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 dissertation titled "**Influence of Forest Fires on Nest Selection Pattern by White-Bellied Heron along Punatshangchhu Basin under Wangdue Phodrang and Punakha Districts**". All the sources of information and assistance received during the course of the study are duly acknowledged.

Sonam Yonten
B.Sc. Forestry
College of Natural Resources
Royal University of Bhutan
Punakha: Bhutan
February 13, 2017

ACRONYMS

ANOVA	:	Analysis of variance
BBSAP	:	Bhutan Biodiversity Strategic Action Plan
BBIRD	:	Breeding Biology Research and Monitoring Database
cm	:	Centimeter
CNR	:	College of Natural Resources
DBH	:	Diameter at Breast Height
DoFPS	:	Department of Forests & Park Services
GPS	:	Global Positioning System
H’	:	Shanon-Wiener Diversity Index
IUCN	:	International Union for Conservation of Nature
LSGM	:	Local Support Group Members
m.a.s.l	:	Meter above sea level
m^3	:	Cubic meter
MoAF	:	Ministry of Agriculture & Forest
RBA	:	Relative Basal Area
RC	:	Relative Cover
RF	:	Relative Frequency
RGoB	:	Royal Government of Bhutan
RSPN	:	Royal Society for the Protection of Nature
S	:	Species richness
SFD	:	Social Forest Division
SPSS	:	Statistical Package for Social Sciences
WBH	:	White-bellied Heron

ACKNOWLEDGEMENT

This study was possible because of the contributions of many people and organizations. First and foremost, I would thank Mr. Jane Raymond and Mr. Josh Cole of Rufford, United Kingdom for supporting my research with generous funding, without which this study would not have materialized.

I wish to thank my referee Mr. Yonten Dorji, Lecturer, CNR for his continuous supervision, encouragement and guidance during this research project. I would remain grateful to Dr. Kinley Tenzin, Executive Director, Royal Society for Protection of Nature (RSPN), Thimphu for facilitating me to finally get to this particular topic. I will always remember the support of Madam Rebecca Pradhan, Ecologist, RSPN for sharing her knowledge and experiences on WBH and also helping in identification of plant specimens collected from the field. Mr. Sonam Tshering, Research Assistant, RSPN is also genuinely thanked for guiding us to the nest trees of Zawa and Nangzina, and for providing the necessary data of WBH. I would also express my gratitude to Dr. Purna Bahadur Chettri, RNR-RDC, Yusipang, Thimphu for providing me with the necessary research inputs.

I would eternally be grateful to my colleagues of CNR; Mr. Rabten, Mr. Ngawang Tenzin and Mr. Jambay Dhendup for accompanying me in a chase to find the nests of WBH on steep cliffs of Tshekhathang and Athang in Punakha and Wangdi Phodrang districts respectively. I would thank Mr.Tashi Phuntsho, Mr. Rinchen Dorji and Mr. Damber Kumar Ghemiray, Forest Rangers, DoFPS for helping with the observational and social data collection. I would also thank Mr. Sangay Tshewang, Forest Ranger, Athang Gewog for providing the logistic support and helping with botanization of plants during the data collection. I sincerely thank the family of Mr. Wangchuk, Mr. Kinley and Mr. Penjor, Local Support Group Members (LSGM) for being a wonderful host and for guiding us to the nest trees of WBH.

I would like to acknowledge the staff of Divisional Forest Office of Punakha and Wangdi Phodrang districts and Mr. Kinley Tshering, Forest Fire Management Section of the Department of Forests and Park Services (DoFPS) for furnishing fire data of these areas.

ABSTRACT

This study is a first attempt in entire home ranges of White-bellied Heron (*Ardea insignis* Hume), to assess the effects of forest fire frequency on vegetation structure and composition in its nesting habitats. Subsequently, to understand the trade-offs of fire frequency on nest-selection and nest-use of White-bellied heron (WBH). The study was conducted in Chhubu and Athang Gewog in Punakha and Wangdiphodrang districts respectively at five sites. The sites were categorized into 3 classes as; i) once burnt ii) twice burnt and iii) frequently burnt sites, in the last 10 years. The vegetation survey was conducted by laying 10 quadrats (10 m X 10 m each) in four transects of 100 m each. Transects were established in four cardinal directions with nest tree as the center point. Social survey was carried out within 500 m buffer from the nest tree. The research findings showed that, twice burnt site had the maximum number of nests built of 66.7% (*n* = 8) and active nests of 78.6% (*n* = 11). Twice burnt site revealed approximately four times more nest presence over once and frequently burnt sites. It was observed that there was a significant relationship of WBH nest-site selection to forest structures such as stem density, canopy cover, tree height and DBH. It is recommended to protect mature Chirpine stands along the water bodies from frequent fires, and creating fire breaks around the nest trees during breeding and nesting seasons. This would help to conserve the nest-sites of WBH.

Keywords: Active nest, fire frequency, nest- site selection, vegetation structure

Table of Contents

List of Tables

List of Figures

List of Appendices

CHAPTER ONE
Introduction

1.1 Background

In 1988, Bhutan was identified as one of the ten biodiversity hotspot of the world. Bhutan is a repository to more than 700 species of birds including 221 global endemic birds, 18 of which are globally threatened, 4 are critically endangered and 28 numbers of White-bellied Heron from the global population of 50-200 birds (BBSAP, 2014). Krishna *et al.* (2012) puts forth that global distribution of WBH is restricted to eastern Himalaya in India (West Bengal, Assam, Arunachal Pradesh, and Nagaland), northeastern Bangladesh, Burma and Bhutan (Punakha, Wangdue and Zhemgang). It is a large and long-necked heron measuring 127 cm in height. It is scientifically known as *Ardea insignis* Hume belonging to the family ardeidae. It is the second largest heron in the world (BirdLife, 2015). Since 2007, IUCN declared it as a critically endangered species. It is classified as a Critically Endangered bird owing to extremely small and declining population. The decline is predicted to increase with multiple agents of disturbance (BirdLife, 2001).

In recent decades, there has been notable decline in the population of White-bellied Heron. In Bhutan, RSPN (2015) reported the drop in population as well. Though the specific cause of this decline lack in-depth studies, however, it is attributed towards predator, habitat loss, fire incidence, water-based recreation, and the alike. In the study by Woinarski and Recher (1997), the main threat behind declining bird species in many environment is the inappropriate fire regime. The reproductive output and dispersal ability is low in fire sensitive threatened species. The author further emphasized on the isolated colonies of birds, wherein, a single fire would wipe enormous proportion of the population.

Punatshangchhu and its tributaries are the permanent habitats of WBH. It includes rivers from Mochu, Phochu, Zawachu, Digchu, Kamichu, Ada, Kisonachu, Hararongchu, Cerichu, Burichu and Dagachu (RSPN, 2011). In the study conducted by RSPN from 2003 to 2011, they found 26 WBHs regularly residing the Punatshangchhu basin and tributaries.

Wangdiphodrang Dzongkhag lies in warm-dry conifers which are principally dominated by Chirpine stands. Therefore, fire has been the part of natural consequence and as well as of anthropogenic origin in these regions. Nests of the WBH are particularly found in the tall Chirpine (*Pinus roxburghii* Sarg) trees at an altitude range of 700-1000 m.a.s.l. (RSPN, 2011). Chirpine stands and its related plant communities are prone to fire mostly during the dry seasons. RSPN (2011) also studied that WBH prefers sparsely dispersed trees without any understory near them. This is found to be strongly evident from the fact that most nesting areas were located on the trees with fire scars, limited ground debris and without mid-story. Thus, the interaction between fire frequency and large open Chir pine trees were probable. There were at least two cases during which nest was destroyed and abandoned in the following year

There is paucity of information regarding the study on WBH and its relationship towards the forest fire as of now (RSPN, 2011). The present study tries to find the impacts of forest fire frequency on nest-site selection by WBH in Punakha and Wangdue Phodrang Dzongkhag along the Punatshangchhu basin. The study will generate benchmark information concerning the interplay between WBH and fire frequency in these areas.

1.2 Problem statement

Punatshangchhu and its tributaries have been identified as a permanent habitat of WBH among the river systems of Bhutan; nevertheless, the noticeable disturbance along this stretch of river basin is forest fire among many others. Fire is known to alter their habitat and other associated ecological functions. RSPN has recorded few instances where the wild fire destroyed the nest and abandoned the following year. Therefore, this study on fire frequency influences on WBH nesting pattern along Punatshangchhu River is felt timely to address the issues related to declining population of WBH due to fire.

1.3 Rationale

It has become inevitable truth of the declining population of White-bellied heron within its global home range owing to disturbances emanating from various natural and artificial sources. In Bhutan also, out of many disturbances fire is perceived to be the prominent one as this region is mostly dominated by Chir pine stands that are susceptible to fire during the winter and spring seasons. There is also a common trend and practice by the community of using fires within this continuum in order to manage grazing ground for their cattle. Exacerbating the scenario people are not cautious about the fires in this locality, which is also the permanent habitat of WBH. On the other hand, birds are considered to be good indicators of environmental monitoring, hence, birds' population have been monitored in many countries. Though only few thorough studies had been conducted on use of birds as a tool in environmental monitoring (Koskimies, 1989). Nath and Shamlai (n.d) asserts on the study of WBH as a potential tool for monitoring environment, which still remains unexplored.

Recently burned forest would help to reduce the population of nest predators; therefore, it is likely that reduced predators would allow higher reproduction success and their dispersal (Saab and Vierling, 2001). Fire also changes the nesting requirements of avifauna due to their preference for moderately burned forests on temporal scales, thus the population is predicted to decline as the risk of fire severity increases (Bull and Jackson, 1995). Fire creates short-term habitat conditions that are dynamic and change over with plant succession (Saab *et al.*, 2007). The sighting of WBH's nests in some of the Chir pine trees along these river substantiate the possible interaction between this bird and the habitats developed due to fire incidences.

1.4 Hypothesis

Null Hypothesis: There is no significant difference in WBH nesting pattern as a result of varying fire frequency.

Alternate Hypothesis: The nest selection by WBH decreases with increase in fire frequency in its habitat.

1.5 Research objectives

1. To assess the structure and composition of vegetation in the nesting habitat of WBH in once burnt, twice burnt and frequently burnt sites in past 10 years in Punakha and Wangdi Phodrang districts.
2. To document the trend of active nesting pattern of WBH in response to fire over the last 10 years in Punakha and Wangdi Phodrang districts.
3. To determine the causes of fire in the nesting habitats of WBH in Punakha and Wangdi Phodrang districts.

1.6 Research questions

1. Do nest selections by WBH depend on different fire frequencies?
2. How does the different vegetation structure and composition from fire, impact the active nesting of WBH?
3. What is the difference in active nesting pattern of WBH with different fire frequencies in the last 1 decade?
4. What is the cause of fire in the nesting habitat of WBH?

1.7 Scope and limitation

This research is the first attempt to understand the influence of forest fires to the nest selection behaviour of White-bellied Heron. None of the range countries have conducted any research pertaining to nesting of this bird in response to forest fires except for the RSPN; it has in general described the nesting characteristics of birds which are perceived to be due to the influence of fires. There is an extreme literature deficit on this topic. The bird is found to select a strategic location to limit the danger from its immediate predators, fires and also to comfort its normal activities (RSPN, 2011). Thus, understanding the vegetation structures altered due the effects of fire may not be the single attribute that determine the nest selection. It is important to consider the above aspects along with the other disturbance regimes to fully understand the nest ecology of this bird. Information generated thus could help to know their specific nesting requirements and adopt appropriate regulation and monitoring approaches to protect these habitats. Moreover, the scarcity of nesting sites of WBH and rugged topography added to the constraints of the study. So, a long term studies is indispensable to know about the impacts of fire regimes inclusive of fire frequency, season, extent, intensity and severity on the nest ecology and biology of the WBH. The study could not cover the impact of fire frequency beyond 10 years, which is also important factor to consider to study the nesting pattern of the bird.

CHAPTER TWO

Literature review

2.1 General Description and status of WBH

White-bellied Heron (*Ardea insignis* Hume) is the second largest heron in the world. It is a Critically Endangered heron and has a very small population (BirdLife, 2015). Apart from the study of a few characteristics, status and distribution, not much information has been documented on its biology and ecology so far (Hancock and Kushlan, 1984). WBH is found in the eastern Himalayan foothills in Bhutan, north-east India, north Myanmar and Bangladesh (RSPN, 2011; BirdLife, 2015). It is usually sighted as a single bird, pairs and rarely in groups of 4-5. By early 1990s it was not found in some of its former ranges and thought to be extinct from Nepal, Tibet and northern India, however, the reasons for its decline remains vague (Mashewaran 2007, as cited in RSPN, 2011). Krishna *et al.* (2012) also describes that WBH is a “solitary, wild and wary” bird and prefers habitats such as river banks with gravel and sand within the subtropical forest and found to breed and roost in Chir pine forest. RSPN (2011) puts forth that, Phochu, Mochu, Punatshangchu, Sunkoshchu, Dagachu and its tributaries in the west and Mangdechu, Bertichu and its tributaries in central region are river systems having a potential habitats of WBH in Bhutan.

2.2 Disturbance and threats to WBH

The population of WBH is declining due to direct exploitation and disturbance (BirdLife, 2015). The decline is suspected to increase due to habitat degradation and pervading disturbances, which do not spare even the remote parts of the species range (Duckworth, 2006 as cited in BirdLife, 2015). In most of the range countries the eminent disturbances reported are from pollution, over-exploitation of resources and rapid growth of aquatic vegetation. Disturbances emerge also from settlements, conversion to agriculture land, harvesting of wetland resources and poaching. In Bhutan, hydroelectric power, road construction and forest fires are the perceived disturbances to this species in its habitat range (BirdLife, 2015). RSPN (2011) found it questionable to whether this bird will recover in its former ranges, since most of the habitat seems densely populated by humans with immense alteration taking place.

2.3 Nesting and breeding behaviour of WBH

WBHs are found in large inland swamp forests and forested rivers and often in sub-montane grassland. It is apparent to depend on mature forest with large trees that are used for nesting. Nesting sites are usually associated with wetlands, rivers or lakes. Information available suggest of nesting taking place around April in Myanmar and July to August in the Himalayas during the peak monsoon (BirdLife, 2001). Generally the herons are found to nest on numerous sites, from pristine forest to disturbed forest (Kushlan and Hafner, 2000). RSPN (2011) discussed that breeding and nesting processes of WBH is complicated. However, they found the bird engaged in courtship displays from January to February. The nest building starts in last week of February through March. The young ones are hatched during first week of May and takes 72 days to fledge.

