LANDUSE CHANGE EFFECT ON HABITAT AND WHITE-BELLIED HERON POPULATION BY HYDROPOWER PROJECT ALONG PUNATSHANGCHU

Tashi Wangdi
Ministry of Energy and Natural Resources, Bhutan

Royal University of Bhutan

College of Natural Resources

LOBESA

LANDUSE CHANGE EFFECT ON HABITAT AND WHITE-BELLIED HERON POPULATION BY HYDROPOWER PROJECT ALONG PUNATSHANGCHU

In partial fulfillment of the requirements for the B.Sc. Forestry Programme (Conservation Science)

Tashi Wangdi

April 2014

DECLARATION

I declare that this dissertation titled **"Landuse change effect on habitat and White-bellied Heron population by hydropower project along Punatshangchu"** is an original work and I have not committed, to my knowledge, any academic dishonesty or resorted to plagiarism in writing the dissertation. All the sources of information and assistance received during the course of the study are duly acknowledged.

Student's Signature: ________________ Date: 09/05/2014

ACKNOWLEDGEMENT

I am extremely grateful to all the following individuals and organizations for their great contribution besides their busy schedules and making me possible to bring this paper out successfully.

I would like to thank heartily my Supervisor, Dr. Om Katel for continuously supporting and guiding me throughout my study period. Besides that he has taken so much of trouble to review my draft paper several times for necessary changes.

I am also very much deeply indebted to Dr. Pema Wangda, the Head of the WMD, DoFPS, MoAF for his valuable advices and support throughout my studies. He is the person who introduced me to Madam Rabecca Pradhan for aid to take up the study. He also helped me to get the topic and develop the research proposal. Besides his busy schedule he spared ample time showing me ways to compile field data and analyse it. Thanks also for providing me space in his office to work.

I thank Madam Rabecca Pradhan, Ecologist, RSPN for providing me fund to carry out the study. She is also one of my mentors who always guided me during my field work. Besides her tight schedule she spared her valuable time for identifying the plant specimens that I have collected from the study areas. Thanks to Mr. Dorji Gyeltshen, FO, WMD, DoFPS, MoAF for helping me analyse data and identifying plant specimen too.

I would also like to thank my research team; Mr. Sonam Tshering, FA, RSPN, Mr. Kinley, Mr. Namgay Wangdi, Mr. Pemba and Mr. Phurba for their kind support during my field data collection work.

Finally, I would like to express my heartfelt thanks to my families who has shown their great understanding and patience till the completion of my B.Sc. course in the College. Without their moral support and patience, I would not have accomplished this thesis. My especial gratitude goes to my sons and daughter, who cared and loved me unfathomably which always reminded me of my responsibility as a student throughout my study period and made me successfully complete my B.Sc. course.

ACRONYMS

CNR:	College of Natural Resources
DBH:	Diameter at Breast Height
DoFPS:	Department of Forests & Park Services
DoL:	Department of Livestock
EIA:	Environment Impact Assessment
FA:	Field Assistance
FAO:	Food and Agriculture Organisation
FNCA:	Forest and Nature Conservation Act
FO:	Forest Officer
GPS:	Global Positioning System
ICEM:	International Conference on Electrical Machines
IUCN:	International Union for Conservation of Nature
MoAF:	Ministry of Agriculture & Forest
MoEF:	Ministry of Environment and Forest
MW:	Megawatt
PHP:	Punatshangchu Hydropower Project
RBA:	Relative Basal Area
RSPN:	Royal Society for the Protection of Nature
SPSS:	Statistical Package for Social Sciences
WBH:	White-bellied Heron
WMD:	Watershed Management Division
TRT:	Tail Race Tunnel

ABSTRACT

Punatshangchu basin is increasingly disturbed and degraded by increasing developmental activities and human population; there is need for research into the change for the rare heron's population and its habitat. The study was focused to determine difference in floristic composition in the habitat of WBH between disturbed and undisturbed sites. The land use change and population dynamic of WBH along Punatshangchu by hydropower projects was also assessed.

Vegetation survey was conducted between altitude range of 1251 to 1386 m a.s.l. at Phochu in Chhubu Geog and Punatshangchu Dam –I in Gasetsho Geog. The size of the sampling plot was 10 x 10 m for trees, 5 x 5 m for shrubs and 2 x 2 m for grass. Height and DBH were measured for trees and tallest height and coverage percentage measured for shrub and grass. The vegetation data were analyzed using Pivot Table of the Microsoft excel and SPSS version 16.0. The population count survey of WBH was done by deploying 22 surveyors in known points.

There was difference in floristic composition between disturbed and undisturbed areas due to land use change and anthropogenic disturbance. A total of 93 species belonging to 38 families were recorded. The species consisted of 3 trees, 21 shrubs, 13 perennial herb, 30 annual herb, 3 climbers, 4 ferns and 19 grasses. Floristically, major life-forms composed of herbs 54% in the disturbed and 61% in the undisturbed area. The species richness count was 7 to 24 in undisturbed and 5 to 16 in disturbed sites. The Shannon's diversity index was 1.1 to 2 in undisturbed 0.9 to 2.1 in disturbed sites. The average regeneration count was 6.8 and 1.83 in undisturbed and disturbed respectively. Pearson chi square test showed significant association between the WBH presence and the disturbed sites, $\chi^2(1) = 10.91$, $p < .01$. The test indicated that WBH preferred sites with no disturbance. Initially the land used area was 406.76 ha and it increased to 804.68 ha with the developmental works of hydropower project. The rate of change calculated was 160.94 ha per year. The maximum recorded population was 30 in 2008 to 2009 and in 2014 it has declined to 22.

Considering the significant loss of population with the commencement of hydro-power project, it is concluded that such project can be a threat to critically endangered WBH. It would be the best for the WBH if the dams were not built, but the development priorities of government cannot forego.

Table of Content

List of Figures

List of Tables

CHAPTER ONE
Introduction

1.1 Background

White-bellied Heron (WBH) is scientifically known as *Ardea insignis*. There are 26 individuals residing regularly in the Punatshangchu river basin and its tributaries below 1,500 m a.s.l. in Punakha and Wangdiphodrang districts (RSPN, 2011). They are categorized as critically endangered species in 2007 by the International Union for Conservation of Nature (IUCN) red list (IUCN, 2008) owing to its total population 200 number in the world (BirdLife International, 2011).

The existence of 26 WBH in Bhutan is an indication of our long sustaining conservation efforts. However, when our country step the path of modern development it is also confronting conservation challenges increasingly.

The installation of continuous hydropower project I and II along the Punatshangchu are quite devastating for the WBH's habitat. Due to accelerated development of large scale hydro-power projects in the Punatshangchu basin the habitat for the WBH is altered irreversibly (RSPN, 2011). This project certainly took away large area of the heron habitat along Punatshangchu.

Punatshangchu hydropower project (PHP) activities along the Punatshangchu have led to major land use change in the habitats of the heron exterminating vegetation that existed in the place. The disturbance from a large number of employees working increase access to the heron, heavy construction and road works significantly change the quality of foraging habitat for herons (RSPN, 2011). The increase in land use change and settlement of thousands of people working for the PHP along the river basin, increased disturbance to WBH and decreased the area of its habitat.

The Environment Impact Assessment (EIA) reported that the construction of 2560 megawatt Sankosh hydropower project would require a land area of 7619 ha (Business Bhutan, 2013). It is assumed that the construction of 1200 megawatt Punatshangchu hydropower project I would require approximately 3500 ha of land. This will result in loss of existing vegetation, area occupied by WBH and habitat fragmentation.

Vegetation clearance is involved at the dam site and associated facilities and along the TRT (Tail Race Tunnel) and the access roads proposed during construction phase in the PHP. Further clearance of vegetation would be resulted owing to construction of camps and other permanent and temporary project structures. The surrounding vegetation will experience changes in species composition towards more riparian species and some vegetation will be permanently lost (Johnson, 1992). Vegetation clearance in the process of construction can also cause destruction to threatened plant species.

1.2 Research problem

The Punatshangchu has been clearly selected as high quality habitat by the heron among the river systems of Bhutan (RSPN, 2011). The Punatshangchu and its tributaries emerged to be the permanent WBH habitat; they generally nested and fed along the river. River mining in Punatshangchu is a disturbance to herons, since it alters the habitat directly (RSPN, 2011). It involves heavy equipment and trucks in or on the bank of the river and large amounts of sand and gravel is removed. The activities of PHP are prevailing along the Punatshangchu. The disturbances caused by workers such as increased access by people to WBH can cause stress upon the population. RSPN (2011) recommended the approach distance of human on foot and in vehicle is not more than 200 m. The noise and vibration from traffic and equipment operation and movement, clearing and excavation, rock breaking by drilling and blasting also cause disturbance to WBH. These disturbances associated to PHP cause threat to the critically endangered WBH.

The construction activities of PHP involve total vegetation clearance from the area. FAO (2010) stated that such construction activities and vegetation clearance would lead to vegetation loss, habitat fragmentation and degradation.

26 numbers of WBH found along the Punatshangchu basin (RSPN, 2011) is the report prior to the major construction phase of PHP (Dorji, 2013). Therefore, study on actual population of WBH and landuse change effect on its habitat after the commencement of PHP is necessary to be carried out.

1.3 Objectives and research questions

The main objectives of this research and research questions are as follow:

- To determine difference in floristic composition and diversity in the habitat of WBH due to disturbance and assess habitat preference,
    1. What is the different ground vegetation species found in disturbed and undisturbed habitat?
    2. Is there difference in species diversity, dominance, richness and composition in disturbed and undisturbed habitat?
    3. Which is the preferred habitat of the heron, the disturbed or the undisturbed?
- To determine area of land use change and population of WBH along PHP.
    1. What is the area of habitat lost by the heron due to PHP?
    2. Is there change in the population of heron due to disturbance caused by PHP?

CHAPTER TWO

Literature review

This chapter reviews information related to study carried out on the change of vegetation and population of WBH by PHP. The information reviewed in this chapter are general background, impact of PHP, habitat loss, nesting, impact on foraging, threat, population change and impact of hydropower project on vegetation.

2.1 General Background

The WBH known as the Imperial Heron, Great WBH or Gentle Giant (RSPN, 2013) is scientifically known as *Ardea insignis*. It is the second largest species of heron in the world exceeding its size only by the Goliath heron (*Ardea goliath*) (BirdLife International, 2011).The rareness of its population rated it as the rarest heron in the world in 2012 in the Guinness Book of World Records.

There are sixty five species of herons recognized in the world (Kushlan, 2007). It was assessed and found that nine species are currently under threat. Four populations of the herons are gone extinct in historic times. Habitat degradation is the main cause of threat to heron. In overall herons are an adaptable group of birds (Kuahlan, 2007) and most of them have been able to co-exist with human in their natural ranges.

The WBH is known from the eastern Himalayan foothills in Bhutan and north-east India to the hills of Bangladesh, north Myanmar and historically it occurred across west and central Myanmar (BirdLife International, 2001). It might have also occurred in south-east Tibet, China, but now it is extinct in Nepal. A complete population census has not been conducted globally for this species (BirdLife International, 2011). There are only about 200 known individuals of WBH population in the world (IUCN, 2008; BirdLife International, 2011). The WBH is protected by the law in Bhutan and it is listed as critically endangered by the 2012 IUCN Red List (RSPN, 2013). The IUCN Red List assigned it the highest risk category as critically endangered which means the natural population of a species has decreased or will decrease by 80% within three generations and the evidence available would show an extremely high risk of its extinction in the wild. The IUCN Species Survival Commission and the Zoological Society of London reported that the WBH was included among the world’s 100 most threatened species in 2012 (Baillie & Butcher, 2012).

The bird is recorded from small or large rivers with sand or gravel bars and regularly within or neighboring to subtropical broadleaved forest from the lowlands not exceeding 1500 m (Tordoff *et al.*, 2006), and also reported from an inland lake. Generally it remains solitary but during winter it gathers into small flocks and family groups (Pradhan, 2007) and moves to unapproachable and undisturbed areas. The bird is known to breed and roost in Chir pine forest (Tordoff *et al.*, 2006), four nests were solitary and located in large Chir pine tree on ridges or steep slopes at 500 to 1500 meter near the confluence of a small stream and a larger river in Bhutan in 2003 to 2007 (Pradhan, 2007).

The appearance of the male WBH is similar to the female, with a blackish head topped with a pale plume of feathers, and a brownish-grey body with grey wings, legs and feet (Kushlan & Hancock, 2005). The underbelly of the chicks differ from the adult in being white is yellow, which turns white as the chicks mature. The massive pointed bill measure about 15 to 18 cm in length.

