Conservation of critically endangered White-bellied Heron and fostering community livelihood in Jigme Dorji National Park under Punakha district, Bhutan

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PLAGIARISM DECLARATION FORM

I declare that this is an original work and I have not committed, to my knowledge, any academic dishonesty or resorted to plagiarism in writing the project "**Conservation of critically endangered White-bellied Heron and fostering community livelihood in Jigme Dorji National Park under Punakha district, Bhutan**". All the sources of information and assistance received during the course of the study are duly acknowledged.

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ACRONYMS AND ABBREVATIONS

BA	Basal Area
CNR	College of Natural Resources
DBH	Diameter at Breast Height
DoFPS	Department of Forests & Park Services
DR1	Day roosting site 1
DR2	Day roosting site 2
FAO	Food and Agriculture Organization
FNCA	Forest and Nature Conservation Act
FO	Forest Officer
GIS	Geographic Information System
GPS	Global Positioning System
IUCN	International Union for Conservation of Nature
IVI	Important Value Index
m.a.s.l.	Meters Above Sea Level
MoAF	Ministry of Agriculture & Forests
N1	Nest site 1
N2	Nest site 2
NBC	National Biodiversity Centre
NPPC	National Plant Protection Centre
NR1	Night roosting site 1
NR2	Night roosting site 2
RBA	Relative Basal Area
RSGF	Rufford Small Grants Foundation
RSPN	Royal Society for Protection of Nature
SD	Standard Deviation
Sp.	Species
SPSS	Statistical Package for Social Sciences
WBH	White-bellied Heron

ABSTRACT

The study was conducted in nesting and roosting habitats of White-bellied Heron along the stretch of Phochu river to determine the floristic composition and vegetation structure. Systematic sampling method was used to collect vegetation data. The sampling plot sizes were 10 x 10 m for trees, 5 x 5 m for sapling and shrubs, and 2 x 2 m for herbs and ground flora. The data were summarized, analyzed and graphically presented using Microsoft Excel 2007 and SPSS version 20. The floristic compositions of six transects selected at different habitats were composed of 33 families with 59 species. The major life-forms of tree species in the entire study area constituted conifer trees, evergreen broad-leaved trees and deciduous broad-leaved trees. Monodominant forest type with *Pinus roxburghii* was found in the study area. The distribution of trees in DBH classes produced unimodal, multimodal and inverse-J type patterns. The presence of human disturbance in the area has affected on forest structure and dynamics. In general, 97% of local residents were much aware of the WBH in the proximity of their village. However, the concern to apply conservation principles remained poor. There was no evidence of direct killing and hunting of birds by human but the movement of people for fishing, animal herding, firewood collection, and rafting were recognized as direct threats and disturbances to the birds. Lack of community support towards species was observed as the most significant indirect threats. Therefore, complete protection of the WBH habitat is voiced as immediate conservation action to be taken in the study area.

Key words: Habitats, species composition, vegetation structure, White-bellied Heron

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CHAPTER ONE

Introduction

1.1 Background

Forest vegetations are essential for life on earth. It provides basic habitats to diverse animal species for their survival. Many animals depend on forest resources for food, water, space, shelter, nesting materials and nest sites. Many animals rely on forest resources as sites for foraging, nesting, and protection that may vary in abundance in forests of different ages (Saara *et al.*, 2003). Yarrow (2009) said that the environment or natural home where a wild animal lives is called its habitat. It is very important to understand about the suitable habitat preferred by the individual species. The amount of suitable habitat for a species of wildlife will determine the number of animals that can survive in the area (University of Illinois Board of Trustees, 2015). The assessment of vegetation composition and structure is a useful tool to examine and understand the habitat characteristics and impacts of disturbance or alteration of habitats on the avian species (Rajpar and Zakaria, 2011). Changes in species composition and structure of vegetation in the forest due to natural as well as human-caused disturbances may have significant impacts on lives of these animals. Saara *et al.* (2003) stated that the changes in tropical forest structure and species composition may have important consequences for wildlife populations. Thus the best way to manage wildlife is to manage the habitats in which they live (Janean *et al.*, 1997). The White-bellied Heron (hereafter referred to as WBH) also known as the Imperial Heron and scientifically named as *Ardea insignis* Hume, is now, suffering from degradation of its natural habitat and declining population.

This heron is classified as Critically Endangered in the IUCN Red List of Threatened Species because of its extremely small and rapidly declining population (BirdLife International, 2013). Again this decline is projected to increase in the near future as a result of the loss and degradation of lowland forest and wetlands, and through direct exploitation and disturbance (BirdLife International, 2015). The worldwide population is roughly estimated to 200, and herons are among the 50 rarest bird species on earth (WWF, 2015).

This bird is known to occur in the eastern Himalayan foothills in Bhutan and north-east India, to the hills of Bangladesh and north Myanmar (BirdLife International, 2001). According to (BirdLife International, 2015), it may also occur in south-east Tibet, China, but is now extinct in Nepal. Literature also suggests in Myanmar, it has evidently declined throughout its range given

the paucity of recent records. In Bhutan, 30 individuals are known to occur in their natural habitat playing a pioneering role in protecting the critically endangered white-bellied heron (RSPN, 2015). This literature suggests that there are 4 individuals in Berti and 26 in Punatsangchu basin.

1.2 Problem Statement

White-bellied Heron today is a species on the edge of extinction, with a small and rapidly declining population. It is important to understand the interrelationships of birds with components of their natural ecosystem in order to manage and conserve their natural environment to protect them from the extinction. If we don't protect this species now, we would not be able to have these species around us soon. It is important to think what is wrong in the ecosystem when such significant indicator species are getting extinction. It is time for us to realize how our environment is changing and how to conserve it. Habitat destruction among other factors could be the one leading towards extinction of the species in question. Wilcove *et al.* (1998) stated that habitat destruction is the leading cause of species imperilment; thus protecting habitat is essential to their recovery. Similarly, the habitat of WBH along the Punatshangchu basin is increasingly being disturbed by increasing developmental activities and human population. Now there is still need to do the study and keep on updating the status of habitat ecology of WBH in order to enhance its survival and recovery of population.

The Royal Society for Protection of Nature (RSPN) has been involved in the White-bellied Heron conservation project since 2003 and has done several works on it. However, data and information on habitat ecology of WBH still requires to be described in more detail. For this reason, it is felt necessary to do detail study on species composition and structure of vegetation in roosting and nesting habitat of WBH in order to provide a scientifically valid justification that refers to scientific literature and make a statement towards conservation.

1.3 Objectives and research questions

Main objective of this research was to assess the species composition and structure of vegetation preferred by WBH for nesting and roosting in order to assist in improving its conservation status and habitats. The specific objectives and research questions were:

- To assess the natural habitats preferred by heron for nesting and roosting.

- ✓ What are the taxonomic compositions and structure of the vegetation preferred by heron for nesting and roosting?
- ✓ Is there difference in species diversity, dominance, richness, vegetation structure and composition in different habitat types?
- ✓ Where do heron nests and roosts, on big or small tree, near to the cultivated land, foraging areas, thick forest, settlements and roads including a full description of the location and condition of the habitat?
- ✓ Find out whether they use same sites for nesting and roosting and also the same tree for roosting throughout the season?

➢ To assess the conservation threats and disturbances towards WBH and its habitats.

- ✓ People's perception in degree of awareness?
- ✓ What are the major threats and disturbances towards conservation of bird and its habitats, and the requirement of immediate conservation actions?

CHAPTER TWO

Literature review

This chapter reviews literature related to study that has been carried out. The information reviewed in this chapter are general background, habitat and diet, nesting and roosting, importance of species composition and vegetation structure, and threats to WBH and conservation efforts in Bhutan.

2.1 General Background

WBH is the world's second largest heron, known historically from the eastern Himalayan foothills of India, Nepal, Tibet, Bhutan, and Burma (Ali and Ripley, 1978; Gimmett *et al.*, 1999; Birdlife International, 2001; RSPN, 2011). It is 1.60 m tall, with distinct white-belly and white crest (RSPN, 2011). It is a very large and long necked bird mostly dark grayish with contrasting white throat, belly and vent, and white-streaked scapulars, foreneck and upper breast. It is found along the riverine chir pine forests in Bhutan. The population size of this species is extremely small and faces the threat of extinction if no protective actions are taken. This study expected that one of the main factors causing rare and critically endangered bird susceptible to extinction was habitat loss and degradation.

2.2 Habitat and diet

Wildlife populations depend on their habitat to receive the basic needs like food, water, shelter and space for survival without which populations of wildlife cannot exist (University of Illinois Board of Trustees, 2015). The WBH is recorded from small or large rivers, usually with sand or gravel bars, and often within or adjacent to subtropical broadleaved forest from the lowlands up to at least 1,500 m, and it has also been reported from an inland lake (Tordoff *et al.*, 2006). Generally it remains solitary but may aggregate into small flocks and family groups during winter (Pradhan, 2007) and tends to move into inaccessible and undisturbed areas. It is an extremely shy bird which feeds on fish in clear fast flowing rivers (Singh, 2015). In Bhutan, it has recorded birds foraging on two major rivers (Punatsanchu and Bertichu), and also at a small lake (Ada). They eat mainly fish and they fish in the river in knee deep shallow water. A young bird eats 9 to 10 small fishes and the adults eat 6 to 8 medium size fishes a day (RSPN, 2011).

2.3 Nesting and roosting

It is important to identify and understand the characteristics of nesting and roosting sites of this bird for its conservation. Nest and roost characteristics are very important factors related to avian habitat selection (Deng *et al.*, 2003). According to RSPN (2011), White-bellied herons are found to be roosts and nests on tall chir pine trees (*Pinus roxburghii*). Other tree species like East Indian almond (*Terminalia myriocarpa*) has also been found to be used for nesting by bird (Singh, 2015). A large tree with open space in front and the tree standing on steep slope of 42-68^0 are chosen for nesting (Wangdi, 2014).

Nest building usually starts from February to March. However, occasionally it gets delayed till May due to accidents like forest fires (RSPN, 2011). In Bhutan eight nesting sites have been identified amongst lofty flowing waters with pebbly substrates and chir pine forests. The nesting locations are near confluences of tributary and main rivers to keep themselves away from predators and human disturbances; and also to forage on rivers depending on season and fish behavior (RSPN, 2011). Breeding and nesting by WBH is in between March and June (BirdLife International, 2011). Beside Bhutan, a nesting site of the WBH has been discovered in a remote part of the Namdapha Tiger Reserve in Arunachal Pradesh, India (Singh, 2015). Large rocks, logs and trees, bare sandy patches are found to be used for roosting by bird (RSPN, 2011).

2.4 Importance of species composition and vegetation structure

Forest vegetations are indispensible resources for almost all the living beings. Vegetation in its most general term refers to the plant cover of the earth (Brocklehurst *et al.*, 2007). It is a vital component of the natural environment, and the terrestrial vegetation includes natural ecosystems, such as native forests and woodlands, shrublands, grasslands or wetlands (Thackway *et al.*, 2006). Knowledge on structural characteristics of vegetation is highly demanded both at global and local level for parameterize global vegetation maps and to compare the vegetation types in terms of structural parameters (Jibrin and Jaiyeoba, 2013). Similarly, Kent (2012) mentioned that in most terrestrial parts of the world, vegetation is the most obvious physical representation of an ecosystem. It represents the base of the trophic pyramid. Vegetation also acts as the habitat within which the organisms live, grow, reproduce and die. These points show the central importance of vegetation to be studied in ecology.

Information about vegetation composition and structure is important to understand in managing wildlife habitat because plant species are closely related to wildlife use. Vegetation composition and structure are key components of wildlife habitat (McComb *et al*., 2010; Morrison *et al.*, 2006). Forest vegetation can provide important resources for nesting, foraging, and protection for a variety of animal taxa. The changes in forest structure and composition may have different implications for different wildlife populations (DeWalt *et al.*, 2003).

2.5 Threats to WBH and Conservation efforts in Bhutan

A species with tiny population size and small gene pool, the WBH is predicted to undergo genetic isolation and inbreeding depression. Therefore, it is considered to be the most important threat to the existence of the species (RSPN, 2011). Habitat fragmentation and degradation due to increasing human use and habitation of river valleys, logging, wildfire intensity, unsustainable fishing, modification of river sediments, water pollution, hydropower projects etc. could be other important threats to WHB and their habitats (RSPN, 2011). The main threats are presumed to be widespread loss, degradation and disturbance of forest and wetlands (BirdLife International, 2015). It said that the wetlands have become degraded as a result of pollution, rapid growth of aquatic vegetation, and the over-exploitation of resources. The Royal Society of Protection of Nature (RSPN) is an only civil society organization working on environment conservation in the Kingdom of Bhutan and it has been involved in the White-bellied Heron conservation project since 2003 (RSPN, 2015).

CHAPTER THREE

Materials and Methods

This chapter describes study area, materials and the methodology used for the research. Both the secondary and primary data were used to meet the research objectives.

3.1 Study area

The study was conducted along the Phochu river under the Punakha district of Bhutan. The upper part of the study area falls under Jigme Dorji National Park (JDNP), located in the north western part of the country. The study area covers the stretch of river ranging in elevation from approximately 1276 to 1464 m.a.s.l. Vegetation around the study area is dominated by chir pine (*Pinus roxburghii*) at lower elevations and mixed broadleaved forests at upper elevations. This area is moderately warm in winter and hot in summer. The settlements are found along the deep and wide valleys of river banks and live with subsistence agriculture and animal husbandry. Rice is grown as the main crop along the river valleys. This area provides support for WBH as their nesting and roosting habitats. The forest in this area has been recognized as one of the most important habitats for WBH conservation in Bhutan and has received legal protection. In 2007, the Royal Government of Bhutan has recognized the significance of the WBH, which is evident from the order issued by the Cabinet Secretariat: Phochu is declared as protected habitat of White-bellied Heron vide the approval of the Cabinet Secretariat letter No COM/04/07/887 dated March 1, 2007 and 336th CCM Sessions (Stanley *et al.*, 2015). Study area map was made using ArcGIS version 10.2.2 (Figure 3.1).

