 Nesting site characteristics

Total of 13 nesting sites were located in the Jomotsangkha Wildlife Sanctuary and adjoining forest. From the total, 12 nest were active and one nest was abandoned. Both live and death trees were used for nesting where 92.31% of nest were on live tree. Five species of tree were used for nesting and 69.23% of nest were found on *Tetrameles nudiflora*. *Tetrameles nudiflora* was used for nesting by Great Hornbill, Oriental Pied Hornbill and Wreathed Hornbill. Whereas no nest of Rufous-necked Hornbill was recorded in this tree species. Mean height of nesting tree was 40.31m and mean diameter at breast height was 82.07cm.

Nesting trees were found both in open forest and dense forest. Out of 13 nest, 8 were found in dense forest. Nest of GH, OPH and Wreathed Hornbill were found both in open as well as dense forest, but nest of Rufous-necked hornbill was found in dense forest. From the total, 7 nests were for Great hornbill, 2 nests for Oriental Pied Hornbill, 3 nests for Wreathed hornbills and one nest for Rufous-necked Hornbill.

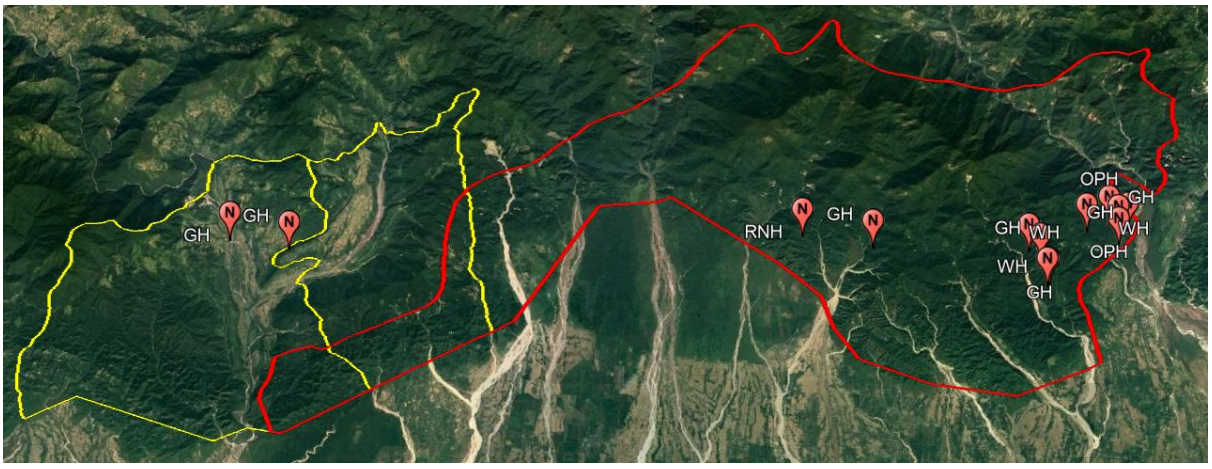


Figure 11. Location of nesting site of hornbills in Jomotsangkha wildlife Sanctuary and adjoining two geogs.

In all the nesting sites, the nesting tree was emerging above all surrounding trees with DBH ≥ 30 cm considered within 15m of radius by keeping nesting tree at the center. Total number of

trees within the circular plot around nesting tree in dense forest range from 7 to 12 whereas less than 5 trees were found around nesting trees in open forest.

The nesting sites were found distributed at various altitudinal range. As shown in the Figure 12, the maximum number of nest were recorded between 250-500masl. Only one nest of RNH was found between 750-1000 m above sea level.

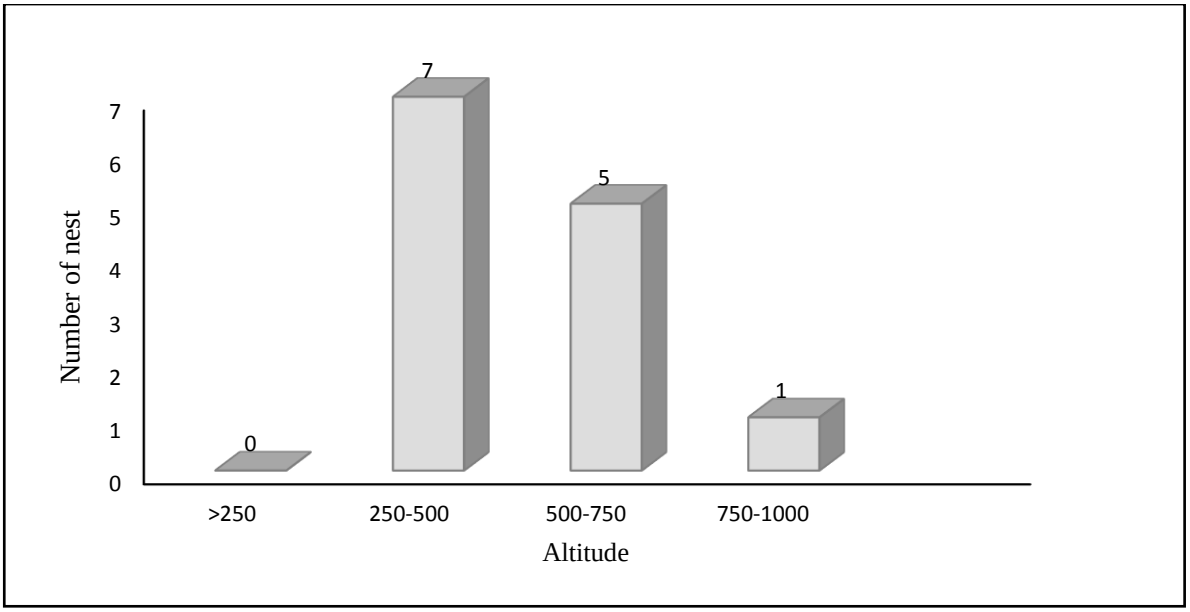


Figure 12. Number of hornbill nest distributed at different altitude range

The distance between nesting site and human habitation ranged between 100 m - 2 km with the mean distance of 453.8m. The distance to road from the nesting area ranged between 3 m – 400 m with the mean distance of 148.15m and the mean distance of nesting site from river was 226.9 m (Figure 13) with the distance to river ranging from 10m-500m.

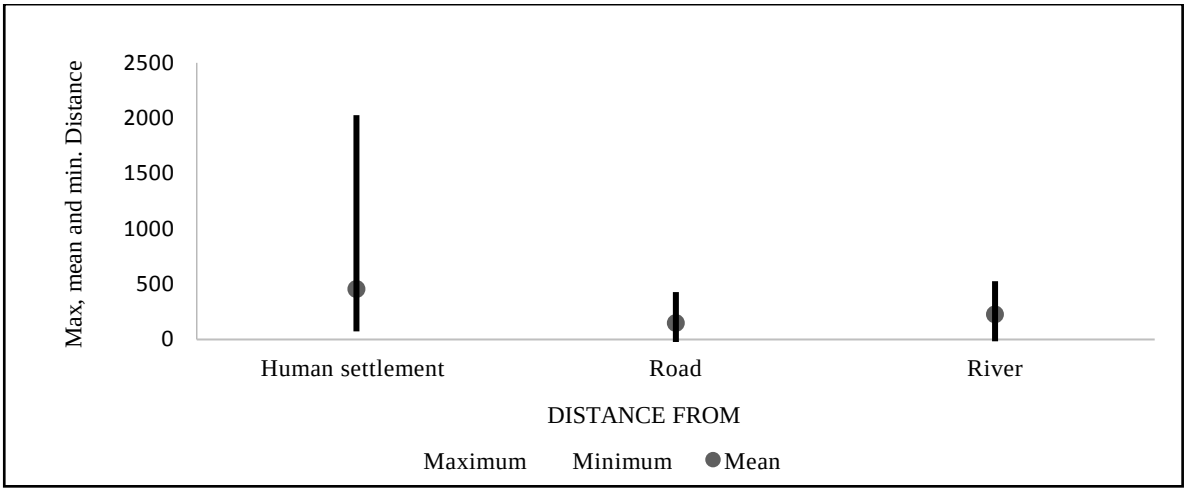


Figure 13. Maximum, mean and minimum distance of nest from human settlement, road and river.