The WBH are of two types, breeding and non-breeding. The herons found along Phochu and Mochu and Kamechu, Gewarongchu and Burichu are non-breeding and the herons found in Ada, Nanzhina, Hararongchu in Wangduephodrang and Bertichu in Zhemgang are breeding (Business Bhutan, 2011).

The breeding and nesting by WBH is in between March and June (BirdLife International, 2011). A greenish to blue egg laid is incubated alternately by the male and female (Kushlan & Hancock, 2005). The hatched chicks are fed on regurgitated fish and leave their nest when they are between two to three months old.

The WBH is a solitary bird with a large territory. During the winter months it may fly up to 30 kilometers to join other members of the species in small family groups or flocks of unrelated individuals (Kushlan & Hancock, 2005). Its large territory and its solitary habit has never been as high population density as some of its more common relatives.

2.2 Impact of PHP

The PHP I and II being built along the Punatsangchu river will have several impacts on endangered fish and bird species, such as the WBH. During the de-water stage, the local migratory fish will get disturbed and there will be no fish available for the bird to feed on. From the construction stage itself the herons are being disturbed. The herons are quiet and shy by nature, and all the noise and infrastructure development of the projects are against them (RSPN, 2011).The river has been deepened in the process of sand extraction from the river, making it impossible for the bird to feed. Punatsangchu is an important habitat for the WBH, and disturbing the river will disturb it. The two hydropower projects will destroy the habitat of about 26 WBH, which account for roughly more than 10% of the world's population. There is no mitigation measure to stop this severe and irreversible alteration of habitat by the ongoing PHP and its development importance to the government (RSPN, 2011).

The PHP along the Punatshangchu will undermine the water quality and impact the health of the ecosystem posing risk to the native fish and other aquatic fauna dependent on the system (DoL, 2008). The benefits of developing hydropower are impossible to overcome, however its effects on the river ecosystem cannot be ignored. The development of the PHP will affect many species of birds, fish and other vertebrates and invertebrates. Decline in fish population will have indirect impacts on the WBH besides direct impacts like loss of habitat and feeding ground.

2.3 Habitat loss

The WBH are found in large inland swamp forests and forested rivers but seldom in sub-montane grasslands (Hume, 1878). It depends on mature forests with large trees for nesting. There is evidence that the choice of habitat varies seasonally, in summer using rivers and in winter slow flowing watercourses (BirdLife International, 2001).

Disturbance caused by people result in nesting failure. The failure is aggravated by rapid industrialization, urbanization, and tourist development, which brings people in closer contact with congregatory sites (Kushlan, 2007). The negative influences on heron populations are either human related or naturally (Simpson, 1984). The common human disturbance and impacts include intrusion, pollution, habitat removal or alteration, noise and persecution. Natural disturbances include predation, storms, fire, flood and disease. Bishop (2012) stated looking at the impact of PHP that a massive hydroelectric scheme in the Sunkosh Valley may have caused WBH termination from the valley.

Tens of trucks line up every day during dry season on the banks of the Punatshangchu to feed the growing construction industry with sand. The involvement of heavy equipment and trucks constitute a major threat to birds and other types of invertebrates and reptiles (MINEO, 2000). The compaction of sandy soil directly kills and disturbs the animals and creates an environment incompatible for life and low productive habitats. Herons also suffer from noise disturbance, light and the movement of heavy machinery. Mining therefore is an important conservation threat deteriorating the habitat and feeding ground of herons.

The Royal Government of Bhutan has declared the riverbed in Punakha-Wangdue as protected habitat for WBH and its main feeding ground.

2.4 Nesting

There are several important features of nesting by the WBH (RSPN, 2011). It needs large territory size for nesting. A large tree with open space in front and the tree standing on steep slope of 42-68^0 are chosen for nesting. Scarce undergrowth with low density of large trees is chosen to avert danger while flying and minimize predators' access to nest tree. The nesting locations are near confluences of tributary and main rivers to keep themselves away from predators and human disturbances; and also to forage on main stream or tributaries depending on season and fish behavior (RSPN, 2011). Nesting is isolated from humans and it prefers low canopy density and dearth of mid-story Chir pine tree to prevent from direct threat of fire. RSPN during their study suggested that migratory movement of fishes up in the small rivers might be an important feature for nesting.

2.5 Impact on foraging

It primarily uses riverine sites for foraging. It is a solitary species that is often observed alone or in pairs but seldom in group of four to five possibly family groups (Hume, 1878). It feeds in fast flowing rivers, slow moving streams and grassy marshes by standing. Primarily it feeds at dusk and seldom during the day hours. Its exact diets have not been documented; however it is known to take large crayfish (RSPN, 2011). The sole source of food for the WBH is rivers and streams. The kind, size and abundance of fishes are supported by the quality of river critical for the survival of herons.

There are effects of the PHP on migratory fishes, on resident fishes and foraging habitat (RSPN, 2011). The continuity of the river is broken by the construction of dam and the migratory route of fishes blocked for spawning habitat (DoL, 2008). The continuance of the same is a concern because fish blocked from their spawning habitat may reabsorb their eggs. This will lead to decline in fish population which will have impacts on the WBH besides loss of habitat for feeding. It was observed that sometimes an individual heron could not catch any fish and had to undergo starvation (RSPN, 2011). Before PHP herons used to get two to three fishes in an hour but now it is difficult for the birds to catch one fish in about three hours. The parent herons spend long hours looking for food which leaves the chicks without care for long hours exposing them to predators (RSPN, 2011). Dam constructions for hydropower project also has an affect on fish passage and kill or injure fish (Ferguson, 2006). The viability and mobility of fish species from different habitats within a river system may diminish substantially or completely.

2.6 Threat

Disturbances caused by human such as boating and walking were revealed to change the bird behavior of feeding (Carney & Sydeman, 1999). Birds that lost foraging time are likely to be in inferior physical condition, which could translate to poor reproductive success on the breeding grounds (Zimmer, *et al.*, 2010). Disturbances during the breeding season reduce reproduction success either through nest abandonment or increased risk of nest predation due to exposure. Dorji (2013) reported that eggs in the nest of Bertichu could not be hatched notwithstanding the breeding pairs sitting on the nest. The reason stated for the failure was disturbance by vehicular noise, conservationist and visitors that caused stress to birds sitting on the nest and unable to maintain constant temperature entailed for incubation.

The use of Ada Lake by cattle and people along the trail may cause disturbance to the birds (Pradhan, 2007). The availability of alternative habitat may affect tolerance of disturbance (Gill *et al.,* 2001; West *et al.*, 2002) The Herons may avoid areas with extensive disturbance and choose roosting or foraging sites with no disturbances. Dorji (2013) reported that the population of the bird declined from thirty numbers in 2009 to eighteen in 2013 could be the cause of disturbance by major construction work of PHP

The widespread loss, degradation and disturbance of forest and wetlands are threat to the WBH (BirdLife International, 2013). The pollution, rapid growth of aquatic vegetation, and the over-exploitation of resources have led to degradation of wetlands. Natural forest fires are also a threat that destroyed nests in Bhutan. The hydropower project and road construction in the areas inhabited by WBH have resulted in habitat degradation. The WBH being large and solitary is thinly spread in terms of its population and caused its decline. The WBH is vulnerable to disturbance and degradation of habitat caused by agriculture expansion, human settlement and poaching and also overfishing. The mature forest is favoured by the WBH, (BirdLife International, 2011) but such habitat has been at risk from degradation for over a century.

The growing competition for food because of displacement of birds and animals from their original feeding habitat along the Punatshangchu led the predators such as serpent eagle, pallas fish eagle, osprey, yellow throated martin and some small cat to prey chicks of the WBH (RSPN, 2011).

2.7 Population change

WBH population is suspected to be declining because of the presence of habitat degradation and widespread disturbance including remote parts of the species range (Duckworth, 2006), and it is expected to become more rapid in the near future.

There is no population census carried out yet for the WBH across its home range (BirdLife International, 2001), WBH is a critically endangered bird with just only 200 of them left in the world (BirdLife International, 2011). The RSPN had counted the population of the WBH during nesting and non-nesting season from 2003 to 2010. Initially when it began its survey in the year 2003 the number of individuals counted was 14, the number of count rose to 30 in 2009 and dropped down to 26 in 2010. The period of population census carried out by the RSPN was before the PHP construction and there was not much impact as the main construction work commenced in 2010 (Dorji, 2013). The researchers from the Royal Manas National Park, Jigme Singye Wangchuck National Park, Royal Society for Protection of Nature and local bird watchers carried out population count of WBH in the entire habitat known for its existence in 2013. RSPN (2013) reported that the population of the bird has dropped to 22 individual from 30 in 2009.

2.8 Impact of hydropower project on vegetation

The EIA (Environment Impact Assessment) report stated that hydropower project would have various terrestrial biodiversity impacts which include effects on land and vegetation, loss of land to the reservoir and increased human access to area, and habitation (Business Bhutan, 2013). The most obvious impact of reservoirs on terrestrial ecosystems is the submergence of forest. The project activity would also result in fragmentation in the project area due to construction of dam and other activities leading to loss of substantial forest land. The main cause of the vegetation cover dynamic is the land use change, (Wang *et al.,* 2008) hydropower development converts the land use to water and the vegetation coverage decrease. The landscape disturbance caused by hydropower development can also serve to introduce invasive species into natural habitats degrading the quality of remaining habitat areas. The conversion of land from its natural state to a developed landscape represents the single greatest impact of increased human activity on native wildlife (Liang, 2012). Development naturally eliminates or changes many important habitat features found in a natural area which alters the habitat value of that area.

When the hydropower project prevails in an area, the area is subject to natural and anthropogenic disturbances. Disturbances such as pollution, conversion of forests to non-forest area, timber harvesting, alteration of natural hydro-periods (flooding), introduction of exotic species, trampling and compaction are anthropogenic disturbances (Binalli *et al.*, 2012). All these disturbances are associated with hydropower project along the habitats of WBH. The disturbances in the area affect resource levels, such as organic matter, water and nutrient which affect plants and animal over time (Binalli *et al.*, 2012). The evidence of species diversity being highest at intermediate frequency of disturbance was found by ecologists (Connell, 1978; Pickett & White, 1985). High frequency disturbance lead to species that colonise rapidly to persist, whereas zero disturbances may eliminate desirable dominant plant species. The change in disturbance regime lead to many species unable to cope with the change and the species will be eliminated (Binalli *et al.*, 2012). The change in species composition and structure changes ecosystem function. When the species are changed in the area wildlife species are also affected because food sources and vegetation cover are modified (Ewel, 1986).

Developmental activities in the habitat generate intense concern because it suffers vegetation loss, habitat fragmentation and degradation (FAO, 2010) which houses most of the described and un-described species (Joppa *et al*., 2011). A substantial amount of work on the effect of forest loss and biodiversity were carried out, but only a little was known about how forest loss and biodiversity interacts with habitat disturbance (Laurance & Bierregaard, 1997; Ewers & Didham, 2006; Fahrig, 2003). Disturbance caused to the habitat result in habitat loss (Harrison & Bruna, 1999; Laurance *et al*., 2002). Birds are suitable for the examination of changes in response to habitat disturbance and loss because they are reliable indicators of broader biodiversity trends (Barlow *et al*., 2007a).

The herons preferred areas with tall Chir pine trees sparsely dispersed, understory vegetation not touching the tree and very little to absence of shrub and small tree layer (RSPN, 2011). The mid and understory vegetation found in nesting habitat of WBH with Chir pine forest are *Curcuma aromatic*, *Cymbopogon khasianum*, *Cymbopogon jwarancusa*, *Ageratina adenopora*, *Duhaldia cappa*, *Phyllanthus emblica*, *Phoenix laureiri*, *Woodfordia fruticosa and Glochidion velutinum.* These plants are prone to forest fire and many of the plants are resistant to fire. RSPN (2011) stated that there was interaction between fire frequency and the open structure of the understory and spacing of large trees.

CHAPTER THREE

Materials and method

This chapter describes research site and the methodology of vegetation survey, heron population survey and land use change survey. It also describes the variables and tool used for data analysis of tree, ground vegetation and regeneration collected from disturbed and undisturbed study sites. Here the term disturbed refers to the site where the forests are logged for house building timber and also converted to non-forested area by PHP, construction of roads and other activities associated to PHP, presence of human population and settlement; while the term undisturbed refers to the site in the absence of activities present in disturbed site.