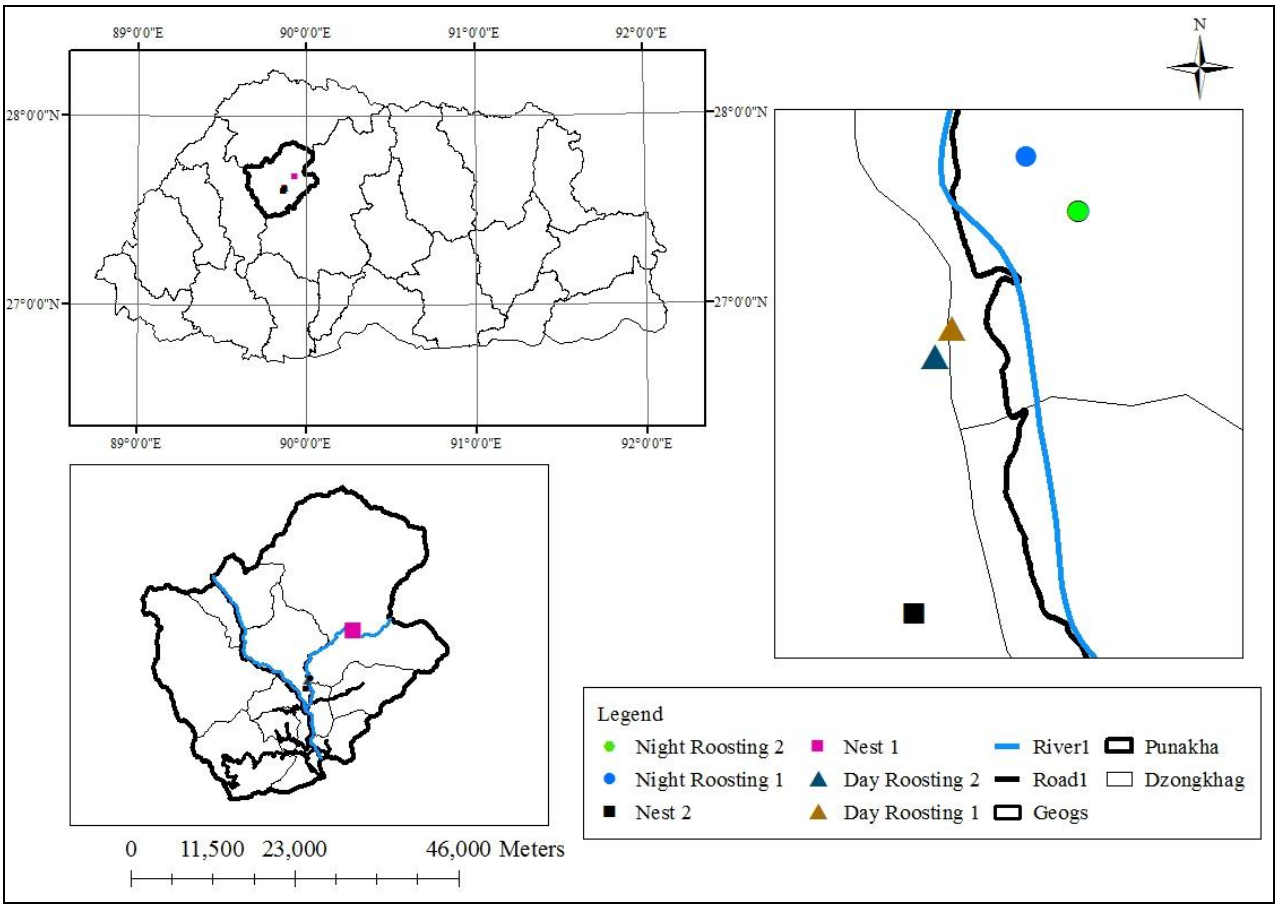


Figure 3.1. Study area

3.2 Survey design

3.2.1 Data collection

Data collection was conducted in January, 2016 using the data collection formats provided in annexure (Annexure 1, 2, 3, 4 and 5). The study area was divided into three habitat types; that are, nesting, night roosting and day roosting sites. Night roosting sites were confirmed in consultation with the local people and finding of their droppings beneath the trees. The day roosting sites were confirmed with repeatedly observed bird resting on a particular sites or trees. Then a single line transacts using "gradsect" or gradient-directed transect (Gillison and Brewer, 1985) were established running along the center of each nesting and roosting trees. Quadrats or observation points of 10 m x 10 m were systematically established at every 50 m rise in altitude from starting point of the transacts. The estimated variables of the vegetation were plant DBH,

plant species diversity, richness and evenness, plant height, dominance and the important value index (IVI).

The plant data were recorded with stratifying the vegetation into layers based on the life-forms and heights of the plant species. The vertical structure of vegetation in the study area constitutes tree layer, sapling layer, shrub layer, and the layer of herbs and ground flora. Any woody perennial that has DBH of above 10 cm were classified as trees, whereas all tree species having DBH above 5 cm but less than 10 cm were identified as sapling. Woody perennial plant more than 0.5 m and less than 5 m high at maturity without a definite crown were considered as shrubs and regenerations, and any soft-stemmed plant with height equal to or less than 2 m were recorded as herbs. In total, 48 plots were sampled in the study sites: 8 plots each in 2 nesting sites; 8 plots each in 2 day roosting sites; 8 plots each in 2 night roosting sites.

In each layer each species is assigned a DBH (tree and sapling), height and cover percent based on its representation in that layer. The determination of cover percent of plant species within a plot/quadrat were estimated ocularly, and it has been broadly classified as: open canopy = 10-39%; moderately closed = 40-69%; and closed canopy = 70-100%. The tree data were collected from 10 m x 10 m plots, sapling and shrubs from 5 m x 5 m plots, and herbs and ground flora from 2 m x 2 m plots.

Distances to the nearest settlements, roads, agriculture field and feeding sites (river banks) from the centered point of nesting and roosting sites were recorded with the help of measuring tape and GPS. At the same time, other physical variables like aspect, slope percent and altitude were also collected.

The equipments like 50 m measuring tape, diameter tape, compass, clinometer, digital camera, binoculars, pens, pencils and data sheets were used to collect data from the field survey. A Garmin GPS (Global Positioning System) was used to mark the location of transects and sampling plots. Later, the GPS coordinates were used to create a map showing the clear location of the plots and to compute the crow-flight distance from nesting and roosting sites to the nearest settlements, agriculture field, feeding ground and the road.

Most of the plant species were identified at the site and recorded in the developed field data format. Those un-identified plant specimens were photographed and collected providing proper coding like plant, plot and transact numbers (e.g. $\mathrm{Fern_1T_1P_1}$) for later on identification. Pteridophytes of Bhutan-A list of Families, Genera and Species (NBC, 2009),

Flowers of the Himalaya (Polunin and Stainton, 2006), Know the Plants of Bhutan (Thinley, 2004), and Weeds of Bhutan (Parker, 1992) were used to cross-check and do proper identification of the plant species.

3.2.2 Social survey

Social survey was conducted in January, 2016 to provide information on degree of awareness, people's perception and attitudes towards the conservation of bird, general disturbances and threats to the WBH and its habitats. The targeted population for the study was aged 15 and above, living in household along the study area. The population was stratified village wise into different groups. Then minimum of 30% sample size were drawn randomly from each village. This sampling frame was used to obtain a better coverage of households in the targeted area. A field sample size of 58 households was selected for the survey from 10 villages, representing two geogs. The survey was conducted face-to-face with an in-person interview using 90% closed ended questionnaire. The questionnaires included questions about familiarity with WBH, frequency of observation, rating for conservation importance, threats and disturbances towards bird and its habitats, and requirement of immediate conservation actions (Annexure 6).

3.3 Data analysis

3.3.1 Vegetation data analysis

The raw data collected from the field were arranged, summarized and presented graphically using Microsoft Office Excel 2007. The statistical significance of the differences between the habitats types were tested with the nonparametric Kruskal-Wallis and Mann-Whitney tests. The species composition in the study area was computed using the following parameters:

1. Relative dominance = (total basal area for a species/total basal area of all species) × 100.
2. Relative density = (number of individuals of a species/total number of individuals) × 100.
3. Relative frequency = (frequency of a species/sum of all frequencies) × 100.
4. Relative diversity = (number of a species in a family/total number of species) × 100.
5. The importance value index (IVI) = relative dominance + relative density + relative frequency.
6. The frequency of a species = the number of transects in which the species occur.

The theoretical range for relative dominance, relative frequency, relative density and relative diversity is 0 – 100%, so that IVI of species and FIV may vary between 0 and 300% (Froumsia *et*

al., 2012). Structural characteristics (DBH, height and basal area, canopy cover) were calculated. To compare diversity between transects, Shannon's measure of evenness (E_H), Shannon-Wiener's diversity index (H') and species richness (S) were calculated. The diameters of tree at breast height (DBH) were used to determine basal area (BA cm^2) and the relative basal area in percent (RBA percentage). The RBA percentage of each species was used as abundance measure of species in a community (Wangdi, 2014). The formulae described by Zobel *et al.* (1987) were used for calculating basal area (BA), relative basal area percentage (RBA %) and species diversity index (H') as shown below:

7. Basal Area (BA) = πr^2 or $\pi d^2/4$

   d = DBH (diameter at the breast height); radius (r) = (diameter / 2)

8. Relative Basal Area (RBA%) = Basal cover of individual species × 100/ Total basal cover of all species

Species diversity index (H') was calculated using Shannon-Wiener diversity equation (Pielou, 1977). The proportion of species *i* relative to the total number of species (P_i) was calculated, and then multiplied by the natural logarithm of this proportion ($\ln P_i$). The resulting product was summed across species, and multiplied by -1 to remove the negative sign of H' value as shown below:

9. Shannon-wiener index (H') = $-\sum Pi \log_n Pi$

Where $Pi = \dfrac{Number.of.individual.of.one.species}{Total.number.of.all.individual(one.forest.only)}$

The height and coverage percent were used to determine the volume and the relative volume or dominance of the herb layers and the ground flora. Important value (*Pi*) was calculated to find the diversity using natural log.

3.3.2 Social data analysis

Microsoft Office Excel 2007 was used to summarize, analyze and also for graphical presentation of the social data.

CHAPTER FOUR

Results and Discussion

This chapter describes the results of the study carried out based on the research objectives. The results include taxonomic composition and structure of the habitats, nest and roost tree characteristics of WBH, degree of awareness and people's perception, nesting and roosting habits, and conservation threats and disturbances.

4.1 Taxonomic compositions and structure of the habitats

4.1.1 Tree species and family composition

The entire tree species recorded in 48 sample plots from the six transects resulted at total of 189 individuals/stems consists of 10 species belonging to six families (Table 4.1). The most common tree species were *Pinus roxburghii* at 86.77% (*n* = 164), followed by *Quercus griffithii* with 3.7% (*n* = 7), *Macaranga pustulata* and *Schima wallichii* at 2.65% (*n* = 5) each. The least recorded tree species were *Albizia lebbeck, Alnus nepalensis, Docynia indica, Lyonia ovalifolia* with 0.53% (*n* = 1) each followed by *Quercus glauca* and *Quercus semecarpifolia* with 1.06% (*n* = 2) each respectively. Among the six families recorded, Fagaceae (39.94%) with three species and Pinaceae (17.49%) represented by a single species were the dominant families (Table 4.1).

Table 4.1. Relative abundance and tree species family composition

Species Name	Stem count	Relative abandance	Family	RBA (%)
Albizia lebbeck	1	0.53	Leguminosae	3.44
Alnus nepalensis	1	0.53	Betulaceae	11.88
Docynia indica	1	0.53	Rosaceae	8.82
Lyonia ovalifolia	1	0.53	Ericaceae	0.28
Macaranga pustulata	5	2.65	Euphorbiaceae	4.05
Pinus roxburghii	164	86.77	Pinaceae	17.49
Quercus glauca	2	1.06	Fagaceae	0.63
Quercus griffithii	7	3.70	Fagaceae	35.12
Quercus semecarpifolia	2	1.06	Fagaceae	4.19
Schima wallichii	5	2.65	Theaceae	14.10

4.1.2 Tree species diversity, richness and major life-forms

Among six transects, the highest tree species (S) was recorded in nest 1 at 62.5% (*n* = 10), followed by 12.5% (*n* = 2) in nest 2, while night and day roosting sites recorded the least number of tree species with 6.25% (*n* = 1) in each. The Shanon's H' diversity was recorded highest in nest 1 (1.84) and the least in nest 2 (0.07), and there is no tree diversity at all in other transects or sites (Table 4.2).

