Foraging behavior, food resources, and habitat use of Rufous-necked hornbill (*Aceros nipalensis*) in Jigme Singye Wangchuck National Park, Bhutan

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Abstract

Rufous-necked hornbill (RNH; *Aceros nipalensis* [Hodgson, 1829]) is one of four hornbill species found in Bhutan and is listed as "vulnerable" under IUCN Red List. Jigme Singye Wangchuck National Park (JSWNP) of Bhutan is one of the important habitats for this highly restricted-range species. Eight sites under three districts inside JSWNP were covered to study the distribution, relative abundance, habitat characteristics, food resources, foraging behavior, flock size, nesting behavior, and conservation threats of RNH from June (2016) to April (2017). RNH was recorded between 644m-1608m elevation range and Lauraceae was the most dominant plant family in surveyed sites. The estimated RNH density was 1.22 birds/km^2 (± 0.12) and the flock size ranged from 1-8 individuals. They were recorded feeding on 35 different species of fruits and also on a few invertebrates. Fruits of Moraceae and Lauraceae were the important tree families that were being consumed. For feeding, RNH choose to feed by plucking fruits within the height range of 4 to 28 m on the fruiting trees. Most of the feeding was carried out from small branches (58.5%). The breeding season of RNH in the sampling sites commenced between 14th - 26th of April (2016 & 2017), and fledging between 25th - 28th of July (2016). Shifting cultivation, grazing, logging, and high power transmission lines were observed as the major threats to the species in the study areas.

Keywords: Hornbill, *Aceros nipalensis*, density, flock size, nesting, foraging behavior, breeding season, Lauraceae, Moraceae, Jigme Singye Wangchuck National Park (JSWNP).

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The hornbills are specialized with regard to habitat, food and nesting sites, and play a very important role in the forest ecosystem as seed dispersers. They are under constant threat of extinction due to various anthropogenic activities (Kinnaird, 1998; Krishna *et al*., 2012). Therefore, it is seen that more significant conservation attention are required for this highly restricted-range species.

There are a total of 54 recognized species of hornbills in the world (Kemp, 1995). The forest of Bhutan harbors four species of hornbills (Bucerotidae); Wreathed Hornbill *Aceros undulates*, Oriental Pied Hornbill *Anthracoceros albirostris*, Rufous necked *Aceros nipalensis*, and Great Hornbill *Buceros bicornis* (Clements, 1992; Webster, 2011), out of which the latter two species occur in Jigme Singye Wangchuck National Park (JSWNP) of Bhutan. The Rufous-necked hornbill (RNH) has been listed as 'vulnerable', while the Great hornbill (GH) has been listed as 'near threatened' by IUCN (Birdlife International, 2017).

The RNH is found in the lower altitude range of broadleaved forests, mostly along the southern and central part of the JSWNP (Penjore, 2010; Dorji, 2013). The park harbors other important key species of birds such as Black-necked Crane (*Grus nigricollis*), wood snipe (*Gallinago nemoricola*), Satyr Tragopan (*Tragopan satyra*), and White bellied Heron (*Ardea insignis*) (JSWNP Annual report, 2013), where all these species are globally concerned and protected directly or indirectly.

In this study, some aspects of feeding ecology, habitat characteristics, density, distribution and nesting of RNH in the broadleaf forest of JSWNP are presented. The major threats to the species, due to various anthropogenic activities are also discussed.

1.2 PROBLEM STATEMENT

Remarkably a few species of birds are proven to have extinct from Asia in historical times, but more than one hundred species are now Critical or Endangered. In the recent time, various international conventions and other mechanisms are relevant to the conservation of threatened species, sites and habitats. In the longer term, the underlying and indirect causes of biodiversity loss will need to be tackled through policy and planning in Important Bird Areas and other networks of key sites for biodiversity.

The RNH is currently known from very few pockets of remaining broadleaf forests on the globe. It is said to be extinct from Nepal and close to extinction in Vietnam (Poonswad *et al*., 2013; Shukla *et al*., 2016; Birdlife International, 2017). It has also disappeared from many areas in Thailand due to various anthropogenic activities (Birdlife International, 2017).

In Bhutan, the RNH is listed as protected species under the schedule I of Forest and Nature Conservation Act, 1995. One of the mandates of JSWNP is to conserve such vulnerable species. However, their habitats are degrading due to various anthropogenic activities. For the conservation of RNH and its habitat, a full understanding of the diet, food availability (Leighton, 1982) and nesting sites are needed because it influences their survival.

Recent studies were carried out to protect RNH around its habitats on the globe (Dorji, 2013; Jinamoy *et al*., 2013; Pattanavibool *et al*., 2013; Shukla *et al*., 2016); however, the study is scanty in most of its habitats in Bhutan. Therefore, it is seen important to carry out more studies determining the use of the various food resources and nesting sites for better understanding of its habitat range, which would help in conservation and management of critical habitats before it is too late.

Moreover, regulation of distribution and abundance is crucial to determine habitat quality and enable the survival of hornbills and sustainability of broadleaved forests of Bhutan. Successful conservation and long term monitoring of Rufous-necked hornbill will ensure conservation of other wildlife, because it has more selective habitat use.

1.3 GENERAL AIMS AND OBJECTIVES OF THE STUDY

This study has general aims and objectives to document the present distribution of Rufous-necked hornbill in Jigme Singye Wangchuck National of Bhutan and to serve as the baseline information for the habitat management and conservation. The study is justified to fill the research gap on RNH in Bhutan. Awareness to the local community and stakeholder is a key player for the protection of the existing habitat, thus the long term goal of this study is the conservation and management of existing habitat through people participation.

1.3.1 Specific objectives

a. To document the habitat characteristics of Rufous-necked hornbill (RNH) in the Jigme Singye Wangchuck National Park (JSWNP) of Bhutan.
b. To document the diet composition of Rufous-necked hornbill in JSWNP.
c. To document the nesting cycle of RNH in JSWNP.
d. To examine the potential threats that affect the survival of RNH in JSWNP.

1.4 RESEARCH QUESTIONS

i. **Research Question for Objective I:** What is the habitat composition of the Rufous-necked hornbill in the broadleaf forest of JSWNP? The habitat characteristics are presented as species composition of trees, its GBH, density and tree basal area.
ii. **Research Question for Objective II:** What are the available food resources (fruiting plants) that are consumed by RNH in JSWNP of Bhutan?
iii. **Research Question for Objective III:** How many days are taken by the RNH to complete its nesting cycle in JSWNP?
iv. **Research Question for Objective III:** What are the potential ecological disturbances that act as prime threats to the survival of Rufous-necked hornbill in JSWNP?

1.5 SIGNIFICANT AND CONTRIBUTION OF THE STUDY

Bhutan forest encompasses the rich biodiversity. The policy and legislation of Bhutan such as Forest and Natural Conservation Act, 1995, National Forest Policy, 1974, and Biodiversity Act, 2003 of Bhutan came to enforcement with a common aims and objectives to conserve, protect and maintain the viability of specific ecosystems, animal and plant communities.

However, in present situation, the long term monitoring for the protection and conservation of wildlife is lacking. Over the year, the developmental activities, logging, shifting cultivation and encroachment of forests have precipitated to forest loss. It is henceforth, imperative to enrich the current knowledge on wildlife conservation in this Himalayan country through the long term monitoring which can be sustained unless local people are attempted.

The present study area is a core habitat for rare and endangered animal species such as musk deer (*Moschus leucogaster*), himalayan black bear (*Ursus thibetanus*), golden langur (*Trachypithecus geei*) endemic to eastern Himalaya, clouded leopard (*Neofelis nebulosa*), red panda (*Ailurus fulgens*) and Royal Bengal tiger (*Panthera tigris tigris*). The literature relating to bird surveys in JSWNP has revealed about 270 species of birds including key species such as Black-necked Crane (*Grus nigricollis*), Great hornbill (*Buceros bicornis*), wood snipe (*Gallinago nemoricola*), Satyr Tragopan (*Tragopan satyra*), and White bellied Heron (*Ardea insignis*) (JSWNP Annual report, 2013).

Therefore, the present study attempt to address the conservation need of these wildlife by integrating local people to value, monitor and conserve wildlife and their habitats using RNH as flagship species. This study specially will address the habitat characteristics and available food resources consumed by Rufous-necked hornbill. It would encourage and inculcate an interest and pride in the rich wildlife and forests of JSWNP for a long-term change in the conservation scenario, thus enhancing local infrastructure to strengthen the capacity of local people to undertake conservation related work. Therefore, the present study is seen as one of the right measures for protection and conservation of wildlife habitats.

CHAPTER 2: REVIEW OF LITERATURE

2.1 AN OVERVIEW OF HORNBILLS

Hornbills are large and conspicuous birds of tropical forests of Asia and Africa, occupying extremes of habitat from moist evergreen forests to arid steppes (Kemp, 1995). They are prominently unusual in appearance, having peculiar features like a disproportionate form and shape, an enormous bill, bright colours with a small face, jerking of the head when making loud, distinctive calls (Delacour & Mayr, 1946) and widely differ in size and mass (Kemp, 1995).

They are considered as good indicators of forest condition and human disturbance because they require large tracts of contiguous primary forest with large trees for nesting sites and food resources, and are targeted for hunting (Poonswad & Kemp, 1993). Besides being a flagship species for conservation, hornbills are among the primary frugivores of the many forests they inhabit, having significant role in seed dispersal (Kemp, 1995).

There are a total of 54 recognized species categorized under two families (two ground hornbills in the Bucorvidae family and 52 true hornbills in the Bucerotidae). Asia harbours 32 species (Poonswad *et al*., 2013; Shukla *et al*., 2016) and Africa harbours 23 species (Kemp, 1995) of hornbills. The remarkable nesting habits of Asian hornbills are such that the female seals herself in a large cavity of a living tree, leaving only a narrow opening hole for her mate to pass food to her and the chicks (Kemp, 1995). They are usually noisy in flight, making them very noticeable to human observers as compared to other birds (Kinnaird & O'Brien, 2007).

However, due to severe deterioration of tropical forests, eight out of 32 Asian hornbill species are threatened species (Kinnaird & O' Brien, 2007; BirdLife International, 2017), in which the Rufous-necked hornbill is classified as a vulnerable species at the global level and is listed in "Schedule 1″ of the Forest and Nature Conservation Act of 1995 and forest rule of 2006 as an endangered species in Bhutan (Vidhidharm *et al*., 1995; Round, 2000; Kuensel, 2010) because its original habitat has disappeared from many areas (Chimchome *et al*., 1998).

2.2 DEFINING RUFOUS-NECKED HORNBILL?

The distinguishing characteristics of Rufous-necked hornbill are large size and an impressive downwardly curved bill. Males have a rufous head and underparts with black back and wings, whereas females are black all over. There is a ring of bare, blue skin around the eyes and the bill is yellow with black and white barcode-like stripes (Figure 1). The RNH have a loud barking *kup* or *kok* notes (Birdlife International, 2017).

Figure 1: Male (A) and female (B) Rufous-necked hornbill (*Aceros nipalensis*) spotted in Jigme Singye Wangchuck National Park of Bhutan.

They have the habit of nest sealing during the breeding season and preferred large trees for nesting (Kemp, 1995). Most of the cavities are located in the trunk of living trees and rarely in the cavity of a dead tree. The same cavities are used in successive years. Female spends over 3 months in the nest, leaving only when the chick fledges (Poonswad *et al*.,1987; Kemp, 1995). The use of canopy levels is related to the diet and foraging strategy and is mostly sighted in the upper canopy layer (Datta, 2009; Shukla *et al*., 2016).

2.2.1 Status and distribution of Rufous-necked hornbill

The RNH is currently known from Bhutan, north-east India, Myanmar, southern Yunnan and south-east Tibet, China, Thailand, Laos and Vietnam (Figure 2). It is said to be extinct from Nepal and close to extinction in Vietnam (Poonswad *et al*., 2013; Shukla *et al*. 2016; Birdlife International, 2017). It has also disappeared from many areas in Thailand. The global population is estimated to be around 1500-7000 individuals (Birdlife International, 2017).

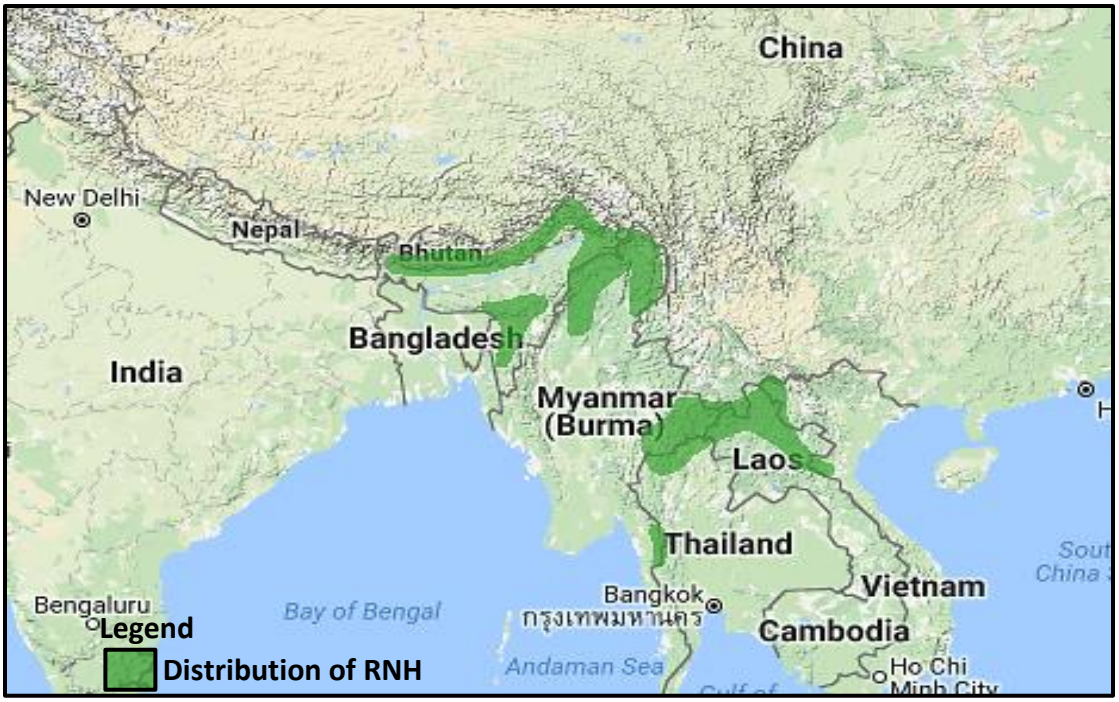

Figure 2: Worldwide distribution of Rufous-necked hornbill (Birdlife International, 2017).

In Bhutan, the Rufous-necked hornbill is still widespread and fairly common (Inskipp *et al*., 1999; Datta, 2009). It is commonly found in Zhemgang district (Gomphu, Buli, Tingtibi, Tama, Nimshong and Tshaidang), Trongsa district (Korphu and Langthrel), Mongar district (Saling and Korila), Lhuentse district, Trashigang district, Samdrup Jongkhar district (Penjore, 2010; Dorji, 2013), Tsirang district, Sarpang district (Jigmecholing geog) and Chhukha district (Personal observation). They are found mainly in broadleaved, evergreen forest, edges of forest clearings, open, moist and groves of large fruit trees (Inskipp *et al*., 1999) (Figure 3). The Healthy populations of RNH elsewhere survive only in Namdapha National Park, India, Nakai-Nam

Theun National Biodiversity Conservation Area, central Laos, Huai Kha Khaeng in west Thailand, and Xishuangbanna Nature Reserve in China (Kinnaird & O'Brien, 2008).

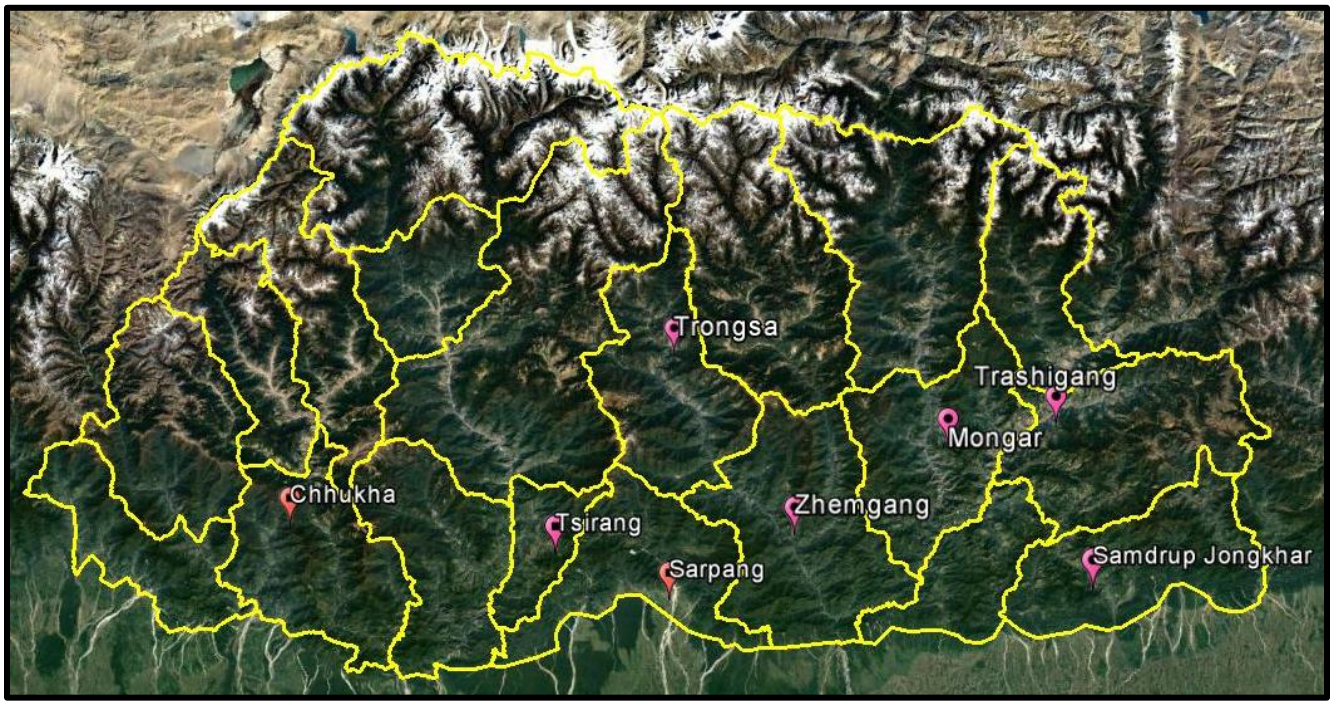

Figure 3: Map showing districts wise distribution of Rufous-necked hornbill in Bhutan.