3.1 Research site

The study was carried out in the WBH habitat site stretching from Phochu (1251 m, 27˚37’02.1’’N, 089˚52’04.8’’E) in the north to the south Phunatshangchu Hydro-power Project Dam I (27˚25’11.4’’N, 089˚54’04.6’’E) under Punakha and Wangduephodrang Dzongkhag respectively. The study site is described as low-altitude xerophytic forest in the dry deeper valley of Punatshangchu watershed (Grierson and Long, 1983; Wangda, 2003) where the forest is purely *Pinus roxburghii*. The range of altitude between the study areas was 1251 m on the other side of the Phochu in Chhubu Geog, Punakha District to 1386 m at Madam-mess at Gasetsho Geog in Wangdiphodrang District (Figure 3.1.A and B).

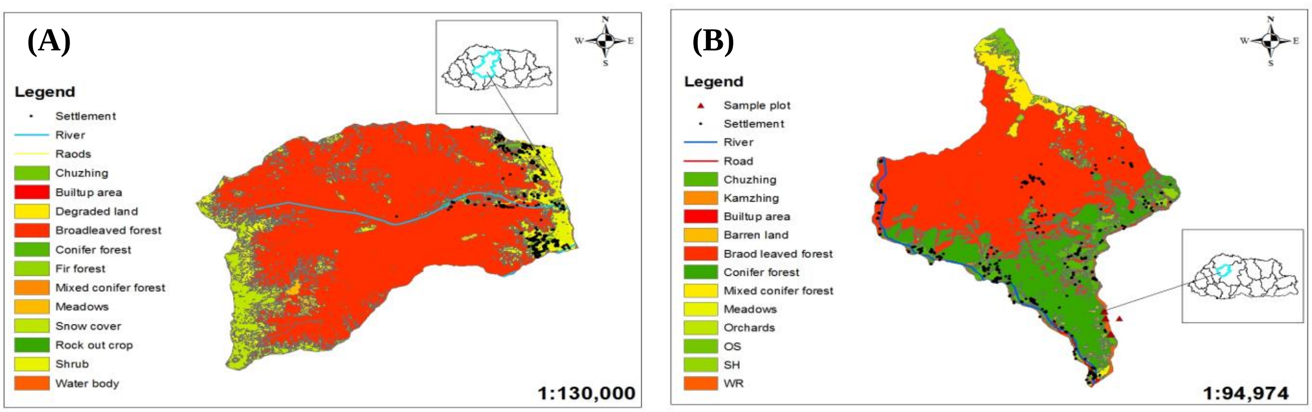


Figure 3.1. (A). Gasetsho Geog in Wangdiphodrang and (B) Chhubu Geog in Punakha the study area

3.2 Survey design

3.2.1 Vegetation survey

Field survey was conducted in the disturbed and undisturbed habitat sites of the WBH. The field data was collected using the forms (Appendix number I, II, III & IV).

The field work to survey vegetation was conducted from December 2013 to January 2014. In total, 27 plots were sampled along transect line of Phochu and Punatshangchu. 15 plots were located along Phochu and 12 along Punatshangchu. Out of 27 plots, 10 plots were sampled in the undisturbed habitat site and rest 17 plots were sampled in disturbed sites.

The size of square quadrat plot measuring 10 x 10 m for tree were adopted while two sub-plots of 5 x 5 m for shrubs and 2 x 2 m for grass and regeneration were selected carefully within the major plot. In the sub-square quadrat of 2 x 2 m, all tree regeneration individuals with height < 1.3 m were recorded in centimeter and its approximate age to determine density. On the ground, the coverage percentage and the height of shrubs and the tallest height of grass were recorded to determine species density, richness, dominance and diversity.

The equipment such as compass, clinometer, Global Positioning System (GPS), diameter tape, measuring tape, one meter wooden ruler, digital camera and binoculars were used to conduct the field survey for data collection.

All the species in the plots were identified either at the site and recorded in the data collection form (Appendix I, II, III & IV). The un-identified specimen were collected and photographed for identification. The un-identified specimen were on the spot coded by writing numbers of transect, plot and species (eg. $T_1P_1S_8$) on masking tape and pasted on the base of the specimen for correct recording later after identification. The nomenclature followed for correct identification of the species were Flora of Bhutan (Grierson *et al.*, 2001); Flowers of Himalaya (Poulin and Stainton, 1984), Weeds of Bhutan (Parker, 1992) and Manual for Bhutan weeds (Parker, 1991) were used.

3.2.2 Heron population survey

Surveyors were deployed in 22 known habitats points of WBH from 24th March to 28th March 2014 to count the observed WBH. The observation started from 6:00 am and ended at

6:00 pm. The observation count was recorded in the WBH monitoring form for compilation at the end of the survey.

3.2.3 Land use change area survey

With reference to the locations of construction sites shown on 3D google image (Appendix XA) developed by the PHP planner prior to the commencement of the project activities in their work plan manual, the images were compared with the present 3D google images (Appendix XB, C, D, E & F).

The Google Earth Pro 4.2 was used to determine the area of land use changed by PHP. First the tool ruler was selected from the tool bar and then the polygon. When the polygon was selected it facilitated to mark the boundary of the area for which area would be generated automatically after enclosing the entire boundary of the area as shown in the (Appendix XC & D). The unit of the area could be selected from the unit of area options such as in hectare, square kilometers, square miles and square meters. In this way the land use changes area due to development activities along Punatshangchu River and increased human settlement near the habitat were determined.

In the first week of March 2014, ground survey was carried out with the help GPS for ground truthing. The area of the disturbed habitat sites were determined automatically by walking around the perimeters of the sites with Garmin GPS-V after enclosing track log.

3.3 Data analysis

3.3.1 Tree data analysis

To determine the first objective of the study that is to determine change in floristic composition and diversity in the habitat of WBH due to disturbance and land use change and habitat preference, the following data analysis were carried out.

The diameter at breast height (DBH) data of tree was used to determine basal area (BA cm^2) and then relative basal area in percent (RBA percentage) was calculated. The RBA percentage of each species was used as abundance measure of species in a community. The calculation of the dominant species of the plots was based on the dominance analysis (Ohsawa, 1984). The statement of 100% relative dominance is for a single species which dominated in a community. The relative dominance is accounted as 50% if two species shared dominance. In the similar way, the relative dominance is accounted as 33.3% if the dominance is shared by three species. The number of dominant species shows the least deviation between the actual relative dominance values and the expected percent share of the corresponding co-dominant model. The equation used was:

$$d = 1/N \left\{ \sum_{i \in T} (\chi_i - \chi')^2 + \sum_{j \in U} \chi_j^2 \right\}$$

Where, χ_i is the actual percent share (relative basal area is adopted here) 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 is the percent share of the remaining species (*U*). *N* is total number of species.

RBA data was used for calculating Shannon & Wienner Diversity Index. The formulae described by Zobel *et al.* (1987) were used for calculating basal area (BA), relative basal area (RBA %) and species diversity index (H) as shown below:

1. Basal Area (BA) = π d2/4 or πr2/2

   d = DBH (diameter at the breast height)

   r = (diameter / 2)

   π = 3.1416.

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

Species diversity index (H) was calculated using Shannon-Wiener diversity index H' (Pielou, 1977).

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

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

In order to determine change in floristic composition in the undisturbed and the disturbed habitat of WBH in the study areas Pivot Table of the Microsoft excels 2010 was used to analyse ground vegetation data.

The height and coverage percent of ground vegetation were used to determine the volume and the relative volume. Important value (pi) was calculated to find the diversity using natural log. The data were analyzed using Pivot Table of the Microsoft excels 2010 for Shannon diversity index (H'), relative dominance, floristic composition and graphical presentation.

Statistical package for social sciences (SPSS version 16.0) was used for conducting the independent *t* test for species diversity, species richness and tree density (Appendix VI & VII). When the normality test was carried out, it showed that the data was normal on 95% confidence interval and also the variables were unrelated (undisturbed and disturbed group).

Microsoft excels 2010 was used for compilation of data of regeneration, WBH population and land use change. It was also used for the generation of graphs.

3.3.2 Land use change and WBH population trend

To determine area of land use change and population of WBH along PHP, the past population data of WBH was collected from RSPN office. Microsoft excels 2010 was used for regeneration of WBH population trend graph with the population data.

Pearson's chi-squared test (χ^2) was carried out since the data was categorical to evaluate which habitat (disturbed or undisturbed) was preferred by WBH (Appendix V).

The land use change data was compiled using Microsoft Excels 2010 and generated trend graph to show difference in land use change before 2006 and after PHP construction.

In order to calculate the rate of land use change per year, the difference of the areas of land use in the past and the present were calculated. With the value of the difference in land use change and the number of year taken to change, the rate of land use change per year was determined.

CHAPTER FOUR

Results and Discussion

This chapter presents the results based on the objectives of the study carried out. The results include floristic composition and major life-forms, species diversity, species richness, tree density, regeneration of *Pinus roxburghii*, presence and absence of WBH in the study area, land use change in the habitat of WBH due to PHP and change in population of WBH.

4.1 Floristic composition and major life-forms

In total 93 plant species belonging to 38 families were recorded at the study site. The study site was in low-altitude xerophytic condition; hence the forest stand was purely *Pinus roxburghii*. There were three trees, 21 shrubs, 13 perennial herbs, 30 annual herbs, three climbers, four ferns and 19 grasses. Among shrub *Indigofera* and *Desmodium* species were widely distributed and present in almost all the disturbed and the undisturbed study sites. Similarly, *Artemisia vulgaris,* a perennial herb and *Oplismenus burmannii;* a grass was present in all the sites (Appendix VIII & IX). The wide distribution of these species in the study area indicated their ability to thrive in forests with varied disturbance intensities.

The major life-form in the study area was composed of perennial herb with coverage 33% in the disturbed (Fig. 4.1) areas and 48% in the undisturbed (Fig. 4.2) area. The coverage percentage of fern remained the same in both the study sites, but in case of climber coverage; there was 1% more coverage in undisturbed than in the disturbed. On contrary to the undisturbed area, the major life-form in the disturbed site was found more with annual herb and grass. There was 31% of grass and 21% of shrub coverage in the disturbed area, which is 21% and 8% more respectively compared to the undisturbed.

When the study areas were compared floristically, it was found that the disturbed area consisted of 72 plant species belonging to 33 families and in the undisturbed area 62 plant species belonging to 28 families. There were 27 (*Acmella uliginosa*, *Adhotoda vasica*, *Alopecurus aequalis*, *Cannabis sativa*, *Desmodium renifolium*, *Digitaria ternate*, *Equisetum diffusum*, *Fimbristylis littoralis*, *Imperata cylindrical*, *Indigofera cassioides*, *Ipomoea purpurea*, *Luculia gratissima*, *Murray koenigii*, *Osyris lanceolata*, *Paspalum distichum*, *Persicaria pubesceus*, *Poa annua*, *Pteridium revolutum*, *Pteris vittata*, *Setaria pumila*, *Siegesbeckia arientalis*, *Solanum americanum*, *Sonchus conyzoides*, *Sonchus deraceus*, *Tagetes minuta*, *Trema* *politoria*, and *Xanthium indicum*) different species of plant present in the disturbed sites and 18 (*Anisochilus sp., Anthraxon quartianus, Campylotropis griffithii, Chenopodium album, Climatis buchananiana, Cymbopogon marginatus, Cyperus iria, Desmodium uncinatum, Duhaldea cappa, Euphorbia heterophylla, Gerbera piloselloides, Jasminium grandiflorum, Leptodermis amoena, Phalaris minor, Phyllanthus officinalis, Stephania elegans, Strobitanthes sp.* and *Urochloa ramose*) in the undisturbed sites that were absent in each other's site.