5.3.2 Nest cavity characteristics

The majority of nest cavity were on middle third of the tree except two in upper third. The mean nesting height was 23.69m and the mean diameter at nest height (DNH) was 49.46cm. The mean distance between nest cavity and canopy top of nesting tree was 16.61m. Majority of nest cavity does not emerge above the canopy top of surrounding trees with only 23.07% emerging above with respect to surround forest strata.

All the nest cavity was on the main tree trunk except two on branch. Apparently 8 nest cavities were formed as a result of heart rot where the branches had broken off whereas rest were excavated by primary cavity nesters. The shape of cavities were generally circular and elongated. The mean width and length of cavity were 14.9cm and 20.23cm respectively. However there was a significant differences in nest cavity length of Great Hornbill and other three hornbill species, shown in Figure 14.

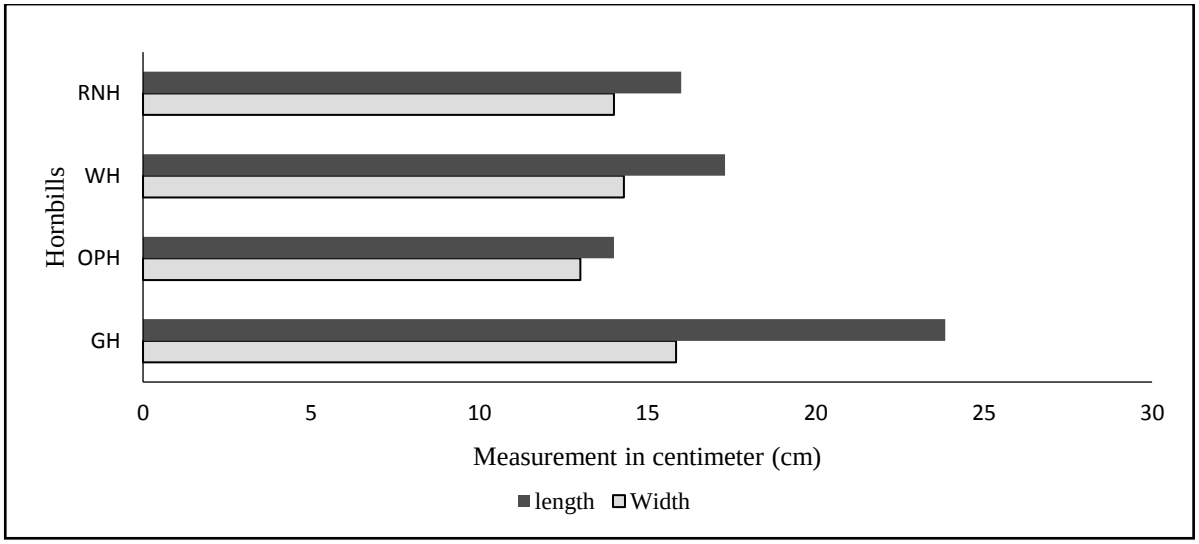


Figure 14. Width and Length of nest holes of four hornbill species.

The orientation of nest cavity was in multi-direction. However most of the nest were oriented towards North East (NE) and North West (NW) accounting 31% each as shown in the Figure 15. The mean degree of nest orientation was 161.08º.

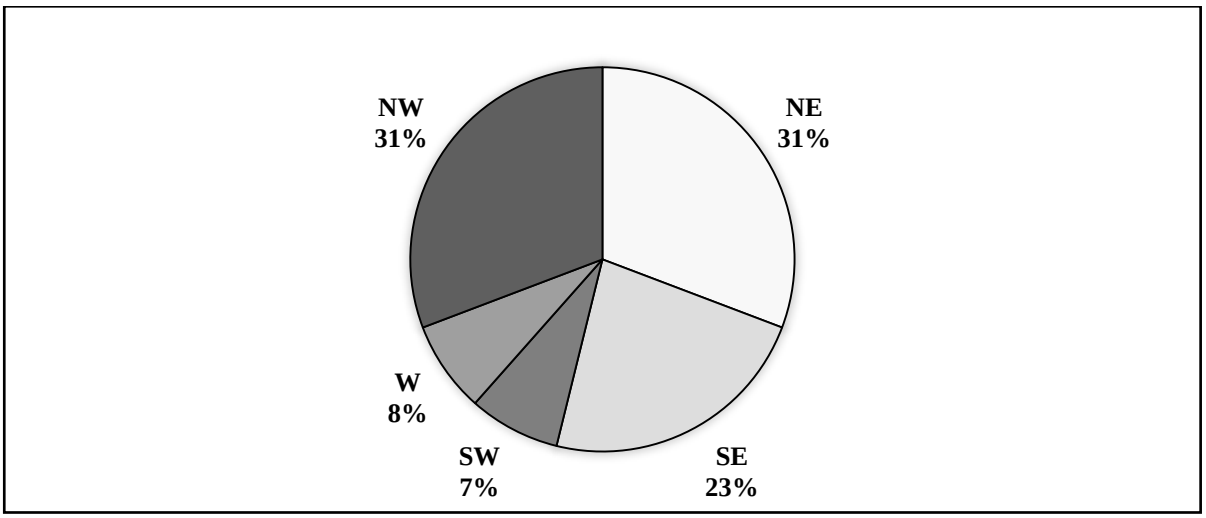


Figure 15. Orientation of nest cavity based on number of nest oriented towards particular direction.

5.4 Roosting site of hornbills

5.4.1 Roosting site characteristics

Nine roosting sites were located in Jomotsangkha Wildlife Sanctuary (JWS) and adjoining forest. All except two roosting site at Dungkarling village were inside of JWS. From the total roosting site located, 7 were for Great Hornbills and one each for Oriental Pied Hornbills and Wreathed Hornbills. No single roosting site of Rufous-necked Hornbills could be located. The structural characteristics of hornbill roost trees are given in Table 4. The mean height of main roosting tree was 38.11m ±5.3 and the mean diameter at breast height was 79.44cm ± 32.2. Thus the hornbills uses smaller trees for roosting than nesting. Five specific tree species used for roosting were *Bombax ceiba, Tetrameles nudiflora, Albizzia procera, Quercus* sp. and *Tectona grandis*. Among all, the *Tetrameles nudiflora* account for 55.56% of the total roosting tree was the mostly used species for roosting in JWS.

Table 4. Roost sites characteristics

Si.no.	Roost site characteristics	Mean
1	DBH of Roost trees	79.44cm ± 32.2, n=9
2	Roost tree height	38.11m ±5.3, n=9
3	Height of lowest limb of roost tree	23m ± 7.9, n=9
4	Distance to human habitation	536.67m ± 118.5, n=7
5	Distance to road	170m ± 99.2, n=9
6	Distance to River	362.22m ± 304.6, n=9
7	Altitude	393masl ± 92.6, n=9
8	Slope	40.66^{o} ± 16.3, n=9
9	Number of trees in the roost plot (15m radius)	7 trees ± 1.6, n=9

Roosting sites were located in open, primary and in plantation forest. All the roosting tree of Great Hornbill emerge above the canopy top of surrounding trees in a roost area, whereas the roosting trees of Oriental Pied Hornbills and Wreathed Hornbills does not emerge above canopy top of surrounding trees. Great Hornbills roost on larger trees as compared to Wreathed Hornbills and Oriental Pied Hornbills with respect to mean height and mean DBH of roosting trees. Figure 16 depict the differences between mean height and DBH of roosting trees among three hornbill species.