2.2.2 Nesting habit

Rufous-necked hornbill are known to require big mature trees, having large sized cavities (Kemp, 1995; Mudappa & Kannan, 1997) for nesting and guard the area against invaders of their own species or other species (Kemp, 1995). The cavities could be those created by excavators like woodpeckers and barbets, or natural cavities that form after the branches break or after other injuries are inflicted upon forest trees (Kemp, 1995; Mudappa & Kannan, 1997).

When a female agrees to use the nest cavity, she begins to seal the nest opening and spends time in the nest. Male continue feeding, and bring her sealing (mud, tree bark, wood dust, and food debris) and lining materials (green leaves, grass, bark flakes, and dry leaves) (Kemp, 1995). The male attempts to copulate with the female after she emerges from the nest during the sealing

process (Kemp, 1995; Tsuji, 1996). A narrow, vertical opening is left in the sealing, through which the male feeds, and the female and the brood defecate (Poonswad, 1991; Kemp, 1995).

The female lays on average of two eggs in April (Datta, 2009; Birdlife International, 2017). From time the nest is sealed until the chicks fledge, the female and the brood are wholly dependent upon the male (Poonswad, 1991). After a total of ≈125 days of incarceration, the female breaks the nest's seal and leaves, the chicks following shortly afterwards (Birdlife International, 2017). The same cavities are said to be reused in successive years (Kemp, 1995).

2.2.3 Feeding behaviour

The Rufous-necked hornbill is largely a frugivorous, feeding mainly on berries, drupes, and capsular fruits of primary forest species belonging to Lauraceae, Meliaceae, Myristicaceae, Annonaceae, and figs (Moraceae) (Datta, 2009). It is also known to eat crabs, beetles, cicadas, lizards, earthworms, frogs and birds, picking these from the leaf-litter and from the trunks and branches of large trees (Chimchome *et al*., 1998). Depending on the size, the fruits may be swallowed whole or torn, and eaten bit by bit. They probably satisfy their need for water from the moisture contents of fruits (Kemp, 1995).

RNH usually feed in pairs or groups of 3-4, rarely 7-8. The use of canopy levels is related to the diet and foraging strategy, which has also been reported by Datta (2009) for Rufous-necked horbill *Aceros nipalensis* and Austen's brown hornbill *Anorrhinus austeni* in Arunachal Pradesh. They leave roosting site early in the morning followed by preening, stretching, and territorial calling. The location of food and time invested in feeding depend on the distance, density, and dispersion of the preferred diet of each species. The feeding method includes from a simple picking up a food item to more complex and energetic feeding like levering over object, digging into the ground, snatching, swooping, plucking and hawking (Kemp, 1995).

Fruits offer two basic types of energy rewards: carbohydrates in the form of sugars and starch, and lipids in the form of fatty acids (Robbins, 1993).The feeding and breeding requirements are driving forces that determine how hornbill species locate and consume preferred food, and where

to place their nests. The dynamic nature of resources such as fruiting and nest tree availability determines the movements, social structure, breeding season and productivity (Kemp, 1995).

2.2.4 Habitat selection

The Asia region extends from the tropics to the Arctic, and includes the highest mountain ranges in the world and support many characteristic bird species. Over the time, its natural habitats have been greatly affected by human activities. The loss of tropical forests and associated biodiversity is a global concern (Datta, 2009). Therefore, little information is available on distribution and abundance patterns of hornbills, particularly in the face of large scale landscape transformations and continuing fragmentation and disturbances (Datta, 1998).

Generally, the hornbills are a group of peculiar, large-bodied birds found only in the Old World tropics that have been the focus of much conservation attention. They occupy extremes of habitat, from moist evergreen forests that measure their rainfall in meters to arid steppes where every drop of rain is precious (Kemp, 1995) and depend greatly on mature, large trees for feeding and nesting, as well as large expanses of forest.

Vegetation provides very important elements of the habitat for wildlife, and any changes in vegetation can, therefore, alter habitat conditions (Michael *et al*., 2006). The Rufous-necked hornbill inhabits mature broadleaved forests, generally between 600-1,800m asl (maximum altitude 2,200 m asl), but locally down to 150m asl. It has also been recorded in dry woodland. Evidence suggests that some populations make seasonal movements between forested areas in response to variations in the abundance of fruiting trees. The altitudinal and lateral wandering is most frequent in the non-breeding season (Dorji, 2013; Birdlife International, 2017).

In Bhutan, the RNH are usually found in tall broadleaved evergreen forest (Inskipp *et al*., 1999). Bhutan has an admirable national policy to maintain 60% of country land into forest cover, and has an extensive protected areas system. The country is therefore extremely important for the conservation of several threatened mountain forest species, and is a stronghold for birds

including Rufous-necked hornbill. However, the specific information on general structural and composition of vegetation is unknown in much of its range in Bhutan.

2.3 CONSERVATION THREATS

RNH requires vast tracts of forest to survive (Datta, 2009). The fragmentation of forested area due to various anthropogenic activities severely impacted hornbill's population (Mudappa & Raman, 2009) in most of its habitat range. Historically, hornbills have also been subjected to hunting all over their range in Asia, adding to their vulnerability (Datta, 2009; Shukla *et al*., 2016).

In Bhutan, the rate of forest loss may be very minimal, but with growing population and increased developmental activities, it is presumed that the forest loss is ever increasing because of shifting cultivation, grazing, forest fire, logging, and landslides (Dorji, 2013).

RNH usually preferred broad and large trees for nesting (Kemp, 1995) and these trees are invariably the first trees to be felled commercially (Dorji, 2013). Furthermore, sizeable areas of continuous forest are required (Kemp, 1995) for seasonal or unpredictable altitudinal movements. Therefore, they tend to suffer the effects of human disturbances more severely.

2.4 PREVIOUS STUDIES ON RUFOUS-NECKED HORNBILL IN BHUTAN

Only two studies are known on ecology of Rufous-necked hornbill from Bhutan which mostly focused on their distribution and habitat characteristics (Clements, 1992; Dorji, 2013). This study is the first attempt to estimate the density of RNH, their food resources and nesting behaviour in Bhutan, which is crucial to outline a conservation strategy. Similar kind of studies were done in Arunachal Pradesh (Datta, 2009), Nameri National Park (Saikia & Saikia, 2011), and Namdapha Tiger Reserve (Naniwadekar & Datta, 2013) in India, Thung Yai Naresuan (east) Wildlife Sanctuary in Thailand (Jinamoy *et al*., 2013) and Eastern Himalaya of India (Shukla *et al*., 2016).

CHAPTER 3: STUDY AREA

3.1 JIGME SINGYE WANGCHUCK NATIONAL PARK: LAND, BIOLOGICAL DIVERSITY AND PEOPLE

Jigme Singye Wangchuck National Park (formerly Black Mountains National Park) covers an area of 1,730 square kilometres in central Bhutan. The park occupies most of the Trongsa District, as well as parts of Sarpang, Tsirang, Wangduephodrang, and Zhemgang Districts, comprising of 10 "gewogs" (village blocks). It is the third largest national park in Bhutan, located in central Bhutan and was founded on 1995. The elevation of park ranges from less than 200m in south to over 5000m in north forming the highest peak known as Black Mountain (Dhendup & Letro, 2016; JSWNP, 2017). The park is connected via biological corridors to other national parks in northern, eastern, central and southern Bhutan (Figure 4).

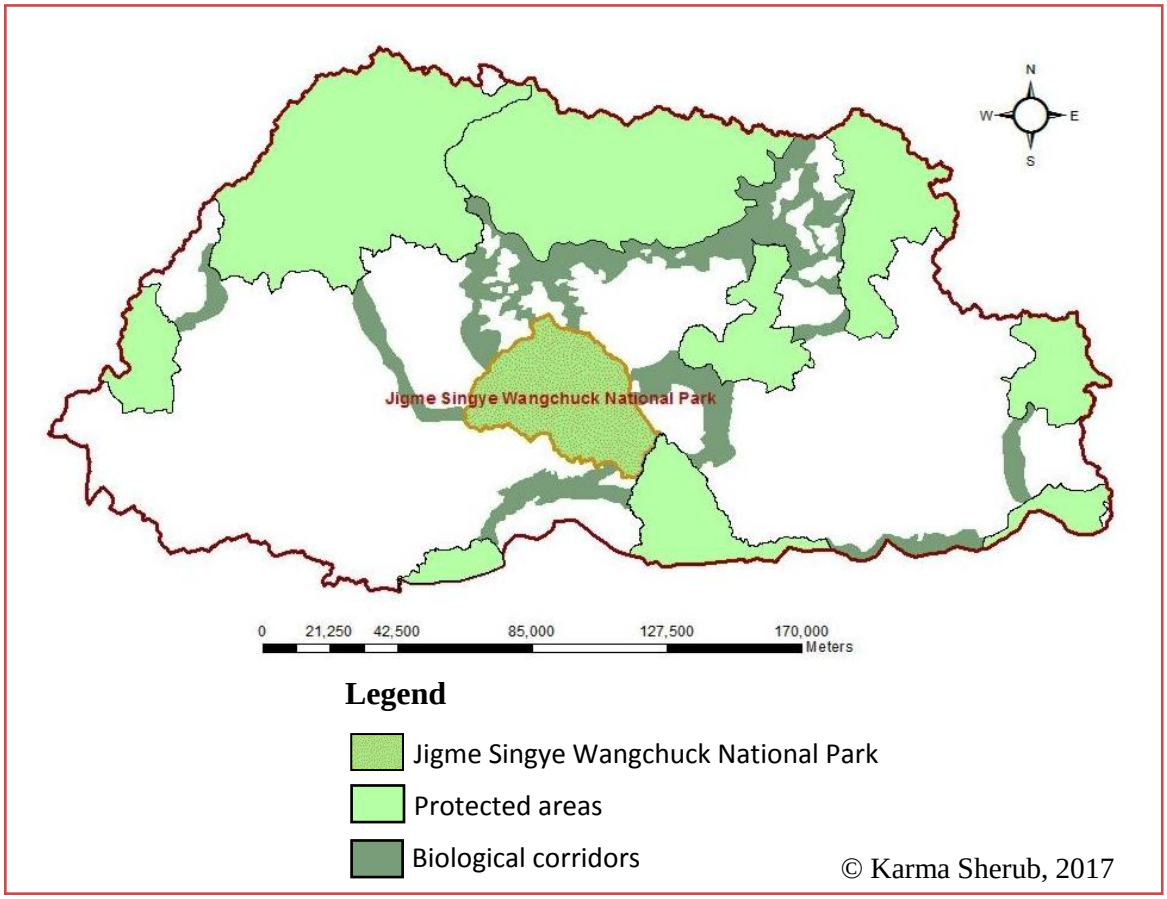

Figure 4: Map showing Jigme Singye Wangchuck National Park connected via biological corridors to other protected areas (PA) in Bhutan.

The park is bisected by several important river system of Bhutan such as Mangde Chhu River, Punatsang Chhu River and Nika Chhu River. There are several major hydropower plants being constructed along these rivers (Premkumar, 2016). Numerous other streams and rivulets originate from the snow-fed alpine lakes in Black Mountain area, and melting snow and monsoon rain contribute to water volume. Soils are generally stagnogleys, podzols & alpine meadow soils, with good permeability and moderate moisture retention (Norbu, 2003). The topography of study area is mostly rugged in most areas.

The rainfall in the area occurs from June-September. Distinct rainy and dry seasons results in wide seasonal variations in river flows with large volumes of sediment-laden water flowing during the monsoon and low volume during dry winter season. The climate is usually cold in winter and moderate in summer months.

Over 5000 to 6000 people of 31 villages reside within the park boundaries. A small group of "Oyleps" resides in "Athang village" under Wangduephodrang district who are believed to be the original Bhutanese whose distinct culture is almost at the verge of extinction. Similar group of people "the Monpa" whose culture is also vulnerable exists in "Langthel village" (Trongsa district), "Berti village" (Zhemgang district) and "Reti village" in Sarpang district but still apparent for the visitors. Most people in the study area practices subsistence agriculture and rear few livestock (JSWNP, 2017).

The park includes a wide range of habitat types, from broadleaf forests at 600 meters to coniferous forests, alpine pasture and lakes, to permanent ice on the peak of Jou Dorshingla at 4,925 meters. It constitutes the largest, richest and most intact temperate forest reserve in the entire Himalaya. Over 5000 vascular plants, 39 mammalian and 270 bird's species inhabits an area (Dhendup & Letro, 2016). The Rapid Biodiversity Survey (RBS) are still going on and more species are expected to occur in the park. The flora and fauna include several rare and endangered species listed in schedule 1 of the forest and Nature conservation act of Bhutan, 1995.

3.2 SAMPLING SITES

The study was carried out in south-eastern part of the park. Eight localities in three "gewogs" (village blocks) under three "dzongkhags" (districts) were selected for the study. Vegetation sampling plots were established in five localities - Nabay and Gonphaii in "Trong Gewog" (Zhemgang district), and Korphu, Nabji and Nimshong in "Korphu gewog" (Trongsa district) (Figure 5), to study the habitat characteristics of RNH, because these sites are the prime habitat harboring major population of RNH (Dorji, 2013) throughout the year and was also confirmed during the preliminary survey. These sites were regularly visited during the entire study periods.

A short duration visits were made in Berti locality in Zhemgang district, and Chungshing and Chakarthang localities in "Jigmichhoeling gewog" (Sarpang district) (Figure 5), because the sightings of RNH was very less in these areas. The general vegetation type of entire tract is classified as warm-broadleaf forest. The forest is mostly multi-storied, dense and with a high diversity and density of woody tree species dominated by broadleaf forest of Lauraceae family.

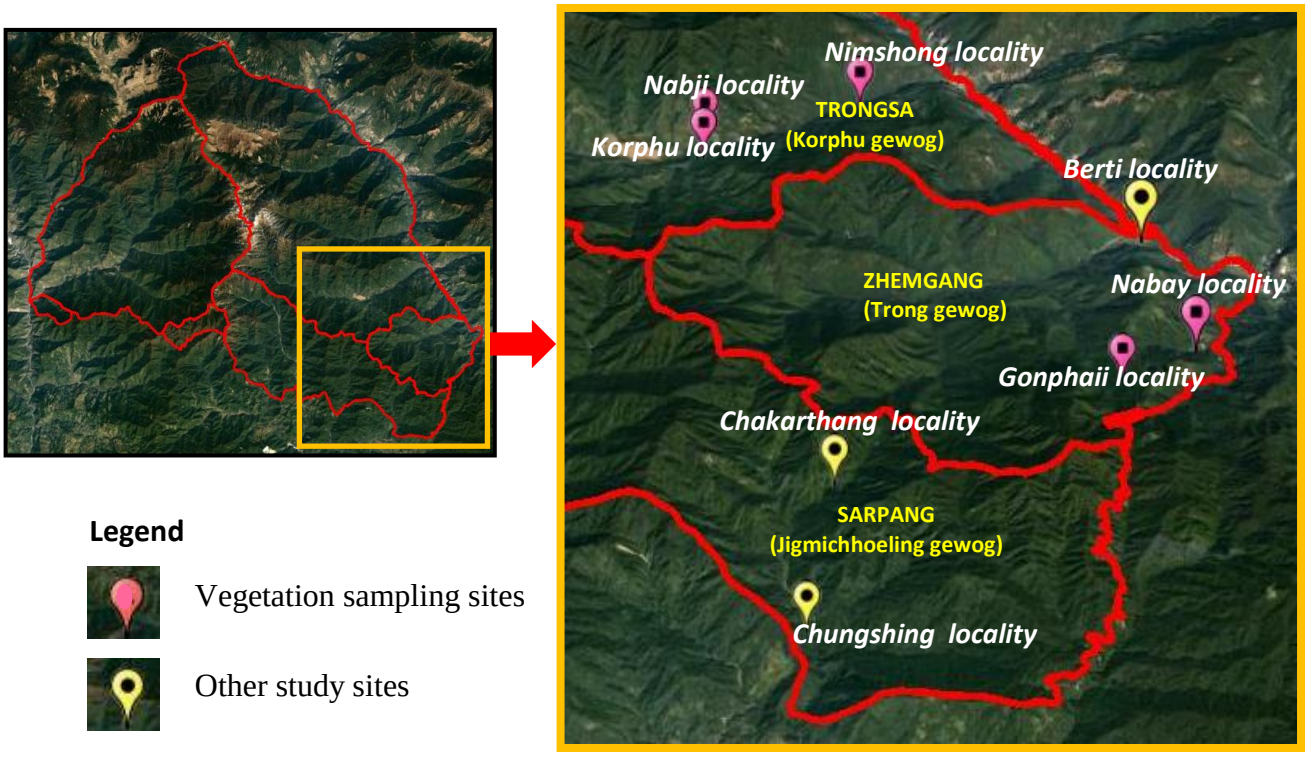

Figure 5: Google Earth map showing five intensive study sites and other three study sites.