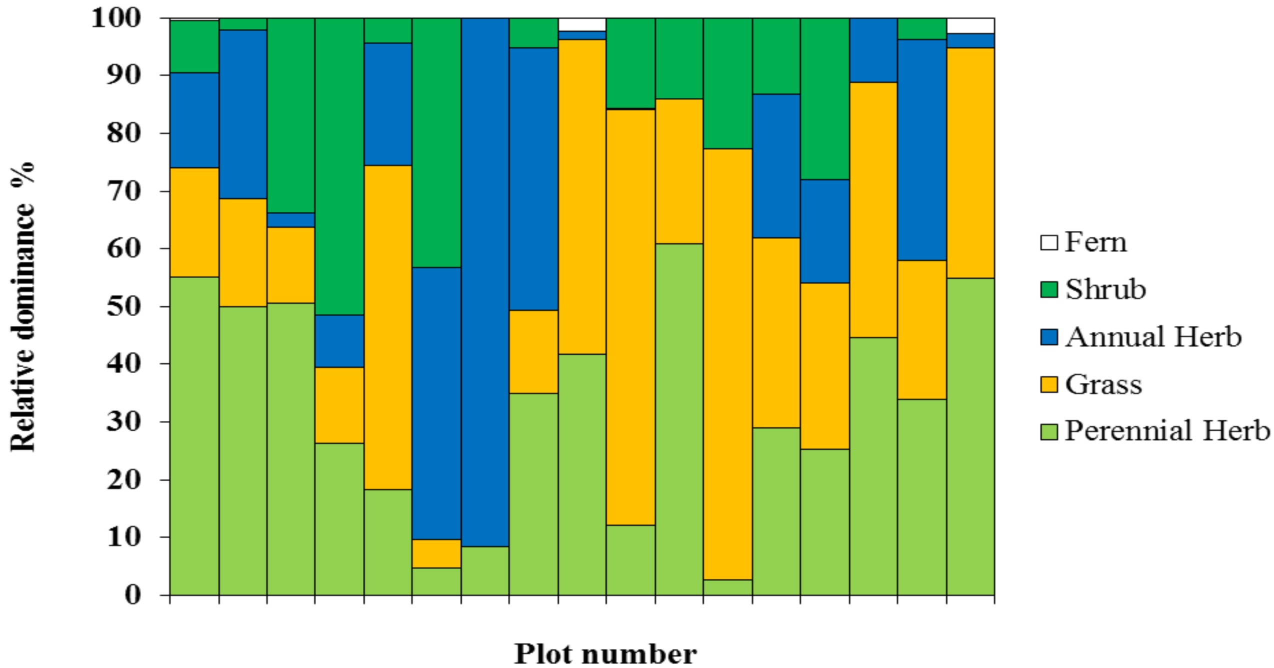


Figure 4.1. Major life-forms of ground vegetation in disturbed plots

Though the ground floristic composition by species was higher in the disturbed areas, the pattern of distribution by life form was quite similar in the two study areas.

In both the study areas the major life-form of tree consisted was Chir pine (*Pinus roxburghii*).

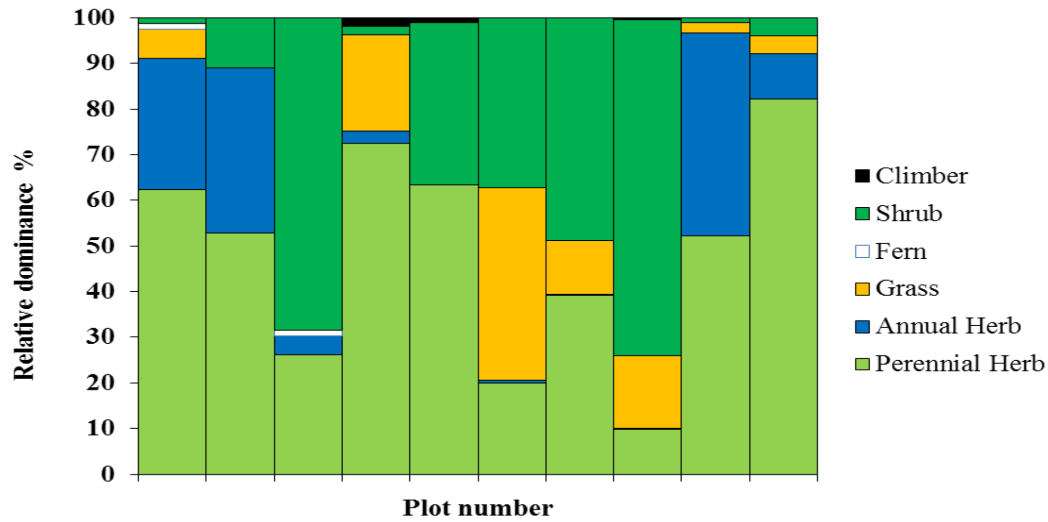


Figure 4.2. Major life-forms of ground vegetation in undisturbed plots

4.2 Species diversity

Statistically, there was no significant (p > .05) difference on Shannon diversity index between disturbed and undisturbed study sites (Table 4.1). The mean value of Shannon diversity index (H') between disturbed (M = 1.66, SD = .37) and undisturbed (M = 1.47, SD = .30); t(df) = 1.36, p > .05. The mean of Shannon diversity index in the disturbed site exceeded by 0.19 when compared to the undisturbed site. The plots where the vegetation survey was carried out were mostly open and in absence of tree. The more species diversity in the disturbed area could be due to more light penetration on the ground resulted by removal of trees and occurrence of woody pioneers and herbaceous species. The finding of this study was similar to Battles *et al.*, (2000) found that the areas which were more open and bare ground had higher plant species diversity compared to the disturbance free area.

Table 4.1. Mean comparison of diversity of ground vegetation

Variables	**Plot**	**Mean**	**SD**	***Df***	***t* value**	***p* value**
Diversity (H')	Disturbed	1.66	.37	25	1.36	.19
	Undisturbed	1.47	.30			

Not significant at the .05 levels.

The hypothesis of Connell (1978) stated that plant species diversity increased with levels of intermediate disturbance, but decreased with severe disturbance. The reason mentioned was that moderate disturbance prevented resources loss but severe disturbance created a stressful environment where only few plants could tolerate. Hence, diversity of plant species decreased in the area associated with severe disturbance. Pickett and White (1985) also reported the evidence of high species diversity in intermediate frequency of disturbance, but high disturbance resulted in low diversity because it led to species that colonise rapidly to persist. From the hypothesis statement of Connell and report of Pickett and White it can be assumed that the study area is not disturbed severely. However, it is evident that disturbance in an area can have an effect on the diversity of plant species and it can contribute to change in the habitat of WBH.

The result of the study is similar to the findings of Li *et al.*, (2012), Pickett and White (1985) and Connell (1978).

4.3 Species richness

There was no significant ($p > .05$) difference on the species richness of ground vegetation between disturbed and undisturbed at study sites (Table 4.2). Statistically, the mean value of species richness between disturbed ($M = 13.50$, $SD = 4.81$) and undisturbed ($M = 11.18$, $SD = 2.72$); $t(\mathrm{df}) = -1.61$, $p > .05$.

Table 4.2. Mean comparison of species richness of ground vegetation

Variables	Plot	Mean	SD	*Df*	*t* value	*p* value
Species richness (no.)	Disturbed	13.50	4.81	25	-1.61	.12
	Undisturbed	11.18	2.72			

Not significant at the .05 levels.

The mean of species richness in the disturbed site was more by 2.32 when compared with the undisturbed site. In the disturbed area tree and shrub richness was very low while herb richness was high compared to the undisturbed area. The difference in species richness could be because of the disturbance that prevailed at the site. The impact of disturbance on species richness depended on the nature of the dominants and rates of successional change of vegetation. Decocq (2004) stated that the clearance of vegetation such as trees and shrubs in the disturbed study area lowered the dominance of species freeing resources for early successional plants and providing chance for herbaceous species to spread rapidly. Comparisons of vegetation in disturbed and undisturbed areas have showed that many herbaceous species were able to survive at intermediate disturbed areas (Watt, 1971). From the conservation point of view, an increase in herbaceous species richness does not mean that the biodiversity is improved in the ecosystem but it deteriorates (Beese, 1999). It is the mosaic of different successional stages in the undisturbed areas which maintains natural ecosystem. The presence of trees, shrub and other native herbaceous species prevent other invasive species to encroach their territory. Hence, undisturbed area could have remained unaffected in species richness, which in change could alter the habitat of WBH.

The species richness count was 7 - 24 from the plots surveyed in disturbed and 5 - 16 in the undisturbed areas. More species richness could be due to intermediate disturbance in the study area. The result of species richness of severely disturbed areas contradicts with the result of intermediate disturbed area. Elliott *et al.,* (1997) found that severe disturbances such as clear cutting, fire suppression and heavy grazing decreased species richness.

Similar to species diversity the species richness is also more when the disturbance is intermediate, but it becomes low when the disturbance is severe. Many authors reported about the species richness of different plants decreased after severe disturbance which impacted forest ecosystems (Palmer *et al.,* 2000). McKinney (2002) reported that intense disturbance led to more similarity of species and it reduced species richness at site.

4.4 Tree density

Statistically, there was no difference on the mean value of tree density between disturbed (M = 4.10, SD = 2.19) and undisturbed (M = 5.88, SD = 3.31); t(df) =- 1.46, p > .05 (Table 4.3). The mean tree density in the disturbed site was found less by 1.78 when compared with the undisturbed site. Less tree density in disturbed site could be due to anthropogenic disturbances associated with the PHP, where workers remove trees for firewood and construction purposes. The removal trees at the construction sites such as dams and roads could also lead to less tree density in the areas.

Table 4.3: Mean comparison of tree density

Variables	**Plot**	**Mean**	**SD**	***Df***	***t* value**	***p* value**
Density (No. per plot)	Disturbed	4.10	2.19	18	-1.46	.16
	Undisturbed	5.88	3.31			

Not significant at the .05 levels.

The undisturbed plot number P12 (Figure 4.3.) falls in the site where WBH roosted consisted of 12 number trees. Five plots in disturbed and two plots in undisturbed were in absence of trees. The absence of trees in undisturbed area was because the plot fell at the site where there was no trees, but in case of the absence of trees in disturbed area was because the trees were felled by people or the plots fell at the site where PHP road and buildings were constructed. Hence the tree density was more in the undisturbed area.

Marcial *et al.*, (2001) found that the tree density decreased with anthropogenic disturbance intensity supporting the finding of the study.

It is very important to maintain the tree density especially the *Pinus roxburghii* (Chir pine) because WBH were known to breed and roost on it. Nest of WBH discovered in Bhutan in 2003 – 2007 were solitary and located in large Chir pine on ridges (Pradhan, 2007). If the Chir pine trees are not protected and let its density degrade through anthropogenic disturbances, it would impact the quality of WBH habitat for nesting, breeding and roosting.

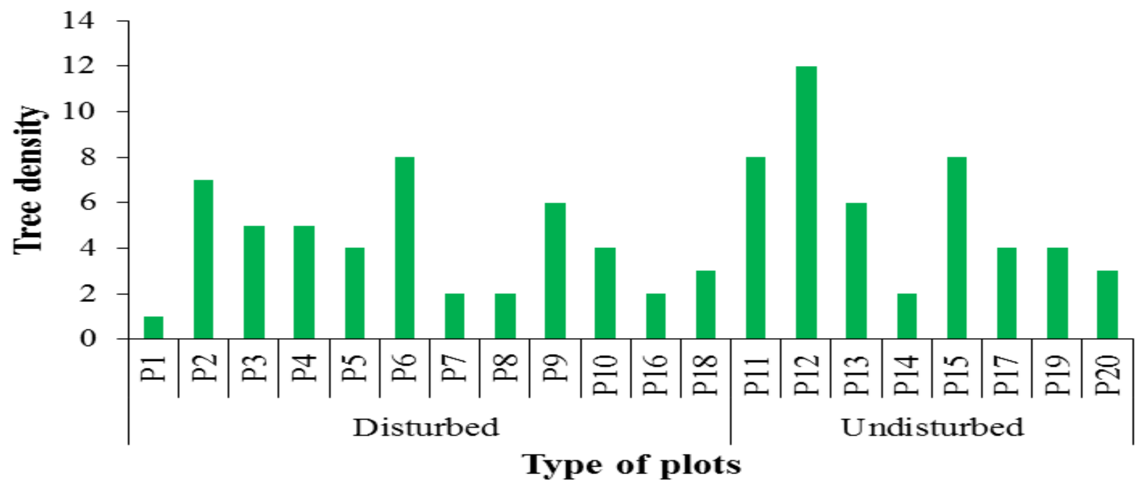


Figure 4.3. Tree density in each individual plot of disturbed and undisturbed sites

4.5 Regeneration of *Pinus roxburghii*

The forest is purely composed of mono canopy dominant conifer species of *Pinus roxburghii*. The maximum regeneration count 17 (Figure 4.4.) was recorded in the undisturbed plot C5 at 1295 m a.s.l. and minimum count one each was recorded in the disturbed plot P1, P3 and P16 and in the undisturbed plot P13 at 1251m, 1265m, 1270 m and 1278 m a.s.l. respectively (Figure 4.4.). The mean regeneration count in the undisturbed study site was 6.8 and the mean in the disturbed was 1.83. In the study area 50% (n = 5) of plots in the undisturbed consisted of regeneration and in 50% (n = 5) the regeneration was absent, but in the disturbed area 35.3% (n = 6) of plots consisted of regeneration and 64.7% (n = 11) of plots were devoid of regeneration.