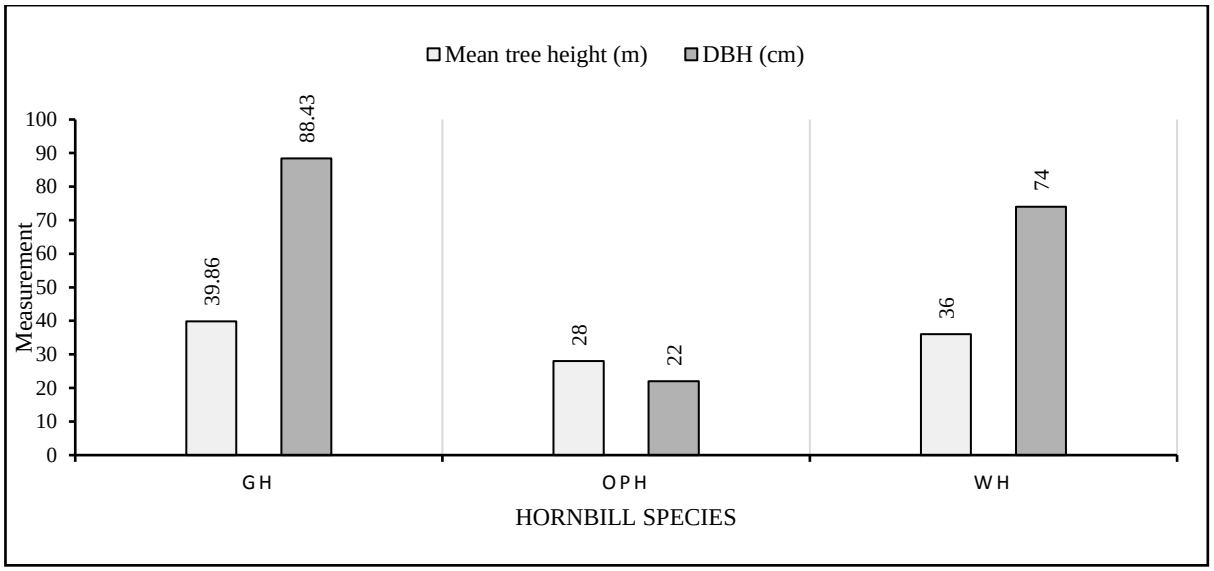


Figure 16. The mean height and mean DBH of roosting trees used by three different hornbills in JWS.

The mean number of trees within 15m radius roost plot by keeping main roosting tree at the center was 7 trees ±1.6. Majority of roosting site were located at forest edge, fringing with human habitation area. As a result, 55.6% of roosting sites were located within 100m from human habitation. One roosting site of Oriental Pied Hornbills was located in plantation forest of *Tectona grandis.* Figure 17 shows location of roosting site in the region.

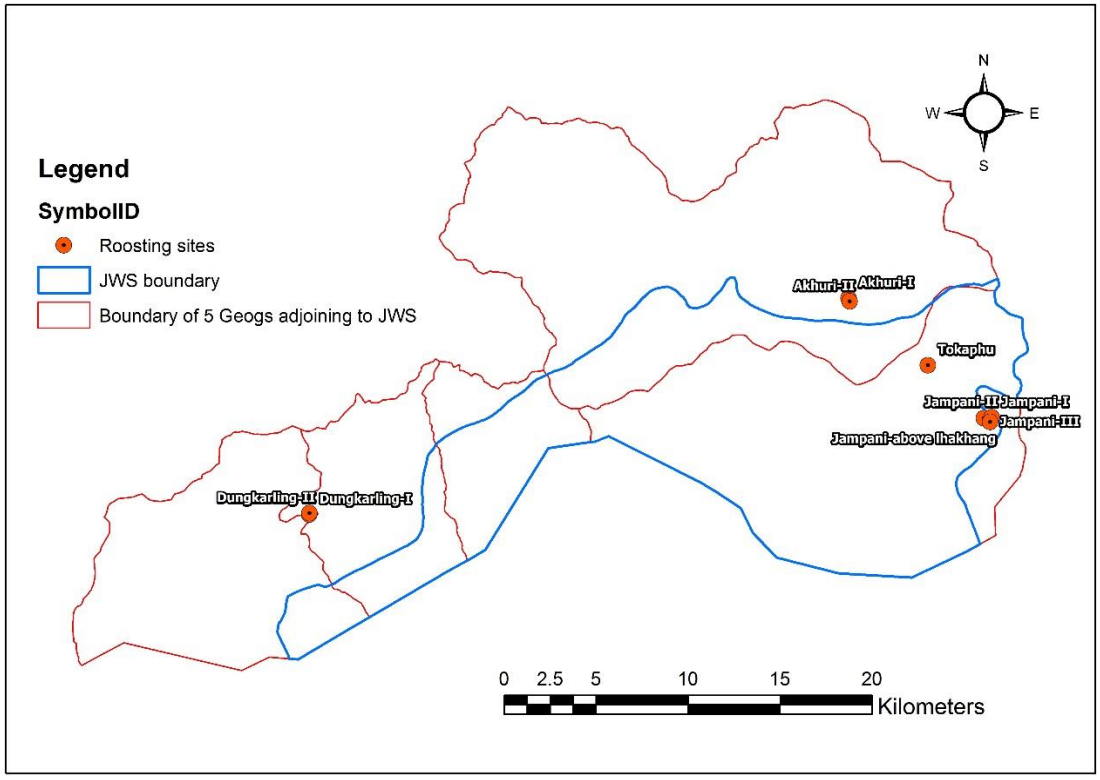


Figure 17. Location of roosting sites of Great Hornbill, Oriental Pied Hornbill and Wreathed Hornbill within Jomotsangkha Wildlife Sanctuary and adjoining five geogs.

The roosting sites were located within the altitude range of 302-539m above sea level. There were no altitudinal variation of roosting site location between different hornbill species. Interestingly two roosting sites of two different species, Great Hornbills and Wreathed Hornbills were located close to each other about 150m apart at Akhuri. In the evening when flying to respective roosting sites, the encroachment of one species into roosting site of another species happens where by result in chasing away by flock of species of respective roosting area were observed. The slope of roosting sites ranged from 12-54 degree, reflecting moderate to very steep. The mean slope at roosting site was 32.9^{o}±14.3.

5.4.2 Count of hornbills at roost sites

After locating roosting sites, the roosts were visited one time each between 16:50 and 18:20 in the evening. With one sighting at each roost, total of 9 sightings were made during the entire study period. Of this, 7 sightings were Great Hornbill and one sighting each of Oriental pied Hornbill and Wreathed Hornbill were made. From this, total of 156 hornbills were counted at roosts, of which 104 were Great Hornbill, 27 Oriental Pied Hornbill and 25 Wreathed Hornbill. The number of Great Hornbill in the roost range from 2 (pair) to 42 individuals (flock), whereas single roosting site were sighted each for OPH and WH and flock size at the roost were 27 and

25 respectively. The sex of the hornbills at roost were determined based on physical appearance. Figure 18 shows the details on sex composition of three hornbill species at the roost.