3.2.1 Descriptions on sampling sites

Nabji locality: Nabji is geographically located at 27°11'25.10"N and 90°32'8.60"E. The settlement in this area is surrounded by a dense and has high diversity woody tree species, which composed the important habitats for RNH. We walked two trails (one below Nabji village and another along river side) in this locality for the study. The elevation of these trails ranged from 1071m -1099m asl. The vegetation data were recorded from the trial along the river side as it composed an important habitat of RNH for resting and feeding, dominated by *Albizia* sp., *Altingia excelsa*, *Lithocarpus* sp., *Manifera sylvatica* and *Ostodes paniculata.* People of Nabji village depend solely on rice and cardamom (*Elettaria cardamomum*) cultivation for their main income.

Korphu locality: Korphu locality (27°10'58.00"N and 90°32'1.30"E) is located at south-west to Nabji. Both cluster and dispersed settlement can be seen. Most people in this site preferred cardamom cultivation for their main income along with some small scale garden vegetable. We have walked three trails (farm road, cattle track near stream and walking trail towards the Korphu River) in this area. The elevation of these trails ranged from 1130m to 1348m asl. Vegetation sampling plots were established along stream side forest as it composed important habitats of RNH, dominated by *Morus laevigata*, *Ostodes paniculata*, *Alnus nepalensis*, *Altingia excelsa*, *Ligustrum compactum* and *Lithocarpus fenestratus*. The area is mostly disturbed through logging and shifting cultivation.

Nimshong locality: Nimshong locality is located at north-east to Nabji and Korphu localities. The RNH in this area was commonly found at 27°12'40.30"N and 90°35'37.10"E; habitats near the Korphu River. We used river side as our walking trail and vegetation data were established along the same trail. Elevation of this trail ranged from 1129m to 1200 m asl. The RNH mostly used this area for feeding, dominated by *Ostodes paniculata*, *Neocinnamomum caudatum*, *Peltophorum pterocarpum*, *Mangefera sylvatica*, *Ficus hispida* and *Persea fructifera*.

Nabay locality: It is geographically located at 27°7'52.10"N and 90°39'55.10"E, bisected by a Sarpang to Zhemgang highway. RNH was sparsely distributed in this locality. We spotted two nests and the vegetation data were collected around these nesting sites. The habitat was dominated by *Phoebe* spp., *Aphanamixis polystachya, Altingia excelsa* and *Castanopsis hystrix*. Main disturbances to this habitat were construction of high power transmission lines, road (& vehicle), grazing, agriculture, logging and firewood collection. We used the highway as our recording trail and its elevation ranged from 784m – 1018m asl.

Gonphaii locality: Gonphii is located at north-east to Nabay. The core habitat of RNH lies in the forested area at 27°07'32.70"N and 90°40'18.10"E. This area was dominated by *Eleocarpus lanceifolius, Phoebe* spp., *Terminalia* spp. and *Phoebe attenuate*. The sites favors large number of RNH than any other sampling sites, because the canopy cover were mostly opened due to selective logging and practice of agroforestry, making an area accessible for RNH in scanning fruits, allowing free movement within the habitat. The elevation of this sampling site ranged from 1041m to 1608m asl.

Other sampling sites: A short duration survey were made in Berti locality (27°9'37.10"N and 90°39'40.00"E) under Zhemgang district, and Chakarthang (27°4'32.50"N and 90°34'35.80"E) and Chungshing (27°2'34.50"N and 90°34'13.20"E) localities in Sarpang district (Figure 5), because the sightings of RNH from these sites was infrequent. We scanned the probable sites in these localities and elevation of sampling trails varied from 644m-1469m asl. However, no vegetation data were collected from any of these sites due to mentioned reason.

CHAPTER 4: MATERIALS AND METHODS

4.1 MATERIALS

Various field materials were used during the field survey. However, some of the important thing that were frequently used and their function in the field are discussed briefly;

The GPS (Garmin etrex 10) was used to mark the location of place. It is an essential tool for tracking route and marking area, which was also used for our study. Additionally, we used the Digital camera (Canon 700D) to photograph various events and activities of this study.

DBH measuring tape and vernier caliper were used to measure the girth of the tree species during the vegetation sampling. The heights of foraging hornbill, nests and trees were obtained using clinometer. Compass was used to look at the orientation (compass direction) of nest hole at nesting sites.

Standard field kits/stationaries such as field note book, datasheet and pen were used to record the data. A field guide book (Flora of Bhutan) was used for identifying tree species. We published the brochure and poster from the finding of this study to sensitize our effort for the conservation of Rufous-necked hornbill, as well as to inculcate people participation towards conservation of habitats.

4.2 METHODS

4.2.1 RESEARCH DESIGN

The terrain of study area is very steep and rugged. Therefore, a randomized line transect was adopted using the accessible area and existing trails for the survey. Before the actual field survey, we classified various forest types of the study area using ArcMap 10.3 and Google Earth explorer to understand the ground reality, especially the distribution range of broadleaf forest, as it encompassed a primary habitat for Rufous-necked hornbill (Figure 6).

Field data was collected as land cover plot with habitat parameter, and RNH ecology with its various behavioral characteristics. Only five sites that harbor major and frequent RNH sightings were selected for vegetation sampling to understand the habitat composition (Figure 5).

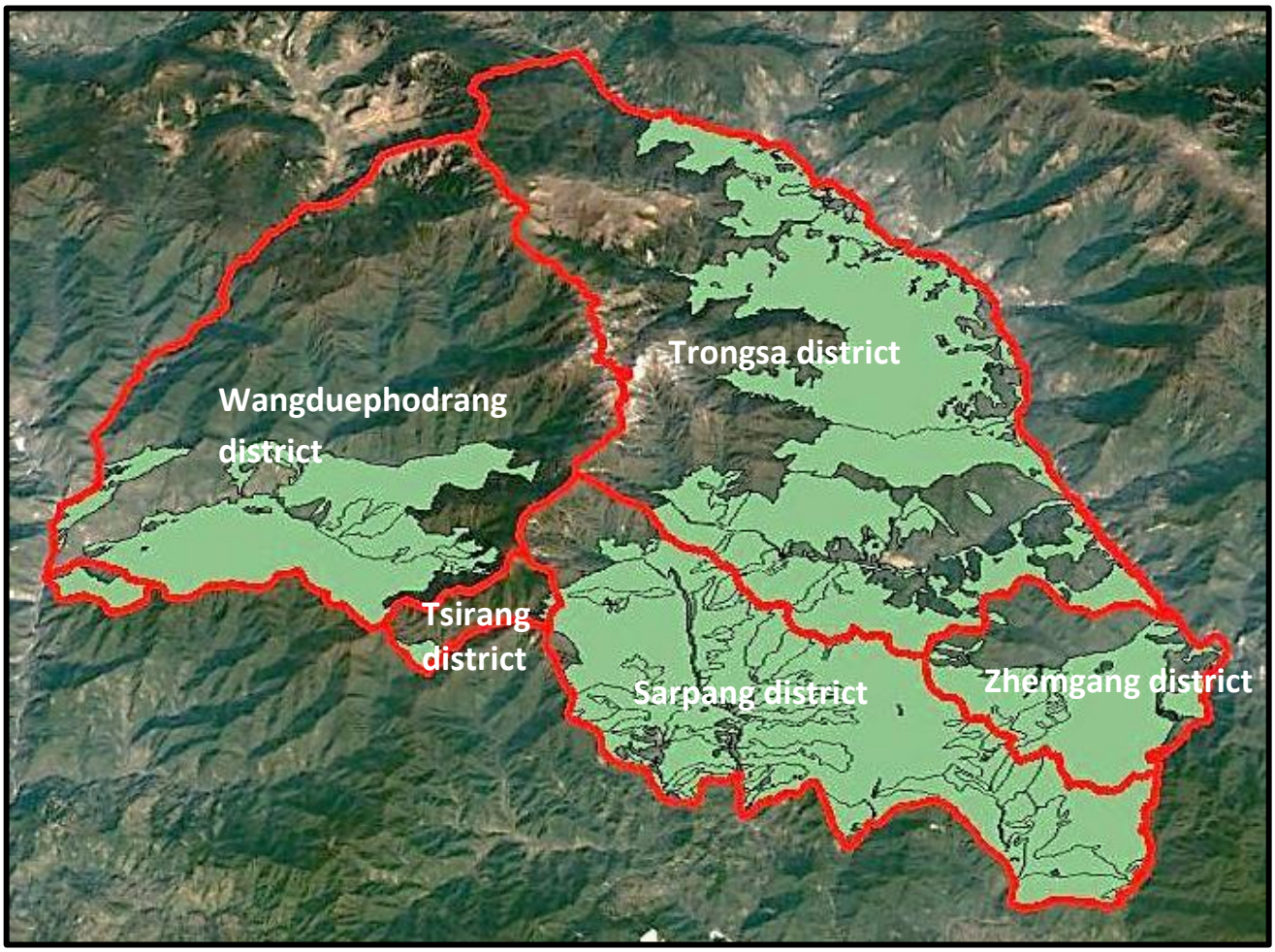

Figure 6: Distribution of broadleaf forest in Jigme Singye Wangchuck National Park (JSWNP) of Bhutan.

4.2.2 PRELIMINARY SURVEY

The preliminary survey was done to gather the information about sightings and abundance of RNH in JSWNP. Based on the accessibility of an area, we sampled 11 trails in 8 localities (sampling sites), mostly along the existing trails/footpath, cattle tracks, farm road, and highway. These trails were repeatedly surveyed from June 2016 to April 2017, representing four seasons;

summer (Jun-Aug), autumn (Sep-Oct), winter (Jan-Feb) and spring (Mar-April). The length of each trails varied from 3-24 km. Our total sampling effort was 361 km, varied from 2-32 km in each trial (Table 1). All these habitats were prone to a range of anthropogenic threats because of its proximity to human settlement, roads or have been encroached by the cattle herder for their cattle to forage.

Observations were recorded from 06.00hr-17.00hr. All RNH seen were recorded for: time, number of individuals and activity (resting, calling, flying, feeding), and food resources. Other base line information such as altitude, latitude, longitude, habitat characteristics (through vegetation sampling), nesting sites and disturbances were also recorded.

4.2.3 VEGETATION SAMPLING

A total of 125 vegetation sampling plots of $10m^2$ were established and marked for study in five study sites (25 plots per habitat) as described in chapter 3, because these areas were mostly preferred by RNH for nesting, feeding and resting. All the trees of GBH $\geq$ 20 cm were enumerated, tagged and GBH of all individuals in the sampling plot were measured to determine the fruit/nest tree density and species composition of the trees.

A sample of unidentified trees were collected and pressed to herbarium for further identification. Habitat characteristics was represented by species composition, density (trees/ha), tree basal area (m^2/ha), and Shannon's diversity index (H'). The density of tree species was calculated using the formula;

$$\mathbf{D} = \frac{\boldsymbol{Total\ number\ of\ trees}}{\boldsymbol{Area\ of\ plot\ X\ Total\ number\ of\ plots}}$$

Where, D = density of trees/ha.

Table 1: Details of the sampled sites inside Jigme Singye Wangchuck National Park. Sampling was carried out from June 2016 – April 2017.

Area	No. of trial	Elevation range (m)	Sampling Duration			Total transect length	Total Effort (km walked)
			Season	Month & year	Days spent		
Nabay locality	1	784-1018 m	Summer	June, 2016	2	15	30
				July, 2016	1		15
			Autumn	October, 2016	2		30
			Winter	February,2017	2		30
			Spring	March, 2017	1		15
				April, 2017	1		15
Gonphaii locality	1	1041-1608 m	Summer	July, 2016	2	5	10
			Autumn	October, 2016	2		10
			Winter	February,2017	2		10
			Spring	March, 2017	1		5
				April, 2017	1		5
Nabji village	2	1071-1099 m	Summer	August, 2016	1	12	2
			Autumn	October, 2016	2		20
			Winter	February,2017	2		20
			Spring	March, 2017	1		10
Nimshong locality	1	1129-1200 m	Summer	August, 2016	4	8	32
			Autumn	September, 2016	2		16
			Winter	January, 2017	1		8
				February,2017	1		8
Korphu locality	3	1130-1348 m	Summer	August, 2016	1	24	2
			Autumn	October, 2016	2		7
			Winter	February,2017	2		15
Berti locality	1	844-1288 m	Summer	July, 2016	2	9	18
			Winter	February,2017	1		9
			Spring	March, 2017	1		9
Chungshing locality	1	1213-1222 m	Summer	July, 2016	1	7	7
Chakarthang locality	1	1224-1469 m	Summer	July, 2016	1	3	3
• Effort walked = Total transect length X no. of days spent						**TOTAL EFFORT**	**361km**

4.2.4 POPULATION DENSITY ESTIMATION

Among the identified areas, we carried out the line transect density estimation. Two or three observers repeatedly walked the trails in mornings from 6:00hr-11:00hr and afternoon's 12:00hr-17:00 hr. The bird spotted perpendicular to line at 10m distance was noted for density calculation. An assumption was made before conducting the survey: "That the flocks were never recounted on the same day of the survey". The population density of RNH in each locality was calculated using the formula (Rahayuningsih & Nugroho, 2013);

$$\mathbf{D} = \frac{\boldsymbol{n}}{\boldsymbol{2WL}}$$

Where;

D = Population density (birds/km^2)

n = Total individuals (RNH)

W = Path width (km)

L = Path length (km)

4.2.5 NESTING SITES

Nesting trees were located by following lone male from feeding sites, inspecting large trees with visible cavities and presence of regurgitated seed/food matters. Once discovered, each nest trees were mapped and identified to genus or if possible species level. Various parameters were studied to understand the nest characteristics such as the GPS location, nest height, nest orientation and the DBH of nest tree.

The length and breadth of nest cavity were measured wherever possible during the non-breeding season. Detail study was done whenever we encountered the abandoned nest, to understand the factor that lead to abandonment, so that the conservation work can be focused in the current active nesting sites. Additionally, the active nests were monitored further to provide the information on nesting cycle.

4.2.6 BREEDING CYCLE

Breeding cycle of RNH was determined by observing at nest sites from 6:00hr to 18:00hr. The observer made a hideout place nearby nesting tree for an observation. Timing of female imprisonment was monitored and the fledging of the chicks was determined by detecting the presence of nest debris. The female imprisonment in JSWNP occurs mostly in April month. Since our study was commenced from June 2016, observation for female imprisonment was done on April 2017 and the fledging on July 2016. We also recorded the frequency of feeding visits and time (hr) of visiting, frequency of regurgitation while feeding female and other observable behaviors.

4.2.7 FORAGING RECORDS

The diet of Rufous-necked hornbill was monitored as food consumption during the breeding and non-breeding season. The data on diet profile in breeding season was obtained by following the feeding lone male and observations of regurgitated seeds, dropped food and faeces below the nesting holes from June-July of 2017 and April 2016, because these are the periods of nesting cycle for RNH in JSWNP.

A diet profile for non-breeding season was obtained from the combination of opportunistic records, observations at fruiting trees and by following the foraging RNH whenever possible from August 2016 to March 2017, after the chick fledged and before the imprisonment of RNH occurred.

Additionally, the foraging behavior of RNH was observed as; used of tree heights for feeding, perch type and methods of feeding. The height classes were assigned at 4 meter class interval from minimum to maximum heights being used while feeding. We have assigned 5 perch types used while feeding; crown foliage, small branch (<75 mm diameter), large branch (> 75 mm diameter) trunk and ground. Direct and indirect observations were made to investigate the foraging methods used, such as cracking, probing, hawking, plucking, snatching, etc. (Poonswad *et al*., 1998).

4.2.8 CONSERVATION THREATS

The anthropogenic activities that lead to habitat degradation were recorded based on direct observation and interviewing with the forest officials and local people. A rapid questionnaire survey was employed and 15 people of different age group, who have been staying in the study areas, were interviewed to get their quick response in hunting threats of focused bird species.

4.2.9 DATA ANALYSES

All statistical analysis was carried out using EXCEL and SPSS. The density of RNH among various sampling areas was calculated using the same method as Rahayuningsih and Nugroho (2013), and compared among various sampling sites. We used only the perching or feeding records (direct sighting) for calculating densities and excluded the records where we noted birds flying over the transects (Shukla *et al*., 2016). SPSS software was used to generate the relationship between various parameters that defined our studies.