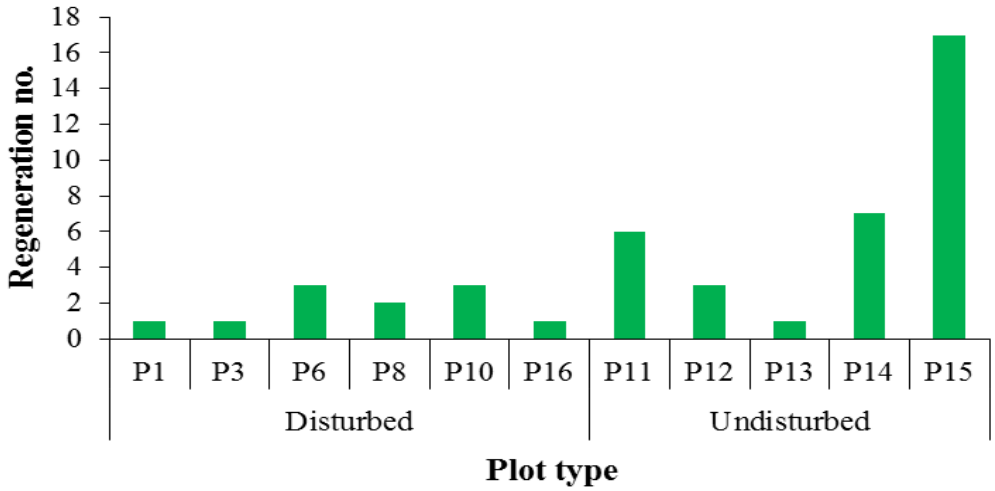


Figure 4.4. Number of regeneration in each plot of disturbed and undisturbed sites

The regeneration of Chir pine tree in the disturbed areas was less compared to the undisturbed area. The result of the study is in contradiction to the finding of Busing (1994) who found regeneration of light demanding species a sharp increase in the open areas. Chir pine is a light demanding tree species and its regeneration could have to be better in the disturbed area where there was opening compared to the closed canopy of undisturbed area. The reason for less regeneration in the disturbed area could be because the area was heavily disturbed by developmental activities of hydropower projects and also heavily grazed by cattle. According to Dangwal and Tajinder (2012) the Chir pine regeneration decreased with the increasing anthropological activities in the forest area. The major anthropological activities they found were deforestation and overgrazing which resulted in loss of Chir pine regeneration. Tenzin (2008) also reported that heavy grazing decreased the regeneration of conifer.

The other reason could be because the disturbed areas were mostly in the absence of trees to produce seed for regeneration to prevail. Tenzin (2008) stated that natural regeneration strategies require maintaining genetically sound mother trees for seed production.

4.6 Relationship between presence and absence of WBH in the study area

In the present study, there was presence of WBH in the entire eight undisturbed site (100% presence) as shown in Table 4.4 and Figure. 4.5. However, in the 12 disturbed sites, there was presence of WBH in three sites (23% presence) and absence in nine sites (73% absence) (Figure. 4.5). This result showed that WBH preferred undisturbed site as habitat.

The statistical Pearson chi square test also showed significant association between the study area and presence of WBH, $\chi^2(1) = 10.91$, $p < .01$. The test indicated that WBH preferred undisturbed area over the disturbed area.

Table 4.4. Contingency table showing relationship between WBH presence and absence in the study area

Plot	WBH		Total
	Absence	Presence	
Undisturbed	0	8	8
Disturbed	9	3	12
Total	9	11	20

The result supported the finding of Eastern Himalayas (2013) that WBH preferred hill streams without disturbance. The study carried out by Eastern Himalayas was along hill streams and the finding of this study was from the study carried out along Punatshangchu. The findings from the two study areas confirm that WBH preferred undisturbed areas. Similarly, RSPN (2011) also confirms WBH preferring undisturbed areas by stating that the heron prefers to roost and breed in Chir pine forest which is undisturbed and inaccessible.

Eight WBH resided near the upper Phochu in Punakha before 2007 but all of them abandoned the area due to disturbance such as logging and quarrying (Kuensel, 2010), therefore the area was declared as protected area in 2007 to restore its habitat. At present three WBH are sighted in the upper Phochu.

The riverbed area of Punakha to Wangdue has been identified as an important WBH feeding site by the Government of Bhutan, and the area has been declared as a protected area to preserve the species (BirdLife International, 2011). The reason for declaring the riverbed area of Punakha to Wangdue could be to spare WBH undisturbed in the area for feeding. The purpose of declaring protected area is stated in (RGoB, 1995) as for the preservation of areas of natural beauty of national importance, protection of biological diversity, management of wildlife, conservation of soils and water. It could be due to disturbance free and the declaration of areas as protected that the BirdLife International (2011) sighted WBHs in numerous protected regions of north-eastern India, including the Kaziranga National Park and the Namdapha Tiger Reserve, where it was believed to breed. Conservation in these areas is planned and improved by creating buffer zones around the borders of the reserve to alleviate disturbances.

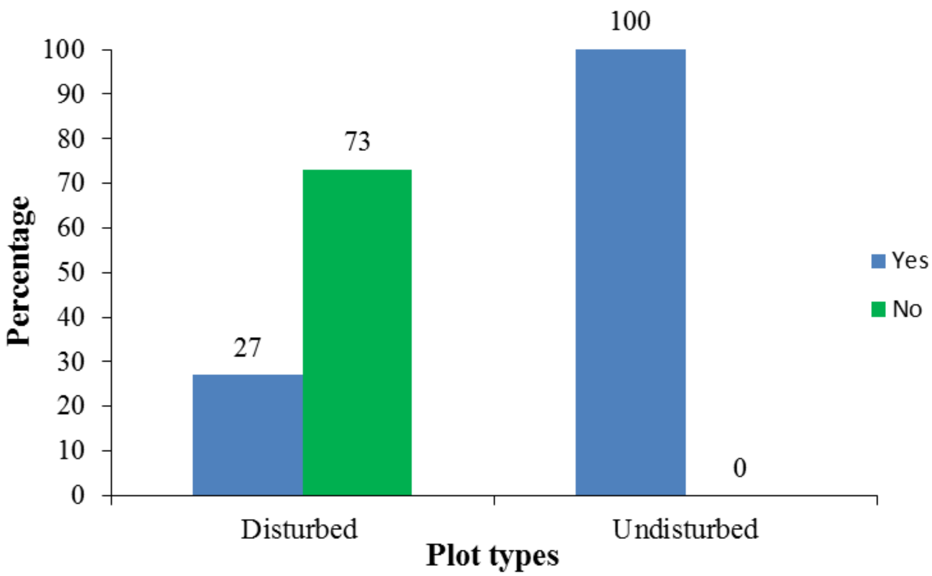


Figure 4.5. Percentage of presence and absence of WBH in undisturbed and disturbed sites

4.7 Land use change in the due to PHP

The total land use changed by the PHP increased significantly from its initial land use area (Figure 4.6). The maximum area of land use change was found at dump site I (Figure 4.7), where 104% of change prevailed and the minimum was found at the dump site II, where 80% of change prevailed. The rate of land use change in these areas was found to be 160.94 ha per year.

The areas of land use change measured in the study area were at the sites where major activities of PHP prevailed but area that would be submerged could not be measured. Therefore, the land use change area calculated for the PHP construction seems minimal when compared to the area EIA reported was 7619 ha required for the construction of 2560 megawatt Sankosh hydropower project. It is assumed that the construction of 1200 megawatt Punatshangchu hydropower project-I (Appendix XG, H, I & J) would require approximately 3500 ha of land. The change in land use will

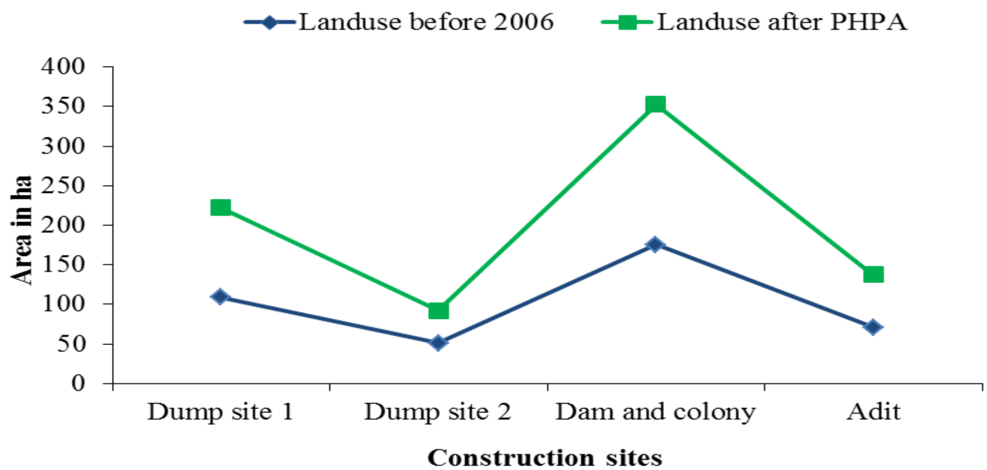


Figure 4.6. Land use change before 2006 and after PHPA

result in loss of existing vegetation in the area (Business Bhutan, 2013), hence also loss of the area occupied by WBH and cause habitat fragmentation.

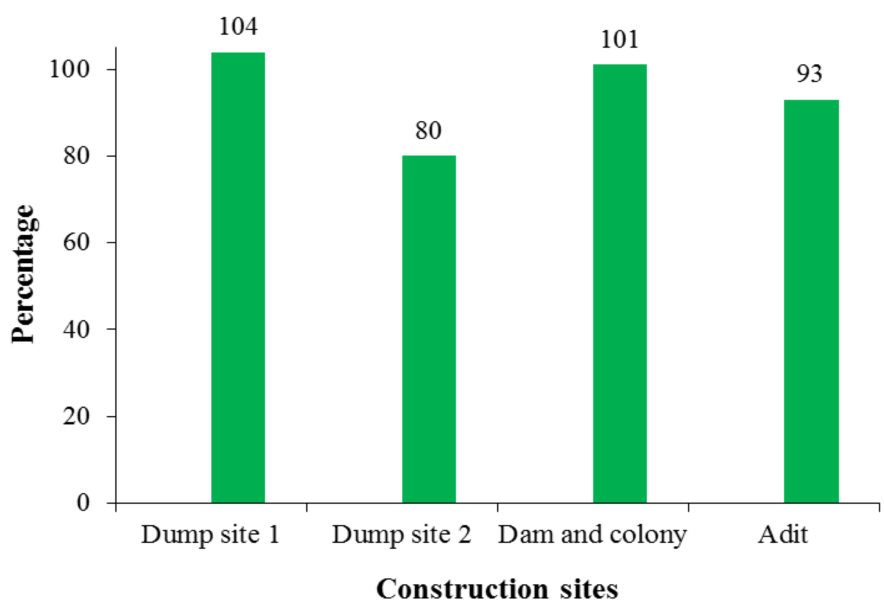


Figure 4.7. Land use increased in percentage at different construction sites after PHP

A large number of workers involved in dam construction (RSPN, 2011) require construction of more buildings in urban and rural parts to accommodate the population. The burgeoning human settlements along the Punatshangchu cause land use change. The human disturbance and land use change along Punatshangchu can impact the habitat and displace the WBH from the site.

Fearnside (1989) reported that the construction of the large Balbina hydroelectric plant in Brazil required 2,360 sq. km as it was located in flat area to produce 250 MW of power generating capacity. Flooding land for a hydroelectric reservoir impacted environment by destroying forest, wildlife habitat, agriculture land and scenic lands. BirdLife International (2001) reported that the hydropower project lead to major land use change. It impacted the provision of ecosystem services and biodiversity conservation (Polasky, 2010). The alteration of land use from natural to any other results in habitat loss, degradation, and fragmentation (Richard, 2001). Such devastations can have effect on WBH. According to Bierregaard (2001) the land use change is the single greatest cause of extinction of terrestrial species. Pandit *et al.*, (2007) has also reported that the deforestation due to multiple land use changes has resulted in species extinctions across various taxonomic groups in the Indian Himalaya.

4.8 Change in population of WBH

The population record of WBH since 2003 to 2014 shows the population trend over the time (Figure 4.8). Initially the RSPN had recorded the population of the bird as 14 individuals in 2003 but the record rose up to 30 in 2008 and 2009. There was an upward trend in the number of heron from 2003 to 2009 but the downward trend began from 2010**.**

Figure 4.8. Population of WBH declined after PHP major work began in 2010

The hydropower plant construction ground was broken in 2008 (Norbu, 2012), but the actual major construction phase began in 2010. With the commencement of the major construction work from 2010 the once stable population records of the WBH declined (Fig. 4.9). The critically endangered heron is even more endangered and is under grave threat of extinction due to accelerated development of PHP in the Punatshngchu basin (RSPN, 2011).