Table 4.2. Transect wise tree community parameters

Transect ID	Diversity (H')	Species richness (S)	Species evenness (EH)	RS	Stem count	Family
N1	1.84	10	0.8	62.5	40	6
N2	0.07	2	0.1	12.5	20	2
NR1	0	1		6.25	23	1
NR2	0	1		6.25	39	1
DR1	0	1		6.25	36	1
DR2	0	1		6.25	33	1

Note: N1 = nest 1; N2 = nest 2; NR1 = night roosting site 1; NR2 = night roosting site 2; DR1 = day roosting site 1; DR2 = day roosting site 2; and RS = relative species richness

P. roxburghii was the dominant species, while *Q. griffithii* and *Q.glauca* were the co-dominant species with regards to relative basal cover. *P. roxburghii* has highest relative density of 86.77, relative frequency of 37.50, relative dominance of 79.93 and important value index of 204.20. It was followed by *Q. griffithii* and *Q. glauca* with relative density of 3.70 and 1.06 respectively. The least recorded tree species were *L. ovalifolia* and *A. lebbeck* with relative density of 0.53 each, relative frequency of 6.25 each, relative dominance of 0.07 and 0.83, and important value index of 6.85 and 7.61 respectively (Table 4.3). Overall analysis showed *P. roxburghii* as the dominant and most important species in the habitat of WBH with higher IVI.

The dominant species refer to the species with considerable and prominent effects on their habitats in respect to size, frequency, production and their activity (Ardakani, 2009). According to Razavil *et al.* (2012), the biotic and abiotic components and metabolic of the habitat will change if the dominant species is removed from the habitat. If riparian vegetation is removed, the resulting changes in water chemistry and temperature may harm fish, aquatic invertebrates,

amphibians, and many songbirds (Janean *et al.*, 1997). Similarly, this study concludes that removal and changes in the amount of vegetation cover will have the greatest influence on birds.

Table 4.3. Important Value Index of individual tree species

Species Name	No. of Individuals	Frequency	BA (cm2)	Relative density	Relative frequency	Relative dominance	IVI
Pinus roxburghii	164	6	92469.33	86.77	37.50	79.93	204.20
Quercus griffithii	7	1	9809.07	3.70	6.25	8.48	18.43
Quercus glauca	2	2	346.43	1.06	12.50	0.30	13.86
Schima wallichii	5	1	3937.28	2.65	6.25	3.40	12.30
Macaranga pustulata	5	1	1131.33	2.65	6.25	0.98	9.87
Alnus nepalensis	1	1	3318.31	0.53	6.25	2.87	9.65
Docynia indica	1	1	2463.01	0.53	6.25	2.13	8.91
Quercus semecarpifolia	2	1	1170.24	1.06	6.25	1.01	8.32
Albizia lebbeck	1	1	962.11	0.53	6.25	0.83	7.61
Lyonia ovalifolia	1	1	78.54	0.53	6.25	0.07	6.85

The life-form spectrum of each forest type was determined based on the relative basal area of their life-forms; evergreen, deciduous, and conifers in each forest community (Wangda and Ohsawa, 2006). The major life-forms of tree species in the entire study area constituted one conifer trees, three evergreen broad-leaved trees and six deciduous broad-leaved trees with relative basal area of 86%, 11% and 3% respectively (Figure 4.1).

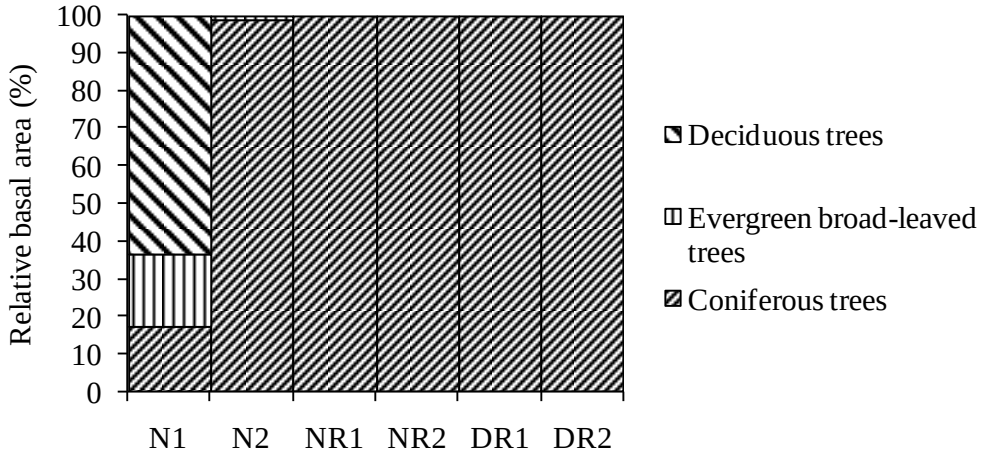


Figure 4.1. Major life-forms of tree species

4.1.3 Comparison of tree species composition among the habitat types

There was significant difference in tree species composition among the habitat types ($H(2) = 52.179$, $p = .000$). The significant differences in species composition were found between nesting site to the day roosting and night roosting sites. However, there was no significant difference in species composition in between two roosting sites (Table 4.4).

This may be due to the result of some nesting site located at an ecotone. In fact, ecotone is a transition zone between two or more different ecological communities or regions (Kark, 2013). An ecotonal area often has a higher density of organisms and a greater number of species than are found in either flanking community (The Ecotone, 2012). Ecotones consist of a mosaic of plants from the two adjacent ecosystems, as well as obligate ecotone species, and creating a mosaic of habitats increase species diversity (Harker *et al.*, 1999). However, monodominant forest was observed thus making no significant difference in species composition in between two roosting sites.

Table 4.4. Mann-Whitney comparison of species composition among different habitats

Statistics	Between nesting and night roosting	Between nesting and day roosting	Between day roosting and night roosting
U	1147.000	1258.000	2108.000
z	-5.179	-5.397	0.000
p	.000	.000	1.000

4.1.4 Structural characteristics of tree species

The DBH of the tree ranges from 10 cm to 107 cm ($M = 22.79$, $SD = 16.15$). The largest individual tree species was *P. roxburghii* with DBH of 107 cm in day roosting site 2, while the smallest individual tree species were *Q. griffithii* and *P. roxburghii* with 10 cm each in nest 1 and nest 2. About 38.62% ($n = 73$) of the tree constitutes DBH class 11-15 cm and included maximum trees in this class. The highest number of individuals with a DBH range of 11-15 cm was found in day roosting 1 (34.25%, $n = 25$), while DBH ranges of 51-55 cm, 61-65 cm, 66-70 cm and 71-72 cm showed least percentage of trees with 0.53% ($n = 1$) in each classes (Figure 4.2).

The height of the tree ranges from 5 m to 39 m ($M = 13.06$, $SD = 6.31$). The maximum individuals 17.46% ($n = 33$) were found within height range of 7-8 m. The highest number of

individuals within a height range of 7-8 m were found in day roosting 1 (85.9%, n = 15), followed by night roosting 2 with 18.2% (n = 6). There was no tree with height range of 37-38 m (Figure 4.2).

Forest canopy cover or crown cover defined as the proportion of the forest floor covered by the vertical projection of the tree crowns (Jennings *et al.*, 1999; Korhonen *et al.*, 2006; Westfall and Morin, 2012) have been estimated visually. The amounts and types of canopy cover and structure influence habitat suitability for many forest-dwelling vertebrate species (Masse and Cote, 2009). The canopy cover in the study area has been recorded at almost open canopy to closed canopy value ranging from 5-40 (M = 12.99, SD = 6.95).

4.1.5 Demographic traits of tree species

Demographic characteristics of the tree species were categorized into three regeneration types; unimodal (emergent), sporadic, and inverse-J types (Ohsawa, 1991). According to this principle, emergent or unimodal type has no offspring within the community and exhibit even-aged population, sporadic or multimodal type has several even-aged populations within the community and exhibit multi-aged population, inverse-J type has offsprings without intermission and exhibit all-aged population. In the study area, the distribution of trees in DBH classes produced a unimodal to multimodal type in the nesting habitats. Both the day and night roosting habitats resulted in inverse-J type patterns (Figure 4.2). Inverted J shaped pattern shows high distribution of individuals of a species in the lower diameter classes and a gradual decrease towards the higher classes (Kuma and Shibru, 2015). This study recorded nesting sites were relatively far away from the human settlements and motorable roads as compared to roosting sites (Figure 4.9). Thus this study observed the occurrence of high disturbance in matured trees along the roosting habitats.

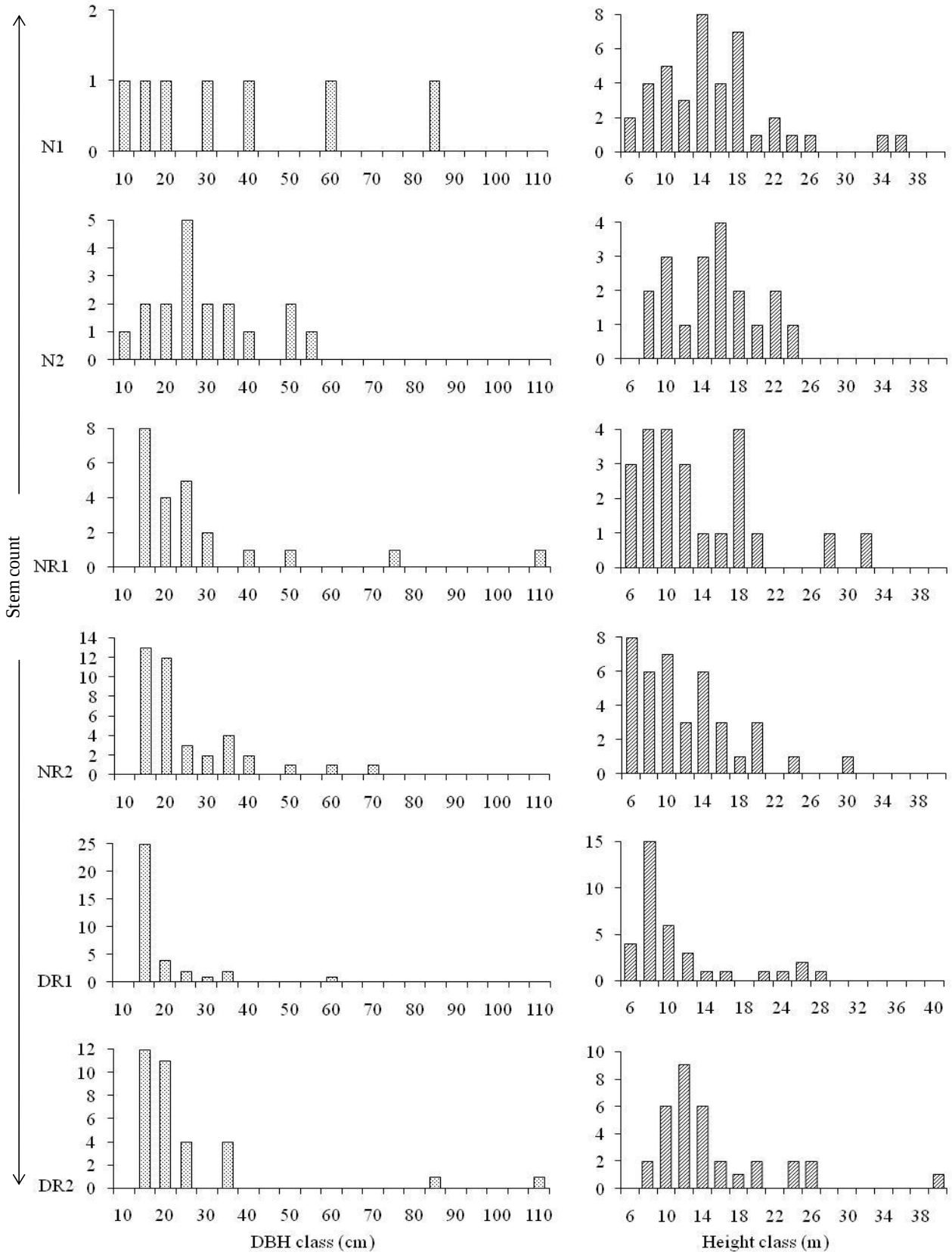


Figure 4.2. Transect wise DBH and height class distribution of tree species

4.1.6 Comparision of structural traits among the classified habitat types.

There were significant differences in DBH ($H(2) = 6.813$, $p = .033$), height ($H(2) = 10.779$, $p = .005$), and canopy cover ($H(2) = 12.363$, $p = .002$) among the habitats. There was no significant difference in DBH but were significant difference in height and canopy cover in between nesting and night roosting habitats. The significant differences were found in all DBH, height and canopy cover in between nesting and day roosting habitats. There was not much significant difference in DBH, height and canopy cover in between day roosting and night roosting habitats (Table 4.5).

Table 4.5. Mann-Whitney comparison on vegetation structure among different habitats

	Between nesting and night roosting			Between nesting and day roosting			Between night and day roosting		
Statistics	DBH	Height	Canopy cover	DBH	Height	Canopy cover	DBH	Height	Canopy cover
U	1716.50	1273.50	1283.50	1508.50	1429.50	1360.50	1683.50	1990.50	2058.50
z	-.583	-2.886	-2.896	-2.406	-2.793	-3.210	-1.979	-.549	-.239
p	.560	.004	.004	.016	.005	.001	.048	.583	.811

The highest mean DBH was recorded at 25.25 cm ($SD = 15.70$) in nesting sites, followed by 23.68 cm ($SD = 16.95$) in night roosting sites, and least mean DBH with 19.86 cm ($SD = 15.56$) in day roosting sites. The highest mean height and canopy cover were also recorded at nesing sites (Table 4.6).