To understand the habitat composition of RNH, vegetation plots were established in the sampling sites. This data was summarized as tree density, tree basal area (m^2/ Ha), Shannon's diversity index (H') and with graphical representation of various variables. Forest structure was represented by the girth class distribution of individual trees. The data on foraging records were obtained monthly and graphically represented as fruiting periods and its availability on that months or summarized seasonally (fruiting phenology).

CHAPTER 5: RESULTS

5.1 HABITAT CHARACTERSTICS: VEGETATION COMPOSITION

The five vegetation sampling sites in RNH habitat yielded a total of 560 individuals of 98 species of trees with DBH ≥20 cm (Annexure 1). These species represent 70 genera and 36 families. The number of species varied from 1 to 18 within each family. Lauraceae was the most dominant plant family in surveyed sites with 18 (18.37%) species. Other important families in hornbill habitat were Euphorbiaceae (8 species), Fagaceae (8 species), Leguminosae (7 species), Moraceae (7 species), Magnoliaceae (4 species), Meliaceae (4 species) and Anacadiaceae (3 species) (Figure 7). The most common genera found in these sites were *Albizia*, *Beilschmiedia*, *Cinnamomum*, *Ficus*, *Helicia*, *Lithocarpus*, *Litsea*, *Macaranga*, *Mallotus*, *Michelia*, *Morus*, *Persea*, *Phoebe*, *Quercus* and *Terminalia*.

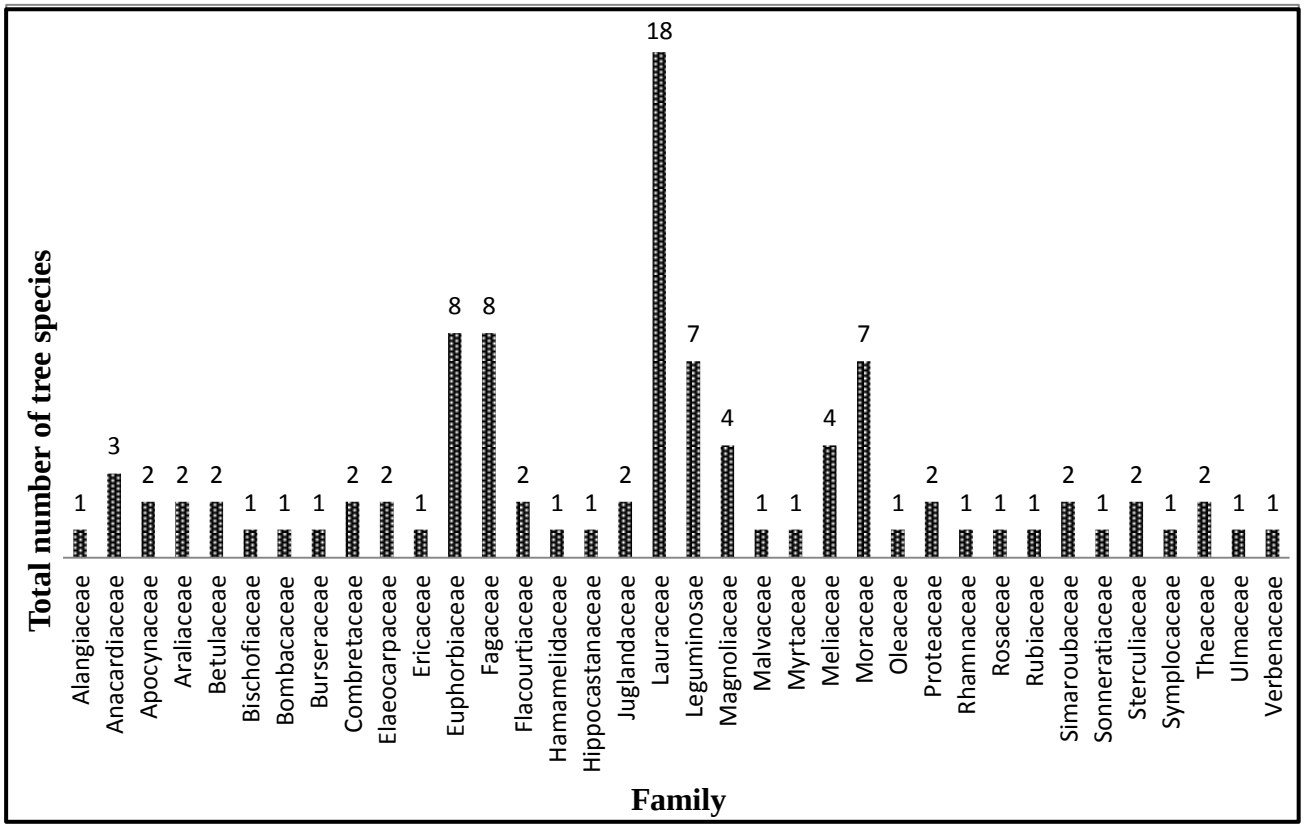

Figure 7: Graph showing the total number of tree species under each family, recorded from five sampling sites inside Jigme Singye Wangchuck National Park (JSWNP) of Bhutan.

5.1.1 Tree densities and forest structure

A comparative analysis was done to study the difference in tree density, diversity index and basal area among five sampling sites of RNH habitats. Tree density was highest in Korphu locality (520 ± 10.8 trees/ha) and lowest at Gonphaii locality (388 ± 8.34 trees/ha). The overall average tree density was 448 ± 58.13 trees/ha. Tree diversity was highest in Nimshong village (H'=1.50) and lowest at Nabay locality (H'=1.39). The basal area of trees in the plots was highest in Korphu village (13.95 sq. m/ha) and lowest in Nimshong village (10.70 sq. m/ha) (Table 2).

Table 2: Habitat status of five habitat sites of Rufous-necked hornbill within Jigme Singye Wangchuck National Park of Bhutan.

Si No.	Study sites	BA (m^2/ha)	No. of trees per ha	Shannon's diversity index	No. of cut stumps per ha	No. of dead trees per ha
1	Nimshong	10.70	396 ± 7.55	1.50	12	8
2	Korphu	13.95	520 ± 10.8	1.48	8	44
3	Nabji	12.24	516 ± 13.66	1.40	4	36
4	Gonphaii	10.58	388 ± 8.34	1.47	24	44
5	Nabay	8.58	420 ± 10.86	1.39	24	32

The girth of individual trees ranges from 20 cm to 244 cm. The average GBH in Nimshong was 50.9 cm, 47 cm in Korphu, 55.6 cm in Nabji, 52.5 cm in Gonphaii and 43.8 cm in Nabay localities. Most of the GBH of trees species were between 20-40 cm (50.2%) and 41- 60 (22.7%) cm girth class (Figure 8). The average GBH was 49.9 cm.

Logging was also observed in these areas and was comparatively higher at Gonphaii (24 cut stumps/ha) and Nabay (24 cut stumps/ha). The lowest was 4 stumps/ha, recorded from Nabji locality (Table 2). The cut stumps were mainly used for construction of houses, furniture and fencing the agricultural land in these sites.

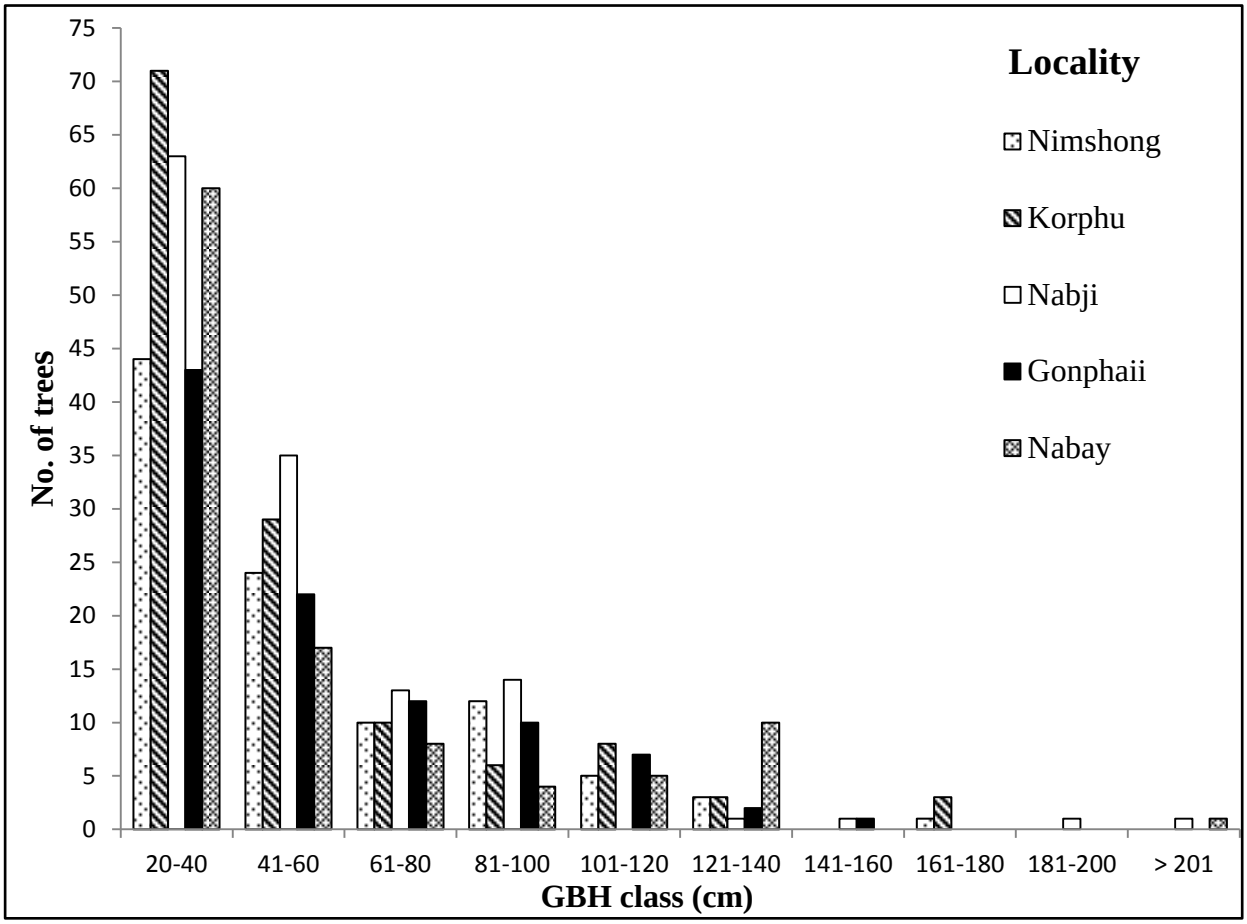

Figure 8: Girth class distribution (GBH ≥ 20 cm) of trees measured across five habitat sites of Rufous-necked Hornbill (n=560).

5.2 DISTRIBUTION AND SIGHTING RECORDS

The relative abundance of RNH was obtained from repeated transect walk from all eight sampling sites. In 361 km of total sampling effort, a total of 245 (total average sighting=161) RNH was sighted over several visits (n=42) from June (2016) to April (2017) (Table 1; Annexure 2). The result of population density analysis showed that RNH's population density in eight different stations varied from 0.01 – 0.41 birds/Km^2 with a total of 1.22 birds/km^2 (± 0.12). The highest density was found in the forest of Gonphaii locality (0.41 birds/km^2 ± 0.05, mean population count= 7.3) and lowest in Chungshing (0.01 birds/km^2) (Table 3).

The maximum RNH encountered in a day during the trail walk was taken to estimate the minimum population of individual. The maximum RNH encounter varied from 2–17 individuals.

The total minimum RNH estimation was 43. Based on our research effort, the RNH were recorded in between 644m-1608m elevation range. Most of the sightings were recorded within the disturbed/secondary forests and edge of river/road, possibly because of free movement and easy access to scan fruit resources. In addition, other hornbill species (Great hornbill) was also present in the study area, especially at Berti, Korphu and Nabay localities.

Table 3: Density estimates of Rufous-necked hornbill from sampling areas within Jigme Singye Wangchuck National Park (JSWNP) of Bhutan.

Si. No.	Area	Days spent	No. of transect	Transect length (km)	Total sightings	Mean	Density rate/km^2
1	Nabay	9	1	15	63	7	0.14 ± 0.014
2	Gonphaii	8	1	5	58	7.3	0.41 ± 0.05
3	Nabji	6	2	12	35	5.83	0.20 ± 0.03
4	Nimshong	8	1	8	46	5.75	0.16 ± 0.015
5	Korphu	5	3	24	29	5.8	0.23 ± 0.02
6	Berti	4	1	9	10	2.5	0.04 ± 0.01
7	Chungshing	1	1	7	2	2	0.01
8	Chakarthang	1	1	3	2	2	0.03
						TOTAL	**1.22 ± 0.12**

5.2.1 Monthly variation in RNH sightings

The sightings of RNH were usually highest during March and February of 2017. The sighting decreases gradually in later months (Figure 9 & 10). Pearson correlation between monthly average sighting of RNH and the number of trees in fruits, available monthly was 0.226 (p=0.558) at 95% confidence level (Table 4), indicating a moderate positive linear relationship between the variables. However, there was a negative correlation between tree density and hornbill density (r= -0.239, p=0.699, 95% confidence level) (Table 5). Having p-value greater than the significance level of 0.05 in both the cases indicates that there is inconclusive evidence about the significance of association or no significant linear relationship between the variables under study.

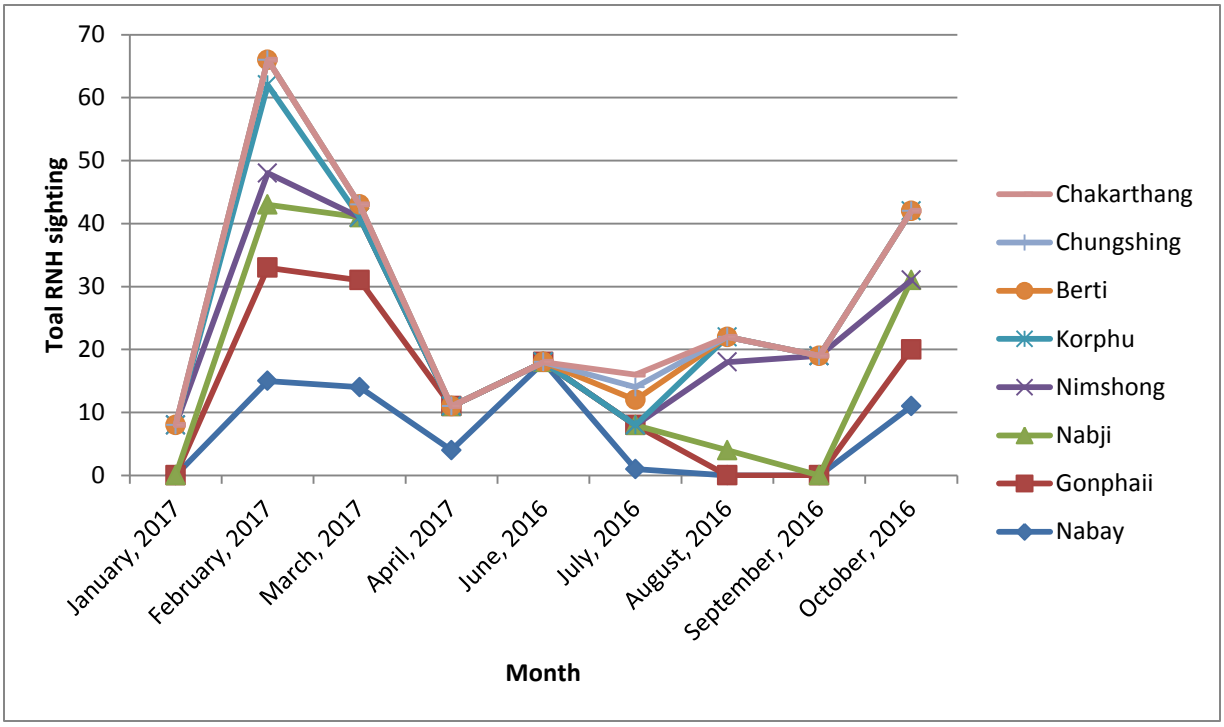

Figure 9: Monthly sighting records of Rufous-necked hornbill (n=245) in the surveyed areas under Jigme Singye Wangchuck National Park, Bhutan (Annexure 2).

