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Vegetation Structure and Species Composition Inside the Habitat of Critically Endangered White-bellied Heron (*Ardea insignis* Hume, 1878) Along the Phochu in Punakha district, Bhutan

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ABSTRACT

Floristic compositions and vegetative structures are key determinants for selecting nests and roosting habitats of Critically Endangered White-bellied Heron. However, none of the Bhutanese researchers had ever studied to date. Gradient-directed transect methods were adopted using systematic sampling. Vegetation surveys were carried out inside 10 x 10 m (trees), 5 x 5 m (shrubs), and 2 x 2 m (herbs) in 48 plots across the Pochu landscape. The result shows that the Phochu landscape recorded 10 trees species belonging to six families. *Pinus roxburghii* is the most dominant species with relative density [RD] (86.77%), relative frequency [RF] (37.50%), relative dominance [RD] (79.93%), and IVI (204.20). While, *L. ovalifolia* and *A. lebbeck* were the lowest (RD (0.53%), RF (6.25%), RD (0.07%), (0.83%), IVI (6.85), and 7.61 respectively. While shrub constitutes 19 species and belongs to 14 families. *Chromolaena odorata* (32.15%, *n* = 933) and *Cymbopogon* sp. (21.26%, *n* = 617) were the most dominant herbs, while, *Galium aparine* (0.03%, *n* = 1) were lowest with 38 herbs species belongs to 20 families. For vegetative structures, maximum trees (38.62%, *n* = 73) DBH ranges from the 11-15 cm, which are found in day roosting site 1 (34.25%, *n* = 25). While, lowest ((0.53%, *n* = 1) was DBH ranges of 51-55 cm, 61-65 cm, 66-70 cm and 71-72 cm respectively. Therefore, similar vegetation composition and structure studies are suggested in other core habitats across Bhutan to deduce its habitat ecology for the long-term conservation of Critically Endangered WBH in Bhutan.

INTRODUCTION

The White-bellied Heron *Ardea insignis* (Hume, 1878) is one among eight heron species which is Critically Endangered since 2007 due to highly fragmented distribution and small population (BirdLife International, 2018; Kyaw et al., 2021). Generally, the geographical range is small (56,300 km²) that extends from Bhutan through northeast India to northern Myanmar, but appears in low densities since 2010 (Kyaw et al., 2021). Low reproduction rates and relatively shorter lifespans (10.5 years) are suggested as the key reasons for higher levels of mortality across the range of countries (BirdLife International 2018, IUCN Redlist, 2018, Kyaw et al., 2021). Globally, WBH is endemic to Bhutan, India, and Myanmar (BirdLife International, 2001, Acharja, 2019) with a population ranging from 50-249 individuals (IUCN Redlist, 2018). In Bhutan, WBH is mostly sighted along Punatsangchu, Mangdichu (Khandu, 2020) and recently sighted along the Drangmichu basin in the east (Wangdi *et al*., 2017, Khandu, 2020). According to the Royal Society for Protection and Nature (2015), Bhutan had recorded 30 individuals in 2015 but now declined to 22 individuals in 2021 (RSPN, 2015; RSPN, 2021). However, the exact reasons for the decline are still unknown in Bhutan.

Studies suggested that habitat degradation and widespread human disturbance are the major causes of population decline (Stanley-Price and Goodman, 2015; IUCN Redlist**,** 2018; Menzies et al., 2020; RSPN, 2021). Besides this, Kyaw et al. (2021) also suggested that dam construction and hunting culture by ethnic group and rapid deforestation also contributes to the declining population in the range countries.