The first nest of WBH was found at Zawa in Athang Gewog, Wangdiphodrang in 2003. A total of eleven nests were recorded from 2003 to 2009 along the Punatshangchu basin. The birds were found to use the nest for three years consecutively before abandoning. In some instances nests were used only for once and moved to different sites. So, it still remains vague to understand about the nesting pattern of this bird. The repeated survey efforts increased the nests from 1 active nest in 2003 to 5 in 2011 all along the Punatshangchu basin (RSPN, 2011). It is understood that the nesting and breeding are important habitat components which determine long term sustainability and viability of this species and therefore forms important basis of study (Dorji, 2012).

2.4 Impacts of forest fires on vegetation structure and composition

Kenny *et al.* (2004) supports that the habitat suitability of fauna changes over the time as vegetation and composition structure changes. The fire interval creates a continuum of vegetation formation corresponded by a wide range of vegetation structures. (Whelan, 1995; Keane *et al.*, 1990; Kenny, 2003) reported of a severe burning and cumulative impacts of frequent fires influencing vegetation composition, structure and successional dynamics over space and time. Frost and Robertson (1987) highlighted that frequent fires decrease recruitment of the young tree into higher classes. Fire also determines the length of time plants require to recuperate before the outset of another one. The slower rate to recover will change the structure and composition of vegetation particular where the fire is found to be frequent.

2.5 Association of bird communities and vegetation in the fire altered habitats

Butchart *et al.* (2010) found that habitat degradation and fragmentation is a major cause in population decline in many taxa, including the birds. “Wildfire is an important disturbance regime that can structure wildlife community and their habitat for many years” (Stephen, 2015). Kenny *et al.* (2004) supports the above studies as adverse fires may lead to loss of species from the landscape, and when restricted to a habitat of particular species, it may result in localized loss.

Brawn *et al.* (2001) also observed many bird species abundance adapted to disturbance-mediated habitats declining. However, abundance of some bird abundance were found to be associated with the vegetation, signaling the forest fires which occurred a year earlier can reduce plant richness and, in turn denote an improvement in habitat quality for some birds (Ponce-Calderon, 2013). The study by Silk and Balen (2006) also revealed twice burned forest had much higher number of birds that prefer open and degraded forest types. Similar research by Smith (2000) and Marx *et al.* (2008) found that fire strongly influence structure and composition of plant communities, which openly alters habitat value of species thriving in it. Further study by Barlow and Peres (2004) revealed that after the fire incidence, the open-forest birds’ increases and closed-forest birds’ decreases in abundance due to the increase in abundance of habitat generalist and decrease in habitat specialist. The bird may increase or decrease depending on the nature of the species, and their population abundance are found to vary depending upon the fire frequency and regime of the fire. So, understanding about association between viability of bird population, scale of disturbance relating to their spatial distribution, nature of disturbance (natural or anthropogenic) and intensity and frequency of disturbance converts to an important component.

2.6 Fire influence on the vegetation and bird nests in context to WBH

Saab *et al.* (2007) concluded that retention of post-fire habitat offers suitable nesting conditions for the bird species. Kotliar *et al.* (2002) also investigated that fire not only lead to alteration of landscape patterns and processes but also bird communities. While different birds prefer different types of nesting but most prefer habitats not burned by fires. Nevertheless, in the long run birds will respond accordingly to the fire and develop adaptability. Warren *et al.* (2005) on the other hand, found the level of nest site selection in the habitats and distribution pattern of birds contrast owing to the local conditions of predators, distribution of food, competitor and other conditions. Similar finding by (Block and Brennan, 1993; Perry *et al*., 2011) also showed that bird distinguish among habitat types is governed by factors which effects availability of food, risk of predation (to adults or nests), and availability of nest sites. Accordingly, vegetation structure, floristic composition and microclimate are the key factors influencing very trait of birds. Vierling and Lentile (2008) discussed that varying fire intensity plays an influential role in shaping the demographic pattern of birds nesting in the habitat. Lance *et al.* (2015) supports the above findings that nest-site selection is also dependent on vertical nesting cover and patches shaped by forest fires. Contrarily, Ladrach (2009) investigated the effect of single spring burn on a bird and revealed that, in general nesting success was not affected but had a substantial impact on nest site selection.

The study by Vogl (1974) stressed on survival of some large birds and as well small birds are dependent upon fire in order to maintain the necessary habitat conditions. Olmstead (2013) found many ecological factors have collective roles in either increasing or decreasing the nesting success of birds. Hence, it becomes imperative to study these mechanisms in order to understand the conservation and nesting habitat requirements of a given species. Brooker and Rowley (1991) described the effects of wild fires on nesting pattern of some birds at Heathland in Australia. Majority of the birds were attracted to the post-fire habitat for nesting, but some with different placement in a favoured substrate, some delayed due to the storage of nesting materials and food for reproduction, while some showed nest failure.

In Bhutan, the nest trees of WBH are seen in the forest with sparse understory and little to no mid-story vegetation. Nesting habitat selection was mostly preferred in a very open forest structure with low densities of large trees nearby. The bird mostly built nests on Chir pine trees unlike in habitat range of other countries where it is found to nest on broad-leaved trees. Chirpine forests are fire adapted communities with many adaptations to tolerate fires and the ability of the trees to withstand strong winds in this region by offering a perfect elasticity than other broad-leaved species (RSPN, 2011). Darabant *et al.* (2012) further reiterated that Chir pine trees with characteristics such as thick bark, deep roots, high self-pruning, long needles, loose crown and tall growth habit prevent permanent damage by surface fires of high intensity. Gupta *et al.* (2009) supports the above conclusions that Chir tree typically occupy dry sites which are frequented by fire. It has an ability to survive low intensity occasional fire in the community. WBH are therefore found to particularly select this species for nesting in this region for its suitable characteristics in this fire prone and windy area. RSPN (2011) further stressed that nesting areas had a strong evidence of fire scars on the trees. Fires are found to maintain the structure of Chir pine forest. So confirms the interaction between the fire frequency and the nesting pattern of WBH, though it was difficult to ascertain the optimum fire frequency for nest selection. RSPN (2011) reported that out of four nest failure in Bhutan, two cases were caused due to fire incidences; one of which was at Hararongchu in 2007 which was due to forest fires although the nest tree and nest was not burned.

2.7 Peoples' attitudes towards WBH and its nesting

Owusu (2008) surmised about the importance of local communities attached to bird conservation in the area was completely dependent on people residing in that particular locality. Also mentions that the two are inseparable from each other as they remain connected in many different ways and at many different levels. Skagen (2001) also justifies that numbers of active heron nest and nest success dropped during the study period. Hence, one of the disturbances was of human activities while other determinants were also attributed to. Disturbances induced by human are found to have a significant negative impact on breeding success often causing heightened predation rate and even nest abandonment (Hockin, 2008).

The nesting sites of WBH are mostly found in remote places (Bertichu, Kisonachu and Zawa) far from the reach of human activities or in less populated areas (RSPN, 2011). Dorji (2012) states that this bird has shared habitat with humans since its existence was known. WBH is found to depend on riverine habitats that are susceptible for alteration by humans such as development activities and clearing of forest for agriculture practices. It is found to adjust with human altered landscapes. Dorji (2012) also reasoned that local people who were aware about the bird lacked social and cultural values to it. However, there was no clue about the poaching of this bird by the people, and supported for its conservation.

CHAPTER THREE

Materials and methods

3.1 Study area

The study was conducted at Chhubu and Athang Gewog under Punakha and Wangdi Phodrang Districts respectively. The study area lies at 27˚36'13.9" E to 89˚52'01.6" N in the north to 27˚12'20.4" E to 90˚06'51.7" N in the south (Figure 3.1 and Figure 3.2), and elevation ranged from 647 m.a.s.l to 1359 m.a.s.l. The climatic condition is hot and wet in summer and cold and dry in winter with mean annual rainfall ranging from 475 mm to 898 mm. Five sites viz. Lopokha, Tshekhathang, Nangzina, Harachu and Zawa were identified for the study, based on presence of WBH nest trees recorded so far by RSPN. Fire frequency varied from 1 to 4 times in the last one decade in these areas. These areas are usually dominated by Chirpine (*Pinus roxburghii)* trees as the overstorey species and shrubs species include *Rhus paniculata, Phyllanthus emblica, Indigofera dosua, Desmodium elegans, Lonicera macrantha, Woodfordia fructicosa and Murraya koenigii*. The understory vegetation are *Carex* sp., *Cymbopogon jwarancusa, Phoeniz loureiroi, Duhaldea cappa, Ageratina adenophora* and *Jasminum nepalense*. Thus, these areas are prone to fire from December to April. As per Wangda (2003), this area falls in low-altitude xerophytic forest usually occurring in dry deeper valleys of Punatshangchhu watershed.

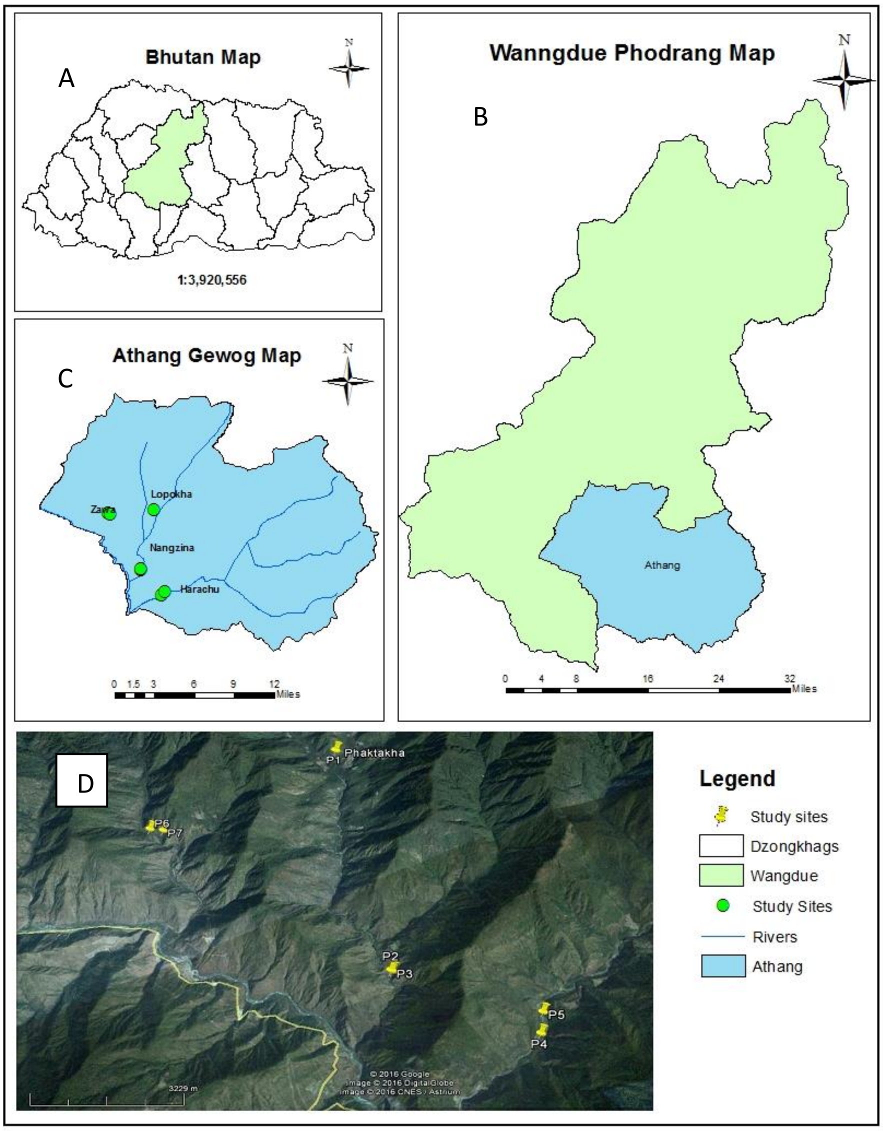


Figure 3.1. Location map of the study area: (A) Bhutan map showing the Dzongkhag map, (B) Dzongkhag map indicating the Gewog, (C) Gewog map indicating the study sites (D) Google earth showing study sites

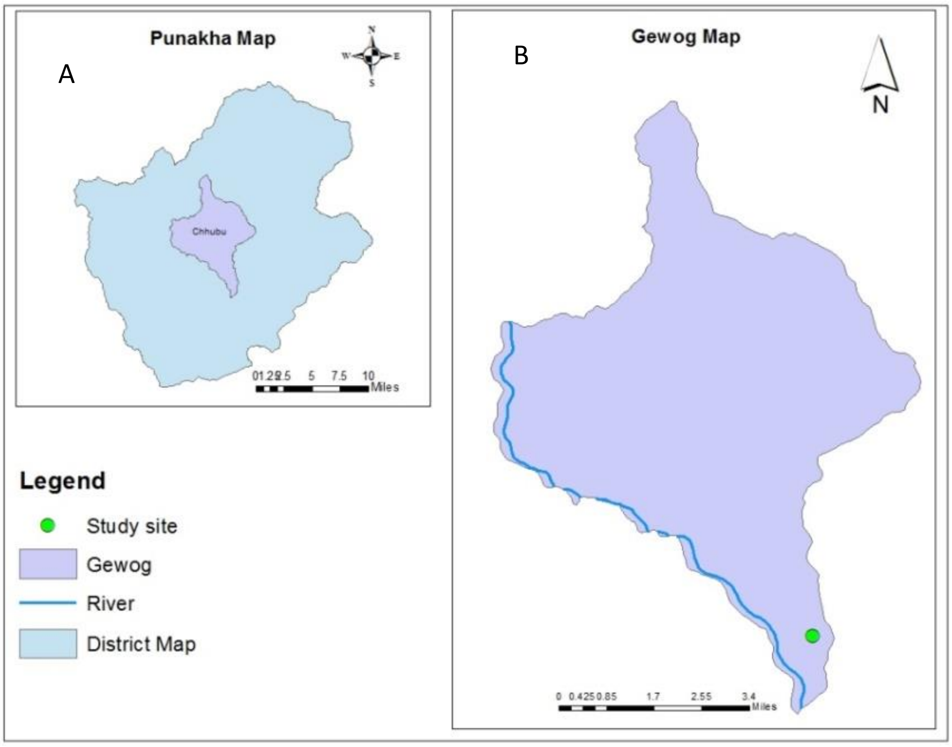


Figure 3.2. Location map of the study area: (A) Dzongkhag map indicating the Gewog, (B) Gewog map indicating the study site

3.2 Survey methods and sampling design

3.2.1 Vegetation survey

The field works were conducted from June 2016 to November 2016. A modified version of the Breeding Biology Research and Monitoring Database (BBIRD) protocol for vegetation measurement was used (Martin *et al.*, 1997). The plots were laid out in targeted nest trees of WBH with fire history. Four transects of 100 m each were established in four cardinal directions with the nest tree as a center point. North and south transects were established perpendicular to the slope and east and west transects were parallel to the slope. A total of 10 quadrats of 10 m X 10 m each were placed around the nest tree. Each quadrant has sub-quadrants of 5 m X 5 m and 1 m X 1 m. 3 quadrats each were placed alternately along the north and south running transects, with one quadrat placed at each end of transect and one at the mid-point separated at an interval of 35 m. Two quadrats, one at the mid-point and other at the end of transect away from the nest tree were placed alternately at the east and west aligned transects at interval of 35 m (Figure 3.3). Vegetation measurement was carried out on three different layers; tree, shrub and ground. All the tree species above 1.3 m in height were enumerated for height and diameter from 10 m X 10 m quadrat size. Heights of trees were used to determine the height class distribution and diameter at breast height (DBH) were used to determine the basal area and DBH distribution class. In 5 m X 5 m, all the shrub species were measured for its frequency and their average height to compute relative frequency. From 1 m X 1 m sub-quadrat, all the herbs were recorded for cover percent and tallest height of individual species to determine the coverage. The unidentified species in the field were developed into a herbarium specimen. A unique identification code was allotted for individual species to minimize the error later.