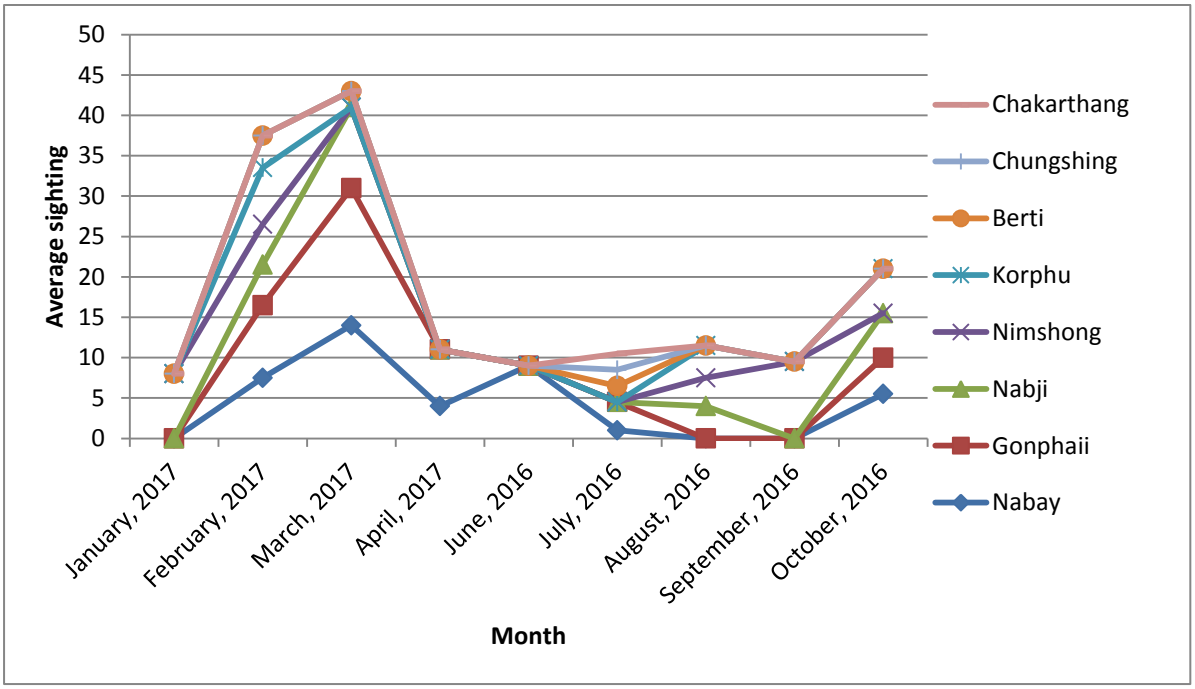

Figure 10: Monthly average sightings of Rufous-necked hornbill (n=161) in the surveyed areas under Jigme Singye Wangchuck National Park, Bhutan (Annexure 2).

Table 4: Relationship between monthly average sightings of Rufous-necked hornbill and the number of trees in fruit, consumed by RNH at that month, recorded from eight sampling sites.

		Number of trees in fruits (monthly)	Monthly average sightings of RNH
Number of trees in fruits (monthly)	Pearson Correlation	1	0.226
	Sig. (2-tailed)		0.558
	N	9	9
Monthly average sightings of RNH	Pearson Correlation	0.226	1
	Sig. (2-tailed)	0.558	
	N	9	9

** Correlation is significant at 0.05 level (95% confidence interval)

Table 5: Relationship between tree density of five vegetation sampling sites and hornbill density recorded in that localities.

		Tree density/ha	RNH density/km^2
Tree density/ha	Pearson Correlation	1	-0.239
	Sig. (2-tailed)		0.699
	N	5	5
RNH density/km^2	Pearson Correlation	-0.239	1
	Sig. (2-tailed)	0.699	
	N	5	5

** Correlation is significant at 0.05 level (95% confidence interval)

5.3 FLOCK SIZE COMPOSITION

In a total of 131 (n) observations, the flock size composition of RNH seen was between 1-8 individuals. The large groups of ≥ 5 were usually sighted at the time of feeding on a single fruiting tree during the non-breeding season between September 2016 to March of 2017 (Table 6).

The frequent sighting of RNH was either lone male or female (46.6 %, n=61) or a flock size of two (both male and female) (37.4%, n=49). The largest flock size of 8 (0.8%, n=1) was spotted only for once in the month of January, 2017 from Nimshong locality (Table 6).

Table 6: Flock size composition of Rufous-necked hornbill recorded from sampling areas inside Jigme Singye Wangchuck National Park of Bhutan.

	Flock size (frequency)						
Month	**1**	**2**	**3**	**4**	**5**	**6**	**8**
Jan, 2017							1
Feb, 2017	9	25	**1**	1			
Mar, 2017	5	2	**2**	4		2	
Apr, 017	1	5					
Jun, 2016	14	2					
Jul, 2016	11	2					
Aug, 2016	4	7		1			
Sep, 2016	4		**2**	1	1		
Oct, 2016	13	6	**3**	2			
TOTAL	**61**	**49**	**8**	**9**	**1**	**2**	**1**

5.4 DIET AND FOOD TYPES

Rufous-necked hornbill has a varied diet. They were recorded feeding on 35 different species (two species unidentified) of fruits (Table 7; Annexure 3) and also on few invertebrates. Fruits eaten as food were classified to 13 families of trees. Important tree families in the diet of RNH were Moraceae (30.3 %, n=10) followed by Lauraceae (27.3%, n=9).

5.4.1 Food consumption in breeding cycle period

Fruits food consumed during the breeding season was recorded through combination of focal observations and the regurgitated food items below the nesting trees. We recorded 21 food plant species, comprising of 18 genera under 11 families such as Anacardiaceae, Burseraceae, Combretaceae, Daphniphyllaceae, Elaeocarpaceae, Flacourtiaceae, Magnoliaceae, Meliaceae, Moraceae, Lauraceae and Rosaceae. Lauraceae (28.6%, n=6 species) and Moraceae (23.5%, n=5 species) represents the highest species, showing food preferences and availability during the breeding season (Table 7).

Table 7: List of fruits food species consumed by Rufous-necked hornbill in sampling sites.

Species	Famiy	Breeding season	Non-breeding season
Alangium chinense	Alangiaceae		x
Aglaia lawii	Meliaceae	x	
*Aphanamixis polystachya**	Meliaceae	x	
Artocarpus lakoocha	Moraceae	x	
*Beilschmiedia assamica**	Lauraceae		x
*Beilschmiedia gammieana**	Lauraceae	x	x
Canarium strictum	Burseraceae	x	
*Casearia glomerata**	Flacourtiaceae	x	
*Choerospondias axillaris**	Anacardiaceae	x	x
Cryptocarya amygdalina	Lauraceae	x	
Daphniphyllum sp.	Daphniphyllaceae	x	
*Eleocarpus lanceofolius**	Elaeocarpaceae	x	
Ficus benghalensis	Moraceae		x
*Ficus benjamina**	Moraceae	x	
Ficus elastica	Moraceae		x
Ficus hederacea	Moraceae		x
*Ficus hispida**	Moraceae		x
Ficus hirta	Moraceae		x
Ficus roxburghii	Moraceae	x	
*Ficus semicordata**	Moraceae	x	x
Ficus spp.	Moraceae	x	x
*Hovenia acerba**	Rhamnaceae		x
Litsea sp.	Lauraceae	x	x
Litsea spp.*	Lauraceae		x
*Mangifera sylvatica**	Anacardiaceae		x
*Neocinnamomum caudatum**	Lauraceae	x	x
Parasassafras confertiflora	Lauraceae		x
Persea spp.*	Lauraceae	x	
Phoebe spp.*	Lauraceae	x	
Prunus spp.	Rosaceae	x	
Terminalia chebula	Combretaceae	x	
Terminalia spp.*	Combretaceae		x
*Talauma hodgsonii**	Magnoliaceae	x	
Unidentified 1	-		x
Unidentified 2	-		x
Note:" x"-fruits being consumed during this season; "*"-species recorded in plots.			

The species that were identified from regurgitated food items below the nests were fruits of *Aglaia* lawii, *Canarium strictum*, *Eleocarpus lanceifolius*, *Ficus roxburghii*, *Ficus* spp., *Litsea* sp. and *Terminalia chebula*; and the remnants of invertebrates such as adult beetles (coleopteran), fresh water crabs (molluscs) and larva of hymenoptera (bee), which were segregated from the dropped faeces (Figure 11 & 12).

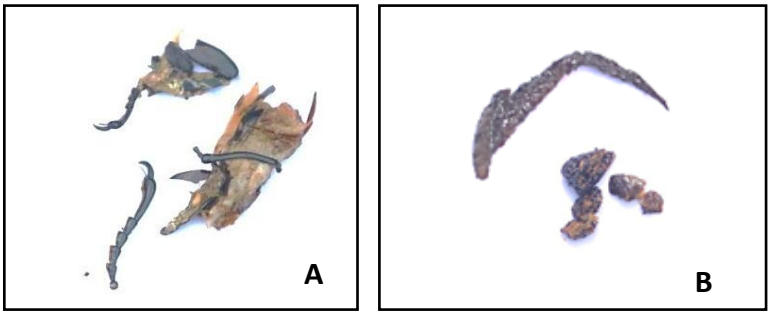

Figure 11: A) Remnants of adult beetle (coleopteran) and B) fresh water crabs (molluscs) identified from the dropped faeces of Rufous-necked hornbill below the nesting trees.

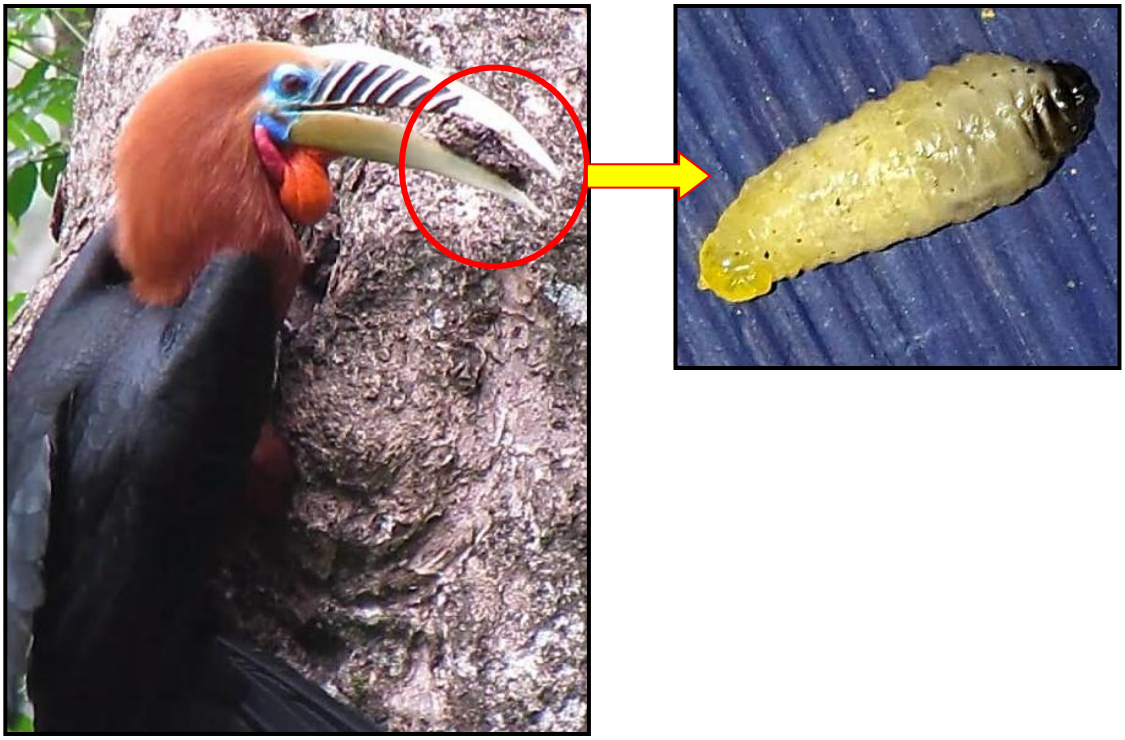

Figure 12: Male RNH with portion of bee hive (left image) in the beak at nest hole. The second image shows the bee larva, which was collected after regurgitation below the nest tree in same day.

5.4.2 Diet composition during non-breeding season

During the non-breeding season, RNH were found consuming the fruits of 20 tree species out of which two couldn't be identified. The rest 18 identified fruit species comprised of 10 genera under six families such as Alangiaceae, Anacardiaceae, Combretaceae, Lauraceae, Moraceae and Rhamnaceae (Table 7). Moraceae (38.9 %, n=7 species) and Lauraceae (33.3%, n=6 species) represented the highest species, whose fruits were being consumed. The larva of Lepidoptera (Caterpillar) and two unknown species of insects were also being consumed (Figure 13).

Figure 13: Rufous-necked hornbill feeding on; A) unknown species of insect, and B) caterpillar (larva of Lepidoptera).

5.4.3 Density and distribution of RNH food plant species

Of 35 different food plants, only 17 (53.3%) species were recorded from the vegetation sampling plots (Table 7). Additionally, we have recorded 5 fruits species (*Arthocarpus lakoocha*, *Ficus roxburghi*, *Ficus benghalensis*, *Ficus elastica*, and *Ficus* spp.) from Berti locality, which were being consumed by RNH. However, none was recorded from Chungshing and Chakarthang localities, probably because the sighting of RNH was very low (two each) or perhaps due to less sampling effort.

In Nabay locality, 13 food plant species (*Aglaia lawii*, *Aphanamixis polystachya*, *Beilschmiedia assamica*, *Beilschmiedia gammieana*, *Choerospondias axillaris*, *Cryptocarya amygdalina*, *Daphniphyllum* sp., *Eleocarpus lanceifolius*, *Ficus hispida*, *Ficus roxburghii*, *Ficus* spp., *Hovenia acerba* and unidentified 2) were recorded, of which 6 were recorded from the study plots such as *Aphanamixis polystachya* (36 trees/ha), *Beilschmiedia gammieana* (24 trees/ha), *Choerospondias axillaris* (16 trees/ha), *Eleocarpus lanceifolius* (4 trees/ha), *Ficus hispida* (4 trees/ha), and *Hovenia acerba* (12 trees/ha).The mean fruit tree density was 16 ± (12.3) trees/ha.

In Gonphaii locality, 8 food plant species (*Beilschmiedia gammieana*, *Casearia glomerata*, *Ficus semicordata*, *Hovenia acerba*, *Persea* spp., *Phoebe* spp., *Terminallia* spp., and *Talauma hodgsonii*) were recorded. Of these, 7 except *Ficus semicordata* were recorded from the study plots. The fruiting tree densities of these species varied from 4 trees/ha to 32 trees/ha and the mean density was 18 ± (9.2) trees/ha.

In Nabji, 6 RNH food plant species (*Alangium chinense*, *Beilschmiedia assamica*, *Choerospondias axillaris*, *Ficus hederacea*, *Mangifera sylvatica*, and *Neocinnamomum caudatum*) were recorded. Of these, 3 species (*Choerospondias axillaris*, *Mangifera sylvatica* and *Neocinnamomum caudatum*) were recorded from the study plots and its densities varied from 4 trees/ha to 44 trees/ha. The mean tree density of these food plant species was 17 ± (23.1) trees/ha.

Kophu village has a combination of various habitat types from open to undisturbed forest. The vegetation data was collected from the forest nearby stream where RNH was frequently spotted. However, only two (*Ficus semicordata* and *Litsea* spp.) of eight species (*Aglaia lawii*, *Ficus hirta*, *Ficus semicordata*, *Ficus herderacea*, *Litsea* sp., *Litsea* spp., *Parasassafras confertiflora* and Unidentified 1) were recorded from the established plots. The fruits tree density was only 4 trees/ha, and feeding occurs less frequently. Therefore, most of its activities remain unknown for this area due to thick canopy cover, although they are being frequently sighted.

In Nimshong village, 8 food plant species (*Aphanamixis polystachya*, *Beilschmiedia assamica*, *Ficus benjamina*, *Ficus herderacea*, *Ficus* spp., *Mangifera sylvatica*, *Neocinnamomum*

caudatum, and *Prunus* spp.) were recorded from the plots. Of these four food plant species (*Beilschmiedia assamica*, *Ficus benjamina*, *Mangifera sylvatica*, and *Neocinnamomum caudatum*) were recorded from the study plots. Adult tree densities of this food plant varied from 12 trees/ha to 28 trees/ha. An overall mean tree density was 20 ± (6.32) trees/ha.

5.5 FRUITING PHENOLOGY

The fruit food consumption by Rufous-necked hornbill varied monthly/seasonally based on its fruiting period and availability. It was observed that the fruiting species (trees in fruit) consumed by RNH was available in highest number during the summer (June-August, 2016; n=24 species) and winter (Jan-Feb, 2017; n=11) season, of which first two months of summer coincided with the breeding period. The proportion of trees in fruit occurs in lesser number during the autumn (Sep-Oct, 2016; n=11 species) and spring (Mar-Apr, 2017; n=7 species) seasons (Figure 14; Annexure 4).