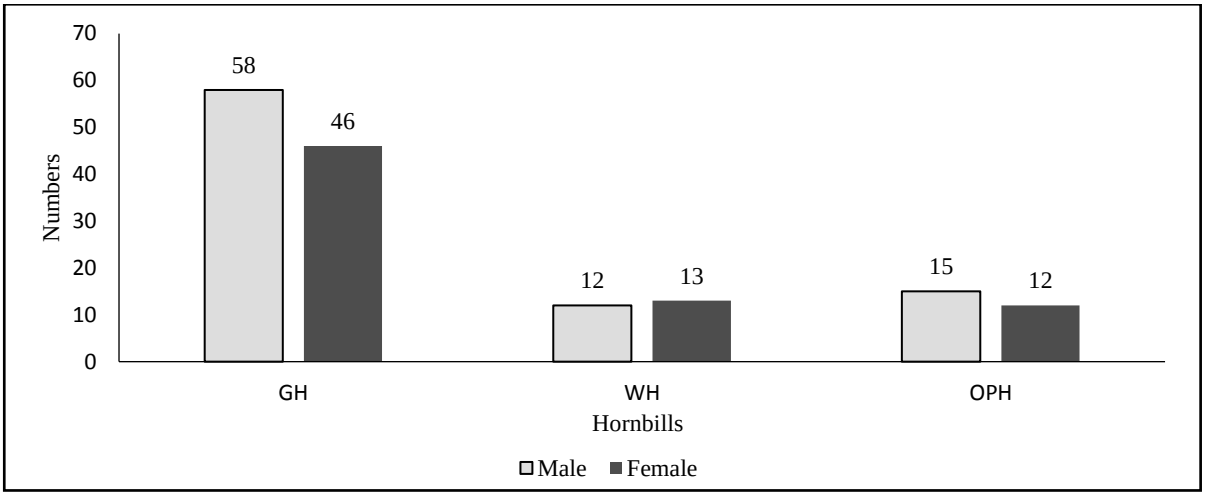


Figure 18. Count of male and female of three hornbill species at the roost.

CHAPTER 6: DISCUSSION

6.1 Population status of sympatric hornbills

This study is the first of its kind in Jomotsangkha Wildlife Sanctuary that focused on any aspects of the ecology of hornbills. From the study the Great Hornbill was the commonest species in the region. This could be because the study was carried mostly in the foothill regions having tall and evergreen old-growth primary forest which is the primary habitat of this largest frugivorous species in the region. We also expected to see Wreathed Hornbill in equal numbers as that of Great Hornbill in the area however that was not the case. We presume this is to do with the distribution range of Wreathed Hornbill in Bhutan as its westernmost limit ends here. This could also be because of wide ranging feeding behavior of Wreathed Hornbill as a result it was sighted less. WH are reported range over 28 km2 during non-breeding season and to feed more on lipid-rich drupaceous fruits even during breeding period while other hornbills feed more on animal matter (Poonswad and Tsuji, 1994; Datta, 1998).

The Oriental Pied Hornbill was encountered second highest after Great Hornbill however the individuals sighted was much less than expected. It could be because the species does not prefers habitat with thick and tall primary forest. Datta (1998) has pointed out the abundance of OPH is negatively correlated with tree height and reported the species to prefer distinctly different habitats of secondary growth forest. Well (1985) says it is lowland specialist and (Payne, 1980) reported the species to usually prefers river-margin forest consequently feeding on fruits of fast growing lianas in riparian forest. On the other hand, Rufous-necked Hornbill was sighted least in the area as it is a species of higher altitudes and this study was limited to the lower elevations. Also the species is red listed Vulnerable and globally has small population which is rapidly declining (Birdlife, 2018), and as a result it occurs in very small numbers.

6.2 Diet of sympatric hornbills

The study on diet of hornbills in the area found the hornbills in the region are overwhelmingly frugivorous. Many studies has reported the several Asian hornbills consume high percentage of fruits (Poonswad *et al*, 1998; Datta, 2001; Anggraini *et al*, 2000) The hornbills were observed feeding on 42 species of fruits from sixteen plant families. The Great Hornbill was observed feeding on maximum fruit species than other species. It could be because the Great Hornbills were sighted more frequently than other hornbills and also the nest of Great Hornbill were located more, simultaneously seeds regurgitated by Great Hornbills were observed more. It is not sure whether hornbills feed more on fig fruits or non-fig fruits because the

quantification on biomass or frequency contribution in diet by each fruit species is not studied. However below nest and roost, the fecal matter and middens were seen mostly of fig fruits and many studies reported fig fruits are keystone food species for hornbills (Poonswad *et al*., 2004; Kinnaird *et al.*, 2004).

Among 34 fruit tree species the Great Hornbill consumed 10 were fig species and the three other hornbills in the area were not observed feeding on all this 10 fig species. The study by Datta (2001) on hornbill's diet in Arunachal Pradesh has reported Great Hornbills feeds more rapidly on fig fruit than non-fig fruits. On other hand, Poonswad *et al*. (1998) has reported Wreathed Hornbills feed more on lipid-rich drupaceous fruits than fig fruits. This study found Wreathed Hornbills feed on 9 species of fig fruits and 14 species of non-fig fruits. But we cannot state for sure Wreathed Hornbill feed more on non-fig fruits because of our limited observations on proportion contribution of individual fruits in the diet.

Hornbills are reported to feed on fruits of 79 plant families particularly of Annonaceae, Lauraceae, Miliaceae, Moraceae and Myristicaceae (Ismail, 2017; Leighton, 1982; Rawat, 2003). This study found hornbills feeding mostly on fruits from Meliaceae and Moraceae. Poonswad *et al*. (1998) a study in Khao Yai National Park (KYNP) in Thailand also reported fruits of Meliaceae was mostly consumed by sympatric hornbills there. Only four species of animal matter were seen in the diet of hornbill even though hornbills are reported feeding on more than 70 species of small animals (Teampanpong, 2014). It is because the data on diet by nest watch was limited. On the other hand, it was very difficult to observe hornbills feeding on or carrying animal matters.

6.3 Nesting site of hornbills

Hornbills has a specialized requirement of large and tall trees for nesting. Mudappa & Kannan (1994) has reported they prefers natural stands for nesting. This study found hornbill nesting in both open and dense forest. It could be because of presence of favorable nest tree with cavity as Erik *et al*. (2000) has reported nest habitat are mainly influence by nest tree and nest cavity and similar was reported by Kannan (1994). If requirement are fulfilled, they nest even near human habitation (Paleri, 2006). Three nest observed during the study were very close to road of which the one that was 30 m below road on slope was abandoned. It could be because of high disturbances from road users since the height of nest cavity was not much high above road, with the cavity facing road. Also it could be because the nest was located in *Ficus* tree, so there are chances of disturbances and threats from other species that comes to feed on *Ficus*

fruits. However another two nest which were 3 m and 5 m close to the road were still active because the nest trees were on plain area and nesting height was more than 25 m above ground and also the roads were farm road with less users.

The Asian hornbills are reported nesting commonly in *Tretamales nudiflora*, *Ailanthus grandis*, *Terminalia* sp. *Altingia excelsa*, *Dipterocarpus sp.*, *Eugenia* sp., *Bombax ceiba*, S*yzygium* sp. and *Ficus* sp (Rawat & Datta, 2004; Datta, 2001). This study found most of the nest were in *T. nudiflora*. It could be because not only it is a large and tall, being softwood its branches are easily broken off by wind or other agents following by decomposition and rotting at the region where the primary cavity nester can easily peck the holes. Thus many holes and cavities were usually seen on *T. nudiflora* and larger cavities were used by hornbills for nesting.