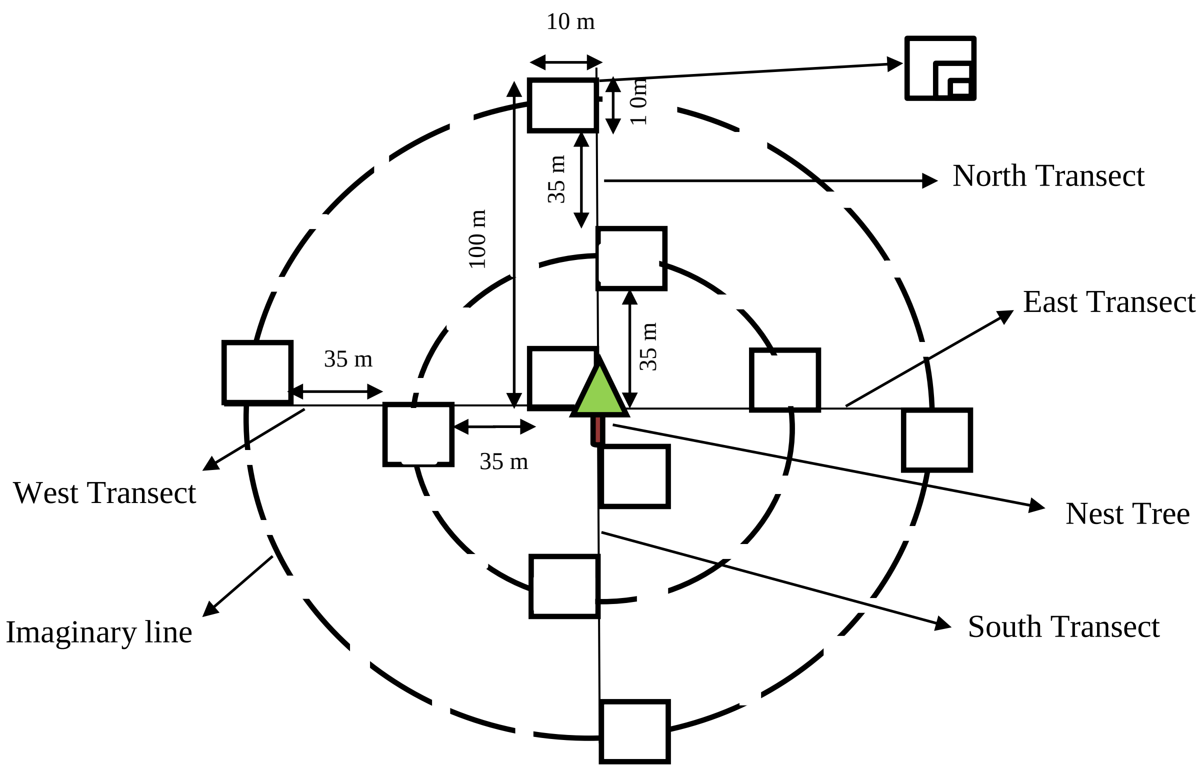


Figure 3.3. Plot layout around the nest tree

3.2.2 Social survey

Social survey was conducted within the study area to understand the views of local people on some of the parameters measured during the observational survey. It was also an opportunity to get their attitude towards the WBH and its nesting behaviour. The questionnaires used were semi-structured questionnaires with majority of it being closed-ended and only few were kept open-ended to get some specific information. All the households falling within the 500 m buffer from the nest trees were selected for an interview. In each household only one individual was selected for the interview. Census was carried out and a total of 67 respondents were interviewed from five study sites. However, few household members were not present during the time of interview.

3.2.3 Secondary data collection

The data on forest fires were gathered from the Fire Section, Social Forestry Division (SFD) under Ministry of Agriculture and Forests (MoAF) and Divisional Forest Office of Punakha and Wangdue Phodrang districts. The WBH nesting and nest use data was obtained from RSPN office.

3.2.4 Field Equipment

Global Positioning System (GPS), Sunto compass, clinometer, diameter tape, binocular, survey datasheets and Cannon digital camera were used during the data collection in the field. The field guide books such as "Flora of Bhutan" and "Know the plants of Bhutan" were used for plant identification.

3.3 Data analyzing

3.3.1 Vegetation data analyzing

Microsoft Office Excel was used for data compilation and sorting of raw data. Basal area was calculated from the DBH data of individual tree and Relative Basal Area (RBA%) was calculated for each species. The RBA of each species was considered as an abundance measure. Formulae used for computing were;

1. Basal Area $(BA) = \pi d^2/4$
2. Relative Basal Area [*RBA %*] = [*BA of individual species / Total BA of all the species*] ** 100*

Frequency of all the shrub species were used to calculate the relative frequency;

3. Relative Frequency (*RF %*) = [*Frequency of individual species / Total Frequency of all the species*] **100*

Tallest height (cm) and cover percent of each ground species was used to find cover volume (m^3), from it the relative density (RD %) for each species was calculated as thus;

4. Volume = Maximum Height (cm) X Cover percent (%)

Shannon-wiener formulae was adopted for computation of species diversity (*H'*) and richness (*S*), it is given by;

5. Diversity index $(H') = -\sum_{i=1}^{N} pi\ ln\, pi$

Where 'pi '= Fraction of the entire population made up of species

'i' = number of individuals of i^{th} species divided by total number of individuals of all species

'ln' = natural logarithm and Species Richness (N) = Total number of species.

For the statistical analysis the data were first checked for normality using Kolmogorov-Smirnov in SPSS. For analyzing the difference among sites in structural parameters of vegetation, one-way ANOVA and Krushal-Wallis tests were performed depending upon the nature of data. Spearman rho correlation test was also conducted to find the association of shrub species height and frequency to different sites. The outcomes of the statistical test in SPSS was reported by presenting the probability (P value) of being true at a significance level $\alpha = 0.05$.

3.3.2 Dominance analysis

For dominance analysis of the tree and shrub species a relative dominance of 100% was assigned to a species, if that species dominated the community. When two species share the dominance in that community, then the relative dominance were quantified as 50% for each species present and for three co-dominants species a relative dominance is 33.3% for individual species Ohsawa (1984). The dominance was calculated until the dominance species is generated. The deviation (d) is calculated by the following equation:

$$\text{Dominance} = d = \frac{1}{N}\{\sum_{jET} (x\text{-}\bar{x})^2 \sum_{jEU} x_j^2\}$$

N is total number of species. Where χ_i is the actual percent share (relative basal area is adopted) of the top species (T), i.e., in the top dominant in the one-dominant model, or the two top dominants in the two-dominant model and so on; χ' is the ideal percent share based on the model as mentioned above and χ_j is the percent share of the remaining species (U).

3.3.3 Nest and fire analysis

The sites were classified into three categories depending upon varying fire frequencies (number of fires) that has occurred over the last 10 years. Out of five study sites: one site had been burnt only once, three sites had been burnt two times and one site had suffered four times of fire (Table 3.1).

Table 3.1. Classification of study sites in relation to fire frequency

Name of location	Classes	Fire Frequency (no. of times)
Ada	Once Burnt	1
Tshekhathang Nangzina and Harachu	Twice Burnt	2
Zawa	Frequently Burnt	4

3.3.4 Survey questionnaire analysis

Questionnaires required for analyzing were assigned with distinct identity number. All questions and responses were coded accordingly. Data processed were summarized and compiled. Different graphs were produced to show the results.

CHAPTER FOUR

Results and Discussion

4.1 Nesting site description

Most of the nests of WBH were located on steep slopes or sometimes on other side of gigantic water bodies in the study areas. Habitats of only two nest trees were surveyed in Nangzina out of four nests as the remaining nests were located on steep cliffs making it extremely inaccessible to carry out the survey. Two nests each were surveyed from Harachu and Zawa and one each from Lopokha and Tshekhathang. Although Tshekhathang in Punakha district has two nesting sites, but since one site had no records of fire incidence in last one decade so it was excluded from the study. Nests were located on a gentle rolling slope of 20% to steep slope of 70% at an altitude ranges from 647 m.a.s.l to 1359 m.a.s.l. (Table 4.1).

Table 4.1. Description of WBH Nest Sites

Plot No	Altitude (m.a.s.l)	Coordinates		Slope %	Aspect	Remarks
		Latitude	Longitude			
Nest 1	1299	27˚17'58.4"	90˚06'18.1"	60	S	Active
Nest 2	1359	27˚36'13.9"	89˚52'01.6"	65	S	Abandoned
Nest 3	647	27˚14'03.0"	90˚05'20.2"	20	SW	Abandoned
Nest 4	663	27˚14'03.6"	90˚05'19.4"	25	SW	Abandoned
Nest 5	749	27˚12'20.4"	90˚06'51.7"	70	NE	Active
Nest 6	770	27˚12'36.9"	90˚07'03.9"	55	NW	Abandoned
Nest 7	997	27˚17'44.8"	90˚02'52.2"	25	NE	Abandoned
Nest 8	937	27˚17'40.4"	90˚03'03.0"	35	SW	Abandoned

4.2 Nest presence and active nest in different sites

In the past 10 years, twice burnt site has the maximum record of nest built (66.7%, n = 8) and active nest (78.6%, n = 11), while once burnt has total nests (16.7 %, n = 2) and active nests (14.3%, n = 2), and frequently burnt has total nests (16.7 %, n = 2) and active nest (7.1 %, n = 1). Twice burnt sites have approximately four times more of nest built compared to once and frequently burnt sites, with a marked difference in the number of nest success as well (Figure 4.1).

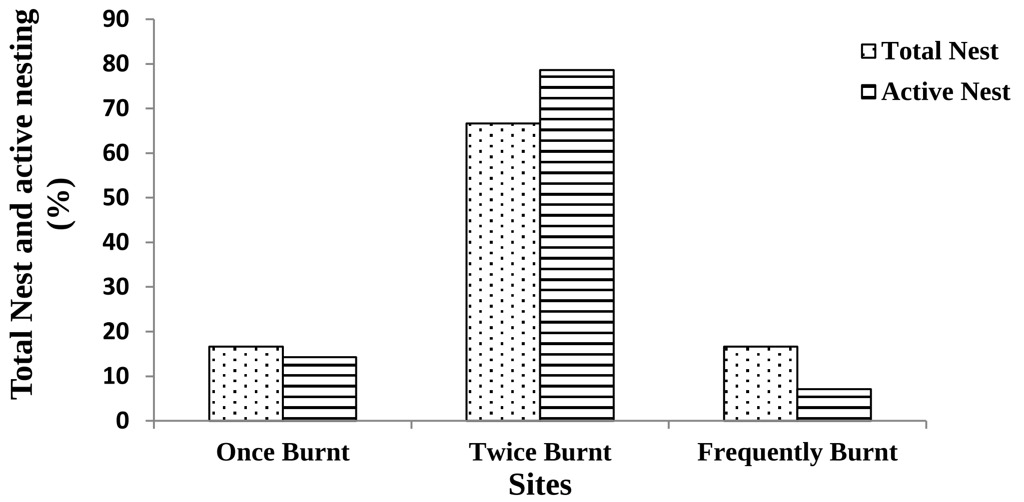


Figure 4.1. Showing total number of nests and active nests in last 10 years of WBH

4.3 Characteristics of the Nest tree of WBH

The mean height of nest trees of WBH were 27.5 m ± 6.8 and mean DBH of 65.4 cm ± 15.5 m. It was found that WBH prefer tall and live mature Chirpine trees as the nest substrate. Though, only few mature trees (DBH > 80 cm) were found in proximity to the nest trees. Most of the occasion lower branches were preferred for nesting with 1 to 3 supporting branches of mean diameter ranging from 4.5 to 11 cm. Nesting limbs were typically chosen based on limited to no concealment by branches above the nest position. Nest was built at the height of 15.4 m ± 5 m from the ground and distance of the nest from the main stem was 5.4 m ± 3.5 (Table 4.2). Nests were situated within a distance of 100 m from the edge of the water source and were solitary in nature.

Table 4.2. Nest tree characteristics

Nest Tree	Tree DBH (cm)	Tree Height (m)	Nest Height (m)	Distance of nest from stem (m)	Number of supporting branches	Mean diameter of supporting branches (m)	Total branches	Branch position*	Obscurity by branches
Nest 1	65	20	15	10	3	5	20	2nd	No
Nest 2	48.2	24	12	4.5	3	8.2	18	4th	No
Nest 3	47.2	25	8.5	3	3	7.7	15	5th	No
Nest 4	74	25	14	2	1	9	12	1st	No
Nest 5	53.5	27	17	10	2	6.5	9	5th	No
Nest 6	63.8	28	19	1	2	7.5	12	1st	No
Nest 7	88.1	28	12.5	5	2	11	17	7th	No
Nest 8	83.5	43	25	7.5	2	4.5	37	13th	No

4.4 Tree Species composition, life forms and dominance

The quantitative study of vegetation recorded a total of 20 families with 23 tree species. Trees were classified into five major life forms; conifer (1 species), evergreen (10 species), deciduous (10 species), palm (1 species) and semi-deciduous tree (1 species). Tree vegetation in the study sites were composed of 64.86 % conifer, 20.19 % evergreen, 10.79 % deciduous, 4.04 % palm and 0.12 % semi-deciduous (Figure 4.2). Overall, dominant analysis showed 2 dominant species (*Pinus roxburghii* and *Quercus lanata*) in the single burnt site and only 1 species (*Pinus roxburghii*) in twice and frequently burnt sites. Evergreen life form in twice burnt sites was approximately two times more than other sites. Whereas, frequently burnt site contains the major portion of deciduous life form compared to once and twice bunt sites. It also shows that tree dominance decreases with increase in fire frequency.