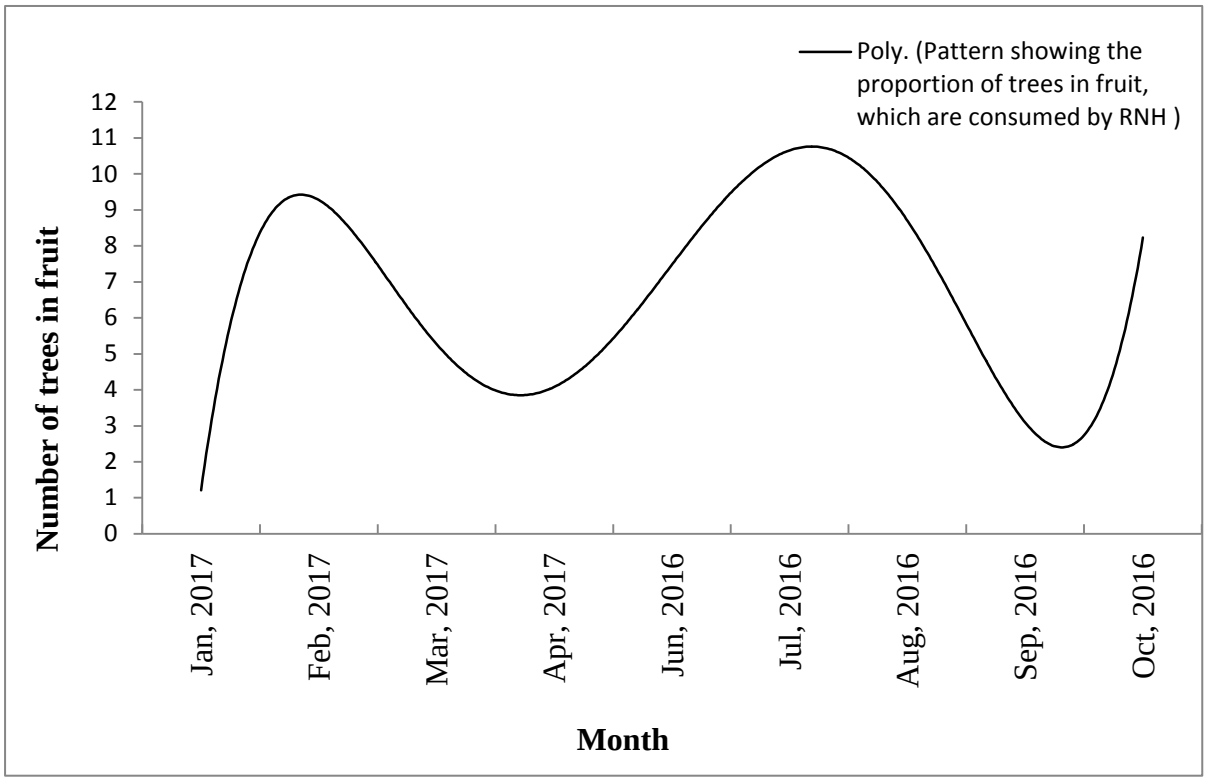

Figure 14: Graph showing the fruiting period and its monthly availability, which were consumed by Rufous-necked hornbill in sampling areas.

5.6 FORAGING BEHAVIOUR

The diet of Rufous-necked hornbill (RNH) and the foraging stations (canopy height) differed based on the availability of the predominant foods and where these foods were in the forest strata. Most of feeding was carried out from small branches (58.5%) or large branches (24.6%) and crown foliage (24.6%) (Figure 15). Trunk and ground were rarely used.

RNH often feed on the ripen food while, resting on a branch or clinging onto the foliage to reach the ripened fruit. For feeding they choose to feed by plucking fruits within the height range of 4 to 28 m above the ground level. Feeding occurred mostly within the height of 8-12 m (27.4%) and 12-16 m (27.4%) above the ground (Figure 16) on fruiting tree species. Active feeding usually occurred between 6:00hr-12:00hr and 15:00hr-17:00hr for non-breeding season. The foraging method on the ground was not observed directly, however, twice a RNH were seen near a water hole (Figure 17). It is possible that my presence sometimes may have deterred birds from descending to the ground or the feeding perches.

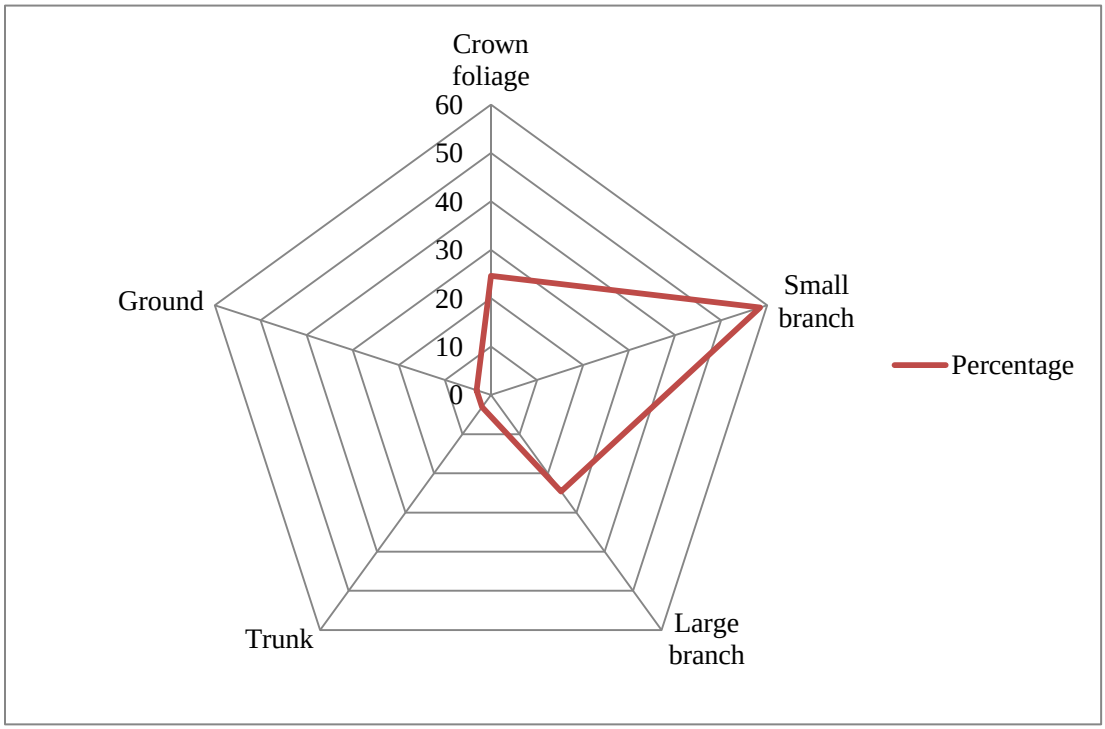

Figure 15: Five types of feeding perches used by Rufous-necked hornbill, recorded from sampling areas within Jigme Singye Wangchuck National Park (JSWNP).

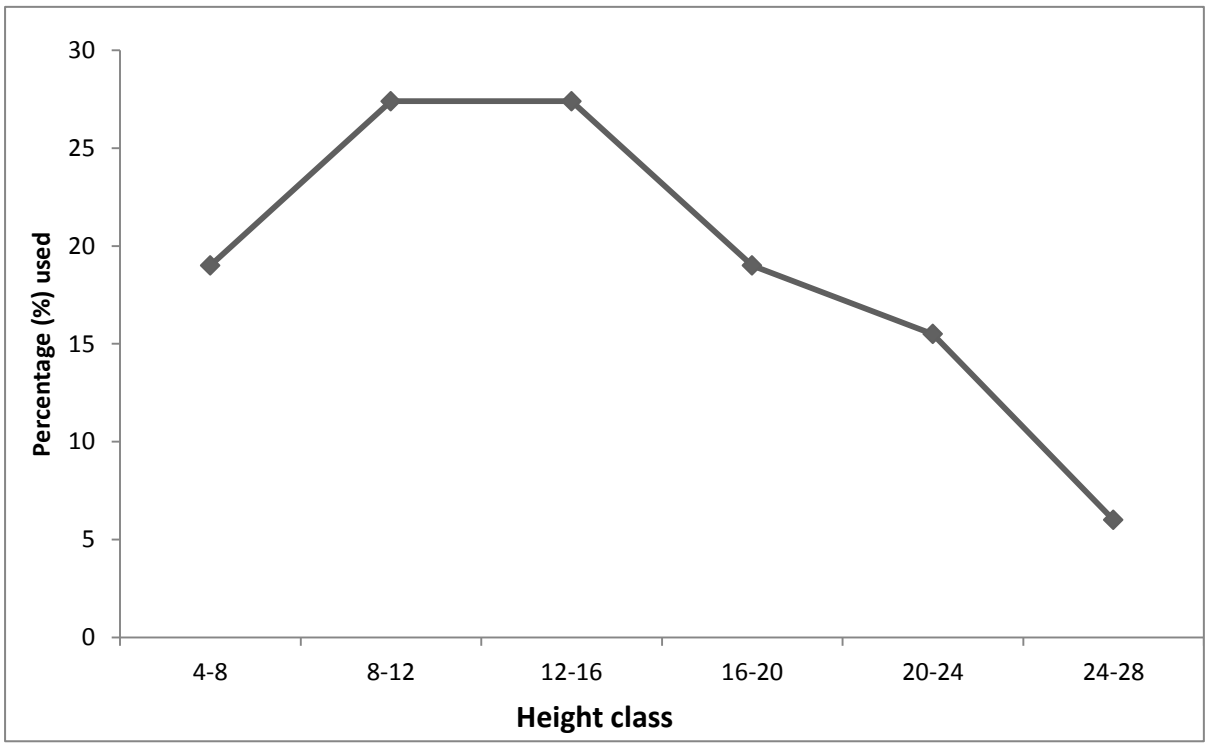

Figure 16: Height preferred for feeding above the ground by Rufous-necked hornbill.

Figure 17: Injured Rufous-necked hornbill near the stream (upper beak was broken).

One nest of RNH was continuously observed for 4 days from 6:00hr-18:00hr during nesting period to study behaviour of male RNH. We observed that the male gathered mixture of food

items and fed the female at minimum of 4 times and maximum of 5 times in a day, spending about 30 to 75 seconds while feeding the female. The initial delivery time starts at 8:15hr to final feeding at 17:17hr. Arrival time interval at nesting hole ranges from minimum 19 minutes to maximum 3 hours 25 minutes (Table 8). It is possible that the presence of disturbances, climatic condition and availability of fruits could have affected the delivery frequency, times of feeding or arrival to the nesting site.

Table 8: Observations on feeding behaviour of male RNH at nesting site (Nest location: Nabay locality (N-1): $27^0$07'08.5''N and $090^0$40'01.6''E).

Si No.	Date	Time of arrival (hr)	Time interval (hr)	Time spent feeding the female (sec)	Climate
1	26-June-2016	8:15	> 3 hr 25 min	30	Partly cloudy
		11:30	**>3 hr 25 min**	46	
		14:21	> 2 hr 33 min	40	
		16:17	**>19 min**	25	
		16:36		15	
2	27-June-2016	9:01	> 2 hr 42 min	**75**	Partly cloudy
		11:26	> 2 hr 27 min	53	
		13:42	> 2 hr 17 min	35	
		15:52	> 1 hr 17 min	37	
		17:02		21	
3	28-June-2016	10:40	> 2 hr 58 min	71	Foggy and showering
		13:15	> 2 hr 32 min	26	
		15:10	> 2 hr 8 min	42	
		17:15		**20**	
4	30-June-2016	8:50	> 2 hr 42 min	69	Showering
		11:15	**>3 hr 25 min**	27	
		14:30	> 1 hr 25 min	61	
		15:45		37	

5.7 STATUS AND CHARACTERISTICS OF NESTING HOLE TREES

We spotted four nests from the sampling areas and all of these nests were located at "Trong gewog" under Zhemgang district (Figure 18; Table 9).

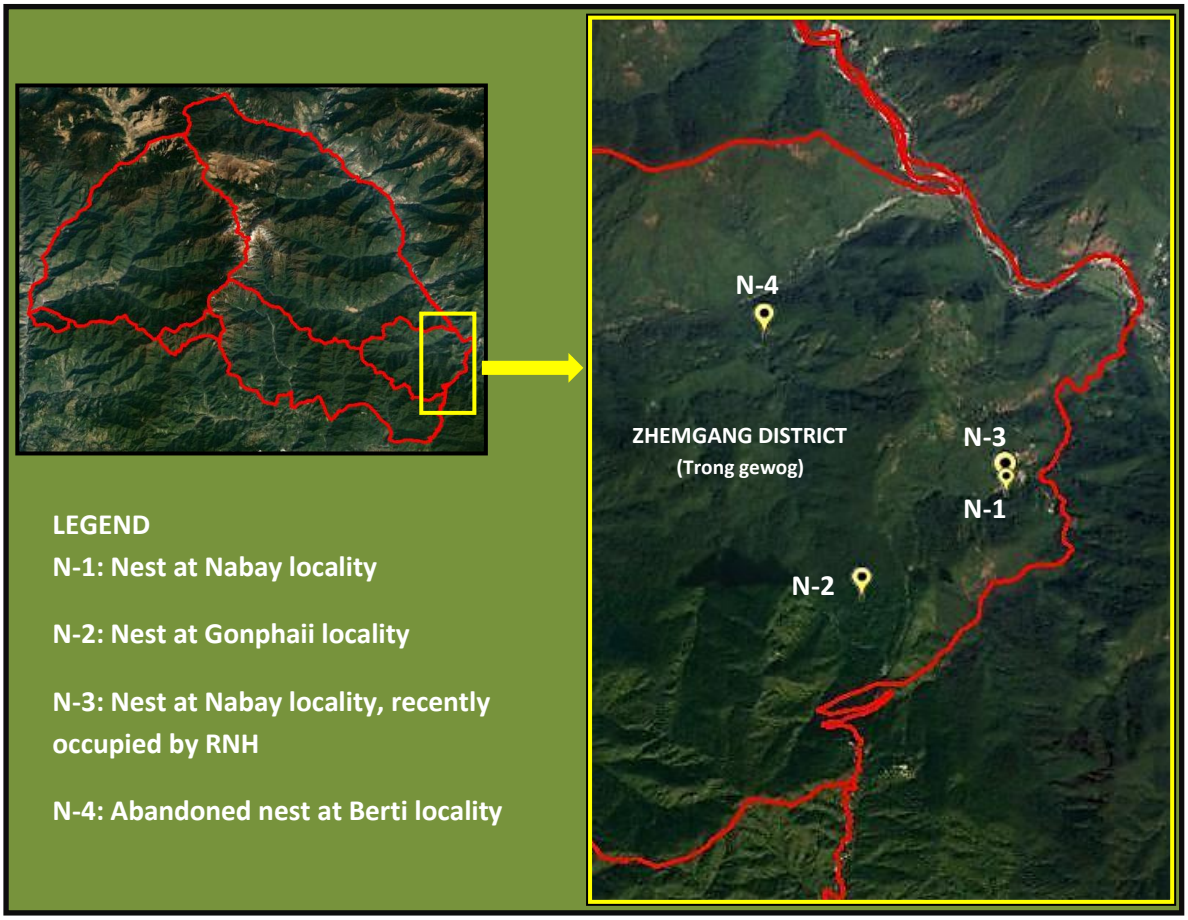

Figure 18: Map showing the location of RNH nesting tree at "Trong gewog" under Zhemgang district.

Of four nests, two were located from the Nabay locality (N-1 & N-3). Both the nests were on the trees of *Altingia excelsa*, located in same habitat range at the distance of 21 m apart. One of these nests was occupied by the RNH (N-1) and another by Great Hornbill (N-3) as of 2016 breeding season. The nest which was occupied by Great Hornbill (GH) was currently occupied by RNH on 26th April of 2017 (Figure 19) and other (N-1) was abandoned. This event of nest sharing or abandonment shows that the two sympatric hornbills compete for nests hole or the same species do not share the same area for nesting.

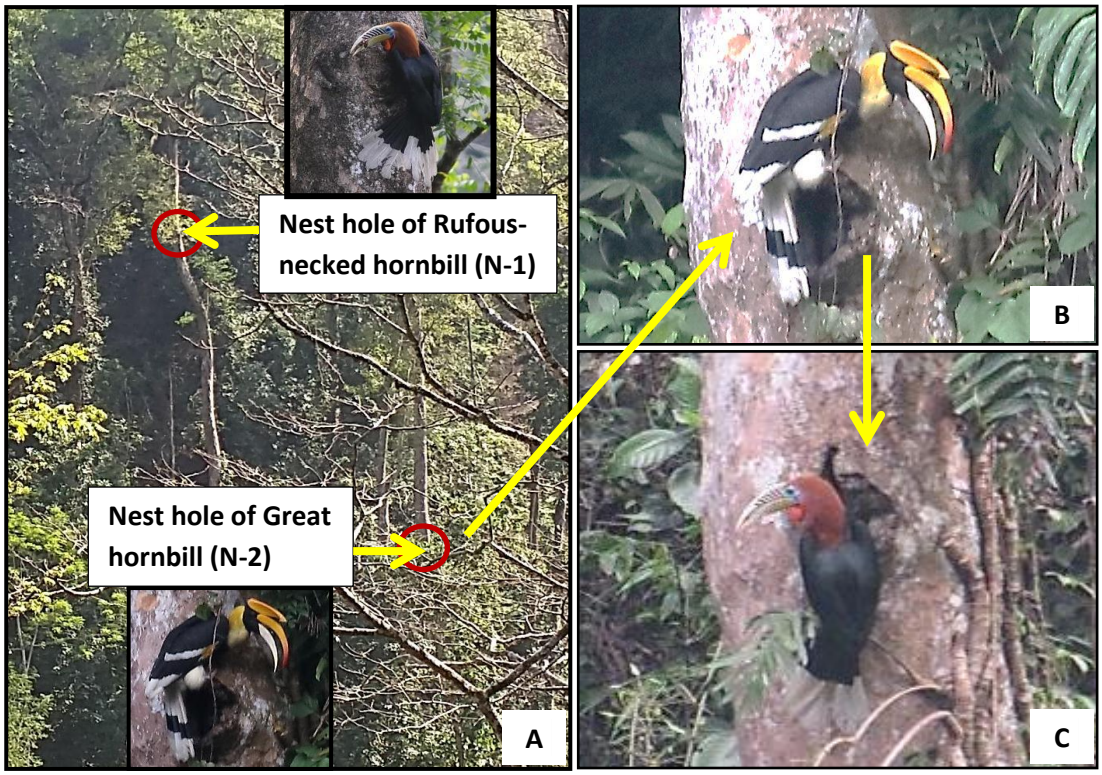

Figure 19: A) Active nests of RNH and Great hornbill located at same habitat range in Nabay locality, 2016; B & C) Nest previously occupied by Great Hornbill in breeding season of 2016 was recently occupied by Rufous-necked hornbill on 26th April of 2017.