Table 4.6. Habitat type wise mean DBH, height and canopy cover percent for trees

	Nesting	Night roosting	Day roosting
Mean DBH (cm)	25.25	23.68	19.86
Mean height (m)	14.8	11.98	12.53
Mean canopy cover (%)	15.25	12.01	11.91

4.1.7 Species composition and structural characteristics of sapling species

The saplings (< 10 cm > 5 cm DBH) were recorded from all the sample plots. In total, 47 individuals/stems with 7 species and 5 families were recorded (Table 4.7). The most common tree species were *P. roxburghii* at 65.96% ($n = 31$) and *S. wallichii* with 14.89% ($n = 7$). The least recorded tree species were *P. emblica, Q. glauca* and *R. chinensis* with 2.13% ($n = 1$) each.

Among the seven species in all nesting and roosting habitats, *P. roxburghii* represented the dominant species with relative dominance value 71.50 (Table 4.7).

Table 4.7. Sapling species composition and relative dominance

Species name	Stem count	Relative abandance	Family	BA (cm2)	Relative dominance
Macaranga pustulata	2	4.26	Euphorbiaceae	90.62	4.75
Phyllanthus emblica	1	2.13	Euphorbiaceae	35.26	1.85
Pinus roxburghii	31	65.96	Pinaceae	1362.75	71.50
Quercus glauca	1	2.13	Fagaceae	58.09	3.05
Quercus griffithii	4	8.51	Fagaceae	155.93	8.18
Rhus chinensis	1	2.13	Anacardiaceae	20.43	1.07
Schima wallichii	7	14.89	Theaceae	182.96	9.60

The mean DBH and height of the saplings in entire transects were 7.09 cm and 5.45 m respectively. The maximum DBH recorded at sapling layers was 9.3 cm and the minimum DBH was 5 cm. The maximum height in the layers was 7 m and shortest one was 4 m. As observed in the tree speies composition, there was a significant difference in sapling species composition among different habitats ($H(2) = 21.492$, $p = .000$). There was no significant difference between two roosting sites ($U = 72.000$, z = .000, $p = 1.000$). However, the significant differences were found between nesting and night roosting ($U = 48.000$, $z = -3.477$, $p = .001$), and between nesting and day roosting ($U = 48.000$, $z = -3.477$, $p = .001$).

4.1.8 Species composition and major life-forms of shrubs and regenerations

Shrub and regeneration layers in the study area comprised of 19 species with 14 families. Fagaceae (15.79%) and Euphorbiaceae (15.79%) with three species each represented the dominant families followed by Leguminosae (10.53%) with two species. The most dominant species were *P. roxburghii* followed by *Ficus* sp. and *Indigofera dosua. Q. semecarpifolia* followed by *Yushania* sp. were the least dominant species recorded at shrubs and regeneration layers in the study area (Table 4.8).

Table 4.8. Shrub and regeneration species composition and relative dominance

Species Name	Stem count	Relative abandance	Family	BA (cm2)	Relative dominance
Aesandra butyracea	15	5.70	Sapotaceae	33.33	4.96
Berberis asiatica	11	4.18	Berberidaceae	34.80	5.18
Bridelia retusa	13	4.94	Euphorbiaceae	67.78	10.09
Cinnamomum sp.	7	2.66	Lauraceae	7.07	1.05
Desmodium elegans	19	7.22	Leguminosae	38.81	5.78
Ficus sp.	22	8.37	Moraceae	98.59	14.68
Indigofera dosua	23	8.75	Leguminosae	98.59	14.68
Lyonia ovalifolia	4	1.52	Ericaceae	4.04	0.60
Macaranga pustulata	10	3.80	Euphorbiaceae	10.10	1.50
Phyllanthus emblica	13	4.94	Euphorbiaceae	62.22	9.26
Pinus roxburghii	74	28.14	Pinaceae	153.20	22.81
Quercus glauca	4	1.52	Fagaceae	4.04	0.60
Quercus griffithii	5	1.90	Fagaceae	5.05	0.75
Quercus semecarpifolia	1	0.38	Fagaceae	1.01	0.15
Rapanea capitellata	24	9.13	Myrsinaceae	24.24	3.61
Rhus chinensis	8	3.04	Anacardiaceae	12.93	1.92
Schima wallichii	7	2.66	Theaceae	8.28	1.23
Wendlandia sp.	1	0.38	Rubiaceae	5.56	0.83
Yushania sp.	2	0.76	Gramineae	2.02	0.30

The major life-forms of shrubs and regenerations based on relative abundance constitute 26% of conifer tree, followed by evergreen shrub and deciduous shrub or tree with 22% and 13% respectively (Figure 4.3).

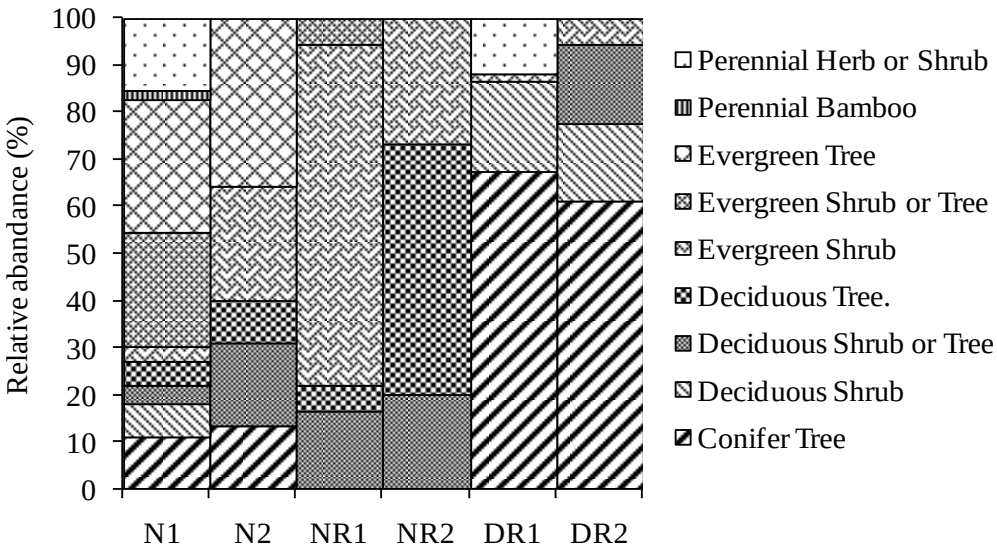


Figure 4.3. Major life-forms of shrubs and regenerations

There were significant differences in species diversity ($H(2) = 19.007$, $p = .000$), species richness ($H(2) = 11.622$, $p = .003$), and species evenness ($H(2) = 11.555$, $p = .003$) in shrubs and regeneration composition among different habitats. The highest mean species diversity, richness and evenness were recorded at nesting sites, whereas the least mean species diversity, richness and evenness were recorded at day roosting sites (Table 4.9).

Table 4.9. Mean species diversity, richness and evenness of shrubs and regenerations among different habitats

	Nesting	Night roosting	Day roosting
Mean Species diversity (H')	1.12	0.35	0.64
Mean species richness (S)	4.69	2.53	4.44
Mean species evenness (HE)	0.76	0.44	0.45

4.1.9 Species composition and major life-forms of herbs and ground flora

The lowest layer comprised of herbs and ground flora. In total, 38 species of 20 families represented the ground flora of entire study area. According to RSPN (2011), *Curcuma aromatic, Cymbopogon khasianum, Cymbopogon jwarancusa, Ageratina adenophora, Duhaldea cappa, Phyllanthes emblica, Phoenix laureiri, Woodfordia fruticosa* and *Glochidion velutinum* were observed as the mid and understory plants of the chirpine forest. In the study area, *Chromolaena odorata* with 32.15% ($n = 933$) and *Cymbopogon* sp. with 21.26% ($n = 617$) were the most

dominant understory plant species. The *Galium aparine* with 0.03% (*n* = 1) and *Gnaphalium affine* with 0.07% (*n* = 2) were the least recorded ground vegetation (Table 4.10).

Table 4.10. Herbs and ground vegetation composition and relative dominance

Species Name	Stem count	Relative abandance	Family	Relative volume (cm3)	Relative dominance
Acmella uliginosa	10	0.34	Compositae	0.07	0.01
Aconogonon molle	20	0.69	Polygonaceae	5.63	0.94
Ageratina adenophora	50	1.72	Compositae	10.52	1.75
Ageratum conyzoides	153	5.27	Compositae	21.91	3.65
Argyreia roxburghii	13	0.45	Convolvulaceae	3.26	0.54
Artemisia myriantha	79	2.72	Compositae	14.86	2.48
Bidens pilosa	25	0.86	Compositae	0.91	0.15
Boehmeria platyphylla	12	0.41	Urticaceae	0.63	0.10
Carex sp.	75	2.58	Cyperaceae	1.69	0.28
Chromolaena odorata	933	32.15	Compositae	297.14	49.52
Clematis sp.	15	0.52	Ranunculaceae	2.25	0.38
Crassocephalum crepidoides	6	0.21	Compositae	0.10	0.02
Curcuma sp.	102	3.51	Zingiberaceae	8.89	1.48
Cymbopogon sp.	617	21.26	Gramineae	167.83	27.97
Cynoglossum furcatum	13	0.45	Boraginaceae	0.14	0.02
Cyperus sp.	19	0.65	Cyperaceae	2.39	0.40
Daphne involucrata	4	0.14	Thymelaeaceae	0.42	0.07
Desmodium elegans	19	0.65	Leguminosae	1.50	0.25
Desmodium sp.	13	0.45	Leguminosae	0.80	0.13
Duhaldea cappa	177	6.10	Compositae	17.39	2.90
Fern 1	12	0.41	Polypodiaceae	2.78	0.46
Fern 2	28	0.96	Polypodiaceae	4.21	0.70
Fern 3	15	0.52	Polypodiaceae	1.25	0.21
Fern 4	19	0.65	Polypodiaceae	3.75	0.63
Galinsoga parviflora	14	0.48	Compositae	0.21	0.03
Galium aparine	1	0.03	Compositae	0.01	0.00
Gnaphalium affine	2	0.07	Compositae	0.02	0.00
Hedychium sp.	13	0.45	Zingiberaceae	3.38	0.56
Hyparrhenia sp.	238	8.20	Poaceae	11.28	1.88
Indigofera heterantha	3	0.10	Leguminosae	1.88	0.31
Jasminum nepalense	5	0.17	Oleaceae	0.46	0.08
Oxalis corniculata	105	3.62	Oxalidaceae	1.00	0.17
Piper sp.	6	0.21	Piperaceae	1.25	0.21
Pteracanthus urticifolia	36	1.24	Acanthaceae	5.50	0.92
Rubia cordifolia	5	0.17	Rubiaceae	1.88	0.31
Rumex nepalensis	22	0.76	Polygonaceae	0.25	0.04
Spergula arvensis	8	0.28	Caryophyllaceae	0.07	0.01
Woodwardia unigemmata	15	0.52	Blechnaceae	2.50	0.42

There were significant differences in species composition ($H(2) = 9.909$, $p = .007$), species diversity ($H(2) = 19.007$, $p = .000$), species richness ($H(2) = 11.622$, $p = .003$), and species evenness ($H(2) = 11.555$, $p = .003$) in herbs and ground flora composition among different habitats. The highest mean species diversity, richness and evenness were found at nesting sites, whereas the least mean species diversity, richness and evenness were recorded at night roosting sites (Table 4.11).

Table 4.11. Mean species diversity, richness and evenness in herbs and ground flora among different habitats

	Nesting	Night roosting	Day roosting
Mean Species diversity (H')	1.12	0.35	0.64
Mean species richness (S)	4.69	2.53	4.44
Mean species evenness (HE)	0.76	0.44	0.45

The major life-forms of herbs based on relative volume constitute 26% of conifer tree, followed by evergreen shrub, and deciduous shrub or tree with 22% and 13% respectively (Figure 4.4).

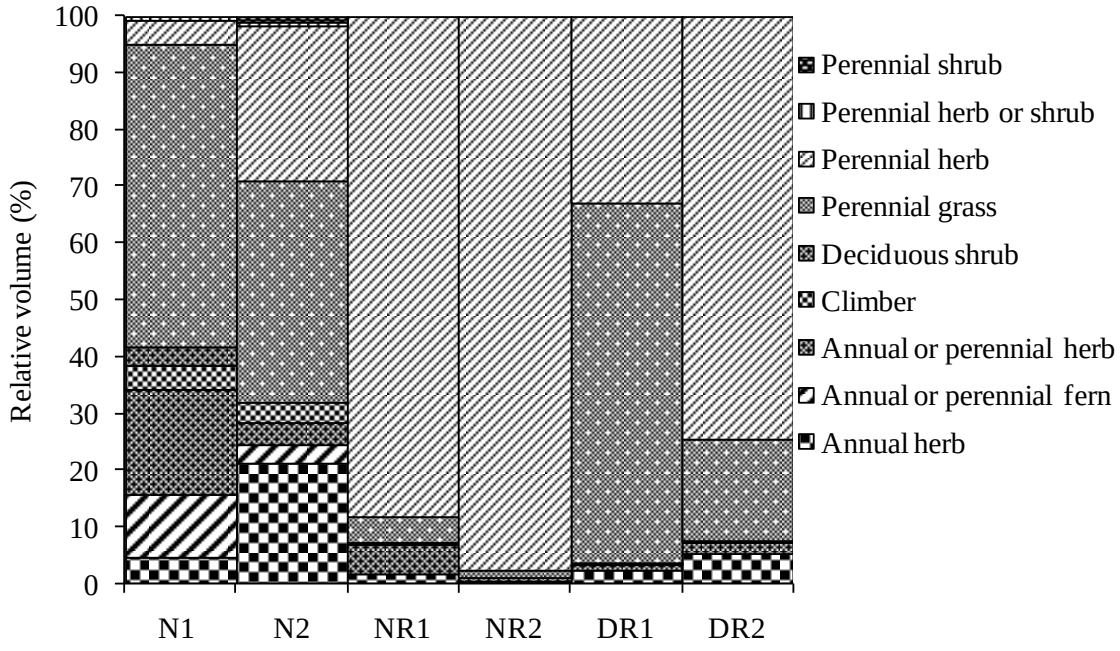


Figure 4.4. Major life-forms of herbs and ground flora

4.2 Nest and roost tree characteristics of WBH

One of the research questions was to describe the nest and roost site characteristics of WBH. According to RSPN (2011), WBH are found to be roosts and nests on tall chir pine trees (*P. roxburghii*). Similarly, in the study area, nesting and roosting were recorded only on chir pine trees. However, there is also an evidence of nesting in broad leaf species like East Indian almond (*Terminalia myriocarpa*), in other parts of the range country like India (Singh, 2015). This may be due to the lack of chir pine forest in that locality.