On other hand, DeWalt et al. (2003) have also reported that even the slightest changes in the floristic composition and structures inside the core habitats will have significant implications for the avian species. Besides this, habitat destruction is also identified as the leading cause of species extinction as per Wilcove et al. (1998). However, in-depth habitat ecology and impacts of changing vegetation composition and structure inside the core habitats of WBH were not adequately studied in Bhutan. Therefore, the current study aims to examine the vegetation composition and structure inside the habitats of WBH to ascertain the habitat characteristics and impacts of disturbance on the WBH (Rajpar & Zakaria, 2011). Through this, mortality and extinction risk of the critically endangered can be lower through various conservation programs which will contribute to the long-term conservation of critically endangered WBH along the landscape of Punatsangchu basin under Punakha district in Bhutan.

METHODS

Study area

The study was conducted along the stretch of Phochu under the Punatsangchu basin which is identified as one of the core habitats of WBH under the Punakha district in Bhutan (Figure 1). The area is located at an elevation range of 1276 -1464 masl (Rabten, 2016). Vegetation is dominated by the Chirpine (*Pinus roxburghii*) at lower elevations and mixed broadleaved forests at the upper elevations with moderately warmer winters and hotter summers. The settlements are found along the valleys of river banks where farmers mostly depend on paddy cultivation due to abundant wetlands. Due to the plain landscape commensurate with diverse shallow pools along the clean-running Phochu, the landscape provides conducive nesting and roosting sites for the critically endangered WBH. Therein, the Royal Government of Bhutan (RGoB) has recognized the significance of the WBH and issued the order from the Cabinet Secretariat that Phochu basin is declared a protected habitat of White-bellied Heron vide letter No COM/04/07/887 on dated 1st March of 2007 during 336th CCM Sessions (Stanley et al., 2015; Rabten, 2016).

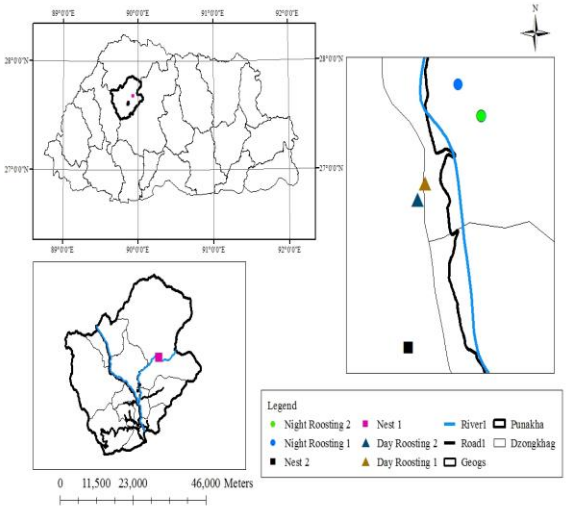

Figure 1. Bhutan map showing the location of Phochu basin (study area) and nesting and roosting sites of WBH along the Phochu basin

Data collection

The study area was stratified into three distinctive habitats based on the nesting and night-day roosting sites along the Pochu landscape. Night roosting sites were confirmed through community consultation and the presence of droppings beneath the trees, while day roosting sites were confirmed through field observations. The single line transacts using gradient-directed transect (Gillison and Brewer, 1985) were runned along the center of each nesting and roosting trees. Observation points were systematically established at every 50 m rise in altitude from starting point of transacts. Any trees that have a DBH more than 10 cm were classified as trees, 5-10 cm (shrubs) and 0-5cm (herbs) whereby trees were enumerated inside10x10m, 5x5m (shrubs), and 2x2m (herbs) respectively. A total of 48 sample plots were laid, out of which 8 plots each in 2 nesting sites; 2-day roosting sites, and 2-night roosting sites. Canopy cover percentages for each sample plot were classified into open canopy (10-39%), moderately closed (40-69%), and closed canopy (70-100%) (Rabten, 2016). Inter-distance between nearest settlements, roads, agriculture fields, and feeding sites (river banks) from the centroid point of nesting and roosting sites were recorded using measuring tape to describe the characteristics of the habitats. Besides these, environmental variables like aspect, slope percent, and altitude were also been collected. Plants species were identified using various field guides authored by (Parker, 1992), (Thinley, 2004), (Polunin and Stainton, 2006), and (NBC, 2009).