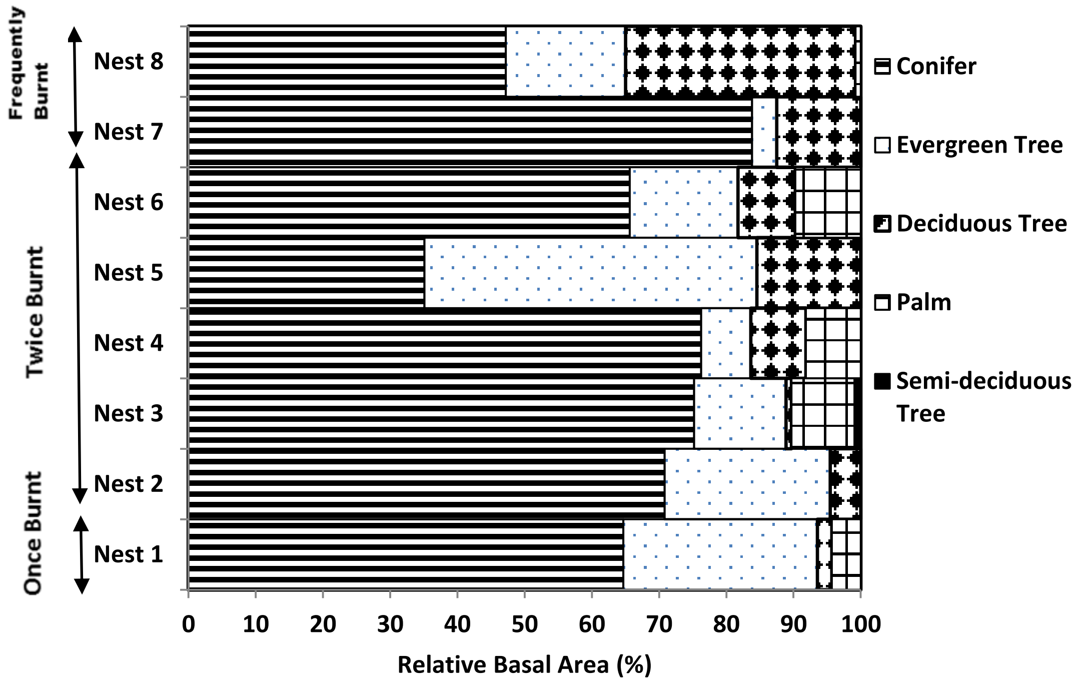


Figure 4.2. Showing the life forms of the tree layer

4.5 Shrub Layer composition, life forms and dominance

Shrub species comprised of 21 species from 15 families. It has four categories of life forms: deciduous shrub (14 species), evergreen (4 species), climbing shrubs (2 species) and woody shrubs (1 species). Two dominant species (*Indigofera dosua* and *Phyllanthus emblica*) were recorded from once burnt. *Woodfordia fructicosa* and *Rhus paniculata* were common dominant species in both the twice and frequently burnt sites. Addition to it, *Indigofera dosua* was observed dominating twice burnt and *Murraya koenigii* in the frequently burnt site. Once burnt was only dominated by deciduous species, whereas, twice and frequently burnt was dominated by both the deciduous and evergreen life forms (Figure 4.3).

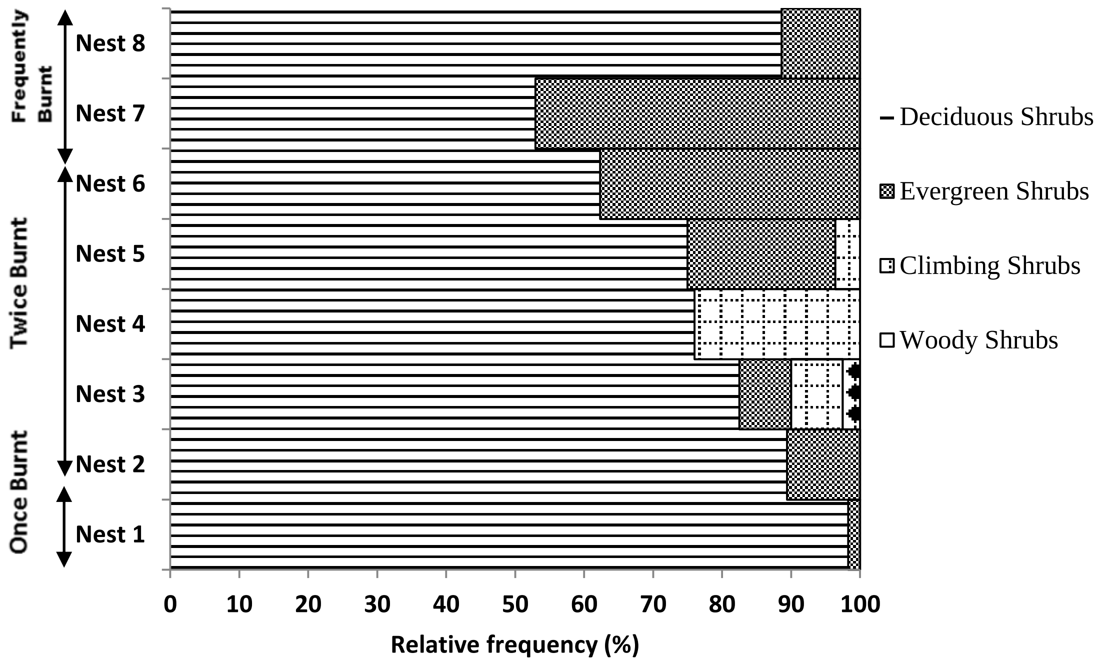


Figure 4.3. Showing the life forms of shrub layer

4.6 Ground Cover Composition, Life forms and dominance

Ground layer comprised of 12 families with 26 species. Out of that, 8 species were found to be grass, 6 species were annual herb, 4 species were perennial herb, 1 species of biennial herb, 4 fern species and 3 climber species (Figure 4.4). *Carex.* sp. showed dominance in all the three sites. Maximum number of ground vegetation dominance was recorded in frequently burnt site with species such as; Graminae (*Cynodon dactylon* and Grass sp.), Compositae (*Ageratina adenophora*) and Compositae (*Artemisia mariantha*) including *Carex* sp. This result shows the degree of fire frequency favouring the growth of diverse ground vegetation by making the environment more conducive, but once or twice fire frequency showed to limit the dominance. This could be that repeated fire ameliorates the environment for invasion by resistant species. Lyon (2000) supports the study as fire burning infrequently results in sparse fuel arrangements which lead to invasion by weedy species altering the vegetation; consequently burning was observed to be more frequent. Annual herbs life form was found maximum in the twice burnt and maximum of perennial was in the frequently burnt site. Yogi (1974) also found the fires encouraging the growth of native annuals and perennial plants. From 26 species, grass life form consisted of 62.03 %, 26.65 % were perennial herb, 8.04 % were annual herb, 2.05 % of climber, 1.18% fern and 0.05% were biennial herb.

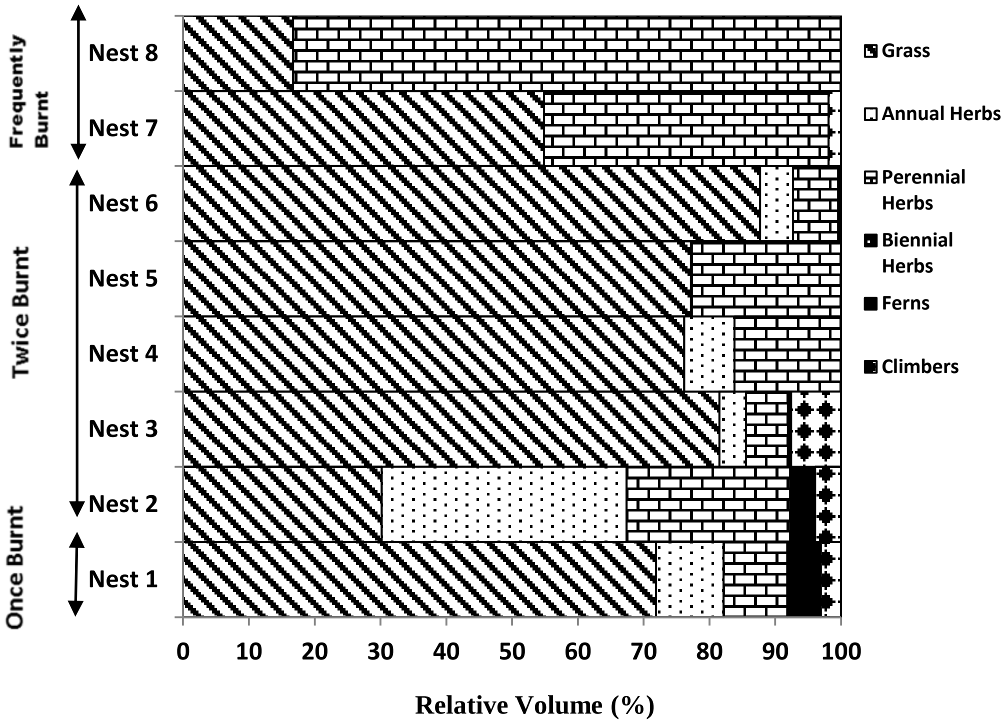


Figure 4.4. Showing the life forms of ground layer

4.7 Species diversity and richness

Shanon-Wiener diversity index (H') varies from 1.06 to 0.62 for trees and 0.86 to 2.05 for shrubs in different sites. Indices in the twice burnt site were higher compared to the single and frequently burnt sites. Species richness (S = 23) for trees species and (S = 18) for shrub species was also observed to be more in twice burnt than the other two sites (Table. 4.3). Yogi (1974) supports with similar findings, where an optimum number of fire times increases the species diversity. In contrast, Weaver (2010) concluded of species composition are sometimes also influenced by the environmental factors. However, the Krushal-Wallis test did not show any significant differences between tree and shrub diversity indices to the sites, $H(2) = 1.37$, $p > .05$ for trees, and $H(2) = 2.43$, $p > .05$ for shrubs. This indicates that there is no effect on nest-site selection by WBH in relation to tree and shrub diversity in the study sites.

Table 4.3. Indices for trees and shrubs species

Location	Tree Diversity Index (H')	Tree Species Richness (S)	Shrub Diversity Index (H')	Shrub Species Richness (S)
Once Burnt	1.07	6	0.86	4
Twice Burnt	1.61	23	2.14	18
Frequently Burnt	1.06	6	1.7	8

4.8 Forest structural traits of nesting habitat of WBH

4.8.1 Influence of tree Height on nest-site selection

The maximum height of Chir pine tree was 35 m recorded in once burnt site. It was followed by 30.5 m in the twice burnt site and 20 m in the frequently burnt site. The mean height of trees in once burnt was 10.37 m ± 2.41, 7.9 m ± 2.3 in twice burnt and 7.6 m ± 3.02 in frequently burnt site. Moreover, the ANOVA test revealed that there were significant differences in mean tree height among three different sites, $F(2, 71) = 5.08$, $p < .05$. RSPN (2011) describes WBH as a high canopy nesting bird which has a mean nest height of 15.34 m from the ground surface. So, it is apparent that short trees do not fulfill this particular requirement of the bird. Burhans and Thompson (2006) documented a positive interaction between nest height and nest survival. The taller trees occurring in once and twice burnt are the much preferred tree height for nesting by WBH. The result corresponds with the findings of RSPN (2011) and Dorji (2012), where the bird preferred tall and mature Chir pine trees of mean height 31.08 m ± 5.91 and 29.9 m ± 9.03 respectively for nesting. However, number of trees were maximum in the height class of 8 m in the twice burnt and frequently burnt sites, whereas, once burnt has maximum trees in height class of 12 m (Figure 4.5). Fires suppressing the height of trees were also recorded by Gandiwa (2011), where trees were comparatively recorded shorter in height due to the effect of burning.

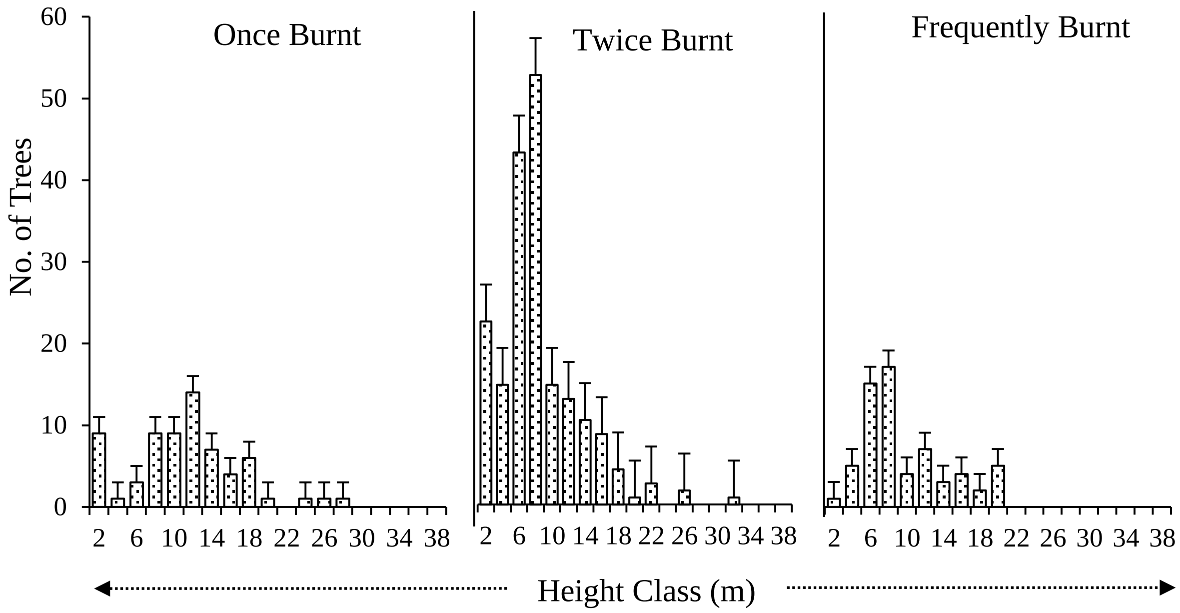


Figure 4.5. Height class distribution in different sites

4.8.2 Influence of tree diameter on nest-site selection

The maximum diameter of Chir pine tree was 79.4 cm noted in once burnt site, followed by 68.5 cm in twice burnt site and 45.9 cm in frequently burnt site. The mean DBH of trees were 17.97 cm ± 5.06 in once burnt, 18.01 cm ± 5.1 in twice burnt and 13.85 cm ± 5.34 in frequently burnt site. Krushal-Wallis test showed a statistically significant difference of mean DBH to different sites, $H(2) = 13.63$, $p < .05$. The once and twice burnt sites were found with larger diameter classes compared to frequently burnt sites that are preferred by WBH for nesting (Figure 4.6). It was found to be congruent with findings of RSPN (2011) and Dorji (2012), which showed that WBH preferred large Chir pine trees of diameter 66.76 cm ± 18.26 and 67.62 cm ± 25.22 respectively as a nest substrate. The results further substantiate the relationship between twice burnt sites of having Chir pine trees of specific diameter to maximum number of nests and active nesting of WBH in the study area. Fire is found to impact the lateral development of trees in the study sites. Kellas *et al.* (1987) also observed that diameter increment of tree decreased following more and severe fires.