In total, six trees were observed: two nesting trees; two day roosting trees; and two night roosting trees. The mean DBH of nesting and roosting trees was recorded with 81.92 cm. The highest DBH was recorded with night roosting tree 1 (106.50 cm), followed by nesting tree 1 with DBH of 105.70 cm. The least DBH was recorded with 46.90 cm at nesting tree 2 (Figure 4.5). The mean height of nesting and roosting trees was recorded at 30.23 m. The height of the nesting and roosting trees ranges from 15.45 m of nest tree 2 to 45.29 m of nest tree 1 (Figure 4.6).

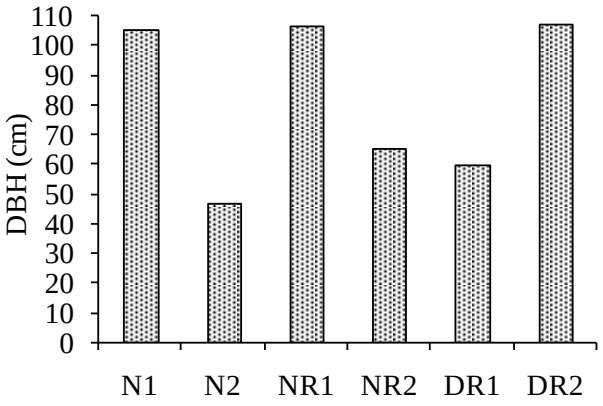


Figure 4.5. DBH of nesting and roosting trees

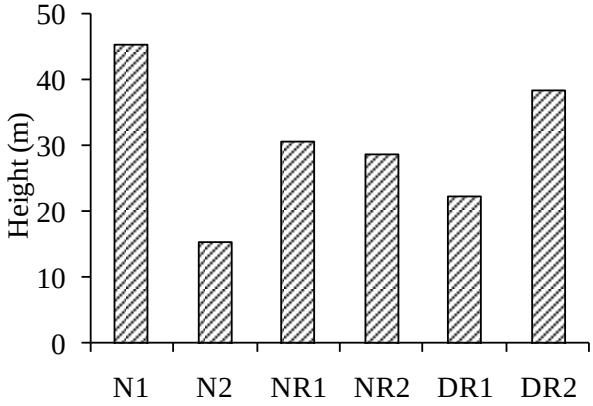


Figure 4.6. Heights of nesting and roosting trees

The slope percent of nesting and roosting sites ranges from 0% each at day roosting 1 and 2 to 95% at night roosting 1. The mean slope percent recorded was 44.83%. Most of the roosting and nesting trees were located at south-west and south–eastern aspects. The WBH uses trees lying in the plain along the river banks for day roosting in winter (Figure 4.7). According to RSPN (2011), usually WBH start roosting on trees when the surounding temperature begins to rise.

RSPN (2011), observed that WBH resided regularly in the Punatsangchu basin and tributaries below 1500 m.a.s.l. and also stated that in Bhutan, all the WBH nests were found on chir pine trees at an altitude of 700 to 1000 m.a.s.l. However, this study revealed that the nesting site 1 at Tshomenchoesa was located at an altitude of 1464 m.a.s.l. In general, it is found that the location of nesting and roosting sites ranges with an altitude of 1260 to 1464 m.a.s.l. in the study area (Figure 4.8).

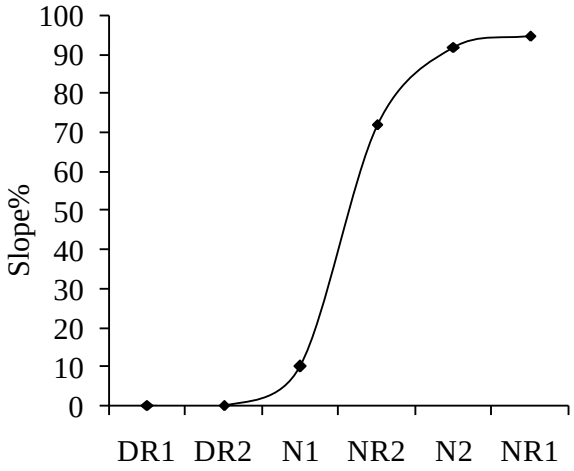


Figure 4.7. Slope% in nesting and roosting sites

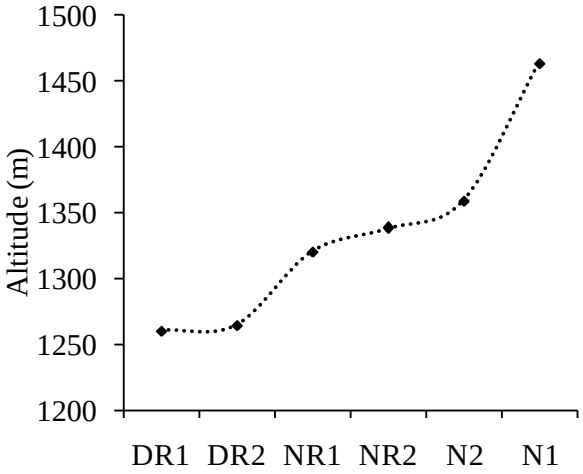


Figure 4.8. Altitudinal location of nesting and roosting trees

The nest trees of WBH were observed near to the feeding areas (river) at average distance of 86 m, and are to some extent isolated from motor road and human settlements with average distances of 1481 m and 618 m respectively. Nest trees were recorded at approximately 487 m away from the nearest agriculture field. As RSPN (2011) stated, WBH seem to need large territories for nesting as the nesting sites were recorded at flight distance about 10.37 km away from one another.

Antczak (2010) suggested that micro-habitat patterns of night-roost selection fulfilled two main functions: thermoregulation and predator avoidance. He further added that the choice of roosting sites during winter might be especially important, as birds face long hours of darkness, low air temperature and consequently enforced fasting. Evergreen trees provide nest sites for birds in spring and thermal cover for wildlife in winter (DeLong, 2009). Similarly, tall chir pine trees with well branched were found to be providing the best thermal cover to the birds in the study area. These roosting trees were observed at closed to agriculture field and human

settlements with average distance of 37 m and 209 m respectively. However, these trees were recorded quite far away from the feeding ground as compared to day roosting sites. The average nearest distance from night roosting trees to the feeding ground is recorded at 497 m.

WBH preferred to roost on the tree when the people and animals approach near to them. The day roosting trees were observed at very closed to the feeding ground with average distance of 10 m (Figure 4.9).

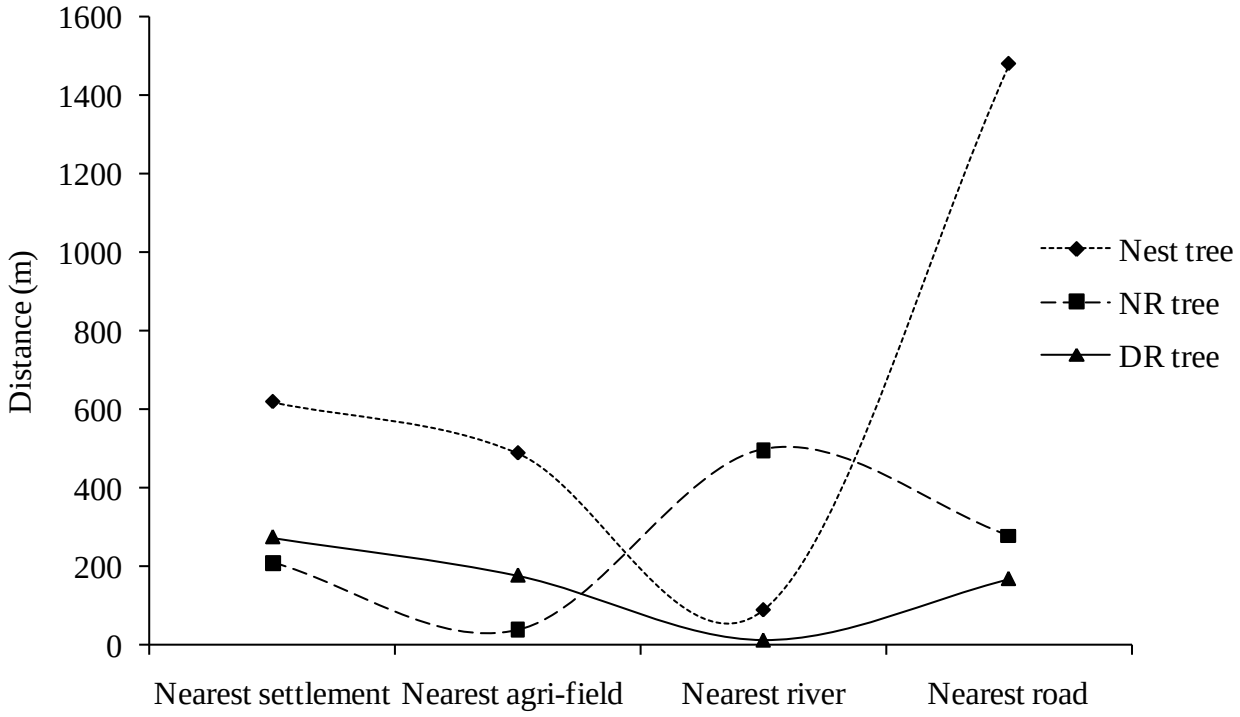


Figure 4.9. Averaged nearest distances to settlements, agri-field, river and road side from nesting and roosting trees.

4.3 Degree of awareness and people's perception

The social survey was conducted with a field sample size of 58 households (40.27% response rate) in order to determine the threats and people's perception towards conservation of WBH and its habitats. Of the 58 respondents, 28 (48.3%) were female and 30 (51.7%) were male. They ranged in age from 18 to 86 years old. In general, it was very clear that 97% of respondents were fully convinced of the presence of WBH in the proximity of their village (Figure 4.10). However, the concern towards application of conservation principles remained poor. When asked about the bird observation frequency, only 10% of responses observe very frequently, with

14% frequently, 17% occasionally, 7% rarely, 4% no idea and 48% accepted that they never observe bird at all (Figure 4.11).

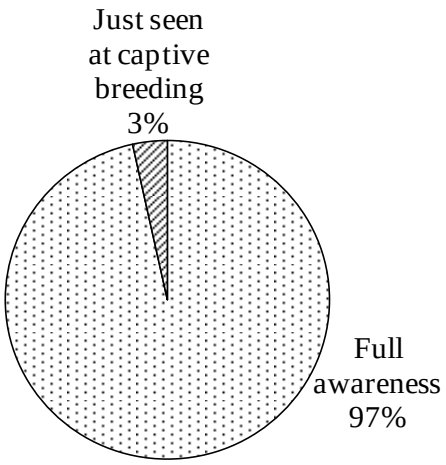


Figure 4.10. Degree of awareness

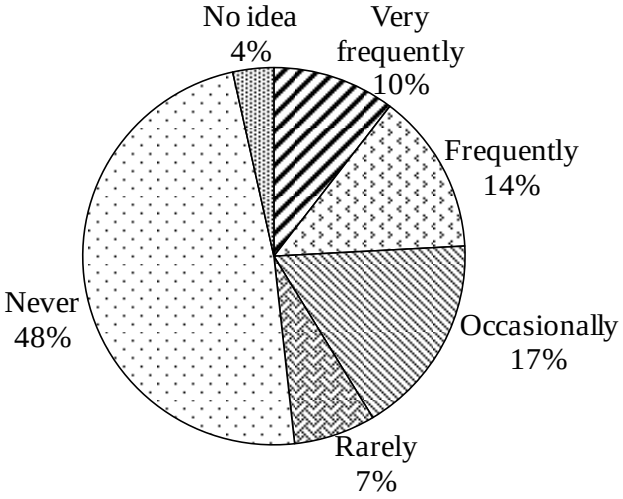


Figure 4.11. Frequency of observation

Amongst the respondents, 97% rated that conservation of the species as very important. However, about 3% of local community still remained unknown why this species has to be conserved (Figure 4.12).

4.4 Nesting and roosting habits

When asked about the nesting and roosting habits of the bird, 90% mentioned no idea about it. About 10% confirmed that the bird do not use same trees for nesting every year. It remained unclear whether WBH typically occupy nest sites continuously for long periods, or whether nest site turnover is naturally high as suggested by RSPN (20011). About 45% said that the bird uses same sites for roosting every year and 55% still remained without any idea about it (Figure 4.13).