The nesting height and shape and dimension of cavity holes preferred by different hornbills for nesting differs depending upon body size (Poonswad, 1994). Generally the shape of nest holes were either circular or elongated. However the mean length of holes of Great Hornbill nest was significantly high indicating the Great Hornbills usually nest in elongated cavities and same was reported by Poonswad (1994) and Datta (2001). Majority of the nest holes were oriented towards Northeast and Northwest direction and Mudappa and Kannan (1997) has also reported maximum nest oriented towards Northeast in their study in Southern India. The orientation of nest is important for thermoregulation, either to keep cavity warm and dry or to protect from solar radiation (Robertson & Rendell, 1994; Reddy, 2017). The orientation in the area seems favor partial requirement of solar radiation for the cavity.

6.4 Roosting site of hornbills

The hornbill roosting trees were almost similar to nesting tree however it was smaller than latter. The roosting sites were mostly in open area on leafless tree such as *Terminalia nudiflora*, *Bombax ceiba* and *Albizzia*. Roosting sites are chosen that is safe from arboreal and nocturnal predators (Datta, 2001). Know predators of hornbills are binturong (*Arctictis binturong*) and yellow-throated martin (*Martes flavigula*) and other predator could be leopard cat (*Prionailurus bengalensis*), marbled cat (*Pardofelis marmorata*), golden cat (*Catopuma temmincki*) and clouded leopard (*Neofelis nebulosa*). All predators hunt actively in forest but it is not known about hunting by such predator in roosting site chosen by hornbills.

The communal roosting of Great Hornbill and Wreathed Hornbills were found at Akhuri, where they roost in same location but on different tree species. Similar communal roosting of GH and WH was also reported in Arunachal Pradesh by Datta in 2001. Hornbills arrive to roost from

various direction in the evening. Wreathed Hornbill despite huge home range, which is believed to be 10 km^2 -28 km^2 arrive at roost earlier than Great Hornbill. Later, when the Great Hornbill arrive, they displace Wreathed Hornbills from their roost. However a flock of Wreathed Hornbill found chasing Great Hornbill from there roost by making loud unusual calls. Hornbills usually do communal roosting when there is food resource available in the locality. However at the beginning of breeding period, the roosting site of Akhuri was abandoned by both the species which could be mainly because the food resources nearby was exhausted.

The flock size of Great Hornbills at the roost range from 2 individual (a pair) to 42 individuals which is very less as compare to the report by Poonswad (1994) of 1000 individuals in Thailand. Oriental Pied Hornbill and Wreathed Hornbill were observed roosting in flock of 27 and 25 individual respectively. In Thailand, > 100 individual of Wreathed Hornbill was reported roosting (Kitamura *et al.*, 2008). The flock size in roost fluctuate seasonally because the flocking of hornbills are also for thermoregulation and protection from predators, addition to information center in tracking food resources.

6.5 Emerging threats and disturbances to the hornbills and habitat

The hornbills are beautiful birds often incorporated in local culture, medicine and religious traditions. No evidence of hunting hornbills for beak, casque or feathers for ornaments in the area, but from the interview with local people, it was told the hornbills are used in their traditional medicine. The hornbill fats are used to treat burnt wound which they believe it has high healing effect. Few people also reported of a seasonal secretion of mucous from the nostril of male hornbills which has high medicinal and economic value. Resource sharing and common ground of habitat has brought hornbill-human a strong integration that any human activity devoid of conservation concern results into serious threats to hornbills and destructions to its habitat. The agriculture expansion has led to felling of 4 nesting trees in the area. Few local people told the felling coincided with breeding season and 3 individuals in the nest suffered death. The tree requirement for people often coincide with tree species of hornbill importance. The felling and logging (permitted or illicit) of trees with high economic value such as *Altingia excelsa* and *Terminalia* sp. which are also use by hornbills for nesting or roosting poses destruction to species habitat. Beside high demand for timber, people collect Non-Timber Wood Products (NTWP) for food, medicine and local tools making. They graze cattle in forest and lop fodder for cattle especially fruiting trees like *Ficus* sp. Clearing forest for road construction (Jomotsangkha-Samdrupcholing high way) and electric transmission line

are also existing habitat destruction in the area. On addition to habitat destruction by road construction, mining of underground mineral by clearing forest adjoining to Jomotsangkha Wildlife Sanctuary near Samdrupcholing range has caused massive destruction of habitat. If those emerging threats and disturbances to hornbill habitat are not intervened with conservation works, those are likely to become serious threats in the future.

Figure 19: Threats to hornbill habitat (mineral mining, road construction and felling for electric transmission line).

Public awareness program

The outreach program to local people on hornbill conservation was conducted to different level of people living within JWS. A presentation was also given to group of conservation enthusiasts in Forest Research Institute, India (after my field work upon reaching university). During the stay in field, I been opportunistic to talk about hornbill conservation to local people whenever there was gathering (even gathering was for different purpose). On addition to that, during my visit to field, many times I took local companion and I talked about importance of its conservation and issues. Also whoever (local people) I met on the way during field visit, I asked them the information about hornbills, since that is how I can start conversation and gradually I tried to educate and convince them about its conservation individually (whomever I talked). Many people were very interested to hear and they told me they were ‘happy to know some people in the world cares hornbill also’ (which would mean they heard about hornbill conservation for the first time). They agreed they will work to conserve and not disturb hornbills and some of them still calls our team and informs us about hornbills in the area, which I feels people are now aware about hornbill conservation.

Figure 20: Outreach programs carried out to local people living within JWS

CHAPTER 7: CONCLUSION AND RECOMMENDATION

7.1 Conclusion

The study in Jomotsangkha Wildlife Sanctuary observed four species of hornbills; the Great Hornbill (GH), Oriental Pied Hornbill (OPH), Wreathed Hornbill (WH) and Rufous-necked Hornbill (RNH). The area fall under tropical region and it has a good coverage of broadleaved forest which indeed is a favorable habitat for hornbills.

This was a first study on hornbills in the area. The study on population status of hornbills found the Great Hornbill was the most common in the region with highest encounter rate (ER=0.8) followed by Oriental Pied Hornbill (ER=0.2). The Wreathed Hornbill and Rufous-necked Hornbill were encountered least (ER=0.1) and their population size in the region could be very low. Among the trails, the highest encounter rate of hornbill was along T2 (Jampani trail) with ER =14.7. Along rest of the trails, the encounter rate of hornbills ranged from 0.2 to 2.0. However, no single individual of hornbill was encountered along T15 (Chemari) trail.

The study on diet of hornbills in the area found the hornbills mainly feed on fruits. During study the hornbills were observed feeding on 46 food items of which 42 were fruits and four animals. The fruits consumed were from sixteen plant families and animal from three families. The fruit diets of the hornbills were comprised of fig and non-fig fruits. The fruits of Meliaceae and Moraceae family were mostly consumed by all the hornbill species in the area. However there is also needs to quantify diet in terms of proportion contribution of each fruit species.

The breeding biology of hornbills in the area was studied by searching nesting site. The total of 13 nests of hornbill were located during the study. They nest in the natural cavity of large and tall trees and most of the nest in the area were found in the *Tetramales nudiflora* (n=9). Majority of the nest located during study were Great Hornbill's nest. Only single nest of Rufous-necked Hornbill was located and it is at higher altitude than nest of other hornbill species. The Great Hornbill nest were usually seen in hole with elongated shape and rarely in circular like other hornbills. The hornbill nest both near human habitation and far in the closed forest.

Upon studying roosting site, the roosting site preferred by hornbills were almost similar to nesting site. However hornbills roost on the tree smaller than they used for nesting. The Great Hornbill roost on tree which emerge above the canopy of surrounding vegetation. The hornbills were found roosting mostly on *Tetramales nudiflora*. Hornbills roost in flock and the number in a flock range from minimum 2 individual (pair) in Great Hornbill and maximum sighted was

42 individuals which was also Great Hornbill. Hornbills roost both on natural and plantation forest if requirements are fulfilled. With season hornbills change roosting site and it is due to change in availability of diet in the area. Despite major disturbances hornbills roost proximity to human habitation.