For the nest located at Gonphaii locality (N-2), we were able to measure the length and width of nest cavity, as the nest hole was located at 4 meter above the ground, but with thick undergrowth-cover of bushes (Figure 20). The female RNH started entering this nest on 22nd April of 2017. The sealing didn't happen as of final observation done on 17th May, 2017. It may be because the pair would breed lately or not breeding. The observation is still undergoing for this nest. However, the nest was active in 2016, when it was first discovered on 15th July.

Additionally, one abandoned nest (2 years before according the personnel of JSWNP) was recorded at Berti locality (Figure 21). Detail study was carried out to find out the causes of abandonment. We observed that the nest tree was located just a meter away from walking trail used by the cattle herder and local people. Other disturbances such as a temporary camp set by cattle herder to hold the night, logging, firewood collection and patches of abandoned (before 1 year) agricultural field were observed within 20m range from the nesting tree. Since the RNH is a shy bird, the listed disturbances factor could be the foremost reasons to abandon the nest.

Table 9: Characteristics summary of RNH nesting site.

Si No.	Parameters	Nabay (N-1)	Gonphaii (N-2)	Nabay (N-3)	Berti (N-4)
1	GPS location	27°07'08.5"N; 90° 40'01.6"E	27°06'15.2"N; 90° 38'44.2"E	27°7'10.62"N; 90°40'1.56"E	27°08'27.4"N; 90° 38'08.4"E
2	Nest status	-2016: Active -2017: Abandoned	-2016: Active -2017: female inside the nest but not sealed (22nd Apr-17th may, 2017)	-2016:Occupied by GH -2017: Same nest occupied by RNH	Abandoned
3	Nesting tree species	*Altingia excelsa*	*Engelhardia* sp.?	*Altingia excelsa*	Unidentified
4	Tree density (trees/ha)	*36*	*8*	36	-
5	Tree height (m)	33	23	31	21
6	GBH (cm)	109	108	105	98
7	Height of nest cavity from ground level (m)	21	4	17	7
8	Girth at nest hole	≈86	98	97	80
9	Nest opening orientation	NW	NE	SE	NW
10	Cavity depth	-	45	-	-
11	Cavity width (cm)	-	36	-	-
12	Altitude (m)	924	1549	919	736

Figure 20: The nest of Rufous-necked hornbill located at Gonphaii locality.

Figure 21: Abandoned nest of Rufous-necked hornbill at Berti locality.

5.8 BREEDING CYCLE

The breeding cycle is defined as the period from the female's imprisonment until the fledging of the chick. Since our study was carried out from June 2016 to April 2017, the observation of fledging was observed on 2016 and imprisonment on 2017, because imprisonment of female was mostly recorded at the month of April in the sampling sites (Table 10).

However, for a nest located at Nabay locality (N-1), we were able to get the complete breeding cycle for a year, as the imprisonment has been recorded by Mr. Namgay Dorji, Senior Forester of JSWNP on 14th April, 2016. The fledging was observed on 25th July of 2016 (Table 10). The complete breeding cycle of RNH from this nest was 102 days. However, the nest was inactive as of observation done on 2017 breeding season. A nest which was previously occupied by Great hornbill (N-3) in 2016 was recently occupied by RNH on 26th April of 2017, which is located at same habitat range as mentioned (Figure 19).

For the nest located at Gonphaii locality (N-2), the female was observed entering the nest on 22nd April of 2017. We have been observing the female still inside the nest, and sealing not yet done as of last observation done on 17th May of 2017. This nest was newly discovered on 15th July of 2016 during their breeding season and the fledging was observed on 28th July of 2016 (Figure 22).

Figure 22: The nest of Rufous-necked hornbill at Gonphaii locality; A) Photograph taken on 15th July of 2016, during the breeding season, B) Nest after fledging of chicks (28 July, 2016).

The time (hr) of fledging and number of juveniles being fledged couldn't be observed from either of nests, because the observer monitored the nests mostly in the evening, coincided with other field survey of the study. However, during the transect walk, twice a single juvenile with adult RNH were seen at Nabay locality (Figure 23). However, a detail study seems to be needed for the breeding cycle to record complete details on activities of female RNH inside the nest, provided that they are not being disturbed, as a baseline approach for conservation.

Figure 23: The juvenile RNH with adult male (left- 29th July, 2016) and female (right- 14thAugust, 2016)

Table 10: Summary for the breeding cycle of Rufous-necked hornbill.

Nesting site	Imprisonment		Fledging	
	Date	Year	Date	Year
Nest 1: Nabay locality (N-1)	14 April	2016	25 July	2016
Nest 2: Nabay locality (N-3)	26 April	2017	-	-
Nest 3: Gonphaii locality (N-2)	22 April**	2017	28 July	2016

** Gonphai locality (N-2): The female was observed entering the nest on 22nd April of 2017 but the nest was not sealed yet, as of last observation done on 17th May, 2017.

5.9 BEHAVIORAL OBSERVATIONS DURING THE BREEDING SEASON

The male RNH was found very vigilant, remaining silent and concealing themselves on disturbances near the nesting trees. While feeding the inmate, the male RNH did not visit the nest directly. They first perch on a nearby branch, scan the area (Figure 24 A) and then approach the nest hole silently. It was observed that the male always visited the nest from same compass direction. However, on disturbance, the male fled over and keep watching from distance. They sometimes avoid visiting the nest hole for an hour. We also observed some pairs not breeding, but still remains in pair, caring for each other (Figure 24 B).

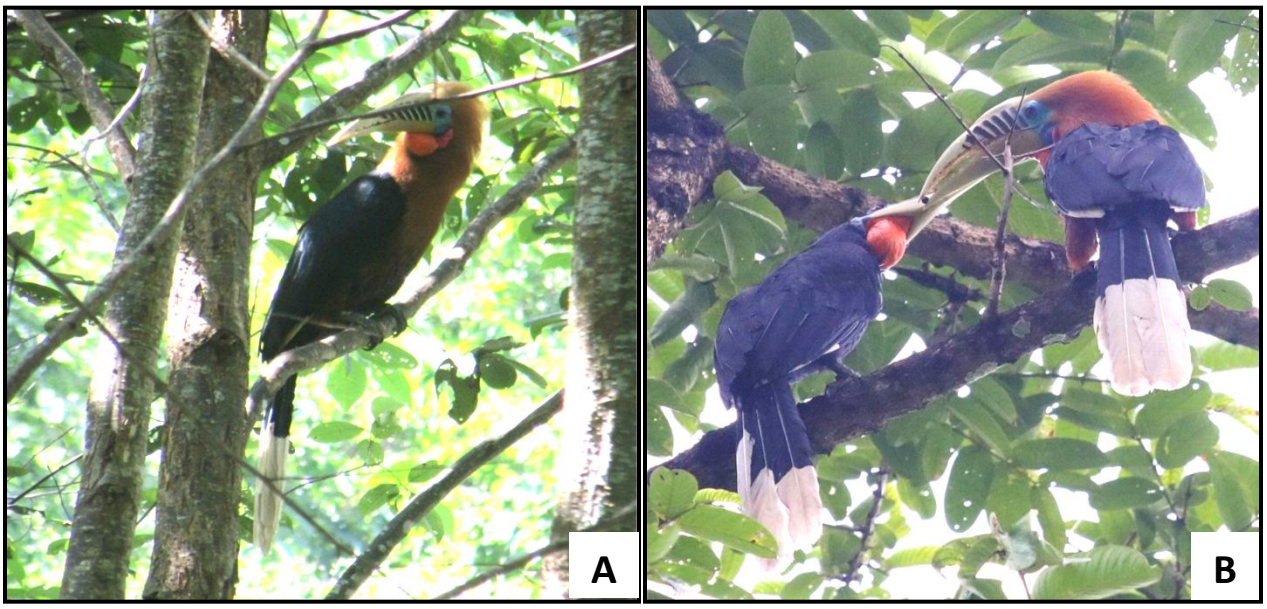

Figure 24: A) Male RNH scanning the area before visiting the nest (27th April, 2016); B) Male feeding the female (8th June, 2016- this pair was not breeding).

5.10 SYMPATRIC RELATIONSHIP

The RNH were seen sharing the same habitat with that of Great hornbill (GH). The nest of RNH located at Nabay locality was at proximity to the nest of GH, 21m apart, and both were nesting as of observation done during the breeding season of 2016. However, the nest previously occupied by Great hornbill in 2016 was occupied by RNH in 2017 (Figure 19), thus showing competition for nesting tree species. Both species seal the nest and have a similar time of visiting frequency

at nest hole (± 5 to 10 minutes for Great hornbill) to feeds the female. The two species were also spotted together on a single tree (Figure 25).

Figure 25: Rufous-necked hornbill and Great hornbill recorded together on same tree in Nabay locality (September, 2016).

While feeding the female, the Great hornbill (GH) spent maximum time (3 to 5 minutes) than RNH. Moreover, they regurgitates minimum of 19 and maximum of 32 times when feeding the female; whereas the RNH regurgitate minimum of 5 and maximum of 15 times, which shows that GH deliver maximum foods than the RNH. Also the female imprisonment of GH was observed on 6th April, 2017 (nest was located at Tingtibi locality, Zhemgang district), which was much more sooner than RNH. To add information, the fledging of Great hornbill was observed on July 24th, 2016 at the nest located at Nabay locality, quite similar timing to that of RNH.

5.11 HABITAT DISTURBANCE AND THREATS TO HORNBILL SPECIES

Forest as the habitat of wildlife is mainly composed of natural resources which is dominated by trees and natural environment, are now mostly facing a critical threat. Almost all the sampling sites were affected by grazing. During winter season, cattle from high altitude were being migrated and spent almost 2-3 months inside the RNH habitats within the study area. Many important saplings of fruiting tree species are being browsed, affecting the regeneration. The

cattle herders cut and fell the trees, including most of RNH food plant species. Temporary camp are being establish inside the forested area, creating immediate disturbances for foraging RNH to visits the area (Figure 26). Twice a forest fire occurred in Korphu locality on February, 2017. We assumed the causes due to car**e**less of these people.

Figure 26: Cattle migration (left) and temporary camp (right) set in the RNH habitat by the cattle herder.

Shifting cultivation was another major threat to the habitats. Higher intensity of this practice was seen in Korphu locality. The forest was encroached, slashed and burnt. Large trees were felled including important fruiting trees (P*hoebe* sp. and *Ficus* sp.), and area was being cleared from its vegetative cover (Figure 27), leading to habitat fragmentation and resource partition.

Figure 27: Clearing of forested area for shifting cultivation.

Another major threat was the high power transmission lines constructed in Nabay and Berti localities. Large trees were being cut down, opening the forested area and creating huge gaps or barriers, where the birds get very wary to traverse those gaps/barriers, leading to abandonment of an area (Figure 28).

Figure 28: The high power transmission lines constructed in the habitat of RNH.

Moreover, the locals inhabiting within or around the sampling sites were all dependent on the forest for timber and firewood, for the construction of houses; big trees are cut down to meet their needs (Figure 29). There are also reports of illegal logging. All these disturbances lead to habitat destruction, directly or indirectly affecting the nesting sites and feeding ground of hornbills. However, no threats of hunting have been so far reported from the area. This was also confirmed from the local villagers.

Figure 29: Logging in RNH habitat.

CHAPTER 6: DISCUSSION

6.1 HABITAT SELECTION BY RUFOUS-NECKED HORNBILL

The hornbills are known to prefer the dense mixed semi-evergreen forest and broadleaved forest patches for foraging and nesting, having plenty of edible wild fruiting trees (Raman & Mudappa, 2003; Saikia & Saikia, 2011). This type of habitat is mainly used for specific acts or needs such as foraging, nesting and roosting, or other life history traits (William & Leonard, 1993; Krausman, 1999). They are also known to play an important role in fruit removal and seed dispersal (Naniwadekar *et al*., 2015).

In JSWNP, the RNH mostly occurs along the southern and central part (Dorji, 2003) in the lower altitude range of warm broad-leaved forests. They are frequently sighted along the edges of forest clearings/river side, open, moist and groves of large fruit trees, similar to those recorded by Inskipp *et al*. (1999). The present study identified five localities (Korphu, Nimshong, Nabji, Nabay and Nimshong) as important habitats of RNH, because of frequent sightings throughout the year and being one of important ground for feeding, resting and nesting.

The habitats were composed of multi-storied woody tree species with a high representation of Lauraceae, similar to those recorded by Dorji (2013). The GBH of tree species occurs mostly between 20-40 cm (50.2%) and 41- 60 (22.7%) cm girth class with an average GBH of 49.9 cm. Michael *et al*. (2006) stated that the vegetation provides very important elements for the habitat of wildlife, and any changes in vegetation can, therefore, alter habitat conditions.

6.2 DISTRIBUTION AND POPULATION DENSITY

The current work was the first attempt to estimate the densities of RNH from the sampling sites within JSWNP. We used the line transect method, following Rahayuningsih and Nugroho (2013) formula for estimating RNH density. Gale and Thongaree (2006) stated that the density estimates are the starting point for monitoring populations and judging the success or failure of conservation and management actions.

Density estimates of RNH from present study was 1.22 birds/ km^2, comparatively lower than Thung Yai Naresuan (East) Wildlife Sanctuary in Thailand (5.55 birds/ km^2) (Jinamoy *et al*., 2013), Namdapha Tiger Reserve in India (6.9 birds/km^2) (Naniwadekar & Datta, 2013) and Subtropical Eastern Himalaya of India, which was 6.12 birds/km^2 (Shukla *et al*., 2016). However, Krishna *et al*. (2012) stated that finding the exact estimates is a difficult task.

Often, the large number of RNH was spotted during the non-breeding season, and the frequent sightings was either lone male or female (46.6 %, n=61). We recorded 8 RNH individuals in one group feeding on the fruits of *Beischimedia assamica* from the study area. Datta (2009) also reported the occurrence of RNH in bigger flocks (>10 birds), mostly at large fruiting trees. Generally, large habitat patches provide larger abundance of high quality food and may thus accommodate higher densities of hornbills (Sitompul *et al*., 2004).

6.3 DIET AND FORAGING BEHAVIOUR

Asian hornbills are dedicated fruit consumers but supplement their diet with animal food (Kinnaird & O'Brien, 2007). We recorded 35 fruits plant species consumed by RNH from the sampling sites. Kinnaird and O'Brien (2007) stated that the hornbills select the fruits that, on average, provide superior energetic rewards and usually more protein per fruit than those eaten by other birds and mammals. Some of the invertebrates such as larvae of lepidoptera and hymenoptera, adult beetles (coleopteran), two unknown species of insects and fresh water crabs (molluscs) were also being consumed.

Most of the feeding was carried out from small branches (58.5%) within the height range of 4 to 28 m above the ground level. They fed mostly at a height of 8-12 m (27.4%) and 12-16 m (27.4%) above the ground. Datta (2009) stated that the difference in use of canopy levels is related to their diet and foraging strategy. The feeding can take place at any time of the day (Kemp, 1995). Our result showed that active feeding occurred mostly between 6:00hr-12:00hr and 15:00hr-17:00hr during non-breeding season.

6.4 BREEDING BIOLOGY

The timing of nesting in hornbills is thought to be an adaptation to cope with seasonal pulses in food availability (Leighton, 1982; Kemp, 1995). The breeding season of RNH in JSWNP commences between 14th (2016), 22nd (2017) and 26th (2017) of April. The entire nesting trees recorded was large and emergent, having GBH ≥ 98 cm and tree height ≥ 21 m. Two of nests were recorded on the trunk of *Altingia excelsa*, showing the preferences, probably due to its large size. Datta and Rawat (2004) stated that the height and size of trees as well as commonness in the habitat are important factors in nest tree selection.

Hornbills show a strong fidelity to their nest sites, returning year after year to the same cavity (Kemp, 1995; Kinnaird & O'Brien, 2007). One nest located in the study area at Gonphaii locality was re-used for consecutive years in 2016 and 2017. Datta (2009) stated that overlap in nesting habitat between the RNH and other hornbill species is largely precluded. However, we have recorded the active nests of RNH and Great hornbill in the same area at the distance of 21m apart in breeding season of 2016.

Event of nest sharing between hornbill species was also observed as the nest previously occupied by Great hornbill on 2016 was occupied by RNH on 2017 in one of our study sites as mentioned. Kemp (1995) and Chuailua *et al*. (1998) stated that the exchange of nest between hornbill species is common, but the availability of cavities and competition for a site between hornbills and other animal species are complex and little studied. We observed that the breeding season of Great hornbill (6th April, 2017) commences earlier than RNH, where similar behaviour was observed by Datta (2009) in Arunachal Pradesh of India.