Data analysis

For calculating the composition and structures of the vegetation, Relative dominance, Density, Frequency, Diversity, and Important value index (IVI) were used:

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 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 the species and FIV may vary between 0 and 300% (Froumsia *et al.*, 2012). While for determining vegetative structure characteristics, DBH (Diameter at breast height), height and basal area (BA), and canopy cover were calculated. Likewise, for comparing species diversity between transects, Shannon's measure of evenness (E_H), Shannon-Wiener's diversity index (H'), and species richness (S) were calculated. DBH was used to determine the basal area (BA cm^2) and the relative basal area (RBA) in % was used as abundance to measure the species in a community (Wangdi, 2014). The formula described by Zobel et al. (1987) was used for calculating basal area (BA), the 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

The species diversity index (H') was calculated using the 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 ($\ln P_i$). Then 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') =
   Where

$$Pi = \frac{\text{Number of individual of one species}}{\text{Total number of all individual (one forest only)}}$$

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 a natural logarithm. Meanwhile, data were sorted using Microsoft excel 2019 and analyzed using SPSS (Version 23) software.

RESULTS AND DISCUSSION

Tree species and composition of families

Phochu landscape has recorded 10 tree species that constitutes 189 individuals/stems that belongs to six families. Among them, *Pinus roxburghii* was the most common species with relative density (RD) of 86.77%, relative frequency (RF) (37.50%), and relative dominance (RD) (79.93%) with IVI of 204.20. While, *L. ovalifolia* and *A. lebbeck were the lowest* with RD of 0.53%, RF (6.25%), RD (0.07%) and (0.83%), and IVI of 6.85 and 7.61 respectively. The overall analysis showed that *P. roxburghii* was the most dominant and most important species in the core habitat of WBH with higher IVI (Table 1). This indicates that the presence of *P. roxburghii* is inevitable for the sustenance of WBH within the core habitat along the Pochu landscape. Thus, studies by Razavil et al. (2012) also reported that the slightest removal of dominant species from the core habitat along the Pochu will have serious implications on the biotic and abiotic components of the habitat. Therefore, constant monitoring by the concerned conservation agency is critically required for the long-term conservation of this critically endangered WBH in those landscapes.

Table 1. Family composition and Important Value Index of 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	37.5	79.93	204.20
Quercus grifithii	7	1	9809.07	3.70	6.25	8.47	18.43
Quercus glauca	2	2	346.43	1.05	12.5	0.29	13.85
Schima wallichii	5	1	3937.28	2.64	6.25	3.40	12.29
Macaranga pustulata	5	1	1131.32	2.64	6.25	0.97	9.87
Alnus nepalensis	1	1	3318.30	0.53	6.25	2.86	9.64
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	78.53	0.53	6.25	0.06	6.85
Grand Total	189	16	115685.70	100	100	100	300

Tree species diversity, richness, and evenness

Among six transects, the highest tree species (S) was recorded in nest 1 (62.5%, n = 10), followed by nest2 (12.5%, n = 2), while, night and day roosting sites were the lowest (6.25%, n = 1). Nonetheless, nest 1 has the highest diversity (1 (1.84) and the lowest was nest 2 (0.07), and there is no tree diversity across the transects or sites (table 2).

Table 2. Transect-wise tree community parameters

Transect ID	Diversity (H')	Species richness(S)	Species evenness	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

Comparison of tree species composition among the habitat types

There were significant differences in tree species composition among the habitat types ($H(2) = 52.179$, $p = .000$). This may be due to some nesting sites being located at an ecotone as it constitutes a mosaic of plants from the two adjacent ecosystems and creates a mosaic of habitats that increases the species diversity (Harker et al., 1999). However, there was no significant difference in species composition between the two roosting sites (table 3) may be due to the existence of a monodominant forest.