Most of the hornbill's nest and roosting site were proximity to human habitation and there is an integrated coexistence between two. Indeed hornbills are in mythology, local and medical tradition long before. Interview with local people told hornbills were hunted for its fats and mucous secreted by hornbills for local medical tradition. Sometime trees needed by people coincide with nesting and roosting tree of hornbills and felling causes serious threats to the species. Agriculture expansion, dependency of local people livelihood on forest resource, clearing of forest for road construction and electric transmission line were observed to be emerging threats and disturbances to the habitat of hornbills in the area.

7.2 Recommendation

The study observed all four species of hornbill in JWS, which are reported in Bhutan. Thus the Jomotsangkha Wildlife Sanctuary is one of the hornbill rich area in the country. However hitherto scientific study of hornbill was lacking and the ecology of hornbills in the area are not known. This study is the first of such on hornbills in the area and yet there are many more to understand. This study was mostly restricted to lower altitude mostly. Most of Northern part of the area remained uncovered due to thick forest, rugged and Terrain Mountain and logistic difficulties. Therefore I recommend more studies to be carried in the north of JWS.

Secondly, the Rufous-necked Hornbill which is of conservation focus needs to be studied in more detail. We had a rare sighting of this species during study and couldn't locate its roosting site. Only single nest of RNH was located and it was on death tree (unknown species). Therefore more detail study can be carried on this species to generate adequate data for the implementation of conservation and management strategy for Vulnerable Rufous-necked Hornbill.

Thirdly, the management body can play key role in conserving hornbills. Within the area, there are certain sites and some tree species of hornbill importance that needs to be protected or conserved. Great Hornbill, Oriental Pied Hornbill and Wreathed Hornbill were sighted mostly in Jampani area. It is because the area has more tree species which are important to hornbills either for food or for nesting and roosting. Therefore, those tree species in the Jampani village and in its vicinity area needs to be managed. Likewise, the Rufous-necked Hornbill was sighted mostly along Chetori stream above Tokaphu village. On both the sides of Chetori stream there are thick dense forest in which Rufous-necked hornbill dwells. Therefore, habitat along Chetori stream site and other similar habitats need to be protected and managed.

The presence of hornbills in the area is a good sign for healthy ecosystem because of the forest seed dispersing role hornbills play in ecosystem. Thus, there is strong need to include hornbill conservation into the management plan of the area. Management should work with local people hand-in-hand. Local people are the ideology of conservation and they can play significant role in conservation. It is important to make local people aware and educate about hornbill conservation. The counterpart local people play in conservation will be much effective than protection or conservation strategy by management body alone.

CHAPTER 8- BIBLIOGRAPHY

Balasubramanian, E. S. (2010). breeding biology and nest tree used by Indian Grey Hornbill Ocyceros birostris in the Eastern Ghats, India. *Forktail*(26), 82-85.

Birdlife, I. (2018, June 15). *Rufous-necked Hornbill Aceros nipalensis*. Retrieved from http://www.birdlife.org

C.S. Reddy, B. N. (2017). Nest-site selection of breeding birds in fragmented landscapes at Mudumalai Tiger Reserve, Tamil Nadu, India. *Bird-o-soar, 32*(7), 30-38.

Cheki, K. (2017, December 12). *KUENSEL*. Retrieved from Timber extraction, a threat to Rufous-necked hornbill: http://www.kuenselonline.com/timber-extraction-a-threat-to-rufous-necked-hornbill/

Corinne P. Kozlowski, K. L. (2015). Reproductive Behavior of the Great Hornbill (Buceros bicornis). *Zoo Biology*(34), 328-334.

Corlett, R. T. (2017). Frugivory and seed dispersal by vertebrates in tropical and subtropical Asia: An update. *Global Ecology and Conservation*, 1-22. doi:http://dx.doi.org/10.1016/j.gecco.2017.04.007

Datta Aparajita, R. N. (2012). *Nature Conservation Foundation.* Retrieved from Hornbill seed dispersal and conservation: http://ncf-india.org/projects/hornbill-seed-dispersal-and-conservation

Datta, A. (1998). Hornbill abundance in unlogged forest, selectively logged forest and a forest plantation in Arunachal Pradesh, India. *Oryx, 32*(4), 285-294.

Datta, A. (2001). *An Ecological study of sympatric hornbills and fruiting patterns in a tropical forest in Arunachal Pradesh.* Dehradun: Wildlife Institute of India.

Dorji, T. (2017). Habitat Modeling and Ecology of Hornbills (Bucerotidae) in Three Gewogs of Panbang, Bhutan. *Unpublished B.Sc. thesis submitted for the partial fulfillment of B.Sc. in Forestry*. Lobesa, Punakha, Bhutan: College of Natural Resources, Royal University of Bhutan.

Erik Klop, E. C. (2000). Breeding biology, nest site characteristics and nest spacing of the Visayan Tarictic Hornbill Penelopides panini panini on Panay, Philippines. *Bird Conservation International*(10), 17-27.

Franck Trolliet, P.-M. F.-L.-F. (2017). Frugivorous birds influence the spatial organization of tropical forests through the generation of seedling recruitment foci under zoochoric trees. *Acta Oecologica*, 69-76.

HRF. (2017). *Hornbill Research Foundation*. (T. H. Project, Producer) Retrieved from Breeding: http://hornbill.or.th/about-hornbills/breeding/

International, B. (2016, December 9). *ASIA*. Retrieved from BirdLife Partnership stretches its wings to Bhutan: https://www.birdlife.org/asia/news/bhutan-%E2%80%98land-thunder-dragon%E2%80%99-joins-birdlifes-flock

Ismail. S.A., G. J. (2017). Evaluating realized seed dispersal across fragmented tropical landscapes: a two-fold approach using parentage analysis and the neighbourhood model. *New Phytol*. doi:http://dx.doi.org/10.1111/nph.14427

K. Anggraini, M. K. (2000). The effects of fruit availability and habitat disturbance on an assemblage of Sumatran Hornbills. *Bird Conservation International*(10), 189-202.

Kannan, D. A. (2009). Nesting Habitat of the Great Hornbill (Buceros bicornis) in the Anaimalai Hills of Southern India. *Ornithology , 121*(3), 485-492. doi:http://dx.doi.org/10.1676/08-022.1

Kannan, R. (1994). Ecology and Conservation of Great Pied Hornbill (Buceros bicornis) in the Western Ghats of Southern India. *Ph.D. Dissertation*.

Kauth, M. E. (1998). Observations on the breeding biology of the Writhed-billed Hornbill (Aceros waldeni) in the Philippines. *Ornithol*(139), 475-483.

Kinley. (2016). *Ecology, people's perception and Conservation status of Rufous-necked Hornbill (Aceros nipalensis, Hodgson 1829) in South-central Bhutan.* Rufford Small Grant. The Rufford Foundation .

Kinnaird, Y.-Y. H. (2004). Foraging characteristics of an assemblage of four Sumatran hornbill species. *Bird Conservation International, 14*, S53-S62. doi:10.1017/S0959270905000225

Kitamura. (2011). Frugivory and seed dispersal by hornbills (Bucerotidae) in tropical forest. *Acta Oecol*(37), 531-541.

Kitamura Shumpei, T. Y. (2008). Aggregated seed dispersal by wreathed hornbills at a roost site in a moist evergreen forest of Thailand. *The Ecological Society of Japan*, 943-952.

Kitamura, S. (2011). Frugivory and seed dispersal by hornbills (Bucerotidae) in tropical forests. *Acta Oecologica*, 531-541.