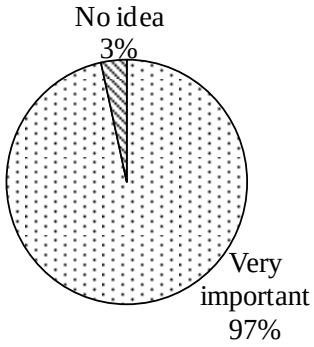


Figure 4.12. Rating for conservation importance

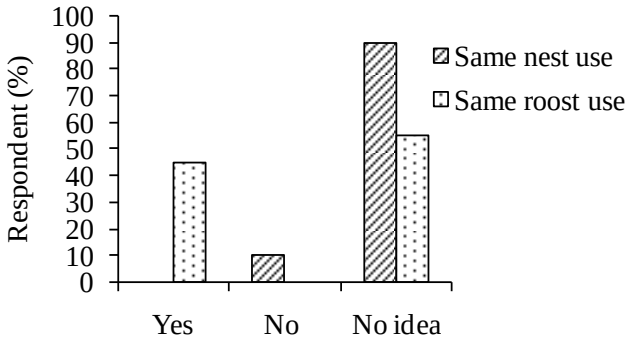


Figure 4.13. Roosting and nesting habits

4.5 Conservation threats and disturbances

4.5.1. Direct threats and disturbances

The direct conservation threats and disturbances were defined as direct killing, hunting, poaching and predation of birds including disturbances like fishing, forest fire, cattle grazing, timber extraction, firewood collection, rafting, habitat loss and degradation, developmental activities, and movement of people and animals. Most of them have become the harmful factors impacting on critically endangered species. As cited in the literatures, WBH is observed as less tolerant of humans, as evidenced by them fleeing at greater distances from an approaching human. There was no evidence of direct killing and hunting the birds by human in the study area. However, two carcasses of the bird have been found under the nesting tree 2 at Tshomenchoesa. One of the carcasses has been found within a radius of 1 m, and another at 17 m from the nesting tree. The causes of the death of bird are unknown.

The disturbance by human was a fairly common event observed by RSPN (2011) along the Phochu river. Similarly, the illegal fishing and movement of people and animal with 15% each, followed by firewood and log collection, and rafting and boating with 14% and 13% respectively were recognized as disturbances with very high extent. Agriculture activities and sand and stone collection with 1% each, followed by human settlements, grazing, illegal felling, and tourists and visitors with 2% each were mentioned as low extent of disturbances. The respondents were not aware of the disturbances from garbage wastage and river pollution towards the bird (Figure 4.14).

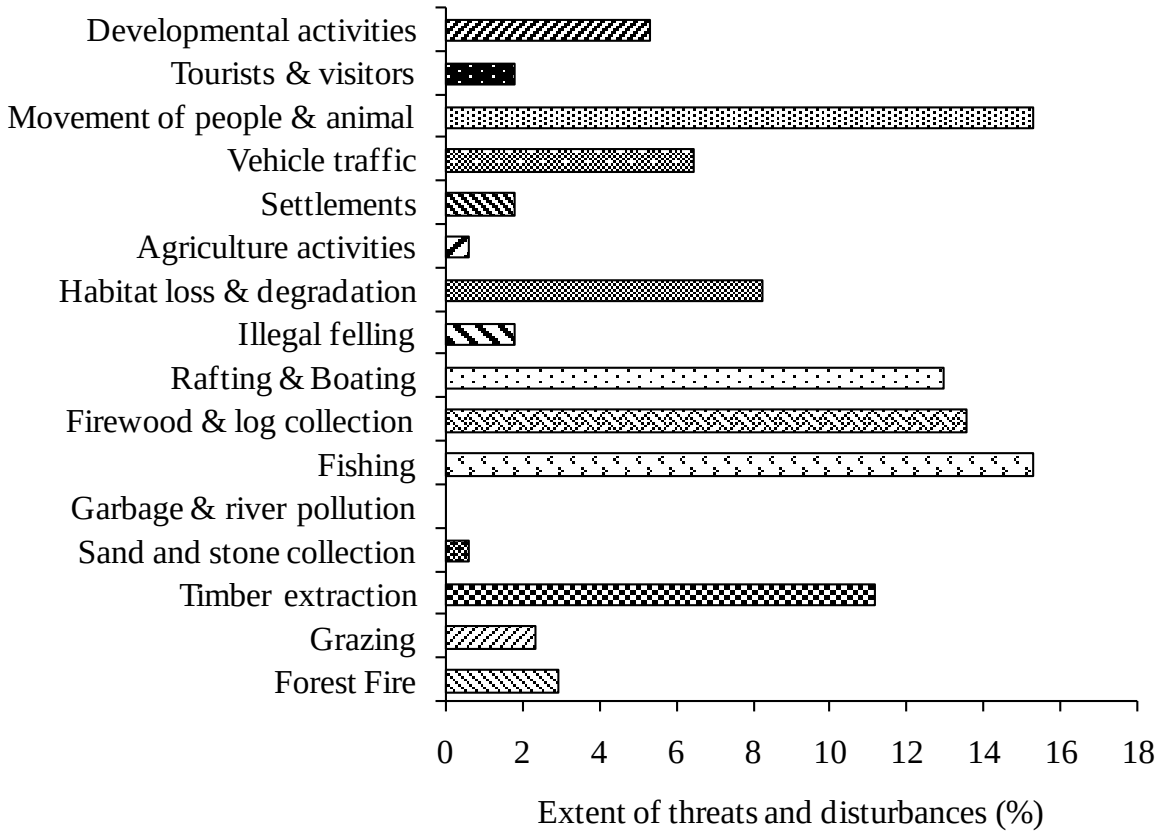


Figure 4.14. Direct conservation threats and disturbances

4.5.2 Indirect threats

The threats caused by lack of awareness, lack of enforcement of law and policy, lack of community support were identified as indirect conservation threats to the birds. Lack of community support towards species conservation is recognized as the most significant indirect threats with 72%, followed by lack of enforcement of law and policy, and lack of awareness with 14% and 3% respectively. About 10% remained without knowledge of indirect threats towards conservation of WBH and its habitats (Figure 4.15).

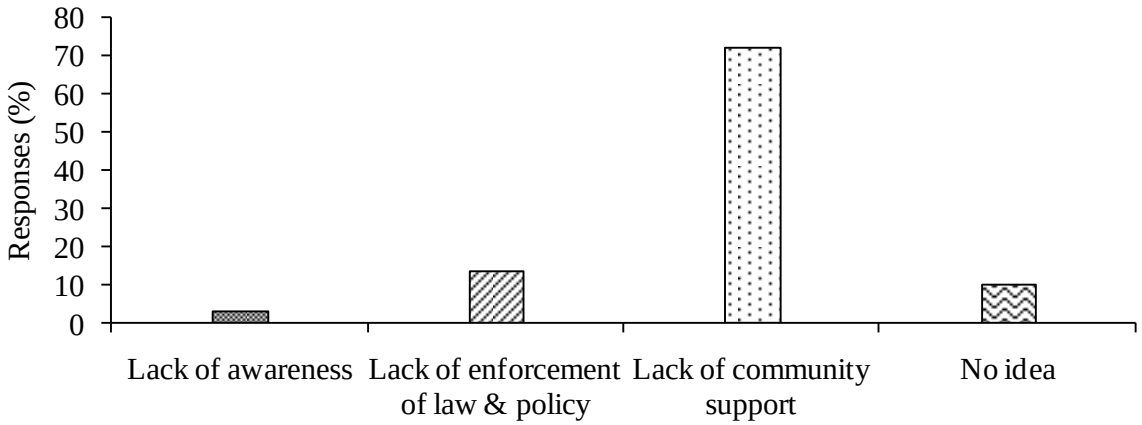


Figure 4.15. Indirect conservation threats

When asked about what immediate action can be taken in order to conserve the bird and its habitat, 52% strongly voiced that the complete protection of the habitat is required, followed by requrement of more awareness with 10%. About 3% felt that there is in need of more research on bird, and 3% mentioned about requirement of enforcement of law and policy. Another 3% expect about direct benefits like incentives to the community from conservation of bird and its habitats. About 21% did not hanve any idea about what action could be taken in favour of the bird (Figure 4.16).

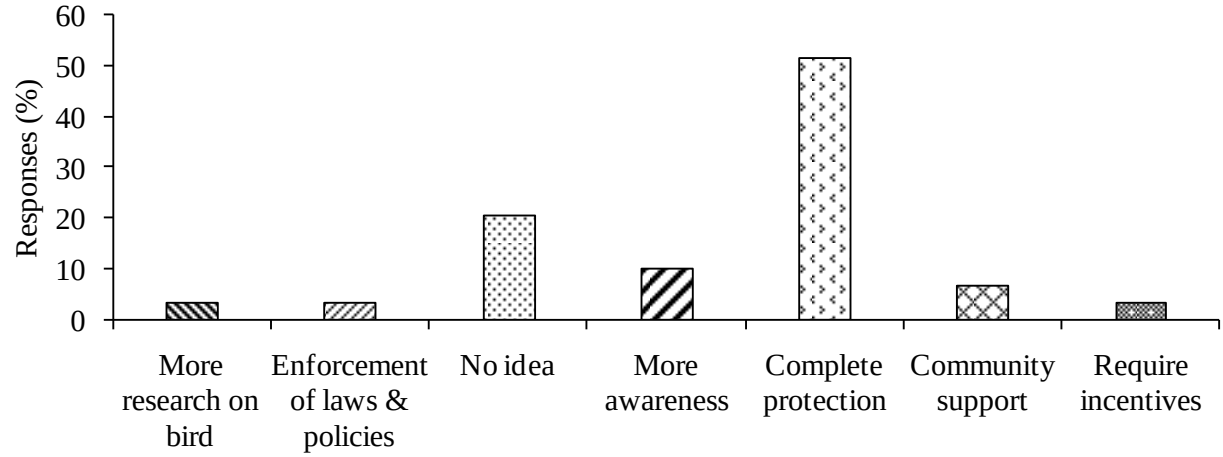


Figure 4.16. Conservation action required

CHAPTER 5

Conclusion and Rrecommendations

The chir pine forest along the stretch of Phochu river is one of the conservation priorities of the country and is a home for critically endangered WBH. The nesting and roosting sites of WBH were found at an altitude range of 1260 to 1464 m.a.s.l. in the study area. Floristically the area was composed of 59 species belonging to 33 families. The major life-forms of tree species in the entire study area constituted conifer trees, evergreen broad-leaved trees and deciduous broad-leaved trees. Monodominant forest type with *P. roxburghii* was found in the nesting and roosting habitats. This study concludes that removal and changes in the amount of vegetation cover (*P. roxburghii*) will have the greatest influence on birds.

The distribution of trees in DBH classes produced unimodal, multimodal and inverse-J type patterns. The result of the study indicated that the presence of human disturbance in the area has affected on forest structure and dynamics. Shrubs and regenerations layer dominated by *P. roxburghii*, and herbs layer dominated by *C. odorata* and *cymbopogon* sp. constituted the main ground cover of the area. These habitats were located at slope ranging from 0% to 95%, and mostly at South-west and South–eastern aspects. Nest and day roosting trees were found much closed to the feeding ground (river) but relatively away from the human settlements and motor roads. Night roosting trees were found very close to the agriculture field.

In general, 97% of local residents were aware about the presence of WBH in the proximity of their village. However, the concern to apply the conservation principles remained almost poor. About 90% of the participants were not sure whether the bird uses same sites for nesting every year. About 45% said that the bird uses same sites for roosting every year and 55% still remained without knowledge about it.

There was no evidence of direct killing and hunting the birds by human in the study area. However, the movement of people for fishing, animal herding, firewood collection, and rafting were recognized as direct threats and disturbances to the birds. Lack of community support towards species was observed as the most significant indirect threats.

Based on the results of this study, the following recommendations were suggested to enhance a better future for critically endangered WBH and to minimize the influence of human on their natural habitats in the study area:

- This study relatively covered a few nest and roost sites, and still it needs detailed investigation on vegetation structure and composition covering more areas for better understanding of bird's nesting and roosting habitats.
- The constant and regular monitoring of bird and comprehensive research on predation is highly required in the study area.
- Continuous raising awareness of local communities on importance of WBH and its habitat conservation and ecological consequences of extinction of bird and destruction of forest vegetations are required.
- There is also a need to have an effective WBH conservation Action Plan through the local stakeholders, conservationist and the governments.

References

Ali, S. & Ripley, S.D. (1978). *Handbookof the birds of India and Pakistan, together with those of Bangladesh, Nepal, Bhutan and Sri Lanka*. NY: Oxford University Press.

Ardakani M.R. (2009). *Ecology*. p. 340. Iran: Tehran university press.

Antczak, M. (2010). Winter nocturnal roost selection by a solitary passerine bird, the Great Grey Shrike *Lanius excubitor*. *Ornis Fennica.* 87: 99-105.

BirdLife International. (2001). Threatened birds of Asia: *the Birdlife International Red Data Book.* Cambridge, UK: Birdlife International.

BirdLife International. (2013). *Ardea insignis*. The IUCN Red List of Threatened Species 2013. <http://dx.doi.org/10.2305/IUCN.UK.2013-2.RLTS.T22697021A49746000.en>. Accessed 21 September 2015.

BirdLife International. (2015). Species factsheet: *Ardea insignis*. < http://www.birdlife.org>. Accessed 8 November 2015.

Brocklehurst, P., Lewis, D., Napier, D. & Lynch, D. (2007). *Northern Territory Guidelines and Field Methodology for Vegetation Survey and Mapping.* Technical Report No. 02/2007D. Department of Natural Resources, Environment and the Arts, Palmerston, Northern Territory.