Table 3. Mann-Whitney comparison of species composition among the different habitats

Statistic	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	0.000	0.000	1.000

Structural characteristics of tree species

The DBH of the tree ranges from 10-106.50 cm (*M* = 22.79, *SD* = 16.15). Maximum trees (38.62%, *n* = 73) falls within the DBH class of 11-15 cm, which were 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 were the lowest (0.53%, *n* = 1). In the case of tree heights, most of the tree height ranges between 5-39 m (*M* = 13.06, *SD* = 6.31) with most of the individuals (17.46%, *n* = 33) height falls between 7-8 m found in day roosting 1 (85.9%, *n* = 15), followed by night roosting 2 (8.2%, *n* = 6) and none of the trees were fallen within the height ranges of 37-38 m (Figure 2). Meanwhile, the canopy cover was classified as open to closed with the value ranging from 5-40 (*M* = 12.99, *SD* = 6.95).

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). Ohsawa (1991) classified vegetative structure into three models. The emergent or unimodal type has no offspring within the community and exhibit an even-aged population, the sporadic or multimodal type has several even-aged populations within the community and exhibit a multi-aged population, inverse-J type has offsprings without intermission and exhibits an all-aged population. In this study area, the distribution of trees constitutes unimodal to multimodal types in the nesting habitats. Both the day and night roosting habitats showed inverse-J-type patterns (Figure 2). While, an inverted J-shaped pattern shows the high distribution of individual species in the lower DBH classes and a gradual decrease toward the higher DBH classes (Kuma and Shibru, 2015). This study revealed that, unlike the roosting sites, nesting sites were relatively far away from human settlements and motorable roads and destruction is more on matured trees along the roosting habitats.