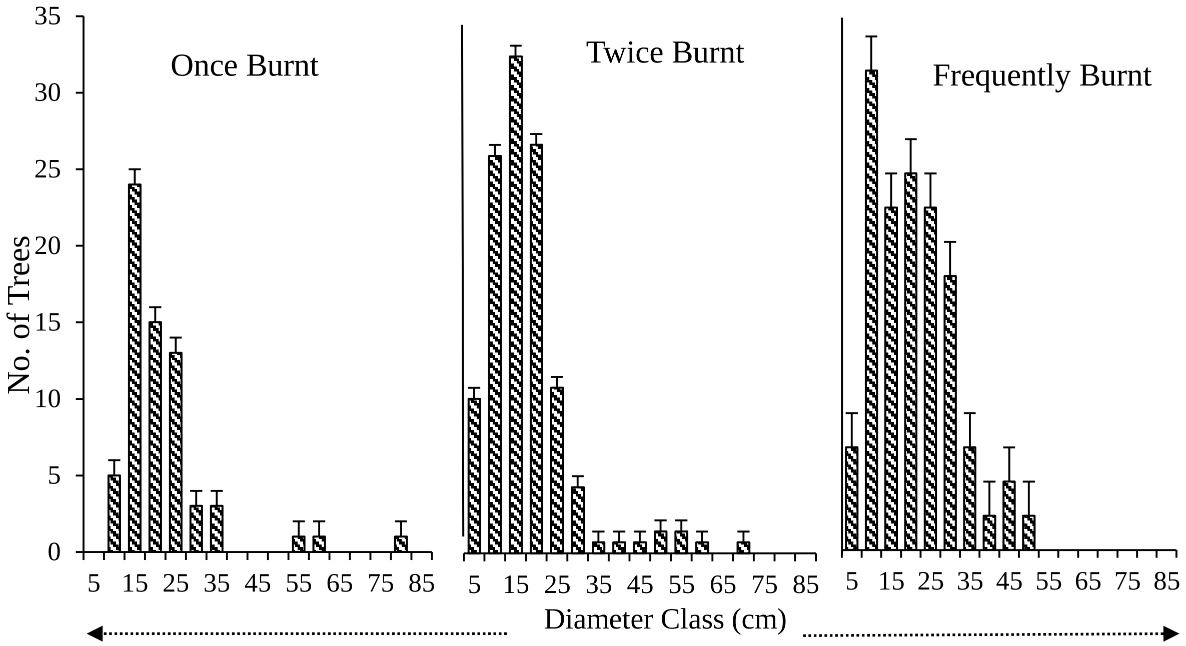


Figure 4.6. Diameter class distribution of trees in different sites

4.8.3 Influence of stem density and basal area on nest-site selection

Density of stems in once burnt site were 740 ha^{-1}, 441 ha^{-1} in twice burnt site and 388 ha^{-1} in frequently burnt site (plot wise stem density is shown in the Figure 4.7). This result shows that increase in fire frequency causes the stem density to reduce. Similar findings were recorded by Renwald (1978), that plots showing an average of 33.6 stem ha^{-1} were much preferred for nest-site selection by birds to plot average of 212.1 stem ha^{-1}. Site used for maximum nesting was found to be six times less in stem density than least used site. The outcomes of Michael *et al.,* (2007) also showed a negative impact of high fire frequency on the occurrence of larger trees, and significantly fewer woody species numbers were recorded at high fire frequency. Krushal-Wallis test on mean stem density revealed a significant difference on sites, $H(2) = 8.68$, $p < .05$. Similar result yielded in study by Lentile *et al.,* (2005), where more number of fire incidences decreased the basal area. Reduction in density of trees of all sizes leading to decreased total basal area and increased spacing of trees were observed due to frequent fires. But trees of larger size survived following repeated fires (Byrne *et al.,* 1991; Lewis, 1993). Purcell and Stephens (2005) studied of some bird species showing preference for open areas with low tree density, which was apparently due to the result of frequent and low-intensity fires. RSPN (2011) supports with similar findings where nest trees were located in a very open forest structure with limited mid-story or understory vegetation which is perceived to be due to the impact of fires. WBH is found to prefer reduced stem density but not severe reduction of stems caused due to repeated fires as to reduce the predation risk. Similar was described by Thogmartin and Schaeffer (2000) of birds preferring reduced woody stems as that aids in greater sight distance, thereby decreases risk of predators. WBH is also found to prefer nesting sites with moderately reduced stem density.

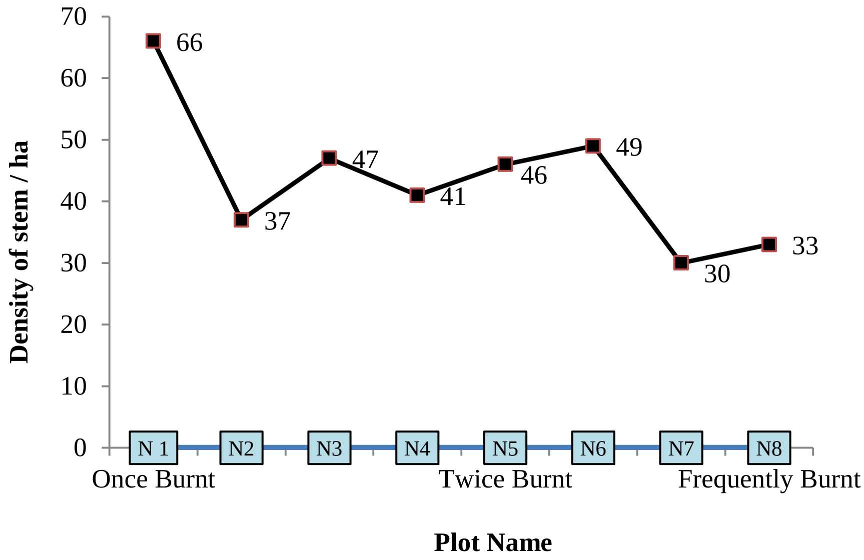


Figure 4.7. Stem density per plot in different sites

4.8.4 Influence of canopy cover on nest-site selection

The canopy cover was classified into four classes viz. < 20%, 20-45%, 45-65% and > 65% and reading was assigned based on visual estimate. The once burnt site showed mean cover 63.25 % ± 18.63, 45.15 % ± 24.35 in the twice burnt and 59.5 % ± 20.79 in the frequently burnt site. Least cover percent was observed in the twice burnt site compared to once and frequently burnt sites. Krushal Wallis test, H (2) = 11.44, $p < .05$, showed a significant difference among the sites of the canopy percent. Therefore, result indicates that bird prefers nest selection with less canopy cover. This result is in line with finding of RSPN (2011), in which this heron species was found to require very open canopy to fly without danger of any obstruction. Cerasoli and Penteriani (1996) suggested that tree nesting birds select trees based on their sizes and structural features such as tall and open canopy to offer unobstructed access to nest. Results also showed that WBH was found to prefer a canopy cover less than 20% (Figure 4.8). The cover of woody species was found to be generally greater in areas less frequently burnt (Waldrop *et al.*, 1992; Peterson, 1998). Although the increase in cover in frequently burnt over twice burnt could be due to other environmental factors. Wangda *et al.* (2006) deduced that structural parameter of vegetation are also influenced by environmental gradients, variations in rainfall, wind, humidity and light.

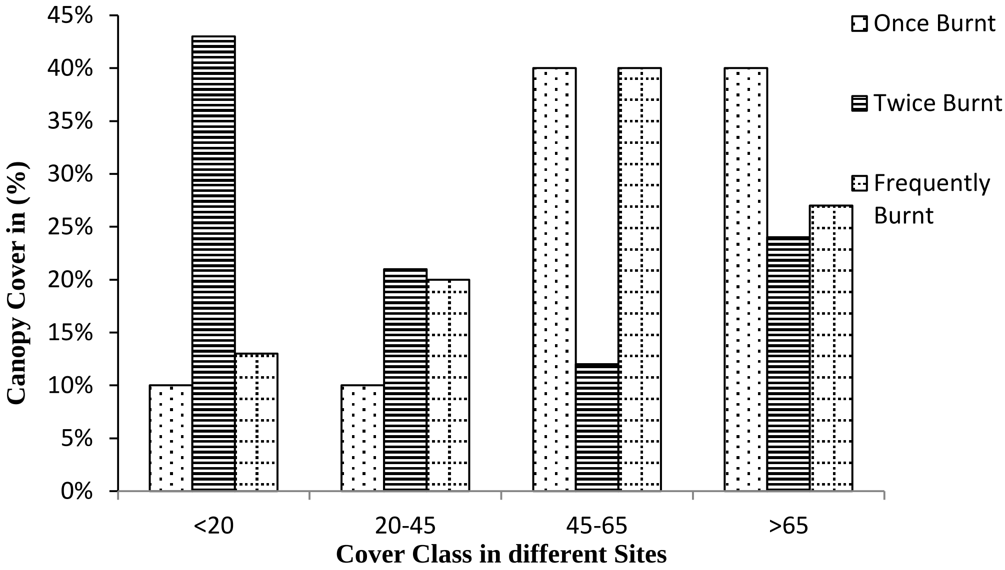


Figure 4.8. Canopy cover percent in different sites

4.8.5 Effects of shrub height and frequency on nest-site selection

The mean height of shrub was 3.73 m ± 1.82 recorded in once burnt site, 3.81 m ± 2.01 in twice burnt and followed by 4.14 m ± 2.19 in frequently burnt site. Spearman rho correlation, r (62) = .084, $p > .05$, showed insignificant association between shrub height and sites. The result shows that nest-site selection is least impacted by the height of the shrubs. However, a significant inverse correlation, r (62) = - 0.25, $p < .05$ was examined between the sites and the shrub frequency

Table 4.4. Correlation between sites and shrub height and frequency

	Site	Shrub height	Shrub frequency
Site	1	0.084	-.25*
Shrub height	72	1	.550**
Shrub frequency	72	72	1

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

The once burnt revealed the maximum shrub frequency of 44% followed by 31.1% in twice burnt and 24.9% in frequently burnt site. The increase in shrubs frequency was due to reduction in fire frequency (Figure 4.9). Anguyi (2010) also concluded that number of shrubs recorded decreased with fire frequency.

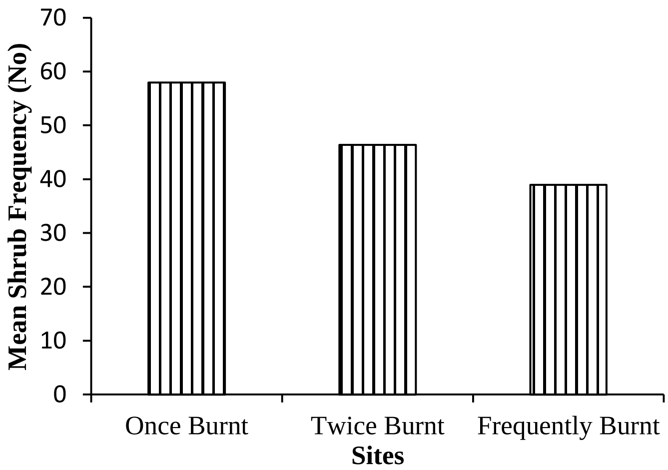
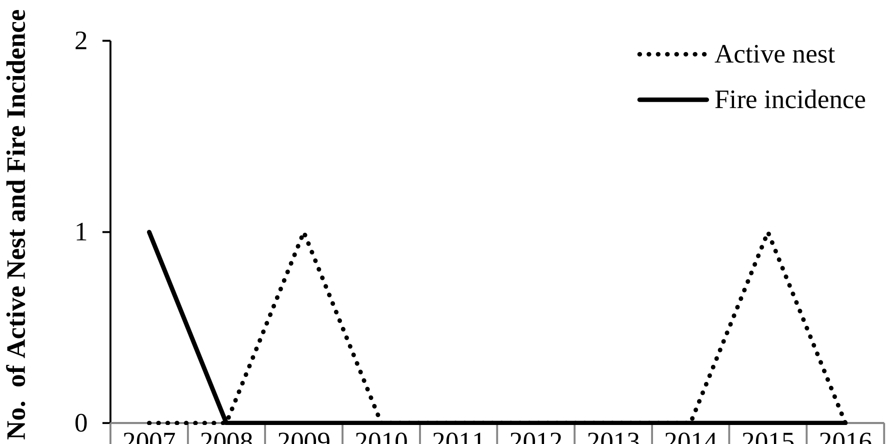


Figure 4.9. Shrub frequency in different sites

4.9 Trend of active nesting by WBH in response to fire incidence

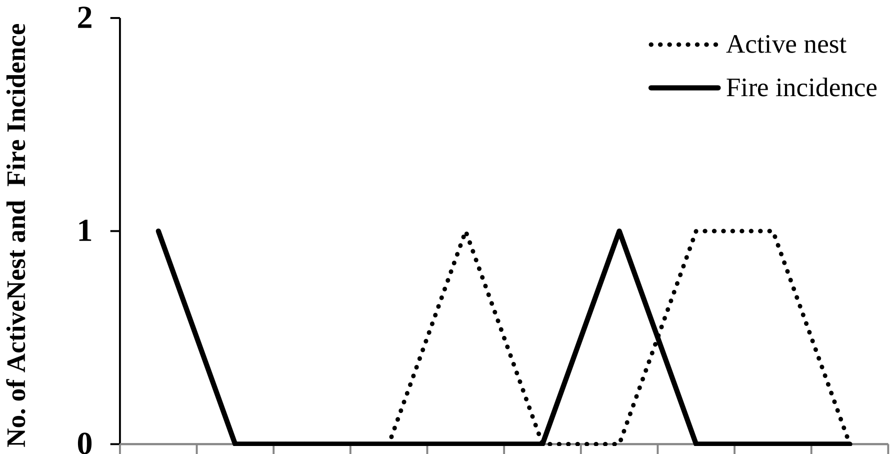
In 2007 there was a forest fire in the locality of Lopokha were nest is located. The nest was not used the following year after the fire. However, after one year of abandoning, the nest was reused in 2009. The nest was again abandoned for four years and it was reused in 2015 (Figure 4.10).