The cavity opening of hornbill are usually longer than its wide and may face in any direction (Poonswad, 1995). During the feeding, the male RNH always visited the nest from same compass direction. Few local people inhabiting in the sites told us that, it is to identify the right partner delivering the foods. If incase the male visit the nest from different direction, female do not receive the food; or if different male RNH is perching next to the nest of another RNH, then the male of nesting female leaves her and never return. At some point, the female dies inside the

cavity due to starvation. Therefore, the RNH are considered as a committed life partners (Personal communication).

6.5 CONSERVATION THREATS

Over the year, the threats of habitat loss and fragmentation have severely impacted the population of Rufous-necked hornbill, thus making more significant for conservation attention (Mudappa & Raman, 2009). Often the large trees were being cut by the local people, reducing the forest structure, which threatens the biodiversity. Throughout Asia, only 7% of forests inhabited by hornbills are under Protected Status, and the average size of these Protected Areas is ~ 350 km^2 (Kinnaird & O'Brien, 2007).

Most of the Asian hornbills are hunted for their body parts (casque and tail feathers for traditional attire), for consumption of their meat, and for their body fat, which is believed to have medicinal properties (Bennett *et al*., 1997; Aiyadurai *et al*., 2010; Naniwadekar & Datta, 2013). In addition, they face significant threats from logging and habitat fragmentation (Raman & Mudappa, 2003).

Our study highlighted the importance of food resources and nesting of RNH in the habitats within JSWNP. For a sustainable population, hornbills require sufficient food and safe nest sites, as provided by intact forests and large tree cavities (Kinnaird & O'Brien, 2007). Poonswad (1991) stated that the population and breeding status of hornbills indicates the health of the forests they inhabit.

JSWNP is currently one of the important habitats of Rufous-necked hornbill, a species considered ‘Vulnerable’ by IUCN. However, it is a Protected Area (PA) that is under varied human pressures such as selective agricultural practices, developmental activities, logging and grazing, which has resulted in park-people conflict and degradation of important habitat. However, no threats of hunting have been so far reported from JSWNP. This was also confirmed from the local villagers.

CHAPTER 7: CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based on the findings of this study, it can be concluded that Jigme Singye Wangchuck National Park is a suitable habitat for Rufous-necked hornbill, either as a place to eat, take a rest, and breed. Our estimation of RNH population density from the sampling sites varied from 0.01 birds/Km^2 to 0.41 birds/Km^2 with a total of 1.22 birds/km^2 (± 0.12). They were sighted in groups of 1-8 individuals and large group of ≥5 were usually sighted at the time of feeding on a single fruiting tree during the non-breeding season. Based on our research effort, the RNH was recorded in between 644m-1608m elevation range. Most of the sightings were recorded within the disturbed/secondary forests, edges of forest clearing and road side which provide them free movement and easy access for scanning fruit resources.

The sightings was usually highest in the months of March and February (2017) during the non-breeding season. The relationship between RNH abundance and number of trees in fruits at particular months of a year was moderately positive (0.226, p=0.558, 95% confidence level). However, there was negative relationship (r= -0.239; p=0.699, 95% confidence level) between tree density and hornbill density. Having p-value greater than the significance level of 0.05 in both the cases indicates inconclusive evidence about the significance of the association.

The result of vegetation sampling showed that the Lauraceae was the most dominant plant family in the sampling sites inside RNH habitats. Overall average tree density was 448 ± 58.13 trees/ha with 98 species (DBH ≥20 cm) representing 70 genera under 36 families. The girth of individual trees ranges from 20 cm to 244 cm with an average of 49.9 cm. Most of the GBH of trees species were between 20-40 cm (50.2%) and 41- 60 (22.7%) cm girth class.

Rufous-necked hornbill was recorded feeding on 35 different species of fruits and also on few invertebrates. The fruits consumed during the breeding and non-breeding seasons belonged to 11 and 6 families respectively. Lauraceae and Moraceae represent the highest species that were being consumed in both the periods. It was observed that the fruiting species consumed was available in highest number during the summer (June-August, 2016) season, of which first two

months coincided with the breeding period. The proportion of trees in fruit occurs in lesser number during the autumn (Sep-Oct), winter (Jan-Feb) and spring (Mar-Apr) seasons.

Most of the feeding was carried out from small branches (58.5%). Trunk and ground were rarely used. For feeding, RNH choose to feed by plucking fruits within the height range of 4 to 28 m above the ground. Mostly preferred height was between 8-12 m and 12-16 m on tree species. Active feeding occurred mostly between 6:00hr-12:00hr and 15:00hr-17:00hr during the non-breeding season.

RNH mostly preferred large and main stem for nesting and it was observed that the nest are being reused for consecutive years or shared with that of Great Hornbill. We recorded a total of 4 nesting trees. A preferred nest tree of RNH was *Altingia excels*a, as two nesting holes were located on this species. The nesting commences between 14th (2016), 22nd (2017) and 26th (2017) of April and fledging between 25th and 28th July of 2016. We were able to get the complete nesting cycle for a year from the nest located at Nabay locality, which completed at 102 days. This nest was not active as of observation done on 2017 breeding season.

During the nesting periods, it was observed that male RNH carry mixture of food items and feeds the female at the maximum of 5 times and minimum of 4 times in a day, spending around 30 sec to 75 sec while feeding the female. The time interval for the arrival of male RNH at nesting hole ranges from minimum 19 minutes to maximum 3 hours 25 minutes. The initial delivery time starts at 8:15 hr to final feeding at 17:17 hr. The male RNH was very vigilant, remaining silent and concealing themselves on disturbances near the nesting trees. They often visit the nest from same compass direction or avoid visiting on disturbances to hide the nesting sites.

The time (hr) of fledging and number of juveniles being fledged couldn't be observed from either of nests. However, during the transect walk, twice a single juvenile was seen with the adults. The main disturbances observed in the sampling sites were shifting cultivation, high power transmission lines, grazing and logging. However, no threats of hunting have been so far reported from the area which was also confirmed from the local villagers during the study.

7.2 RECOMMENDATIONS

We couldn't surveyed some areas where RNH was known to be occurred, due to various difficulties of logistics including travel, and unpredictable weather patterns, because terrain of these areas were rugged and inaccessible due to thick primary forest and big rivers, which makes us difficult to cross. Among districts, Sarpang was poorly covered and requires more field survey in the future. Although some local knowledge is available on the distribution of RNH, the lack of published information made it difficult to relate our findings with past information on distribution. However, the present survey presents baseline information across localities on RNH population density and various parameters describing them.

During the survey, RNH were also spotted from various sites, outside the boundary of designated PA. Looking ahead, it is essential to establish baselines through population estimation, monitoring of nest and roost sites in this areas as well as in the sites identified as critical for hornbill conservation by this survey. The larger hornbills, particularly the Great hornbill also occur in this region. Therefore, it becomes necessary for the protection and conservation of areas much larger than their "preferred" or even nesting habitats of both the species.

There is a need to develop a management and action plan for long term monitoring of Rufous-necked hornbill by the forest department and a field/conservation biologist. Conservation education and awareness to the local people residing within or proximity to the RNH habitat need to go hand-in-hand with all protection and conservation efforts as suggested by Mudappa and Raman (2009). The habitat of JSWNP should be well managed for the conservation of all other important species for our future generation.

Annexures

Annexure 1: List of tree species recorded from RNH habitat in five sites spread over the Jigme Singye Wangchuck National Park of Bhutan.

Si. No.	Tree species	Family
1	*Acrocarpus fraxinifolius*	Leguminosae
2	*Actinodaphne obovata*	Lauraceae
3	*Aesculus assamica*	Hippocastanaceae
4	*Aglaia lawii*	Meliaceae
5	*Ailanthus integrifolia*	Simaroubaceae
6	*Aphanamixis polystachya*	Meliaceae
7	*Alangium chinense*	Alangiaceae
8	*Albizia chinensis*	Leguminosae
9	*Albizia gamblei*	Leguminosae
10	*Albizia lebbeck*	Leguminosae
11	*Alcimandra cathcartii*	Magnoliaceae
12	*Alnus nepalensis*	Betulaceae
13	*Altingia excelsa*	Hamamelidaceae
14	*Alstonia scholaris*	Apocynaceae
15	*Bauhinia purpurea*	Leguminosae
16	*Beilschmiedia assamica*	Lauraceae
17	*Beilschmiedia gammieana*	Lauraceae
18	*Betula alnoides*	Betulaceae
19	*Bischofia javanica*	Bischofiaceae
20	*Bombax ceiba*	Bombacaceae
21	*Brassaiopsis glomerulata*	Araliaceae
22	*Bridelia retusa*	Euphorbiaceae
23	*Canarium strictum*	Burseraceae
24	*Callicarpa arborea*	Verbenaceae
25	*Casearia glomerata*	Flacourtiaceae
26	*Castanopsis hystrix*	Fagaceae
27	*Castanopsis tribuloides*	Fagaceae
28	*Celtis tetrandra*	Ulmaceae
29	*Choerospondias axillaris*	Anacardiaceae
30	*Chukrasia tabularis*	Meliaceae
31	*Cinnamomum bejolghota*	Lauraceae
32	*Cinnamomum impressinervium*	Lauraceae
33	*Duabanga grandiflora*	Sonneratiaceae
34	*Elaeocarpus lanceifolius*	Elaeocarpaceae

35	*Engelhardia spicata*	Juglandaceae
36	*Erythrina arborescens*	Leguminosae
37	*Eurya acuminata*	Theaceae
38	*Ficus benjamina*	Moraceae
39	*Ficus elastica*	Moraceae
40	*Ficus hispida*	Moraceae
41	*Ficus semicordata*	Moraceae
42	*Gynocardia odorata*	Flacourtiaceae
43	*Helicia nilagirica*	Proteaceae
44	*Helicia* spp.	Proteaceae
45	*Hovenia acerba*	Rhamnaceae
46	*Juglans regia*	Juglandaceae
47	*Kydia calycina*	Malvaceae
48	*Ligustrum compactum*	Oleaceae
49	*Lithocarpus elegans*	Fagaceae
50	*Lithocarpus fenestratus*	Fagaceae
51	*Lithocarpus listeri*	Fagaceae
52	*Litsea albescens*	Lauraceae
53	*Litsea cubeba*	Lauraceae
54	*Litsea* spp.	Lauraceae
55	*Litsea sericea*	Lauraceae
56	*Lyonia ovalifolia*	Ericaceae
57	*Macaranga denticulata*	Euphorbiaceae
58	*Macaranga peltata*	Euphorbiaceae
59	*Macaranga* spp.	Euphorbiaceae
60	*Mallotus nepalensis*	Euphorbiaceae
61	*Mallotus philippensis*	Euphorbiaceae
62	*Mangifera sylvatica*	Anacardiaceae
63	*Michelia champaca*	Magnoliaceae
64	*Michelia kisopa*	Magnoliaceae
65	*Morus australis*	Moraceae
66	*Morus macroura*	Moraceae
67	*Morus laevigata*	Moraceae
68	*Neocinnamomum caudatum*	Lauraceae
69	*Neolitsea foliosa*	Lauraceae
70	*Ostodes paniculata*	Euphorbiaceae
71	*Peltophorum pterocarpum*	Leguminosae
72	*Persea clarkeana*	Lauraceae
73	*Persea duthiei*	Lauraceae

74	*Persea odoratissima*	Lauraceae
75	*Persea* spp.	Lauraceae
76	*Phoebe attenuata*	Lauraceae
77	*Phoebe lanceolata*	Lauraceae
78	*Phoebe* spp.	Lauraceae
79	*Picrasma javanica*	Simaroubaceae
80	*Pterospermum acerifolium*	Sterculiaceae
81	*Quercus acutissima*	Fagaceae
82	*Quercus glauca*	Fagaceae
83	*Quercus griffithii*	Fagaceae
84	*Sapium insigne*	Euphorbiaceae
85	*Schefflera tenuis*	Araliaceae
86	*Schima wallichi*	Theaceae
87	*Sloanea tomentosa*	Elaeocarpaceae
88	*Spondias pinnata*	Anacardiaceae
89	*Sorbus wallichii*	Rosaceae
90	*Sterculia villosa*	Sterculiaceae
91	*Symplocos lucida*	Symplocaceae
92	*Syzygium cumini*	Myrtaceae
93	*Talauma hodgsonii*	Magnoliaceae
94	*Terminalia myriocarpa*	Combretaceae
95	*Terminalia* spp.	Combretaceae
96	*Toona ciliata*	Meliaceae
97	*Wendlandia puberula*	Rubiaceae
98	*Wrightia arborea*	Apocynaceae

Annexure 2: Sampling records of Rufous-necked hornbill in terms of days spent, total and average sightings and mean population of Rufous-necked hornbill.

Sites No.	Area	Season	Month & year	Days spent	Total Sightings	Total average sighting	Mean population count
1	Nabay	Summer	June, 2016	2	18	9	7
			July, 2016	1	1	1	
		Autumn	October, 2016	2	11	5.5	
		Winter	February,2017	2	15	7.5	
		Spring	March, 2017	1	14	14	
			April, 2017	1	4	4	
2	Gonphaii	Summer	July, 2016	2	7	3.5	7.3
		Autumn	October, 2016	2	9	4.5	
		Winter	February,2017	2	18	9	
		Spring	March, 2017	1	17	17	
			April, 2017	1	7	7	
3	Nabji	Summer	August, 2016	1	4	4	5.83
		Autumn	October, 2016	2	11	5.5	
		Winter	February,2017	2	10	5	
		Spring	March, 2017	1	10	10	
4	Nimshong	Summer	August, 2016	4	14	3.5	5.75
		Autumn	September, 2016	2	19	9.5	
		Winter	January, 2017	1	8	8	

			February,2017	1	5	5	
5	Korphu	Summer	August, 2016	1	4	4	5.8
		Autumn	October, 2016	2	11	5.5	
		Winter	February,2017	2	14	7	
6	Berti	Summer	July, 2016	2	4	2	2.5
		Winter	February,2017	1	4	4	
		Spring	March, 2017	1	2	2	
7	Chungshing	Summer	July, 2016	1	2	2	2
8	Chakarthang	Summer	July, 2016	1	2	2	2
				TOTAL	**245**	**161**	

Notes:

a. Total average sighting= Total sighting / days spent

b. Mean population count= Average of "total average sighting"

Annexure 3: Images of fruits that were being consumed by Rufous-necked hornbill within Jigme Singye Wangchuck National park.

1. *Alangium chinense*

2. *Aglaia lawii*

3. *Aphanamixis polystachya*

4. *Beilschmiedia assamica*

5. *Beilschmiedia gammieana*

6. *Canarium strictum*

7. *Casearia glomerata*

8. *Choerospondias axillaris*

9. *Cryptocarya amygdalina*

10. Daphniphyllum sp. *11. Eleocarpus lanceofolius* *12. Ficus benghalensis*

13. Ficus roxburghii *14. Ficus hederacea* *15. Ficus hispida*

16. Ficus hirta 17. *Ficus* sp. *18. Ficus semicordata*

19. Mangifera sylvatica

20. Litsea sp.

21. Litsea spp.

22. Neocinnamomum caudatum

23. Persea sp.

24. Terminalia sp.

25. Talauma hodgsonii

26. Unidentified 1

27. Unidentified 2

Annexure 4: Monthly availability of trees in fruit that were being consumed by Rufous-necked hornbill within Jigme Singye Wangchuck National Park

Jan-2017

1. *Beilschmiedia assamica*

Feb-2017

1. *Beilschmiedia gammieana*
2. *Ficus benghalensis*
3. *Ficus elastica*
4. *Ficus hederacea*
5. *Ficus semicordata*
6. *Litsea* spp.
7. *Neocinnamomum caudatum*
8. *Parasassafras confertiflora*
9. *Persea* sp.
10. *Terminallia* spp.

Mar-2017

1. *Beilschmiedia assamica*
2. *Beilschmiedia gammieana*
3. *Ficus hederacea*
4. *Ficus* spp.
5. *Terminallia* spp.

Apr-2017

1. *Beilschmiedia gammieana*
2. *Terminallia* spp.

Jun-2016

1. *Aglaia lawii*
2. *Aphanamixis polystachya*
3. *Beilschmiedia gammieana*
4. *Canarium strictum*
5. *Choerospondias axillaris*
6. *Cryptocarya amygdalina*
7. *Daphniphyllum* sp.
8. *Eleocarpus lanceofolius*
9. *Ficus roxburghii*
10. *Ficus* spp.
11. *Litsea* sp.

Jul-2016

1. *Aglaia lawii*
2. Artocarpus lakoocha
3. *Casearia glomerata*
4. *Ficus roxburghii*
5. *Ficus semicordata*
6. *Persea* sp.
7. *Phoebe* spp.
8. *Talauma hodgsonii*

Aug-2016

1. *Ficus benjamina*
2. *Ficus hederacea*
3. *Neocinnamomum caudatum*
4. *Prunus* spp.
5. *Ficus* spp.

Sep-2016

1. *Beilschmiedia assamica*
2. *Ficus hederacea*
3. *Mangifera sylvatica*

Oct-2016

1. *Alangium chinense*
2. *Beilschmiedia assamica*
3. *Choerospondias axillaris*
4. *Ficus hispida*
5. *Hovenia acerba*
6. *Mangifera sylvatica*
7. Unidentified 1
8. Unidentified 2

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