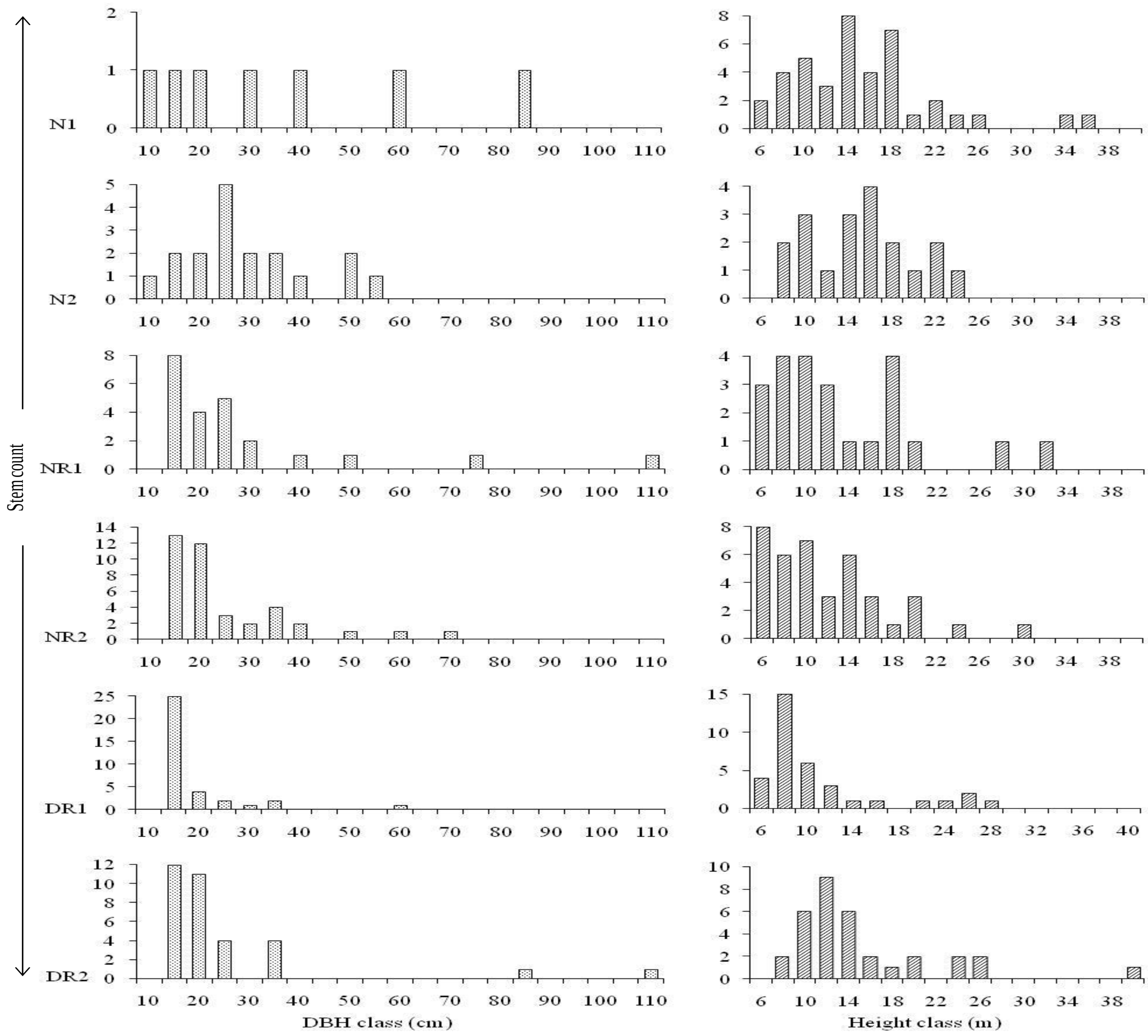

Figure 2. Transect-wise DBH and height class distribution of tree species

Comparison of structural traits among different habitats

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 different habitats. However, there was a slight difference in DBH between nesting and night roosting habitats. While, there were significant differences 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 between day roosting and night roosting habitats (table 4).

Table 4. Mann-Whitney comparison of vegetation structure among different habitats

Between nesting & night roosting				Between nesting & day roosting			Between night & day roosting		
Statistic	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	-2.406	-2.406	-2.793	-3.210	-1.979	-549	-239
p	560	.004	.016	.016	.005	.001	.048	583	811

The highest mean DBH was 25.25 cm (*SD* = 15.70) in nesting sites, followed by 23.68 cm (*SD* = 16.95) in night roosting sites, and the lowest mean DBH with 19.86 cm (*SD* = 15.56) in day roosting sites. The highest mean height and canopy cover were also recorded at nesting sites (table 5).

Table 5. 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)	14.80	11.98	12.53
Mean canopy cover (%)	15.25	12.01	11.91

Species composition and structural characteristics of sapling species

The saplings (< 10 cm > 5 cm DBH) were recorded from all the sample plots. In total, the study area had recorded 47 individuals/stems of 7 species that belong to 5 families (table 6). *P. roxburghii* was the most common sapling with the highest RA (65.96%, *n* = 31), followed by *S. wallichii* (14.89%, *n* = 7). While, *P. emblica, Q. glauca* and *R. chinensis were the lowest* (2.13%, *n* = 1). Among seven species in all nesting and roosting habitats, *P. roxburghii* was the dominant species with a relative dominance of 71.50 (table 6).

Table 6. Sapling species composition and relative dominance

Species name	Stem count	Relative abundance	Family	BA(cm^2)	Relative dominance
Macaranga pustulata	2	4.26	Euphorbiaceae	90.62	4.75
Phyllanthus emblica	1	2.13	Euphorbiaceae	35.26	1.85
Pinus roxburgii	31	65.96	Pinaceae	1362.75	71.50
Quercus glauca	1	2.13	Fagaceae	58.09	3.05
Quercus graffithii	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 was 5 cm. The maximum height in the layers was 7 m and the shortest was 4 m. Like tree species composition, there was a significant difference in species composition of the saplings 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).