Some of the reasons associated with reducing population of WBH could be due to the construction boom to accommodate huge population of workers and the activities associated with the PHP which exacerbated disturbance to rivers from gravel and sand extraction flooding heron’s habitat (RSPN, 2011). Bhutan is home to about 10% of the world’s total population of WBH, but the PHP have destroyed some nesting habitat of the bird (BirdLife International, 2011). The size of the feeding habitat reduced due to development work, but predation on fishes increased and migration disturbed (Business Bhutan, 2011). Before herons used to get two to three fishes in an hour, but now the situation is such that the parent herons have to spent long hours looking for food which leaves the chicks without care for long time exposing them to predators (RSPN, 2011). The predators such as serpent eagle, pallas fish eagle, osprey, yellow throated martin and some small cats prey on the chicks of the WBH (Business Bhutan, 2011).

The hydroelectric power developments and road improvements in Bhutan have resulted in significant habitat degradation of WBH (Duckworth, 2006). The effects of the development are displacing all the birds and animals from their usual habitat along Punatshangchu to inner valleys and along the small streams due to increased competition for food (Business Bhutan, 2011). Habitat degradation and increased competition for food could affect the population of WBH.

The other reason affecting the population of the birds is the disturbances caused by bird watchers, mostly by conservationist and visitors who kept visiting the area on regular basis to take photographs and monitor the nesting site (Dorji, 2013). The eggs in the nest at Burichu could not be hatched regardless of the breeding pairs sitting on the nest till the end of June 2013. The reason for the failure was assumed to be the disturbance by vehicular noise that caused stress to bird sitting on the eggs unable to maintain constant temperature required for incubation.

The population of WBH may be declined owing to PHP because the Punatsangchhu river basin is the largest habitat for WBH in Bhutan. If there was no disturbance in their habitat, the population would have either remained stable or increased with the passage of time as before.

Although the only resource that can take care of our country's future is hydropower, the survival for WBH will be decided by the availability for it to feed, roost and breed in the Punatshangchu basin.

CHAPTER FIVE

Conclusion

The community of floristic composition, dominance, diversity, density and regeneration responded to anthropogenic disturbances and land use change caused by PHP. There was more species diversity and richness in the disturbed area compared to the undisturbed area. Although both the study areas were dominated by herbs, grass was second dominant species in the disturbed area while shrub in the undisturbed. The regeneration numbers was more in the undisturbed area. Therefore, there is difference in floristic composition and diversity in the habitat of WBH. The preferred habitat of WBH was found to be the undisturbed area from the study.

The study carried in the PHP area showed major land use change along Punatshangchu basin when compared to land use before 2006. The average land use change in different sites increased along Punatshangchu by 94% after the PHP. If the survey was carried out considering land use change prevailed by construction of building to accommodate people working for the project and the resources it used, the rate of change per year would be even greater. The land use change gravely contributed to the degradation of WBH's habitat and posed threat to its survival in the area. Considering the fact of the land use change by hydropower project from other researchers, it could be the main cause of WBH population declination from 2010 – 2014.

The difference in floristic composition in the disturbed and undisturbed study areas indicated prevalence of vegetation change due to land use change and anthropogenic disturbances. Therefore, in the future researchers should invest more time and resources to study on vegetation change, which could lead to habitat change and loss of biodiversity. The government and DoFPS should monitor and take into account the disturbances and land use change while framing management plans.

People should be created awareness on WBH being critically endangered bird by conducting workshops, disseminating the information on television channels, broadcasting in radio and erecting sign boards. Poaching of the bird should be strictly monitored and strong law enforcement should be in place.

References

Baillie, J. E. M. & Butcher, E. R. (2012). Priceless or Worthless? Zoological Society of London.

Barlow, J., Gardner, T. A., Araújo, I. S., Ávila-Pires, T. C., Bonaldo, A. B., Costa, J. E.,Esposito, M. C., Ferreira, L. V., Hawes, J., Hernandez, M. I. M., Hoogmoed, M. S.,Leite, R. N., Lo-Man-Hung, N. F., Malcolm, J. R., Martins, M. B., Mestre, L. A. M.,Miranda-Santos, R., Nunes-Gutjahr, A. L., Overal, W. L., Parry, L., Peters, S. L.,Ribeiro-Junior, M. A., Silva, M. N. F., Silva Motta, C. & Peres, C. A. (2007a). Quantifyingthe biodiversity value of tropical primary, secondary, and plantation forests. *PNAS.* **104:**18555–18560.

Battles, J. J., Shlisky, A. J., Barrett, R. H., Heald, R. C. & Allen-Diaz, B. H. (2000). The effectsof forest menegeement on plant species diversity in a Sierran conifer forest. Forest Ecology and Management. **146(2001):** 211-222.

Beese, W. J. (1999). Effect of alternative silvicultural systems on vegetation and bird communities in coastal montane forests of British Columbia, Canada. Forest Ecology and Management. **115(2-3):** 231–242.

Bierregaard, R., Claude, G., Thomas E., Lovejoy & Rita M. (2001). *The ecology and conservation of a Fragmented Forest*. Amazonia.

Binelli, E. K., Henry L., Gholz, H. L. & Duryea, M. L. (2012). *Plant succession and disturbances in the urban forest ecosystem.* USA: University of Florida.

BirdLife International. (2013). Species factsheet: Ardea insignis. < http://www.birdlife.org>. Accessed 1 October 2013.

BirdLife International. (2011). Species factsheet: Ardea insignis. < http://www.birdlife.org>. Accessed 1 October 2013.

BirdLife International. (2001). *Threatened birds of Asia: the BirdLife International Red Data Book.* BirdLife International. U.K.: Cambridge.

Bishop, K. D. (2012). Bhutan highlights. Victor Emanuel nature tours, Inc. 2525 Walling wood Drive, Suite 1003 Austin.

Business Bhutan. (2013). Sankosh to have serious implication on environment. <http://www.businessbhutan.bt/?p=11108. Accessed 13 August 2013.

Business Bhutan. (2011). The future is black for the white-bellied heron. <http://www.businessbhutan.bt/?p=11108>. Accessed 13 August 2013.

Busing, R. T. (1994). Canopy cover and tree regeneration in old-growth cove forests of the Appalachian mountains. Vegetation. **115:** 19 – 27.

Carney, K. M. & Sydeman, W. J. (1999). A review of human disturbance effects on nesting colonial waterbirds. *Waterbirds.* **22:** 68-79.

Connell, J. H. (1978). Diversity in tropical rain forests and coral reefs. *Science*. 1**99:** 1302-1310.

Dangwal, L. R. & Tajinder, S. (2012). Comparative vegetational analysis and *Pinus* competition in a forest management unit in Western Bhutan. Bhutan: Thimphu.

Decocq, G., Aubert, M. & Dupont, F. (2004). Plant diversity in a managed temperate deciduous forest: understorey response to two silvicultural systems. Journal of Applied Ecology. **41:** 1065–1079.

DoL. (2008). Proposal for fish conservation measures at PHPA dam Sites. Ministry of Agriculture. Bhutan: Thimphu.

Dorji, J. (2013). WBH: no hatching in 2013. Ministry of Agriculture and Forests. <http://www.moaf.gov.bt/moaf/?p=16160> Accessed 20 November 2013.

Duckworth, J. W. (2006). *Wildlife conservation society Asia programme.* USA: New York.

Eastern Himalayas. (2013). Saving the white-bellied heron from extinction. <http://atree.org/newsletters/eastern_himalayas/EHP_Newsletter2.1.pdf>. Accessed 22 January 2014.

Elliott, K. J., Boring, L. R., Swank, W. T. & Haines, B. R. (1997). Successional changes in plant species diversity and composition after clearcutting a southern Appalachian watershed. Forest Ecology and Management. **92:** 67-85.

Ewel, J. J. (1986). Invasibility: Lessons from South Florida. In *Eecology of biological invasions of North America and Hawaii,* edited by H. A. Mooney and J. A. Drake. Berlin, Germany: Springer-Verlag.

Ewers, R. M. & Didham, R. K. (2006). Confounding factors in the detection of species responses to habitat fragmentation. *Biol. Rev*. **81:** 117–142.

Fahrig, L. (2003). Effects of habitat fragmentation on biodiversity. *Annu. Rev. Ecol. Evol. Syst.* **34:** 487–515.

FAO. (2010). *Global forest resources assessment 2010.* FAO, Rome.

Fearnside, P. M. (1989). Brazil's Balbina Dam: Environment versus the legacy of the Pharaohs in Amazonia. Environmental Management. **13(4):** 401-423.

Ferguson, J. W., Absolon, R. F., Carlson, T. J. & Sandford, B. P. (2006). Evidence of delayed mortality on juvenile Pacific salmon passing through turbines at Columbia River Dams. *Transactions of the American Fisheries Society***. 135 (1):**139-150.

Gill, J. A., Norris, K. & Sutherland, W. (2001). Why behavioural responses may not reflect the population consequences of human disturbance. *Biological Conservation*. **97:** 265-268.

Grierson, A. J. C. & Long, D. G. (1993). *Flora of Bhutan (Vol. 1 part 1)*. London: Royal Botanic Garden, Edinbrugh.

Grierson, A. J. C., Long, D. G. & Springate, L. S. (2001). *Flora of Bhutan including a record of plants from Sikkim and Darjeeling.* **Vol. 2**, Pt. 3. UK: Royal Botanic Garden, Edinburgh.

Hancock, J. (1990). *The heron's handbook.* London, England: Christopher Helm Publishers Ltd.

Harrison, S. & Bruna, E. (1999). Habitat fragmentation and large-scale conservation: what do we know for sure? *Ecography*. **22:** 225–232.

Hume, O. A. (1878). *Conservation of WBH Ardea insignis habitat in Namdapha national park*, India: Namdapha National Park, Arunachal Pradesh.

IUCN. (2008). White-bellied Heronn. Iinternational Union for Cconservation of Nature 2008 RedList. http://www.birdlife.org/datazone/search/species.search.hmtl?action.spcHTMDetails.asp&sid=3723&m=0> Accessed 12 October 2013.

Johnson, W.C. (1992). Dams and riparian forests: case study from the Upper Missouri River. *Rivers.* **3:** 229–242.

Joppa, L. N., Roberts, D .L. & Myers, N., Pimm, S.L. (2011). Biodiversity hotspots house most undiscovered plant species. *PNAS*. **108:** 13171–13176

Kuensel. (2010). White-bellied heron the highly endangered bird is losing its habitat. <http://www.bhutanmajestictravel.com/news/2010/white-bellied-heron-the-highly-endangered-bird-is-losing-its-habitat.html>. Accessed 22 January 2014.

Kushlan, J. A. (2007). Conserving Herons, a conservation action plan for the Herons of the world. *Heron specialist group and station biologique de la tour du valet.* France: Arles.

Kushlan, J. A. & Hancock, J. (2005). *Herons: bird families of the world*. UK: Oxford University Press.

Laurance, W. F. & Bierregaard, R. O. (1997). Ecosystem decay of Amazonian forest fragments: a 22-year investigation. *Conservation Biology*. **16:** 605–618.

Li, Z., Zhang, Z. W. & Wang, Y. J. (2012). Influence of anthropogenic disturbance on understory plant diversity of urban forest in Wuhan, Central China. *Sains Malaysiana*. **41(12).**

Liang, Y. Q. (2012). Influence of land use change on vegetation cover dynamics in Dapeng Peninsula of Shenzhen, Guangdong Province of South China. <http://www.ncbi.nlm.nih.gov/pubmed/22489500>. Accessed 20 January 2014.

Marcial, N. R., Espinosa, G. M. & Guadalupe, W. G. (2011). Anthropogenic disturbance and tree diversity in Montane Rain Forests in Chiapas, Mexico. Forest Ecology and Management. **DOI:** 10.

McKinney, M. L. (2002). Urbanization, biodiversity, and conservation. BioScience. **52(10):** 883-890.

MINEO (2000). Review of potential environmental and social impact of mining. <http://www2.brgm.fr/mineo/UserNeed/IMPACTS.pdf>. Accessed 13 November 2013.

Norbu, P. (2012). Punatshabgchu I & II: Ahead of schedule. Kuensel. <http://www.raonline.ch/pages/bt/ecdu/bt_ecohydel0105.html.>. Accessed 13 August 2013.

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

Palmer, M. W., McAlister, S. D., Arevalo, J. R. & DeCoster, J. K. (2000). Changes in the understory during 14 years following catastrophic wind throw in two Minnesota forests. Journal of Vegetation Science. **11:** 841-854.

Pandit, M. K., Sodhi, N.S., Koh, L. P., Bhaskar, A. & Brook, B. W. (2007). Unreported yet massive deforestation driving loss of endemic biodiversity in Indian Himalaya. Biodiversity Conservation. **16:**153–163.