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Active nest	0	0	1	0	0	0	0	0	1	0
Fire incidence	1	0	0	0	0	0	0	0	0	0

Figure 4.10. Trend of active nest in once burnt (Lopokha)

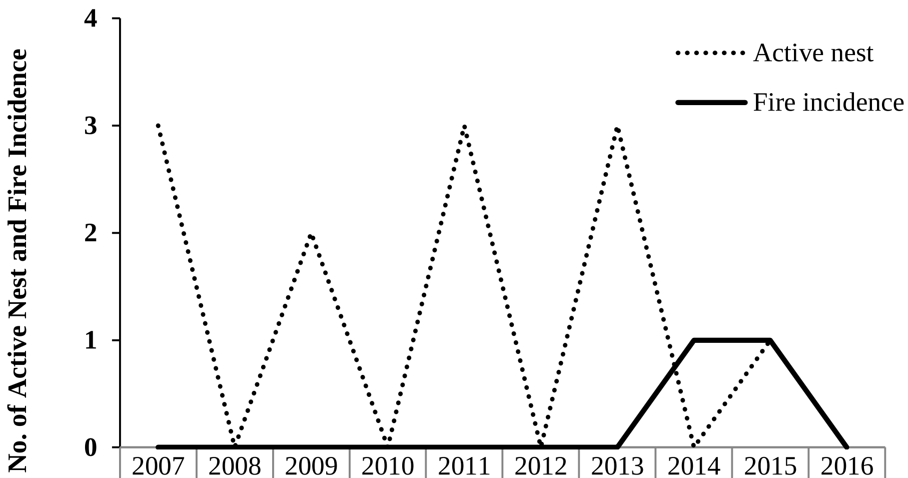
The nest used in Harachu seems constant in the last one decade even though fire occurred in 2007 during the nest use season and also in 2013 (Table 4.11). In the finding by RSPN (2011), however, mentioned that during the fire instance of 2007 at Harachu, the nest was nearly consumed by fire and was not used in the following years.



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Active nest	1	0	0	0	1	0	0	1	1	0
Fire incidence	1	0	0	0	0	0	1	0	0	0

Figure 4.11. Trend of active nest in twice burnt (Harachu)

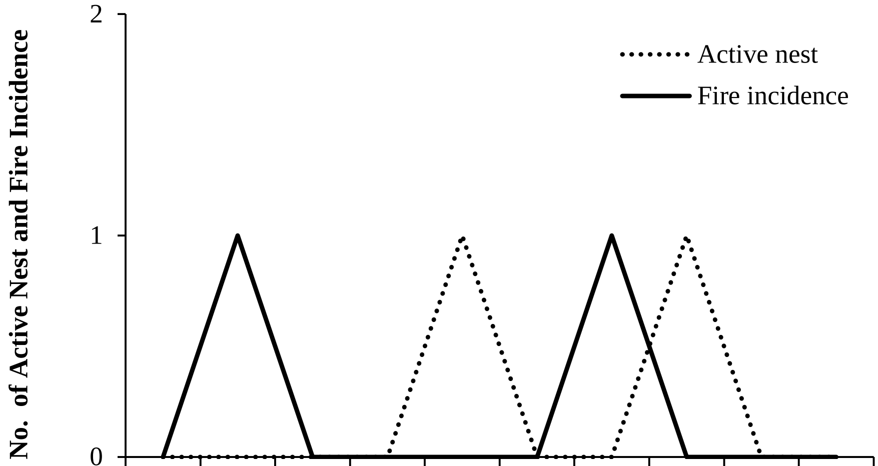
Active nests of 3,2,3,3 and 1 were recorded in 2007, 2009, 2011, 2013 and 2015 respectively at Nangzina. Nangzina has the maximum nest success in the last 10 years. There was fire for two consecutive years in 2014 and 2015 when the nest-use suddenly dropped to one (Figure 4.12).



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Active nest	3	0	2	0	3	0	3	0	1	0
Fire incidence	0	0	0	0	0	0	0	1	1	0

Figure 4.12. Trend of active nest in twice burnt (Nangzina)

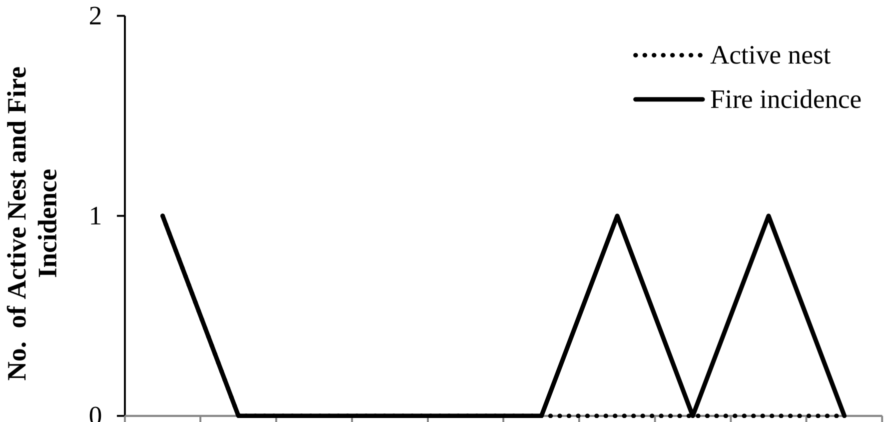
The nest use in Tshekhathang is same as that of Harachu, as the number of nest use does not fluctuate much with the fire incidence of 2008 and 2013 in the last one decade (Figure 14.13)



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Active nest	0	0	0	0	1	0	0	1	0	0
Fire incidence	0	1	0	0	0	0	1	0	0	0

Figure 4.13. Trend of active nest in twice burnt (Tshekhathang)

Different case was observed in Zawa where after the fire occurrence there was no sign of using the nest again leading to permanently abandonment (Figure 4.14). The study shows the impacts of fire to the nesting behaviour of WBH in this site.



	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Active nest	1	0	0	0	0	0	0	0	0	0
Fire incidence	1	0	0	0	0	0	1	0	1	0

Figure 4.14. Trend of active nest in frequently burnt (Zawa)

Only two cases were encountered in Bhutan where forest fire destroyed heron nests. One was in 2007 at Basochu, Wangdiphodrang. The location of where heron nest was present were found to be without fire for more than 10 years and fire was very severe as the fuel depth was approximately 30 cm high. Forest fires are usually found to be severe due to the exclusion of fires as it leads to accumulation of the fuel on the forest floor. Higher fuel depth accelerates the burn severity which causes mortality of the woody vegetation (personal communication with Madam Rebecca Pradhan, 2016). Great amount of fuel loads could have catalyzed the burning and have led to destruction of the nest. Lyon (2000) stressed on similar result of fire occurring at the interval greater than 10 years caused substantial changes in the forest structure and birds. Lyon (2000) also observed some birds preferring a moderate frequent understory fires. Since the study sites are known for experiencing fires, the fuel loads accumulation was noted to be narrow on the ground. There is not an event of nest damage reported due to forest fires in the study sites. This underscores the necessity of moderate fire frequency to maintain the vegetation in and around the nesting habitat of the WBH. Yet overlapping the fire incidence with the breeding and nesting seasons of the bird may however may be lethal to the birds. Fire may act as a source of abiotic stressor to the bird leading to abandonment of the nests permanently. However, nest abandonment should not be entirely attributed to influence of fire as to understand nesting pattern of this bird, the detail ecology of the bird should be known. During data collection a carcass of WBH was found on the river bank at an approximate distance of 200 m from the upstream nest tree at Harachu (Figure 14.15). The reasons for its mortality could not be ascertained due to absence of damage signs on the bird. On top the corpse was found almost disintegrated.

Figure 4.15. Carcass of WBH found at Harachu

4.10 Peoples Attitude towards WBH and its nest

Social survey showed that 83 % of the respondents were aware about the existence of nest in their vicinity. Out of 67 respondents, 43 were male and 24 were female. Within the last 10 years, 16 % of the respondent (n =11) felt that population of the heron in their locality has decreased, 47 % (n = 31) felt the increase in population and 37 % (n = 25) indicated that population is constant. This is in line with the findings of RSPN (2011), where nest count has increased over the years. An increase in nests count is found to be relative with increase in the population of bird over the years.

4.11 Disturbances in the Nesting habitat

Forest fire and predator together exhibited the highest intensity of threat factor in the nesting habitat of WBH (27%, n =18) followed by forest fire and hydropower (19%, n = 13), and fishing (13%, n = 9). Overall, the major disturbance in the nesting habitat was found to be forest fires (Figure 4.16). However, forest fire is not the sole determinant to be considered as a disturbance. The impacts of hydroelectric dam, predators and fishing activities were the collective disturbances happening along with forest fires.

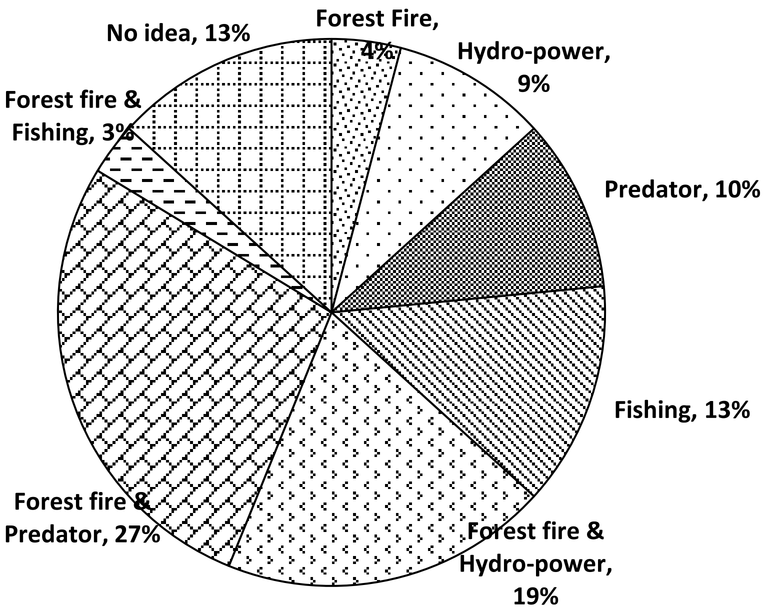
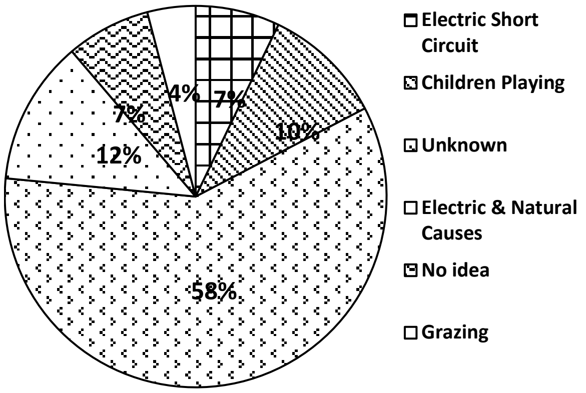


Figure 4.16. Disturbances in nesting habitat

In the study by Dorji (2012), it reports about fire as one of the factors that has a significant disturbance to the WBH. RSPN (2011) supports that, forest fires are a direct threat to heron nest unless an appropriate fire management are applied.

4.12 Causes of fire and local attitude to WBH

The result showed a thin margin about the basis or cause of fire incidences in the nesting habitats of WBH. Some responded that fire is of natural origin in their area, while others pointed that fire occurred mostly due to children setting up accidentally (10%, n = 7) or at times from electric short circuit (7%, n = 5). Major portion of the respondents did not have idea about it (58%, n = 39). This huge negligence on the part of the people could be due to the lack of social value attached to the bird (n =34). Still, a positive pointer is, some of the respondents see the bird as a source of community benefits (n = 15), aesthetic value (n = 7) and symbol of good omen (n = 5). So, it is yet another challenge to make local people come forward to work towards the conservation of the bird alongside with RSPN and other relevant line departments by providing reasonable incentives.



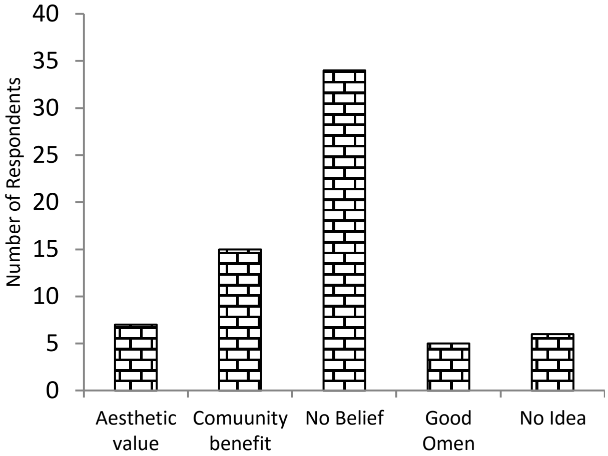
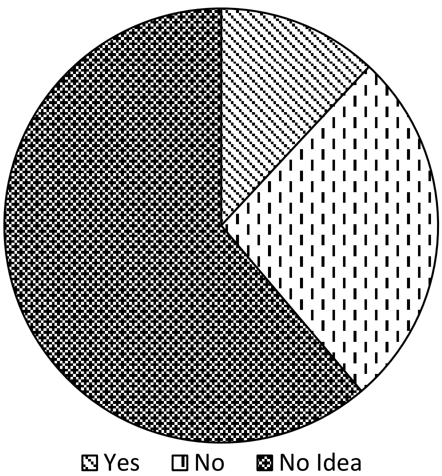


Figure 4.17. Causes of fires in nesting habitat **Figure 4.18.** People's attitude towards WBH

4.13 Nest Use after fire and Return Interval of WBH

Twelve percent (*n* = 8) of the respondents had seen the bird reusing the nest after the fire. While 27% (*n* = 18) responded that birds do not use and 61% (*n* = 41) were not aware. The reuse of nest could possibly be due to the vegetation getting reinstated after fire occurrence. Similar result was stated by Lyon (2000), birds escape during burning to avoid from injury, but some are found to return back to take the advantage of the altered habitat. Marks (1986) deliberated that nesting sites by birds are more probable to be reoccupied in following years with successful nesting attempts, while it abandoned after nest failures.