Species composition of shrubs and regenerations

Shrub and regeneration layers comprised 19 species that belong to 14 families. Fagaceae (15.79%) and Euphorbiaceae (15.79%) were the most dominant families followed by Leguminosae (10.53%). In the case of the shrubs species, *P. roxburghii* was the most dominant and *Q. semecarpifolia* was the least (table 7).

Table 7. Shrub and regeneration species composition and relative dominance

Species Name	Stem count	Relative abundance	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 semicarpifolia	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
Grand Total	263	100		671.67	100.00

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 the nesting sites, while, day roosting sites has the lowest (table 8).

Table 8. 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(E)	0.76	0.44	0.45

Species composition of herbs and ground flora

The lowest layer is comprised of herbs and ground flora which constitutes 38 species that belong to 20 families representing the ground flora of the entire study area. Among them, *Chromolaena odorata* (32.15%, *n* = 933) and *Cymbopogon* sp. (21.26%, *n* = 617) were the most dominant understory plant species, while *Galium aparine*

(0.03%, *n* = 1) and *Gnaphalium affine* (0.07%, *n* = 2) were the lowest (table 10).

However, 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 in nesting sites, while, night roosting sites were the lowest in terms of mean species diversity, richness, and evenness (table 9).

Table 9. 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 (E)	0.76	0.44	0.45

Table 10. Herbs and ground vegetation composition and relative dominance

Species Name	Stem count	Relative abundance	Family	Relative volume	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 flexuosus	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
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
Nephrolepis sp.	12	0.41	Nephrolepidecaeae	2.78	0.46
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
Pteridium sp. 1	28	0.96	Polypodiaceae	4.21	0.70
Pteridium sp. 2	15	0.52	Polypodiaceae	1.25	0.21
Pteridium sp. 3	19	0.65	Polypodiaceae	3.75	0.63
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
Grand Total	2902	100.00		600.00	100.00

Nest and roost tree characteristics of WBH

RSPN (2011) mentioned that WBH roosted and nested on the tall Chir pine trees (*P. roxburghii*) which is consistent with the current study. However, in the case of other range countries like India where vegetation is completely different from Bhutan, there is also evidence of nests in broadleaved species like East Indian almond (*Terminalia myriocarpa*), (Singh, 2014) which clearly indicated that WBH doesn't exhibit selective behavior in selecting specific trees species for nesting and roosting, rather its selection completely depends upon the types of vegetation present in respective range countries. The current studies recorded six trees: two nesting trees; two-day roosting trees, and two-night roosting trees. The highest DBH recorded for night roosting tree 1 was 106.50 cm, followed by nesting tree 1 (105.70 cm) and the lowest was 46.90 cm at nesting tree 2 (Figure 3) with a mean height of 30.23 m for nesting and roosting trees respectively. Meanwhile, the height of nesting and roosting trees ranges from 15.45 m (nest tree 2) to 45.29 m (nest tree 1) (Figure 4).