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

Parker, C. (1991). *A first manual of Bhutan weeds*. Bhutan: Department of Agriculture, Research and Extension Division.

Pickett, S. T. A. & White, P. S. (1985). *The ecology of natural disturbance and patch dynamics*. New York: Academic Press, Inc.

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

Polasky, S., Pennington, D. & Johnson, K. A. (2010). *The impact of land use change on ecosystem services, biodiversity and returns to landowners.* USA: University of Minnesota.

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

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

Richard, B. (2001). *The Ecology and Conservation of a Fragmented Forest*. UK: Yale University Press.

RSPN. (2013). RSPN members marked international biodiversity day. *Rangzhin.* **6(2):** 3.

RSPN. (2011). *The critically endangered WBH*. Thimphu: Bhutan: Royal Society for Protection of Nature.

Simpson, K. (1984). *Factors affecting reproduction in Great Blue Herons (Ardea herodias).* Columbia: University of British.

Tenzin, K. (2008). *Regeneration and gap dynamics in mixed conifer forests of the Bhutan Himalayas*. Vienna: Institute of Forest Ecology.

Tordoff, A. W., Appleton, T., Eames, J. C., Eberhardt, K., Htin, H., Khin, M. M. T., Sao, M., Zaw, S. M. & Sein, M. A. (2006). *Avifaunal surveys in the lowlands of Kachin state, Myanmar (2003–2005).* Myanmar: Nat. Hist. Bull.

Wang, D., Zhao, C., Cheng, H., Gong, L., Hao, F. & Shi, X. (2008). *Temporal-spatial dynamic characteristic of vegetation in the area of cascade hydropower station construction in the upper reach of the Yellow River.* China: Beijing Normal University.

Wangda, P. (2003). *Forest Zonation Along the Complex Altitudinal Gradients dry Valley of Punatsang Chu, Bhutan*. Japan: The University of Tokyo.

Watt, A. S. (1971). Rare species in Breckland, their management for survival. Journal of Applied Ecology. **8:** 593-609.

West, A. D., Goss-Custard, J. D., Stillman, R. A., Caldow, R. W. G. & Durrell, S.E.A. (2002). Predicting the impacts of disturbance on shorebird mortality using a behaviour- based model. Biological Conservation. **106:** 319-328.

Zimmer, C., Boos, M., Petit, O. & Robin, J. P. (2010). Body mass variations in disturbed mallards Anasplatyrhynchos fit to the mass dependent starvation-predation risk trade-off. *Journal of Avian Biology*. **41:** 637-644.

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

Appendices I: Basal Measurement (above 10 cm)

Transect No. ___________________________ Plot No. ______________________

Co-ordination for the Plot centre North _______________________________________

South _______________________________________

Location ____

Date ___________________________________ Altitude ____________________________

Sl. No.	Spp. Name	DBH (cm)	Height (m)	Ephiphyte ++	Transect /Plot	LF	LB

Enumerator _______________________________________

Field Team ____

Appendices II: Shrub

Measurement %

Transect No. ____________________________ Plot No. ________________________

Co-ordination for the Plot centre North ____

South ____

Location ____

Date ____________________________________ Altitude _____________________________

Sl. No.	Spp. Name	No.	%	Plot No.	Remarks

Enumerator _____________________________________

Field team ______________________________________

Appendices III: Herbs

Measurement %

Transect No. ____________________________ Plot No. _______________________

Co-ordination for the Plot centre North ____

South ____

Location ____

Date ____________________________________ Altitude _____________________________

Sl. No.	Spp. Name	No.	%	Plot No.	Remarks

Enumerator _____________________________________

Field team ______________________________________

Appendices IV: Basal Measurement (below 10 cm)

Transect No. ___________________________ Plot No. ______________________

Co-ordination for the Plot centre North _______________________________________

South _______________________________________

Location ____

Date ___________________________________ Altitude ____________________________

Plant No.	Spp. Name	DBH (cm)	Height (cm)	Remarks

Enumerator ____

Field Team ____

Appendix V: Non- parametric chi square test for WBH presence in types of plots

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	10.909[a]	1	.001		
Continuity Correction[b]	8.089	1	.004		
Likelihood Ratio	14.030	1	.000		
Fisher's Exact Test				.001	.001
N of Valid Cases[b]	20				

a. 2 cells (50.0%) have expected count less than 5. The minimum expected count is 3.60.

b. Computed only for a 2x2 table

Appendix VI: Independent t test for the variables of ground vegetation

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
diversity	Equal variances assumed	.657	.425	1.358	25	.187	.18882	.13902	-.09750	.47514
	Equal variances not assumed			1.442	22.521	.163	.18882	.13092	-.08232	.45997
richness	Equal variances assumed	2.053	.164	-1.612	25	.119	-2.32353	1.44126	-5.29186	.64480
	Equal variances not assumed			-1.401	12.455	.186	-2.32353	1.65898	-5.92356	1.27650

Appendix VII: Independent t test for the variables of trees

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
density	Equal variances assumed	1.716	.207	-1.462	18	.161	-1.79167	1.22565	-4.36666	.78333
	Equal variances not assumed			-1.345	11.084	.205	-1.79167	1.33179	-4.72020	1.13687

Appendix VIII: Floristic composition of all the ground vegetation in the disturbed habitat site.

Plot ID	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
Altitude (m)	1251	1265	1268	1274	1254	1270	1309	1309	1260	1293
Relative Dominance %	RD%	RD %	RD %	RD %	RD %	RD %	RD %	RD %	RD %	RD %
Perennial herb	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10
Artemisia vulgaris	28.2	42.1	42.6	10.7	6.3		2.0	6.5	14.8	8.3
Eupatorium adenophorum	23.2	2.5	3.2	14.9			6.3	25.3		2.6
Clinopodium umbrosum	3.6	4.4	4.1		7.2	3.3		2.9		0.9
Oxalis latifolia		0.5	0.6	0.7	4.8	1.5	0.1	0.3		0.1
Centella asiatica		0.4								
Gnaphalium affine									26.9	
Artemisia spp										0.2
Persicaria pubesceus										
Oxalis corniculata										
Acmella uliginosa										
Sub-total	**55.0**	**49.9**	**50.5**	**26.3**	**18.3**	**4.7**	**8.5**	**35.0**	**41.8**	**12.0**
Annual herb										
Euphorbia hirta	7.3									
Sonchus oleraceus	7.3									

Conyza floribunda	1.8									
Siegesbeckia orientalis		16.4								
Sonchus asper		11.2	0.5	5.8		5.1		4.9		
Ageratum conyzoides		1.6	1.5		7.2	5.1		5.2		
Solanum khasianum			0.4		1.0					
Cassia occidentalis				3.3	6.7	34.0		27.4		
Verbuscum thapsus					3.4				0.3	0.1
Sonchus deraceus					2.9					
Cerastium glomeratum						2.8				
Sonchus conyzoides							64.3		1.0	
Acanthospermum hispidum							27.3	7.9		
Spergula arvensis										
Tagetes minuta										
Solanum americanum										
Capsella bursa-pastoris										
Amaranthus viridis										
Sub-total	**16.4**	**29.3**	**2.4**	**9.1**	**21.2**	**47.0**	**91.5**	**45.4**	**1.3**	**0.1**

Note: All species were categorized into life-form of perennial herb, annual herb, shrub, fern, climber and grass. D1, D2… represent disturbed plots and C1, C2… represent undisturbed plots of the study area. RD% represents relative dominance of the species and it is represented by shaded in the table 4.1.

Plot No.	D11							
Altitude	1336	1320	1351	1231	1336	1231	1223	
Relative Dominance%	RD %	RD %	RD %	RD %	RD %	RD %	RD%	
Perennial herb								
Artemisia vulgaris	45.8	2.1	22.7	24.7	42.8	31.0	46.1	376.8
Eupatorium adenophorum	15.0				1.4	2.3	8.8	105.5
Clinopodium umbrosum								26.5
Oxalis latifolia								8.6
Centella asiatica								0.4
Gnaphalium affine		0.5	0.3	0.6	0.3			28.6
Artemisia spp								0.2
Persicaria pubesceus			5.7					5.7
Oxalis corniculata			0.2					0.2
Acmella uliginosa						0.6		0.6
Sub-total	**60.8**	**2.7**	**28.9**	**25.3**	**44.5**	**33.9**	**54.8**	**553.1**
Annual herb								

Euphorbia hirta								7.3
Sonchus oleraceus								7.3
Conyza floribunda			0.2		0.1	1.3	0.2	3.6
Siegesbeckia orientalis								16.4
Sonchus asper				2.0		2.1	0.4	32.1
Ageratum conyzoides						0.7		21.4
Solanum khasianum						4.7		6.1
Cassia occidentalis						27.5		98.9
Verbuscum thapsus								3.8
Sonchus deraceus								2.9
Cerastium glomeratum								2.8
Sonchus conyzoides								65.3
Acanthospermum hispidum								35.2
Spergula arvensis			9.3					9.3
Tagetes minuta			8.3					8.3
Solanum americanum			4.9	5.5				10.4
Capsella bursa-pastoris			2.3	10.2	0.6	2.1	1.0	16.1
Amaranthus viridis					6.3			6.3
Xanthium indicum					3.1			3.1
Cannabis sativa					1.2			1.2
Amaranthus hybridus							0.6	0.6
Solanum nigrum							0.3	0.3
Ipomoea purpurea				0.3				0.3
Sub-total	**0.0**	**0.0**	**24.9**	**18.0**	**11.2**	**38.3**	**2.5**	**358.7**

Plot ID	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
Altitude	1251	1265	1268	1274	1254	1270	1309	1309	1260	1293
Relative Dominance %	RD%	RD %	RD %	RD %	RD %	RD %	RD %	RD %	RD %	RD %
Shrub										
Luculia gratissima	6.0									
Desmodium elegans	3.0									1.4
Desmodium triflorum		1.4			4.3					
Indigofera cassioides		0.3	33.0			43.3				
Sida rhombifolia		0.3								
Sida acuta			0.9							
Indigofera dosua				51.4						6.2
Berberis asiatica										6.7
Lespedeza juncea										1.3
Osyris lanceolata										

Murray koenigii										
Buddleja asiatica										
Desmodium renifolium										
Trema politoria										
Barleria cristata										
Adhotoda vasica								5.3		
Sub-total	**9.0**	**2.1**	**33.9**	**51.4**	**4.3**	**43.3**	**0.0**	**5.3**	**0.0**	**15.6**
Fern										
Pteridium aquilinium	0.5									0.1
Equisetum diffusum									2.4	
Pteris vittata										
Pteridium revolutum										
Sub-total	**0.5**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.4**	**0.1**
Climbar										
Argyreia roxburghii				0.3		0.9				
Sub-total	**0.0**	**0.0**	**0.0**	**0.3**	**0.0**	**0.9**	**0.0**	**0.0**	**0.0**	**0.0**
Grass										
Imperata cylindrica	11.9									
Cynoglossum furcatum	5.0									
Paspalum scrobiculatum	2.2	6.3						2.1		
Oplismenus burmannii		6.7	7.7	9.1	12.5			8.8		
Paspalum distichum		5.7	3.4	2.6		2.3				
Alopecurus aequalis			2.1		4.6				4.7	0.1
Brachiaria ramosa				1.2						
Fimbristylis littoralis					39.0	1.3				0.5
Eleusine indica						0.5		3.4		

Plot ID	**D11**	**D12**	**D13**	**D14**	**D15**	**D16**	**D17**	**Total**
Altitude	1336	1320	1351	1231	1336	1231	1223	
Relative Dominance%	RD %	RD %	RD %	RD %	RD %	RD %	RD%	
Shrub								
Luculia gratissima								6.0
Desmodium elegans	2.9	2.8						10.1
Desmodium triflorum								5.8
Indigofera cassioides								76.6
Sida rhombifolia								0.3
Sida acuta	0.2					2.1		3.1
Indigofera dosua								57.6
Berberis asiatica	7.1	19.3						33.2

Lespedeza juncea								1.3
Osyris lanceolata	2.4							2.4
Murray koenigii	1.3							1.3
Buddleja asiatica			13.3	28.0				41.3
Desmodium renifolium						1.0		1.0
Trema politoria						0.6		0.6
Barleria cristata		0.5						0.5
Adhotoda vasica								5.3
Sub-total	**14.0**	**22.6**	**13.3**	**28.0**	**0.0**	**3.7**	**0.0**	**246.3**
Fern								
Pteridium aquilinium							1.1	1.8
Equisetum diffusum								2.4
Pteris vittata							0.8	0.8
Pteridium revolutum							0.7	0.7
Sub-total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.7**	**5.7**
Climber								
Argyreia roxburghii								1.1
Sub-total	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	1.1
Grass								
Imperata cylindrica								11.9
Cynoglossum furcatum			2.7		43.4	0.5		51.7
Paspalum scrobiculatum								10.6
Oplismenus burmannii	9.0	5.5			0.8	1.8		62.0
Paspalum distichum								14.1
Alopecurus aequalis								11.6
Brachiaria ramosa								1.2
Fimbristylis littoralis								40.8
Eleusine indica			27.1	20.5				51.5