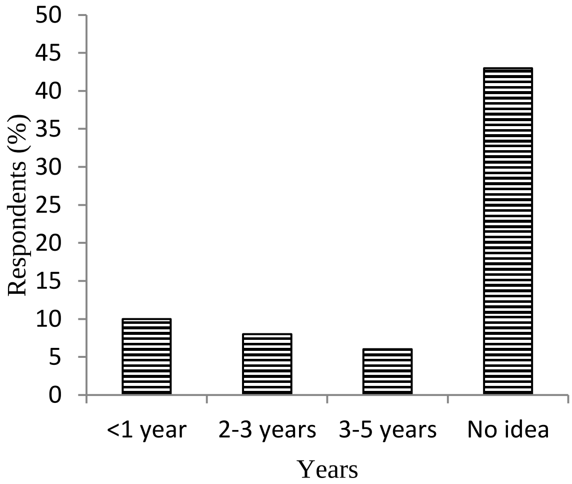


Figure 4.19. Nest use by WBH after fire **Figure 4.20.** Post-fire return interval of WBH

CHAPTER FIVE

Conclusion

On basis of the results of this research, it can be concluded that the vegetation structure and composition were altered as a result of different fire frequencies in the nesting habitat of WBH in Athang. The post-fire impacts on structural aspects such as; stem density, tree height, diameter and canopy covers were found to be the major attributes preferred by the bird for nest-site selection. It prefers tall and mature Chirpine trees as a nest substrate in an open forest with less canopy coverage.

As it is a critically endangered bird, fires should be strictly monitored in their nesting habitats, so as to assure that fire does not disturb its nest and nest-sites. Moderate fire frequency may not harm the nest and its substrate, however care should be taken to avoid fire occurrence during the breeding and nesting seasons of the bird. It is very important to protect mature Chirpine trees along the water bodies in their habitats from frequent fires. Also creating of fire breaks around the nest tree during nesting season would help to protect the bird and improve their nesting success.

The bird is also found to abandon the nest even in absence of fire. So, it is found crucial to have a large scale and long term research on fire regime inclusive of fire frequency, intensity, severity, season and extent, and other disturbances such as food resources availability and predators. So as to identify all the underlying mechanisms that influences the nest-site selection by WBH. This will help in creating more holistic guidelines that can be prescribed to protect the specific nesting habitat requirements of WBH.

Reference

Anguyi, A.G. (2010). *Effects of fire frequency on plant species diversity and composition in Queen Elizabeth National Park, Southwestern Uganda*. Dissertation, Makerere University, Uganda.

Barlow, J. & Peres, C.A. (2004). Ecological responses to el Niño-induced surface fires in central Brazilian Amazonia: management implications for flammable tropical forests. *Biological Sciences*. 359 (1443): 367-380.

BBSAP. (2014). *Bhutan Biodiversity Strategic Action Plan*. National Biodiversity Centre, Ministry of Agriculture, Royal Government of Bhutan. Thimphu: Bhutan.

BirdLife International. (2001). Species factsheet: *Ardea insignis*. <http://www.birdlife.org>. Accessed 15 November 2015.

BirdLife International. (2015). *Threatened birds of Asia: the BirdLife International Red Data Book*. BirdLife International. United Kingdom: Cambridge.

Block, W.M. & Brennan, L.A. (1993). The habitat concept in ornithology: Theory and applications. *Current Ornithology.* 11: 35-91.

Brawn, J.D., Robinson, S.K. & Thompson, F.R. (2001).The role of disturbance in the ecology and conservation of birds. *Annul Ecology System.* 32: 51-76.

Brooker, M.G. & Rowley, I. (1991). Impact of wildfire on the nesting behaviour of birds in Heathland. *Wildlife Research.* 18: 249-263.

Burhans, D.E. & Thompson III, F.R. (2006). Songbird abundance and parasitism differ between urban and rural shrublands. *Ecological Applications.* 16: 394-405.

Butchart, S.H., Walpole, M., Collen, B., Van, S.A., Scharlemann, J.P., Almond, R.E. & Carpenter, K.E. (2010). Global biodiversity: indicators of recent declines. *Science*. 328 (5982): 1164-1168.

Byrne, R., Edlund, E. & Mensing, S. (1991). Holocene changes in the distribution and abundance of oaks in California. *Proceedings of the symposium for oak woodlands and hardwood rangeland management. General Technical Report.* 182-188.

Cerasoli, M. & Penteriani, V. (1996). Nest-site and aerial point selection by common buzzards (*Buteo buteo*) in Central Italy. *Raptor Res*. 30: 130-13.

Cody, M.L. (1985). *Habitat Selection in Birds.* Orlando: Academic Press.

Darabant, A., Rai, P.B. & Dorji. (2012). *Fire as a land management tool in Chir Pine forests with Lemon Grass understory.* Department of Livestock, Ministry of Agriculture and Forests, RNR-RDC, Jakar.

Dorji, J. (2012). *Protecting White-Bellied Heron habitat: extent of anthropogenic threats and people's attitude towards their conservation in Bhutan along Punatshangchu and Mangdechu basins*. Dissertation, Royal University of Bhutan, College of Natural Resources, Lobesa, Punakha.

Frost, P.G.H. & Robertson, F. (1987). Fire- The ecological effects of fire in savannas. *IUBS MONOGR. SER. ecology*.4 (2): 46-6.

Gandiwa, E. (2011). Effects of repeated burning on woody vegetation structure and composition in a semi-arid southern African savanna. *International Journal of Environmental Sciences*. 2 (2): 458- 471.

Gupta, B., Mehta, R. & Mishra, V.K. (2009). Fire ecology of ground vegetation in *Pinus roxburghii* sargent plantations in north-west Himalaya - floristic composition and species diversity. *Caspian Journal of Environmental Sciences.* 7 (2): 71-78.

Hancock, J. & Kushlan, J.A. (1984). *The heron's handbook.* New York: Croom Helm.

Hockin, D., Ounsted, M., Gorman, D.H., Keller, V. & Barker, M.A. (2008). Examination of the effects of disturbance on birds with reference to its importance in ecological assessments. *Journal of Environmental Management.* 36 (4): 253-286.

Keane, R.E., Arno, S.F. & Brown, J.K. (1990). Simulating cumulative fire effects in ponderosa pine/ Douglas-fir forests. *Ecology.* 71: 189-203.

Kellas, T.D., Edgar, J.G. & Squire, R.O. (1987). Response of messmate stringy bark regrowth to release in irregular stands of mixed eucalypts. 50: 253-259.

Kenny, B., Sutherland, E., Tasker, E. & Bradstock, R. (2004). *Guidelines for Ecologically Sustainable Fire Management.* Australia: Hurstville press.

Koskimies, P. (1989). Birds as a tool in environmental monitoring. *Annual Zoology Fennici.* 26: 153-166.

Kotliar, N. B., Hejl, S. J., Hutto, R.L., Saab, V.A., Melcher, C.P. & McFadzen, M.E. (2002). *Effects of fire and post-fire salvage logging on avian communities in conifer-dominated forests of the western United States.* USDA press.

Krishna, C.M., Ray, P.C., Sarma, K. & Kumar, A. (2012). Conservation of White-bellied Heron *Ardea insignis* (Hume, 1878) habitat in Namdapha National Park, Arunachal Pradesh, India. *Correspondence Current Science.* 102 (8).

Kushlan, J.A. & Hafner, H. (2000). *Heron Conservation.* London: U.K. Academic Press.

Ladrach, W. (2009). The effects of fire in agriculture and forest ecosystems. *ISTF News*. USA: Grosvenor Lane Bethesda.

Lance, B. M., Winder, V. L., Pitman, J. C. & Sandercock, B. K. (2015). Alternative rangeland management strategies and the nesting ecology of greater prairie-chickens. *Rangeland Ecology & Management*. 68: 298-304.

Lewis, H.T. (1993). *Patterns of Indian burning in California: ecology and ethno-history***.** In Before the wilderness: environmental management by native Californians. eds. T. C. Blackburn & K. Anderson, pp. 55-116. Menlo Park: Ballena Press.

Lyon, L.J., Huff, M.H., Hooper, R.G., Telfer, E.S., Schreiner, D.S. & Smith, J.K. (2000). *Wildland fire in ecosystems: effects of fire on fauna*. USDA Forest Service: JFSP.

Marks, J.S. (1986). Nest-site characteristics and reproductive success of long-eared owls in southwestern Idaho. *Wilson Bull.* 98: 547-560.

Martin, T.E., Paine, C., Conway, C.J., Hochachka W.M., Allen, P. & Jenkins, W. (1997). *The Breeding Biology Research and Monitoring Database (BBIRD) - Field Protocol.* Missoula: Montana.

Marx, D.E., Hejl, S.J. & Hering, J. (2008). Wintering grassland bird habitat selection following summer prescribed fire in a Texaz Gulf coast tall grass pairie. *Fire ecology*. 4 (2): 46-62.

Michael, H., Jan, S., Budzanani, T. & Michael, M.H. (2007). The relevance of fire frequency for the floodplain vegetation of the Okavango Delta, Botswana. *African Journal of Ecology.* 46: 350-358.

Nath, L. & Shamlai. (n.d). New Horizon rescues the Critically Endangered avian species White bellied Heron (*Ardea insignis*) from Koilamoila. *New Horizon.* 24 (2).

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

Olmstead, M. (2014). Nesting Ecology of White-throated Sparrows (*Zonotrichia albicollis*): The Effects of Variation in Clutch-initiation Date and the Application of Prescribed Fire on Nesting Success. *Ecological journal.* 22 (1).

Owusu, E. H. (2008). The perceptions of local communities towards the conservation of birds in an important bird area in Ghana. *West African Journal of Applied Ecology*. 13 (1): 111-116.

Perry, J.J., Kutt, A.S., Garnett S.T., Crowley G.M., Vanderduys, E.P. & Perkins. (2011). The relative effects of fire, vegetation type and climate. *The Emu.* (111): 120–131.

Peterson, D.W. (1998). *Fire effects on oak savanna and wood- land vegetation in Minnesota*. Dissertation. University of Minnesota. USA: Saint Paul.

Ponce-Calderon, L.P, Rodriguez-Trejo, D.A., Aguilar-Valdez, B.C. & Lopez-Perezysis, E. (2013). *Forest fire impact on bird habitat in a mixed oak-pine forest in Puebla, Mexico.* Albany: USDA Forest Service.

Purcell, K.L. & Stephens, S.L. (2005). Natural and anthropogenic fire regimes, vegetation effects, and potential impacts on the avifauna of California oak woodlands**.** *USDA Forest Service General Technical Report.* 191.

Renwald, J.D. (1978). The effects of fire on woody plant selection by nesting nongame birds. *Journal of rangeland management*. 27 (8): 468.

Royal Society for Protection of Nature. (2011). *The critically endangered White-bellied Heron.* Thimphu, Bhutan.

Royal Society Protection of Nature. (2015). <http://www.rspnbhutan.org>. Accessed on 20 February 2016.

Saab, V.A, Kotliar, N.B. & William, M. (2005). Relationships of fire ecology and avian communities in North America. *USDA Forest Service General Technical Report.* 191.

Saab, V.A. & Vierling, K.T. (2001). Reproductive success of Lewis's Woodpecker in burned pine and cottonwood riparian forests. *The Condor*.103: 491–501.

Saab, V.A., William, B., Robin, R., John, L., Lisa, B. & Rachel, W. (2007). Birds and burns of the interior west: descriptions, habitats, and management in western forests. *General Technical Report.* 712 (23).

Silk, J.W.F. & Balen, S.V. (2006). *Bird community changes in response to single and repeated Fires.* Alcoy press.

Skagen, S.K., Melcher, C.P. & Muths, E. (2001). The interplay of habitat change, human disturbance and species interactions in a waterbird colony. *The American Midland Naturalist.* 145 (1): 18-28.

Stephens, J.L. (2015). Fire severity affects mixed broadleaf-conifer forest bird. *The Condor.* 27: 430-446.

Thogmartin, W.E. & Schaeffer, B.A. (2000). Landscape attributes associated with mortality events of wild turkeys in Arkansas. *Wildlife Society Bulletin.* 28 (4): 865-874.

Vierling, K., & Lentile, L. (2008). Indirect effects of fire severity on avian communities in ponderosa pine and aspen forests in western North America: *A review. Fire Ecology Special Issue*. 4: 133-149.

Vogl, R.J. (1974). *Effects of fire on grasslands.* In Fire and ecosystem, eds. T.T. Kozlowski & C.E. Ahlgren, 1st edn., pp.139- 194. New York: Academic Press.

Waldrop, T.A., White, D.L. & Jones, S.M. (1992). Fire regimes for pine-grassland communities in the southeastern United States. *Ecology Management.* 47: 195-210.

Wangda, P. (2003). *Forest zonation along the complex altitudinal gradients in a dry valley of Punatsangchu, Bhutan*. Masters, The University of Tokyo, Japan.

Wangdi, T. (2014). *Landuse change effect on habitat and White-bellied Heron population by hydropower project along Punatshangchhu*. Dissertation, Royal University of Bhutan, College of Natural. Lobesa, Punakha.

Warren, K.A. & Anderson, J.T. (2005). Grassland songbird nest-site selection and response to mowing in West Virginia. *Wildlife Society Bulletin.* 33 (1): 285-292.

Watts, B.D. (1989). Nest-Site Characteristics of Yellow-Crowned Night-Herons in Virginia. *The Condor*. 91 (4): 979–983.

Whelan, R.J. (1995). *The ecology of fire*. United Kingdom: Cambridge University of Press.

Woinarski, J. C. Z. & Recher, H. F. (1997). Impact and response: a review of the effects of fire on the Australian avifauna. *Pacific Conservation Biology*. 3 (3): 183-205.

Appendix I - Household Survey Questionnaires

General Information

Name of respondent : ☐ Date: ☐

Age : ☐ Gender: ☐

Village : ☐ Gewog: ☐

Dzongkhag : ☐

Relation to Household head:

Household head ☐ Wife ☐ Daughter ☐ Son ☐ Others ☐

Occupation of respondent (tick)

Farmer ☐ Govt. servant/private ☐ Monk ☐ Student ☐

Business ☐ Armed Forces ☐ Others
(Specify)…………………………….