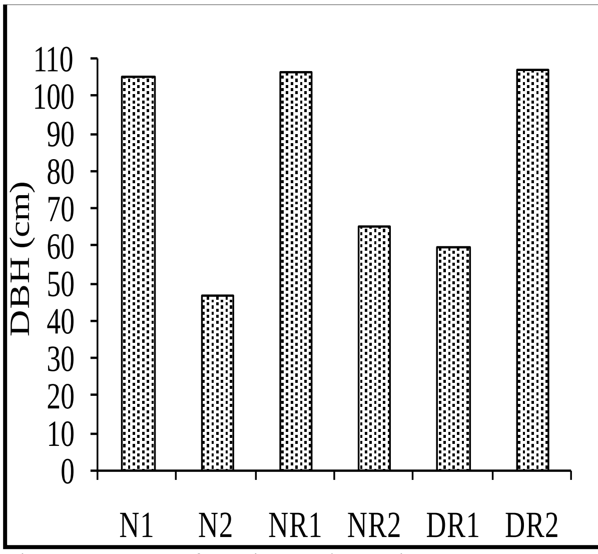

Figure 3. DBH of nesting and roosting trees

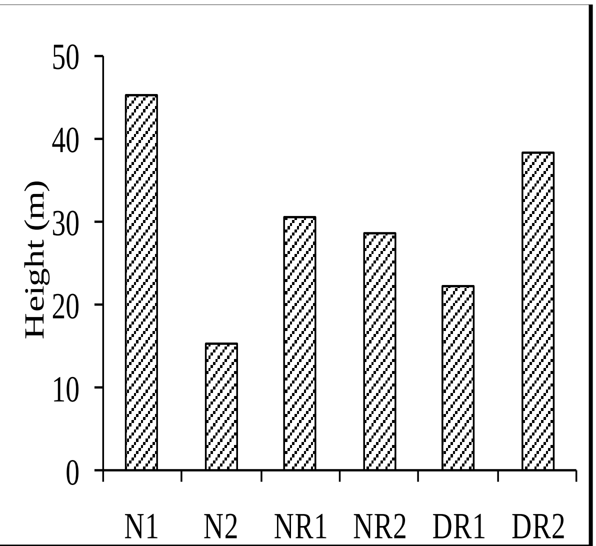

Figure 4. Heights of nesting and roosting trees

The slope percent of nesting and roosting sites ranges from 0% each at day roosting 1 and 2 to 95% at night roosting 1 with a mean slope percent of 44.83%. Most of the roosting and nesting trees were located in the southwest and southeastern aspects whereby WBH prefers day roosting trees which are lying in the plain area along Phochu river banks in winter. However, the selection of day roosting trees for the summer season needs to study in this same landscape.

RSPN (2011) observed WBH below 1500 masl regularly along the Punatsangchu basin and most of the nests were found on Chir pine trees within the elevation ranges of 700-1000 masl. However, the current study revealed that the highest nest recorded was at an elevation of 1464 masl (Tshomenchoesa) and the lowest at 1260 masl which is slightly lower than the previous studies in the Phochu area.

Most of the nest trees were observed nearby the feeding sites (river) at mean distance of 86 m, and some are away from the motor road (1481m), human settlement (618 m), and agriculture field (487 m) respectively. RSPN (2011) also reported that WBH needs larger territories for nesting as the nesting sites were recorded at a flight distance of 10.37 km away from other.

DeLong (2009) reported that evergreen trees provide nest sites for birds in the spring and thermal cover in winter. Similarly, tall Chir pine trees with well-branched provide the best thermal cover to the birds in the study area. These roosting trees were close to agriculture fields and human settlements with an average distance of 37 m and 209 m respectively. However, these trees were 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 497 m. Meanwhile, WBH preferred to roost on the tree when people and animals approaches near to them. The day roosting trees were very close to the feeding ground with an average distance of 10 m.

CONCLUSION

The Chir pine forest along the stretch of Phochu landscapes serves as a core habitat for Critically Endangered WBH which has become one of the conservation priorities for Bhutan. Floristically, *P. roxburghii* was the monodominant species widely prevalent within the nesting and roosting habitats, and even a modest change in the vegetation covers nearby the nesting and roosting sites will have significant implications on the persistence of critically endangered birds. However, a human disturbance was identified as the main factor that affects the forest structure and dynamics of these core habitats. Therefore, an in-depth investigation of vegetation structure and composition covering the entire core nesting and roosting habitats across Punatsangchu, Mangdichu, and Drangmichu basins is suggested to understand more about the habitat ecology. Besides this, the demarcation of Pochu landscapes constituting core conservation habitat and restriction of development activities within this landscape is suggested for the long-term conservation of this critically endangered heron within the landscape of Phochu under the Punatsangchu basin in Bhutan.

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