Krishna C. M, K. S. (2012). Rapid assessment of Wreathed Hornbill Aceros undulatus (Aves: Bucerotidae) populations and conservation issues in fragmented lowland tropical forests of Arunachal Pradesh, India. *Journal of Threatened Taxa, 14*(4), 3342-3348.

Leighton. (1982). Food resource and patterns of feeding, spacing andgrouping among sympatric bornean hornbills (Bucerotidae). *Unpublished Ph.D. thesis*. University of California, Davis.

Margareta Rahayuningsih, N. E. (2017). Short Communication: The nest characteristics of Wreathed Hornbill (Rhyticeros undulatus) in Mount Ungaran, Central Java, Indonesia. *BIODIVERSITAS*, 1130-1134. doi:10.13057/biodiv/d180334

Morea, R. E. (1937). The Comparative breeding biology of African Hornbills (Bucerotidzae). *African Agriculture research station,Amani*, 331-346.

Mudappa, D. (2000). Breeding biology of the Malabar Grey Hornbill Ocyceros griseus in southern Western Ghats, India. *Bombay Natural History Society*, 15-24.

Mudappa, K. R. (1997). Nest site characteristics and nesting success of Malabar Grey Hornbill in Southern Western Ghats, India. *Wilson Bull, 109*(1), 102-111.

Naish, D. (2011, June 22). *ScienceBlogs*. Retrieved from Tetrapod Zoology; An introduction to hornbills: http://scienceblogs.com/tetrapodzoology/2011/06/22/hornbill-introduction/

O'Brien, M. F. (2007). *The ecology and conservation of Asian hornbills:farmers of the forest* (Vol. 27). University of Chicago Press.

Ornithology. (2016). *Ornithology-The science of the Birds*. Retrieved from Saia-Bird list: ornithology.com/travel-guides/asia-bird/

Paleri, A. (2007). Malabar Grey Hornbill Ocyceros griseus nesting near human habitation. *Indian Birds, 2*(3), 152–153.

Payne, J. (1980). Competitors. In Malayan Forest Primates. (D. Chivers, Ed.) 261-277. doi:https://doi.org/10.1007/978-1-4757-0878-3_9

Pilai Poonswad, A. T. (2004). Estimation of nutrients deliver to the nest inmates of four sympatric species of hornbills.

Poonswad P, A. C. (2013). *Hornbills of the World; A photographic guide.* Draco Phublishing.

Poonswad P, A. T. (1998). Some Aspects of food and feeding ecology of Sympatric hornbill species in Khao Yai National Park, Thailand. *Thailang Hornbill Project*, 137-157.

Poonswad P, A. T. (2004). Estimation of nutrients delivered to nest inmates by four sympatric species of hornbills in Khao Yai National Park, Thailand. *Ornithological Science*(3), 99-112.

Poonswad, P. (1994). Nest site characteristics of four sympatric species of hornbills in Khao Yai National Park, Thailand. *IBIS*(137), 183-191.

Poonswad, P. T. (1994). Ranges of males of the Great Hornbill Buceros bicornis, Brown Hornbill Ptilolaemus tickelli and Wreathed Hornbill Rhyticeros undulatus in Khao Yai National Park, Thailand. *IBIS, 136*, 79-86. doi:10.1111/j.1474-919X.1994.tb08133.x

Raman, D. M. (2009). A conservation status survey of hornbills (Bucerotidae) in the Western Ghats, India. *Indian Birds, 5*(4), 90-102.

Ra-online. (2000). *Bhutan's Nature-Animal-Birds* . Retrieved from Bhutan - The last bastion of the hornbill: https://www.raonline.ch/raohomefr00.html

Rawat, A. D. (2004). Nest-site selection and nesting success of three hornbill species in Arunachal Pradesh, north-east India: Great Hornbill Buceros bicornis, Wreathed Hornbill Aceros undulatus and Oriental Pied Hornbill Anthracoceros albirostris. *Bird Conservation International, 14*, S39-S52. doi:10.1017/S0959270905000213

Rawat., A. D. (2003). Foraging Patterns of Sympatric Hornbills during the Nonbreeding Season in Arunachal Pradesh, Northeast India. *BIOTROPICA, 2*(35), 208-218.

Robertson, W. B. (1994). Cavity entrance orientation and nest site use by secondary hole nesting birds. *Fielf Ornithol, 65*(1), 27-35.

Robin C. Whytock, B. J. (2018). Quantifying the scale and socioeconomic drivers of bird hunting in Central African forest communities. *Biological conservation, 218*, 18-25.

Rohit Naniwadekar, C. M. (2014). Farming the forest: hornbills govern the spatial distribution of tropical trees.

Sherub, K. (2017). Foraging behavior, food resources, and habitat use of Rufous-necked hornbill (Aceros nipalensis) in Jigme Singye Wangchuck National Park, Bhutan. Dehradun, Forest Research Institute (FRI): Unpublished, M.Sc. thesis.

Shumpei Kitamura, S. S. (2004). *Tropical Ecology*(20), 421–427.

Shumpei Kitamura, S. S. (2009). Evidence of the Consumption of Fallen Figs by Oriental Pied Hornbill Anthracoceros albirostris on the Ground in Khao Yai National Park, Thailand. *Ornothological Science, 8*(1), 75-79. doi:http://dx.doi.org/10.2326/048.008.0110

Shumpei Kitamura, T. Y. (2004). Characteristics of hornbill-dispersed fruits in a tropical seasonal forest in Thailand. *Bird Conservation International*(14), 81-88.

Teampanpong, J. (2014). *Maintaining Hornbills in the Working Landscape of the Southern Tenasserim Western Forest Complex Corridor in Thailand.* UNIVERSITY OF MINNESOTA.

Tsuji, P. P. (1994). Ranges of males of the Great Hornbills Buceros bicornis, Brown hornbillsPtilolaemus tickelli and Wreathed hornbill Rhyticeros undulatus in Khao Yai National Park. *Ibis, 136*, 79-86.

UWICER. (2017). *Report on HORNBILLS: Connecting Environment, Economy and Culture in Bhutan (Case study on Nesting Ecology and Diet Sources of Rufous-necked hornbill in the east and south-east buffer zone of Phrumsengla National Park under Lhuentse and Mongar).* Department of Forests and Park Services. Lamai Goempa, Bumthang : Ministry of Agriculture and Forests. Royal Government of Bhutan.

Well, D. R. (1985). The forest avifauna of western Malesia and its conservation. In conservation of Tropical Forest Birds . *International Council for Bird Preservation, Cambridge* , 213-132.

Williams, R. R. (1986). Breeding the Great Indian hornbill Bureros bicomis at the Cotswold Wild Life Park. *Int. Zoo Yb, 25*(24), 248-252.

WWF. (2009, January 1). *WWF Global*. Retrieved from An ecological study of Rufous-necked Hornbill: http://wwf.panda.org/wwf_news/?156721/rufous-necked-hornbill-in-Bhutan

WWF. (2017). *WWF Global*. Retrieved from Habitat loss: http://wwf.panda.org/our_work/wildlife/problems/habitat_loss_degradation/

Y. C. Wee, K. C. (2008). Oriental Pied Hornbill: two recent failed nesting attempts on mainland Singapore. *BirdingASIA, 9*, 72-77.

Y. H. Chan, M. Z. (2007). Infanticide-cannibalism in the Oriental Pied Hornbill Anthracoceros albirostris. *Forktail*, 170-173.