PART- I

1. Do you see the White-bellied Heron around your locality now? (Tick √)

Yes ☐ No ☐ Previously ☐

2. If previously, since when did you stop sighting the bird?

1-3 years ☐ 4-6 years ☐ 7-9 years ☐ 10 years above ☐

3. When was the bird first sighted in your locality?
1-3 ☐ 3-5 years ☐ 5-9 years ☐ 10 years above ☐

4. What do you think about the population trend of WBH in your locality for last 10 years?
Increasing ☐ Decreasing ☐ Same ☐ No idea ☐

5. Has the WBH population increased or decreased over the last decade?
If increased, by how much?
………………………………………………………………………………………………
If decreased, by how much?
………………………………………………………………………………………………..

6. Do you see nesting site of WBH in your area?
Yes ☐ No ☐

7. If yes (Q-7), how many nests have you seen?
1 ☐ 2 ☐ 3 ☐ 4 ☐

8. In which year was the nest first seen?
…………………………………………………………………………………………………

9. Is the nest still used or abandoned?
Active ☐ Abandoned ☐

10. If abandoned, in which year was it abandoned?
…………………………………………………………………………………….............

11. Do you know that WBH is a Critically Endangered bird in the world?
Yes ☐ No ☐

PART- II

1. What are the disturbances or threats in the habitat of WBH in your locality?
Forest fire ☐ Hydro-power ☐ Predator ☐ Fishing ☐
Others (specify)……………………………..

Proceed to next question only if the disturbance or threat is FOREST FIRE

2. How often do the fires occur in their habitat?
Once in every 5years ☐ Twice in every 5 years ☐ Once in 10 years ☐
Other (Specify) ………………………..

3. What are the causes of fire?
Burning Agriculture debris ☐ Electric short circuit ☐ Children playing ☐
Construction worker ☐ Others (Specify)……………………………………

PART- III

1. What was the population status of WBH after fire incident?
Increasing ☐ Decreasing ☐ Same ☐ No idea ☐

2. Does WBH abandon their nesting habitat following the fire occurrence?
Yes ☐ No ☐ No Idea ☐

3. If yes (Q-2), where do they move to after fire in their habitat?
…...……………………………………………………………………………………

4. Do you see any WBH returning back to previous nesting habitat area after the fire disturbed area is reinstated with vegetation ?
Yes ☐ No ☐ No Idea ☐

5. If yes (Q-4), how many years do they take to return back to their nesting habitat?
1-2 years ☐ 3-5 years ☐ 5 years above ☐

Thank You

Appendix II - Tree Data format

Plot No.:

Quadrat No.: Transect no. :

Coordinates :- Northing : . Location :

Easting : Altitude :

Slope % : Aspect :

Forest Type :

Trees					
Sl. No.	**Species Name**	**Height (m)**	**DBH (cm)**	**% cover**	**Remarks**

Appendix III - Shrub data format

Plot No:
Quadrat No.:
Coordinates :-Northing :
Easting :
Slope % :
Forest Type :

Location :
Altitude :
Aspect :

Shrubs				
Sl. No.	**Species Name**	**Height (m)**	**Frequency (Nos.)**	**Remarks**

Appendix IV - Ground data format

Plot No:
Quadrat No.:

Coordinates :-Northing :
Easting :
Slope % :
Forest Type :
Location :
Altitude :
Aspect :

Sl. No.	Species Name	Height (m)	% cover	Frequency (Nos.)	Remarks

Appendix V - Nest Data format

Location:							**Date:**					
Nest No / Plot No.:							**GPS :**		**Way point Name:**			
Wheather Condition:									**Latitude:**			
Slope %:									**Longitude:**			
Elevation:							**Aspect:**					
							Temperature :					
Tree Information												
Nest Tree	Nesting Height of	DBH (cm)	Canopy Inclinatio	Top broken		Total Branches	Branch Position	Health*				
				Yes	NO			L	MA	MA	D	
			N= S = E= W= Uniform = CR=									
Note: * **L=Live, MA=Mostly Alive, MD=Mostly Dead, D=Dead**												

Nest Information

Distance of nest	Distance of nest to the foilage edge	No. of supportin	Diamter of	Obscure d by	Orientation	Distance between the Nest Trees (m)

Appendix VI - Tree vegetation composition

Species Name	Family	Acronym	Lifeform	N1	N2	N3	N4	N5	N6	N7	N8
				Once Burnt	Twice Burnt					Frequently Burnt	
Relative Basal Area (%)				**RBA**	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**	**RBA**
Conifer											
Pinus roxburghii	Pinaceae	CT	Conifer	64.69	70.84	75.23	76.27	35.11	65.65	83.83	47.22
Sub-Total				**64.69**	**70.84**	**75.23**	**76.27**	**35.11**	**65.65**	**83.83**	**47.22**
Evergreen Tree											
Quercus lanata	Fagaceae	ET	Evergreen Tree	15.01	20.60	1.78	1.68				
Schima wallichi	Theaceae	ET	Evergreen Tree	13.87							
Aesandra butyracea	Sapotaceae	ET	Evergreen Tree		2.08	4.30					
Quercus glauca	Fagaceae	ET	Evergreen Tree		1.93	4.73	1.66			3.69	
Mallotus philippensis	Euphorbiaceae	ET	Evergreen Tree			1.87					
Celtis tetendra	Cannabaceae	ET	Evergreen Tree			0.97					
Wrightia coccinea	Apocynaceae	ET	Evergreen Tree				4.02	14.43	8.58		
Pterospermum acerifolium	Sterculiaceae	ET	Evergreen Tree					17.98			
Daubanga grandiflora	Lythraceae	ET	Evergreen Tree					9.76			
Boehmeria rugulosa	Urticaceae	ET	Evergreen Tree					7.26	7.50		
Sub-Total				**28.89**	**24.61**	**13.66**	**7.36**	**49.43**	**16.08**	**3.69**	
Deciduous Tree											
Lyonia ovalifolia	Ericaceae	DT	Deciduous Tree	1.77	1.23						
Bridelia retusa	Phyllanthaceae	DT	Deciduous Tree	0.34		0.18	5.63	0.58	0.21	5.83	26.49
Quercus griffithii	Fagaceae	DT	Deciduous Tree		3.31					6.65	7.73
Casearia graveolens	Salicaceae	DT	Deciduous Tree			0.56	0.54				
Albizia lebbeck	Fabaceae	DT	Deciduous Tree			0.07	0.03				
Terminalia chebula	Combretaceae	DT	Deciduous Tree				2.01				17.79
Grewia eriocarpa	Tiliaceae	DT	Deciduous Tree					8.95	8.15		
Engelhardia spicata	Juglandaceae	DT	Deciduous Tree					3.37			
Bombax ceiba	Malvaceae	DT	Deciduous Tree					1.66			
Sterculia villosa	Malvaceae	DT	Deciduous Tree					0.90	0.16		
Sub-Total				**2.10**	**4.55**	**0.81**	**8.21**	**15.45**	**8.52**	**12.48**	**52.02**
Palm											
Phoenix loureiroi	Arecaceae	P	Palm	4.32		9.38	8.15		9.75		0.77
Sub-Total				**4.32**		**9.38**	**8.15**		**9.75**		**0.77**
Semi-deciduous Tree											
Heynea trijuga	Meliaceae	SDT	Semi-deciduous Tree			0.92					
Sub-Total						**0.92**					
Grand Total				**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(The shaded portion of the relative basal area represents the dominant & co-dominant species)

Appendix VII - Shrub vegetation composition

Species Name	Family	Acronym	Lifeform	Nest 1	Nest 2	Nest 3	Nest 4	Nest 5	Nest 6	Nest 7	Nest 8
				Once Burnt	Twice Burnt					Frequently Burnt	
Relative Frequency (%)				**RF**	**RF**	**RF**	**RF**	**RF**	**RF**	**RF**	**RF**
Deciduous Shrub											
Indigofera dosua	Leguminosae	DS	Deciduous Shrub	68.97	48.48	25.00	36.00	14.29	28.99	8.82	
Phyllanthus emblica	Phyllanthaceae	DS	Deciduous Shrub	20.69	18.18	7.50	4.00	7.14		8.82	9.09
Rhus paniculata	Anacardiaceae	DS	Deciduous Shrub	8.62	4.55	2.50	36.00	32.14	23.19	23.53	31.82
Rhus chinensis	Anacardiaceae	DS	Deciduous Shrub		10.61			17.86			
Desmodium elegans	Leguminosae	DS	Deciduous Shrub		6.06	7.50					4.55
Desmodium sp.	Leguminosae	DS	Deciduous Shrub		1.52						
Lonicera macrantha	Caprifoliaceae	DS	Deciduous Shrub			22.50					
Holarrhena pubescens	Apocynaceae	DS	Deciduous Shrub			7.50					
Cryopteris bicolor	Lamiaceae	DS	Deciduous Shrub			5.00					
Wendlandia pendula	Rubiaceae	DS	Deciduous Shrub			5.00					
Desmodium confertum	Leguminosae	DS	Deciduous Shrub						10.14	8.82	
Indegofera heterantha	Fabaceae	DS	Deciduous Shrub							2.94	
Murraya koenigii	Rutaceae	DS	Deciduous Shrub					3.57			38.64
Indigofera heterantha	Fabaceae	DS	Deciduous Shrub								4.55
Sub-total				**98.28**	**89.39**	**82.50**	**76.00**	**75.00**	**62.32**	**52.94**	**88.64**
Evergreen Shrub											
Ficus sp.	Moraceae	ES	Evergreen Shrub	1.72							
Berberis asiatica	Berberideceae	ES	Evergreen Shrub		10.61						
Woodfordia fructicosa	Lythraceae	ES	Evergreen Shrub			5.00		21.43	37.68	47.06	11.36
Eriolena spectibilis	Malvaceae	ES	Evergreen Shrub			2.50					
Sub-total				**1.72**	**10.61**	**7.50**		**21.43**	**37.68**	**47.06**	**11.36**
Climbing Shrub											
Capparis olacifolia	Capparaceae	CS	Climbing Shrub			7.50	24.00				
Butea parviflora	Fabaceae	CS	Climbing Shrub					3.57			
Sub-total						**7.50**	**24.00**	**3.57**			
Woody Shrub											
Tetrastigma leucostaphylum	Vitaceae	WS	Woody Climber			2.50					
Sub-total						**2.50**					
Grand Total				**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(The shaded portion of the relative basal area represents the dominant & co-dominant species)

Appendix VIII - Ground vegetation composition

Species Name	**Family Name**	**Acronym**	**Lifeform**	**Nest 1**	**Nest 2**	**Nest 3**	**Nest 4**	**Nest 5**	**Nest 6**	**Nest 7**	**Nest 8**
				Once Burnt			**Twice Burnt**			**Frequently Burnt**	
Relative Dominance (%)				**RD**	**RD**	**RD**	**RD**	**RD**	**RD**	**RD**	**RD**
Grass											
Carex sp.	Cyperaceae	Gr	Grass	71.73		67.06	54.82	69.15	78.05	21.86	4.75
Eragrostic uniloides	Gramineae	Gr	Grass	0.16							
Grass sp.1	Gramineae	Gr	Grass		27.88			8.03	6.22	23.56	11.96
Cymbopogon flexuosus	Gramineae	Gr	Grass		2.18						
Grass sp.2	Gramineae	Gr	Grass		0.11						
Cymbopogon jwarancus	Gramineae	Gr	Grass			13.68	17.60				
Cynodon dactylon	Gramineae	Gr	Grass			0.81			3.45	9.42	
Cymbopogon sp.	Gramineae	Gr	Grass				3.77				
Sub-total				**71.89**	**30.17**	**81.55**	**76.19**	**77.18**	**87.72**	**54.85**	**16.71**
Annual Herb											
Duhaldea cappa	Asteraceae	AH	Annual Herb	10.26	36.38	4.03	7.62		4.44		
Bidens pilosa	Compositae	AH	Annual Herb		0.65						
Oxalis corniculata	Oxalidaceae	AH	Annual Herb		0.23						
Anisomeles sp.	Labiatae	AH	Annual Herb						0.41		
Spergula arvensis	Caryophyllaceae	AH	Annual Herb						0.14		
Spermadictyon suaveolens	Rubiaceae	AH	Annual Herb					0.17			
Sub-total				**10.26**	**37.26**	**4.03**	**7.62**	**0.17**	**0.54**		
Perennial Herbs											
Ageratina adenophora	Compositae	PH	Perennial Herb	9.03	21.59	3.87	10.66	22.65	6.63	28.35	72.21
Chromolaena odorata	Asteraceae	PH	Perennial Herb	0.66	3.27	2.49	5.53				
Artemesia mariantha	Compositae	PH	Perennial Herb							14.92	11.08
Isodon ternifolius	Labiatae	PH	Perennial Herb						0.24		
Sub-total				**9.70**	**24.85**	**6.35**	**16.19**	**22.65**	**6.87**	**43.27**	**83.29**
Biennial Herb											
Gnaphalum affine	Asteraceae	BH	Biennial Herb						0.43		
Sub-total									**0.43**		
Climber											
Jasminum nepalense	Oleaceae	C	Climber	3.03	2.94						
Climatis sp.	Ranunculaceae	C	Climber		0.97						
Argyreia venusata	Convolvulaceae	C	Climber			7.56				1.88	
Sub-total				**3.03**	**3.91**	**7.56**				**1.88**	
Fern											
Fern sp.1		Fr	Fern	2.66	2.61						
Nephrolepis cordifolia	Lomariopsidaceae	Fr	Fern	2.26		0.50					
Pteredium sp.		Fr	Fern	0.21	0.65						
Fern sp.2		Fr	Fern		0.54						
Sub-total				**5.13**	**3.81**	**0.50**					
Grand Total				**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

(The shaded portion of the relative basal area represents the dominant & co-dominant species)

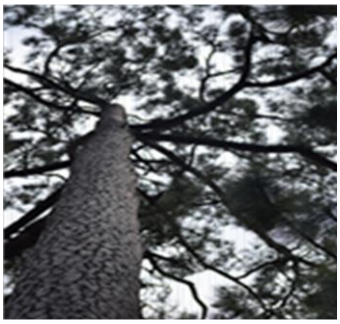
Appendix IX - Field photographs

Nest tree data in once burnt site

Data collection in twice burnt site

Fire evidence on a nest tree in twice burnt site

Fire evidence on a nest tree in frequently burnt site



Nest at frequently burnt site

Nest at once burnt (Athang)

Nest tree at twice burnt (Zawa)