De-Jun, K., Xiao-Jun, Y., Qiang, L., Xing-Yao, Z. & Jun-Xing, Y. (2011). Winter habitat selection by the vulnerable black-necked crane *Grus nigricollis* in Yunnan, China: *implications for determining effective conservation actions.* 2011 Fauna & Flora International, Oryx. 45 (2): 258–264

DeLong, C.A. & Brittingham, M.C. (2009). *Wildlife-Habitat Relationships.* Penn State Extension.

Deng, W.H., Wei, G. & Guang-Mei, Z. (2003). Nest and roost habitat characteristics of the Grey-faced Buzzard in Northeastern China. *Journal of Raptor Research*. 37(3):228-235.

DeWalt, S.J., Maliakal, S.K. & Denslow, J.S. (2003). Changes in vegetation structure and composition along a tropical forest chronosequence: implications for wildlife. *Forest Ecology and Management.* 182: 139–151

Froumsia, M., Zapfack, L., Mapongmetsem, P.M. & Nkongmeneck, B.A. (2012). Woody species composition, structure and diversity of vegetation of Kalfou Forest Reserve, Cameroon. *Journal of Ecology and the Natural Environment.* 4 (13): 333-343.

Gillison, A.N. & Brewer, K.R.W. (1985). The use of gradient directed transects or gradsects in natural resource surveys. *Journal of Environmental Management.* 20: 103-127.

Grimmett, R., Inskipp, C. & Inskipp, T. (1999). *A guide to the birds of India, Nepal, Bangladesh, Bhutan, Sri Lanka and the Maldives*. Princeton NJ: University Press.

Harker, D., Libby, G., Harker, K., Evans, S. & Evans, M. (1999). *Landscape Restoration Handbook.* 2nd edn., p. 35. New York: CRC Press LLC.

Janean, H., Creighton, M.S., David, M. & Baumgartner, D.M. (1997). *Wildlife Ecology and Forest Habitat.* Washington: Washington State University.

Jennings, S.B., Brown, N.D. & Sheil, D. (1999). Assessing forest canopies and understory illumination: canopy closure, canopy cover and other measures. 72 (1): 59-73.

Jibrin, A. & Jaiyeoba, I.A. (2013). Characterization of Structural Composition and Diversity of Vegetation in the Kpashimi Forest Reserve, Niger State, Nigeria. *Journal of Geography and Geology.* 5 (3): 75

Kark, S. (2013). Chapter 9 Ecotones and Ecological Gradients. *The Encyclopedia of Sustainability Science and Technology.* New York: Springer Science+Business Media. pp. 147-160.

Kent, M. (2012). Vegetation Description and Data Analysis: *A Practical Approach.*< https://books.google.co.in/books?hl=en&lr=&id=xHnXf0wHdgQC&oi=fnd&pg=PT9&dq=example+of+using+circular+quadrats+in+vegetation+survey&ots=HT4G0fXF0-&sig=8hQfdeXKgmOX70SqicqB1gOAQi8#v=onepage&q&f=false>. Accessed 30 November 2015.

Korhonen, L., Korhonen, K.T., Rautiainen, M. & Stenberg, P. (2006). Estimation of forest canopy cover: a comparison of field measurement techniques. *Silva Fennica research articles.* 40 (4): 577–588.

Kuma, M. & Shibru, S. (2015). Floristic composition, vegetation structure, and regeneration status of woody plant species of Oda Forest of Humbo Carbon Project, Wolaita, Ethiopia. *Journal of Botany*. 2015: 1-9.

Masse, A. & Cote, S.D. (2009). Habitat selection of a large herbivore at high density and without predation: Trade-off between forage and cover? *Journal of Mammalogy.* 90: 961-970.

McComb, B., Zuckerberg, B., Vesely, D. & Jordan, C. (2010). *Monitoring animal populations and their habitats: a practitioner's guide*. p.277. New York: CRC Press.

Morrison, M. L., Marcot, B.G. & Mannan, R.W. (2006). *Wildlife-habitat relationships: concepts and applications*. 3rd edn. p.493. Washington, DC: Island Press.

National Biodiversity Strategies and Action Plan of Bhutan. (2014). National Biodiversity Centre, Ministry of Agriculture and Forests, Royal Government of Bhutan.

Ohsawa, M. (1984). Differentiation of vegetation zones and species strategies in the subalpine region of Mt. Fuji. Vegetation. 57: 15-52.

Ohsawa, M. (1991). *Life Zone Ecology of the Bhutan Himalaya II*. Japan: Chiba University.

Ohsawa, M. (2002). *Life Zone Ecology of the Bhutan Himalaya III*. Institute of Environmental Studies. Japan: The University of Tokyo.

Parker, C. (1992). *Weeds of Bhutan*. Bhutan: National Plant Protection Centre, Simtokha.

Pielou, E.C. (1977). Mathematical ecology. Wiley, NewYork. Pinus ponderosa forests, Montana, USA. *Journal of Applied Ecology*. 43: 887-897.

Polunin, O. & Stainton, A. (1984). *Flowers of the Himalaya.* UK: Oxford University Press.

Pradhan, R. (2007). *WBH project 2005-2007: annual report December 2005- December 2006.* Bhutan: Royal Society for Protection of Nature, Thimphu.

Rajpar, M.N. & Zakaria, M. (2011). Bird species abundance and their correlationship with microclimate and habitat variables at Natural Wetland Reserve, Peninsular Malaysia. *International Journal of Zoology*. 2011: 17.

Razavi1, S.M., Mattaji, A., Rahmani, R. & Naghavi, F. (2012). The Assessment of Plant Species Importance Value (SIV) in Beech (Fagus orientalis) Forests of Iran. *International Research Journal of Applied and Basic Sciences.* 3 (2): 433-439.

Royal Society for Protection of Nature. (2011). *The Critically Endangered White-bellied Heron.* Thimphu Bhutan.

RSPN. (2015). <http://www.rspnbhutan.org/news-and-events/news/373-research-on-white-bellied-heron-abstract.html>. Accessed 17 November 2015.

Saara, J. DeWalta, S.J., Maliakala, S.K. & Denslowa, J.S. (2003). Changes in vegetation structure and composition along a tropical forest chronosequence: implications for wildlife. *Forest Ecology and Management*. 182: 139-151.

Singh, S.S. (2015). *The Hindu.* India's first nesting site of white-bellied heron found. <http://m.thehindu.com/sci-tech/energy-and-environment/indias-first-nesting-site-of-whitebellied-heron-found/article6603325.ece/>. Accessed 17 November 2015.

Thackway, R., Sonntag, S. & Keenan, R.J. (2006). Assessment of Vegetation Condition: An indicator of sustainable, productive ecosystems. Science for Decision Makers.

The Ecotone. (2012). *Journal of environmental studies.* Environmental studies program. University of Oregon.

Thiney, U. (2004). *Know the Plants of Bhutan*. Volume – 1, 2nd edn. Bhutan: Thimphu.

University of Illinois Board of Trustees. (2015). *Natural Resources, the Environment and Ecosystem:* Wildlife - Just One Piece of the Picture. University of Illinois Extension. <http://extension.illinois.edu/ecosystems/teacherguide2.cfm>. Accessed 9 November 2015.

Wangda, P. & Ohsawa, M. (2006). Forest pattern analysis along the topographical and climatic gradient of the dry west and humid east slopes of Dochula, western Bhutan. *Journal of Renewable Natural Resources.* 2 (1): 1-17.

Wangdi, T. (2009). *Pteridophytes of Bhutan-A list of Families, Genera and Species*. Bhutan: National Biodiversity Centre, Serbithang.

Wangdi, T. (2014). *Landuse change effect on habitat and White-bellied Heron population by hydropower project along Punatsangchu.* In partial fulfillment of the requirements for the B.Sc. Forestry Programme (Conservation Science). Lobesa, Punakha.

Westfall, J.A. & Morin, R.S. (2012). Canopy cover estimator for individual tree attributes. *Moving from Status to Trends: Forest Inventory and Analysis Symposium 2012. GTR-NRS-P-105:* 248-253.

Wilcove, D. S., Rothstein, D., Dubow, J., Phillips, A. & Losos, E. (1998). Quantifying Threats to Imperiled Species in the United States: Assessing the relative importance of habitat destruction, alien species, pollution, overexploitation, and disease. *American Institute of Biological Sciences*. 48 (8): 607-615.

WWF. (2015). WWF Bhuta/White Bellied Heron. <http://www.wwfbhutan.org.bt/projects_/species/white_bellied_heron/> . Accessed 21 September 2015.

Yarrow, G. (2009). Habitat Requirements of Wildlife: Food, Water, Cover and Space. Fact Sheet 14. Forestry and Natural Resources, Clemson Extension.

Zobel, D.B., Jha, P.K., Yadav, U.K.R. & Behan, M.J. (1987). *A practical manual for ecology*. Nepal: Ratna Book Distributors, Kathmandu.

Zuffi, M.A.L. & Rovina, L. (2006). Habitat characteristics of nesting areas and of predated nests in a Mediterranean population of the European pond turtle, *Emys orbicularis galloitalica.* Italy: Pisa, Lungarno Galilei.

Annexure 1. Tree Data (DBH > 10 cm)

Transect No:		Name of the place:		Date:	
Plot No:		GPS Coordinates: N:		E:	
Slope (%):		Elevation:		Aspects:	
Sl. No.	Species	DBH (cm)	Height (m)	Canopy cover (%)	Remarks
Observations/Comments:					
Name & signature of surveyor:					

Annexure 2. Sapling Data (DBH < 10 cm > 5 cm)

Transect No:		Name of the place:		Date:	
Plot No:		GPS Coordinates: N:		E:	
Slope (%):		Elevation:		Aspects:	
Sl. No.	Species	DBH (cm)	Height (m)	Canopy cover (%)	Remarks
Observations/Comments:					
Name & signature of surveyor:					

Annexure 3. Shrubs & Regeneration Data (0.5 m to 5 m tall)

Transect No:		Name of place:		Date:	
Plot No:		GPS Coordinates: N:		E:	
Slope (%):		Elevation:		Aspects:	
Sl. No.	Species	Layer height (m)	Cover percent (%)	No. of individual	Remarks
Observations/Comments:					
Name & signature of surveyor:					

Annexure 4. Herbs & Ground flora (≤ 1 m tall)

Transect No:		Name of place:		Date:	
Plot No:		GPS Coordinates: N:		E:	
Slope (%):		Elevation:		Aspects:	
Sl. No.	Species	Layer height (m)	Cover percent (%)	No. of individual	Remarks
Observations/Comments:					
Name & signature of surveyor:					

Annexure 5. Nesting/Roosting Tree Data Collection Form

Tree/Plot ID:	Name of the place:	Date:
Forest type:	GPS coordinates: N:	E:
Slope (%):	Aspect:	Elevation:
Dominant vegetation cover type:	Main understory type:	

Species	DBH (cm)	Height (m)	Nest/Roost height (m)	Branch position	Total No. of branches	Remarks

Distance (m) to nearest……..

Settlement	Agri-field	Feeding sites (River)	Road	Other nest/roost tree	Remarks

From Nesting/Roosting trees to……	Nearest Trees								
	1	2	3	4	5	6	7	8	Remarks
Angle (Degree)									
DBH (cm)									
Height (m)									
Distance (m)									
Condition of tree									

Annexure 6. Questionnaire for Assessment of Degree of Awareness and Attitudes towards conservation of WBH

Date:…… ….. Respondent's Name: …… Gender: M/F
Age:…… Occupation:…… Villavge:…….……..…….
Geog:……..…….. Dzongkhag:……

1. Are you familiar with WBH?
   (a) Yes…… (b) No……. (c) Never heard of it (d) Others:……

2. How did you first hear about the bird?
   (a) Forestry official (b) RSPN (c) Neighbour/relatives/friends (d) TV (e) Personal observation (f) Not sure (g) Other:…….

3. When did you see the bird for first time?
   (a) In 1980s (b) Since 1990s (c) Not sure (d) Other:……..

4. What was the number of birds when you see for the first time?
   (a) One (b) Two (c) Three (d) Four (e) Five (f) Other…….....

5. How do you see the trends of its population?
   (a) Increasing (b) Decreasing (c) Remaining same (e) Do not know

6. How often do you observe the bird?
   (a) Very frequently (b) Frequently (c) Occasionally (d) Rarely (e) Never (f) Do not know

7. Do you know what type of habitats does WBH choose for roosting?
   (a) Yes (b) No (c) Not sure
   If yes, describe the main characteristics of roosting habitats……..

8. Does WBH use same sites/tree for roosting throughout the season?

(a) Yes (b) No (c) Not sure (d) Other:……..…….

9. Do you know what type of habitats does WBH choose for Nesting?

   (a) Yes (b) No (c) Not sure

   If yes, describe the main characteristics of nesting habitats…….……...

10. Does WBH use same sites/tree for nesting every year?

    (a) Yes (b) No (c) Not sure (d) Other:……..

11. Do you know why WBH and its habitats have to be conserved?

    (a) Yes (b) No

12. If yes, give the reason?

    (a) Provide benefits (b) Global concern (c) Government law & policy (d) Not sure

    (e) Other:…….

13. How do you rate the conservation importance of the bird?

    (a) Utmost importance (b) Very important (c) Of moderate importance (d) Of little importance (e) Of very little or no importance (f) Not sure

Questionnaire to assess the conservation threats of WBH and its habitats.