CHAPTER 9: ANNEXURES

9.1 ANNEXURES - I. List of fruit and animal species consumed by hornbills

Si. no	List of fruits/ animal matters consumed by hornbills	Family	Ripen (R) or unripe (UR)
1	*Aglaia spectabilis*	Meliaceae	R
2	*Aglaia* sp.1	Meliaceae	R
3	*Aglaia* sp.2	Meliaceae	R
4	*Aphanamixis polystachya*	Meliaceae	R
5	*Amoora wallichi*	Meliaceae	R
6	*Beilschmiedia* sp.1	Lauraceae	R
7	*Beilschmiedia* sp.2	Lauraceae	R
8	*Beilschmiedia* sp.3	Lauraceae	R
9	Bettle		
10	Bulbul (chicks)		
11	*Bridelia glauca*	Phyllanthaceae	R
12	*Connarus* sp.	Connaraceae	R
13	*Canarium resiniferum*	Burseraceae	R
14	*Chisocheton cumingianus*	Meliaceae	R
15	*Dimocarpus longan*	Sapindaceae	R
16	*Diploknema butyracea*	Sapotaceae	R
17	Crap		
18	Bettle		
19	*Dysoxylum binectariferum*	Meliaceae	R
20	*Dysoxylum arborescens*	Meliaceae	R
21	*Dysoxylum excelsum*	Meliaceae	R
22	*Dysoxylum gotadhora*	Meliaceae	R
23	*Elaegnus* sp.	Elaeagnaceae	UR
24	*Elaeocarpus ganitrus*	Elaeocarpaceae	R
25	*Elaeocarpus sp.*	Elaeocarpaceae	R
26	*Ficus altissima*	Moraceae	R
27	*Ficus benjamina*	Moraceae	R
28	*ficus drupacea*	Moraceae	R
29	*Ficus nervosa*	Moraceae	R
30	*Ficus racemosa*	Moraceae	R
31	*Ficus* sp.1	Moraceae	R
32	*Ficus* sp.2	Moraceae	R
33	*Ficus* sp.3	Moraceae	UR
34	*Ficus* sp.4	Moraceae	R

35	*Ficus* sp.5	Moraceae	R
36	*Garcinia* sp	Clusiaceae	R
37	*Horsfieldia kingii*	Myristicaceae	R
38	*Mangifera* sp.	Anacardiaceae	R
39	*Prunus ceylanica*	Rosaceae	R
40	*spondias pinnata*	Anacardiaceae	R
41	*Syzygium cuminii*	Myrtaceae	R
42	*Syzygium* sp.	Myrtaceae	R
43	*Taluma hodgesonii*	Magnoliaceae	R
44	Unknown1		UR
45	Unknown2		R
46	Unknown3		R

9.2 ANNEXURE- II. Data sheet for trail walk data collection (Population status)

Si. no.	Trail location (ID)	Date	Time	Lat. (N)	Lon. (E)	Elev. (m)	Hornbill sp.	Sight / call	Number	Male
1										
2										
3										
4										
5										
6										
7										
8										

Female	Juvenile / Sub-adult	Unknown	Sighting distance	Cue / Activity	Perching tree sp.	Height (m)	DBH (cm)	Canopy %

9.3 ANNEXURES-III. Data sheet for study of diet of hornbills

Si.no	Date	Time	Hornbill species	Foraging/ below roosting/ perching/nest/	Tree species	Fruit type	Family	Ripen/ Unripe	Fig / non figs	Animal matter
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										

9.4 ANNEXURES-IV. Data sheet for hornbill roosting site characterization

Si. no.	Roost location (ID)	Date	Time	Lat.	Lon.	Elev.	Slope	Roosting tree sp.	Tree height	DBH	Height of 1st branch	Roosting height	Distance from river
1													
2													
3													
4													
5													
6													
7													

Distance from road	Distance from human habitation	Time of arrival	Hornbill sp.	Number	Male	Juv/ sub adult	Direction from it came	Tree sp. around 15 radius	Tree height	DBH	Canopy

9.5 ANNEXURES-V. Data sheet for hornbill nesting site characterization.

Si. no.	Nest location (ID)	Lat.	Lon.	Elev.	Hornbill sp.	Nesting tree	Tree height	DBH	Nest height	Orientation	Shape of hole	Dia. at nest cavity
1												
2												
3												
4												
5												
6												
7												
8												

Cavity width	Cavity length	Emergence of nest tree	Position of nest hole in forest strata	Distance from road	Distance from river	Distance from human habitation	Tree sp. around 15 radius	Tree height	DBH	Canopy

9.6 ANNEXURES-VI. Four species of sympatric hornbills in Jomotsangkha Wildlife Sanctuary

Male Wreathed Hornbill

Male (right) and female (left) Wreathed Hornbill

Male Great Hornbill

Male (left) Great Hornbill offering fruits to female (right) during courtship

Great Hornbill (male) leaving nest after feeding female.

Male Rufous-necked Hornbill

Male Rufous-necked Hornbill

Female Oriental Pied Hornbill

Male Oriental Pied Hornbill perching on wood nob in front of nest hole

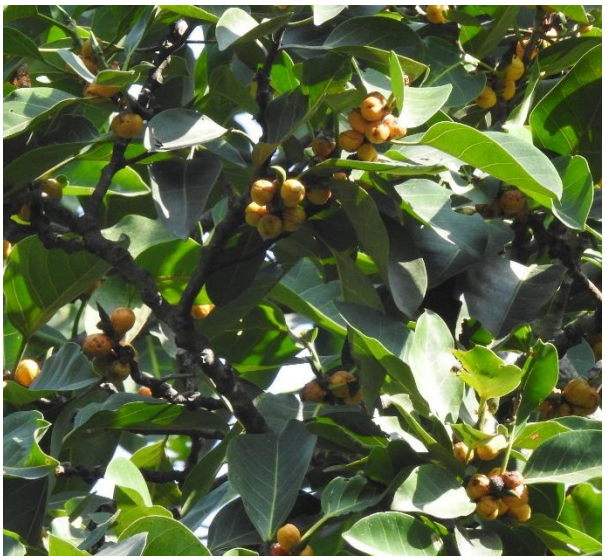
9.7 ANNEXURE-VII. Image of some of the fruits consumed by hornbills

Fruits of Meliaceae (*Aglaia* sp.)

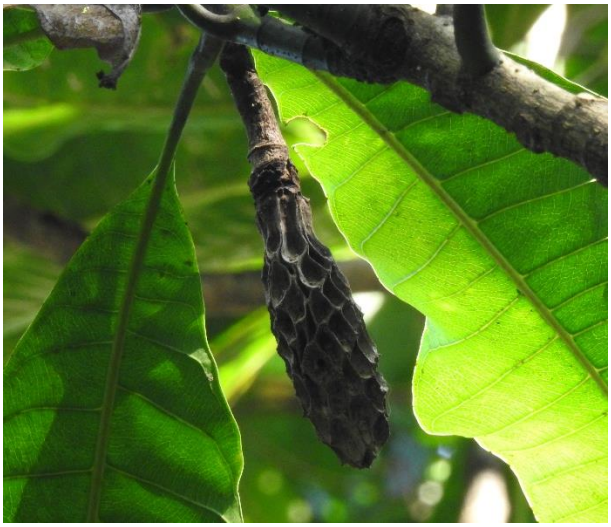
Fruits of Meliaceae (*Dysoxylum binectariferum* (a) and *Dysoxylum gotadhora* (b))

Fruits of Meliaceae (*Chisocheton cumingianus* (a) and *Dysoxylum arborescens* (b))


Fruit of Lauraceae, *Beilschmiedia* sp. (a) and fruit of Burseraceae, *Canarium resiniferum* (b)

Fruits of Moraceae (*Ficus nervosa* (a) and *Ficus altissima* (b))

Fruit of Anacardiaceae (*Spondias pinnata* (a) and fruit of Magnoliaceae, *Taluma hodgesonii* (b))