14. General information on direct threats & disturbances

Disturbance and/threads	**Extent of disturbance**			
	Heavy	Moderate	Light	Not sure
Forest fire				
Grazing				
Timber extraction				
Sand and stone collection				
River pollution from garbage wastage				
Illegal fishing				
Firewood and log collection				

Natural predation				
Rafting & Boating				
Illegal felling				
Habitat loss & degradation				
Direct killing and hunting the birds				
Agriculture activities				
Human settlements				
Vehicle movement				
Movement of people & animal				
Tourists & visitors				
Developmental activities				

15. What could be the potential indirect threats to the conservation of birds and their nesting and roosting habitats?

    (a) Lack of awareness (b) Lack of enforcement of law & policy (c) Lack of community support (d) Unknown (e) Other:…….....

16. What action can be taken in order to conserve the bird and its habitats?

    (a) More research on bird (b) Enforcement of conservation law & policy (c) Not sure

    (d) More Awareness (e) Complete protection (f) Other:……

Annexure 7. Floristic composition and life-forms of tree species

Species Name	Family Name	Acronym	Life Form	N1	N2	NR1	NR2	DR1	DR2
Conifer									
Pinus roxburghii	Pinaceae	CT	Conifer Tree	17.49	98.68	100.00	100.00	100.00	100.00
Sub-total				**17.49**	**98.68**	**100.00**	**100.00**	**100.00**	**100.00**
Evergreen Tree									
Schima wallichii	Theaceae	ET	Evergreen Tree	14.10					
Quercus semecarpifolia	Fagaceae	ET	Evergreen Tree	4.19					
Quercus glauca	Fagaceae	ET	Evergreen Tree	0.63	1.32				
Sub-total				**18.92**	**1.32**				
Deciduous Tree									
Alnus nepalensis	Betulaceae	DT	Deciduous Tree	11.88					
Docynia indica	Rosaceae	DT	Deciduous Tree	8.82					
Macaranga pustulata	Euphorbiaceae	DT	Deciduous Tree	4.05					
Quercus griffithii	Fagaceae	DT	Deciduous Tree	35.12					
Albizia lebbeck	Leguminosae	DT	Deciduous Tree	3.44					
Lyonia ovalifolia	Ericaceae	DT	Deciduous Tree	0.28					
Sub-total				**63.59**					
Grand Total				**100**	**100**	**100**	**100**	**100**	**100**

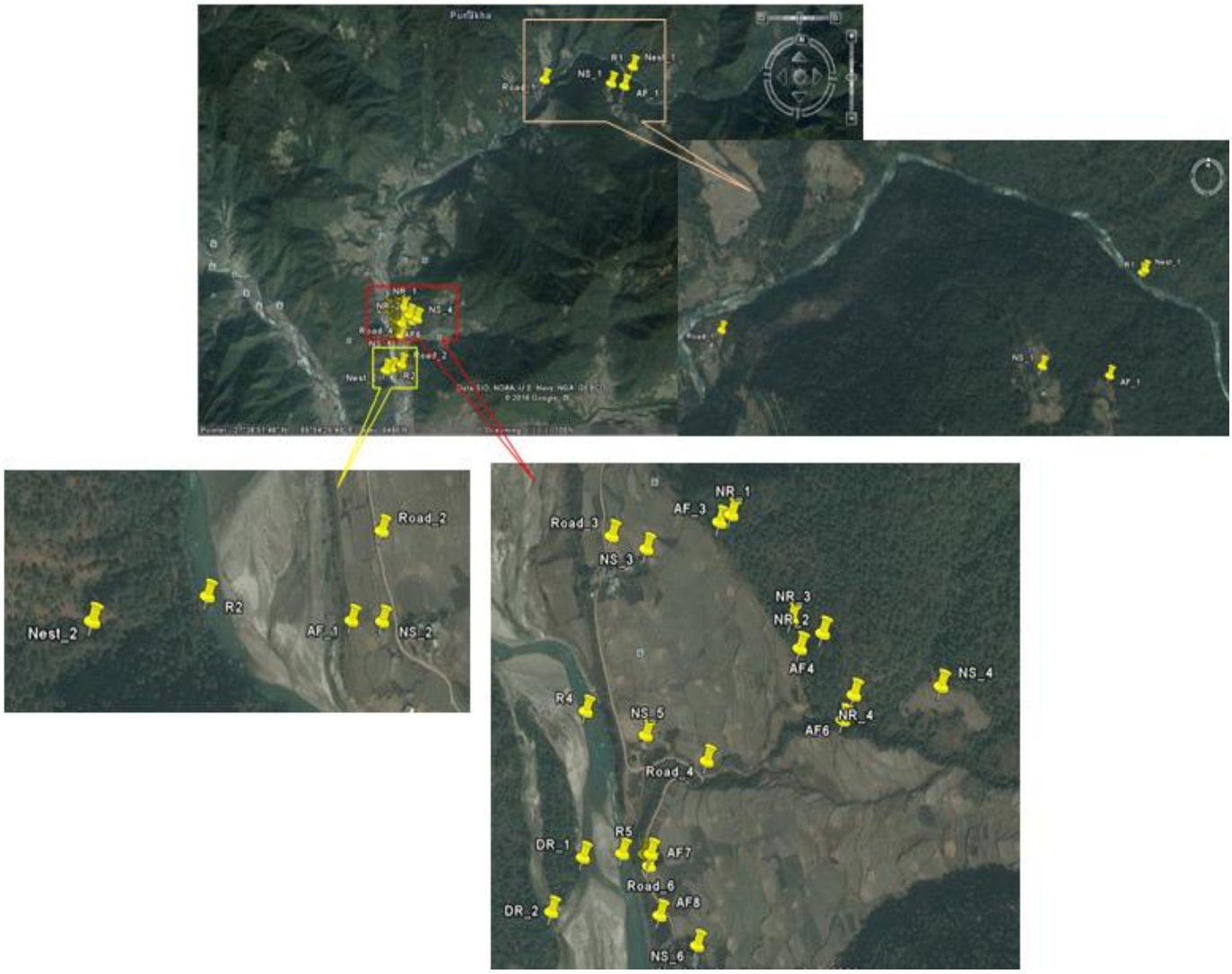
Annexure 8. Floristic composition and life-forms of shrubs and regenerations

Species Name	Family Name	Acronym	Life Forms	N1	N2	NR1	NR2	DR1	DR2
Conifer Tree									
Pinus roxburghii	Pinaceae	CT	Conifer Tree	11.11	13.33			67.65	61.11
Sub-total				**11.11**	**13.33**			**67.65**	**61.11**
Deciduous Shrub									
Desmodium elegans	Leguminosae	DS	Deciduous Shrub	3.03				19.12	16.67
Lyonia ovalifolia	Ericaceae	DS	Deciduous Shrub	4.04					
Sub-total				**7.07**				**19.12**	**16.67**
Deciduous Shrub or Tree									
Phyllanthus emblica	Euphorbiaceae	DST	Deciduous Shrub or Tree		8.89	16.67	20.00		16.67
Rhus chinensis	Anacardiaceae	DST	Deciduous Shrub or Tree	4.04	8.89				
Sub-total				**4.04**	**17.78**	**16.67**	**20.00**		**16.67**
Deciduous Tree.									
Bridelia retusa	Euphorbiaceae	DT	Deciduous Tree.		8.89	5.56	53.33		
Quercus griffithii	Fagaceae	DT	Deciduous Tree.	5.05					
Sub-total				**5.05**	**8.89**	**5.56**	**53.33**		
Evergreen Shrub									
Berberis asiatica	Berberidaceae	ES	Evergreen Shrub		15.56	5.56	6.67	1.47	5.56
Ficus sp.	Moraceae	ES	Evergreen Shrub	3.03	8.89	66.67	20.00		
Sub-total				**3.03**	**24.44**	**72.22**	**26.67**	**1.47**	**5.56**
Evergreen Shrub or Tree									
Rapanea capitellata	Myrsinaceae	EST	Evergreen Shrub or Tree	24.24					
Wendlandia sp.	Rubiaceae	EST	Evergreen Shrub or Tree			5.56			
Sub-total				**24.24**		**5.56**			
Evergreen Tree									
Aesandra butyracea	Sapotaceae	ET	Evergreen Tree		33.33				
Cinamomum sp.	Lauraceae	ET	Evergreen Tree	7.07					
Macaranga pustulata	Euphorbiaceae	ET	Evergreen Tree	10.10					
Quercus glauca	Fagaceae	ET	Evergreen Tree	4.04					
Quercus semecarpifolia	Fagaceae	ET	Evergreen Tree	1.01					
Schima wallichii	Theaceae	ET	Evergreen Tree	6.06	2.22				
Sub-total				**28.28**	**35.56**				
Perennial Bamboo									
Yushania sp.	Gramineae	PB	Perennial Bamboo	2.02					
Sub-total				**2.02**					
Perennial Herb or Shrub									
Indigofera dosua	Leguminosae	PHS	Perennial Herb or Shrub	15.15				11.76	
Sub-total				**15.15**				**11.76**	
Grand Total				**100**	**100**	**100**	**100**	**100**	**100**

Annexure 9. Floristic composition and life-forms of herbs and ground flora

Species Name	Family Name	Life Forms	N1	N2	NR1	NR2	DR1	DR2
Annual herb								
Ageratum conyzoides	Compositae	Annual herb		20.83	0.95		0.03	0.10
Bidens pilosa	Compositae	Annual herb		0.31				0.60
Crassocephalum crepidoides	Compositae	Annual herb		0.05			0.06	
Curcuma sp.	Zingiberaceae	Annual herb	1.13		0.64	0.38	2.13	4.61
Galinsoga parviflora	Compositae	Annual herb					0.17	0.04
Galium aparine	Compositae	Annual herb					0.01	
Gnaphalium affine	Compositae	Annual herb					0.02	
Hedychium sp.	Zingiberaceae	Annual herb	3.38					
Spergula arvensis	Caryophyllaceae	Annual herb					0.03	0.04
Sub-total			**4.50**	**21.19**	**1.59**	**0.38**	**2.44**	**5.39**
Annual or perennial fern								
Fern 1	Polypodiaceae	Annual or perennial fern		2.78				
Fern 2	Polypodiaceae	Annual or perennial fern	3.75	0.46				
Fern 3	Polypodiaceae	Annual or perennial fern	1.25					
Fern 4	Polypodiaceae	Annual or perennial fern	3.75					
Woodwardia unigemmata	Blechnaceae	Annual or perennial fern	2.50					
Sub-total			**11.25**	**3.24**				
Annual or perennial herb								
Acmella uliginosa	Compositae	Annual or perennial herb					0.03	0.05
Aconogonon molle	Polygonaceae	Annual or perennial herb	5.63					
Carex sp.	Cyperaceae	Annual or perennial herb			1.43	0.26		
Cynoglossum furcatum	Boraginaceae	Annual or perennial herb					0.07	0.07
Duhaldea cappa	Compositae	Annual or perennial herb	7.38	3.80	3.87	0.46	0.73	1.16
Oxalis corniculata	Oxalidaceae	Annual or perennial herb		0.11			0.17	0.72
Pteracanthus urticifolia	Acanthaceae	Annual or perennial herb	5.50					
Sub-total			**18.50**	**3.90**	**5.30**	**0.72**	**1.00**	**2.00**
Climber								
Argyreia roxburghii	Convolvulaceae	Climber	1.25	2.01				
Clematis sp.	Ranunculaceae	Climber		1.54	0.35		0.36	
Piper sp.	Piperaceae	Climber	1.25					
Rubia cordifolia	Rubiaceae	Climber	1.88					
Sub-total			**4.38**	**3.55**	**0.35**		**0.36**	
Deciduous shrub								
Desmodium elegans	Leguminosae	Deciduous shrub	1.38				0.03	0.10
Indigofera heterantha	Leguminosae	Deciduous shrub	1.88					
Sub-total			**3.25**				**0.03**	**0.10**
Perennial grass								
Cymbopogon flexuosus	Gramineae	Perennial grass	53.13	39.04	4.45	1.28	56.82	13.12
Hyparrhenia sp.	Poaceae	Perennial grass					6.45	4.83
Sub-total			**53.13**	**39.04**	**4.45**	**1.28**	**63.27**	**17.95**
Perennial herb								
Ageratina adenophora	Compositae	Perennial herb	3.75	5.56	1.21			
Artemisia myriantha	Compositae	Perennial herb		8.33	1.95		3.79	0.80
Chromolaena odorata	Compositae	Perennial herb	0.63	11.11	85.16	97.61	28.94	73.69
Cyperus sp.	Cyperaceae	Perennial herb		2.39				
Rumex nepalensis	Polygonaceae	Perennial herb					0.17	0.07
Sub-total			**4.38**	**27.39**	**88.31**	**97.61**	**32.90**	**74.56**
Perennial herb or shrub								
Boehmeria platyphylla	Urticaceae	Perennial herb or shrub	0.63					
Desmodium sp.	Leguminosae	Perennial herb or shrub		0.80				
Sub-total			**0.63**	**0.80**				
Perennial shrub								
Daphne involucrata	Thymelaeaceae	Perennial Shrub		0.42				
Jasminum nepalense	Oleaceae	Perennial shrub		0.46				
Sub-total				**0.88**				
Grand Total			**100**	**100**	**100**	**100**	**100**	**100**

Annexure 10. Cross section profile of study area



Annexure 11. Photographs

A. WBH on the roosting tree at Namsethang (DR1)

B. Old nest of WBH above Namsethang (N2)

C. Nest tree at Tshomenchoesa (N1)

D. Carcass of WBH found at Tshomenchoesa

E. Forest fire at Namsethang (DR1)

F. Deforestation along the habitats of WBH