Plot ID	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**
Altitude	1251	1265	1268	1274	1254	1270	1309	1309	1260	1293
Relative Dominance %	RD%	RD %	RD %	RD %	RD %	RD %	RD %	RD %	RD %	RD %
Grass										
Cymbopogon spp									49.8	71.5
Arthraxon lancifolium										
Dactylotenium aegyptium										
Pennisetum flaccidum										
Poa annua										
Setaria pumila										

Digitaria ternate										
Sub-total	**19.1**	**18.8**	**13.2**	**12.9**	**56.1**	**4.1**	**0.0**	**14.3**	**54.6**	**72.1**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Plot ID	**D11**	**D12**	**D13**	**D14**	**D15**	**D16**	**D17**	**Total**
Altitude	1336	1320	1351	1231	1336	1231	1223	
Relative Dominance%	RD %	RD %	RD %	RD %	RD %	RD %	RD%	
Grass								
Cymbopogon spp	9.1	69.2					38.4	238.0
Arthraxon lancifolium	7.1							7.1
Dactylotenium aegyptium			1.6			18.7		20.3
Pennisetum flaccidum			1.4	6.9			0.8	9.1
Poa annua			0.1	1.4				1.5
Setaria pumila						3.1		3.1
Digitaria ternate							0.8	0.8
Sub-total	**25.2**	**74.7**	**32.9**	**28.8**	**44.2**	**24.1**	**40.0**	**535.1**
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	

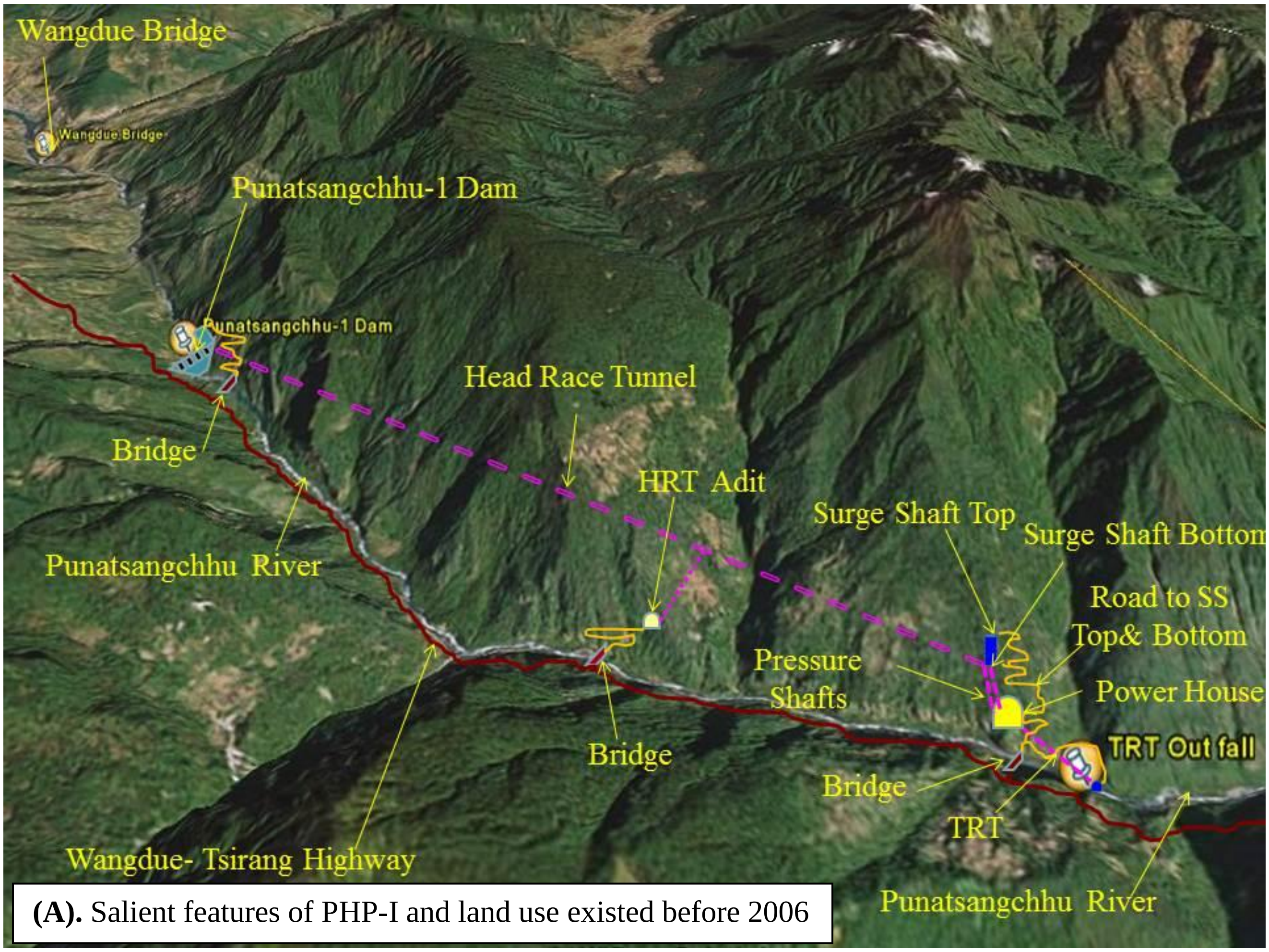
Appendix IX: Floristic composition of all the ground vegetation in the undisturbed habitat site

Plot ID	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	Total
Altitude	**1262**	**1310**	**1278**	**1291**	**1295**	**1345**	**1353**	**1386**	**1295**	**1308**	
Relative Dominance %	RD %	RD %	RD %	RD %	RD %	RD%	RD %	RD %	RD %	RD%	
Perennial herb											
Artemisia vulgaris	32.3	3.4	11.9	57.7	52.6	7.2	25.8	2.3	51.7	74.6	319.5
Oplismenus burmannii	18.4			4.1		0.8	11.3	6.0		1.3	41.9
Clinopodium umbrosum	9.6	41.2		1.8	0.6						53.2
Oxalis latifolia	1.8		0.3	0.2	0.2						2.5
Centella asiatica	0.2										0.2
Cynoglossum furcatum		5.8							0.1	2.3	8.2
Eupatorium adenophorum		2.4	14.0	8.8	10.0	12.1	0.8	0.9			48.9
Gerbera piloselloides						0.0		0.0			0.1
Artemisia sp.							1.0	0.8		1.3	3.1
Gnaphalium affine							0.2		0.1	0.8	1.1
Oxalis corniculata									0.3	0.5	0.8
Anisochilus sp.										1.3	1.3
Sub-total	**62.4**	**52.9**	**26.2**	**72.5**	**63.4**	**20.0**	**39.2**	**9.9**	**52.2**	**82.2**	480.8

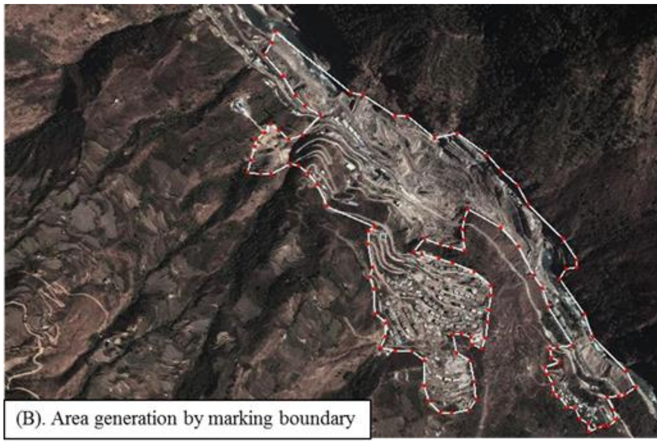
Annual herb											0.0
Sonchus asper	22.6	11.4							0.5		34.5
Cerastium glomeratum	5.9			0.7							6.6
Conyza floribunda	0.1					0.5	0.3	0.1	0.1	1.3	2.4
Cassia occidentalis		24.0									24.0
Acanthospermum hispidum		0.8									0.8
Verbuscum thapsus			4.1	0.1							4.2
Euphorbia heterophylla				1.8							1.8
Ageratum conyzoides									26.4	4.4	30.8
Solanum khasianum									11.0		11.0
Cyperus iria									2.5		2.5
Capsella bursa-pastoris									1.4	2.6	4.0
Amaranthus hybridis									1.3		1.3
Chenopodium album									0.7		0.7
Sonchus oleraceus									0.3		0.3
Strobitanthes sp.									0.1		0.1
Amaranthus viridis									0.1	1.1	1.2
Solanum nigrum									0.1		0.1
Spergularia sp.									0.1		0.1
Euphorbia hirta										0.5	0.5
Sub-total	**28.6**	**36.2**	**4.1**	**2.7**	**0.0**	**0.5**	**0.3**	**0.1**	**44.5**	**9.9**	126.9
Shrub											0.0
Desmodium triflorum	0.7										0.7
Sida rhombifolia	0.3	2.1									2.4
Lespedeza juncea	0.3		3.7	0.3	5.4						9.8
Desmodium elegans		8.9	2.6			2.4	5.3	0.3	0.2		19.6
Berberis asiatica			56.2		28.8	17.5	22.9	40.5			165.9
Jasminium grandiflorum			5.1					0.4			5.5
Leptodermis amoena			0.9								0.9
Indigofera dosua				1.7		15.9	6.4	6.6	0.5		30.9
Desmodium uncinatum					1.3						1.3
Duhaldea cappa						1.4	0.7				2.1
Phyllanthus officinalis							12.7	25.0			37.7
Sida acuta							0.7	0.2		1.6	2.5
Barleria cristata							0.2	0.6		2.4	3.2
Boehmeria sp.									0.5		0.5
Campylotropis griffithii									0.1		0.1
Sub-total	**1.3**	**11.0**	**68.4**	**1.9**	**35.6**	**37.3**	**48.9**	**73.6**	**1.2**	**4.0**	283.1
Fern											0.0

Pteridium aquilinum	1.2		1.3								2.5
Sub-total	**1.2**	**0.0**	**1.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	2.5
Climber											0.0
Argyreia roxburghii				1.4	1.0						2.4
Stephania elegans				0.5							0.5
Climatis buchananiana								0.6			0.6
Sub-total	**0.0**	**0.0**	**0.0**	**1.8**	**1.0**	**0.0**	**0.0**	**0.6**	**0.0**	**0.0**	3.4
Grass											0.0
Anthraxon quartianus	6.5										6.5
Cymbopogon sp.				15.1		7.7	9.4	15.9			48.1
Paspalum scrobieulatum				5.9							5.9
Arthraxon lancifolium						32.1					32.1
Urochloa ramosa						2.4					2.4
Cymbopogon marginatus							2.2				2.2
Dactylotenium aegyptium									1.0		1.0
Eleusine indica									0.9	2.5	3.4
Pennisetum flaccidum									0.2		0.2
Phalaris minor										1.5	1.5
Sub-total	**6.5**	**0.0**	**0.0**	**21.0**	**0.0**	**42.2**	**11.6**	**15.9**	**2.1**	**4.0**	103.3
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	

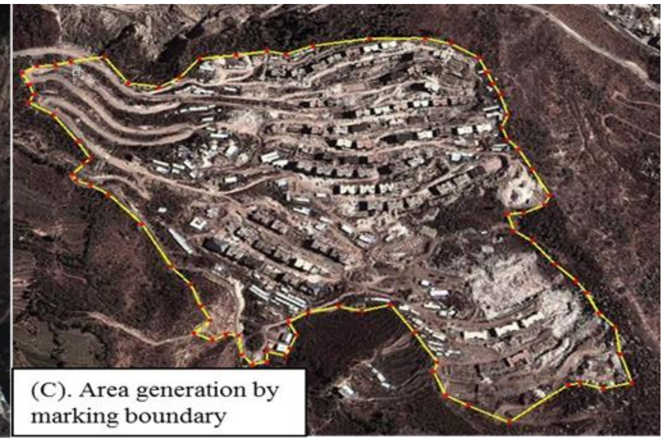
Appendix X: Photographs



(A). Salient features of PHP-I and land use existed before 2006

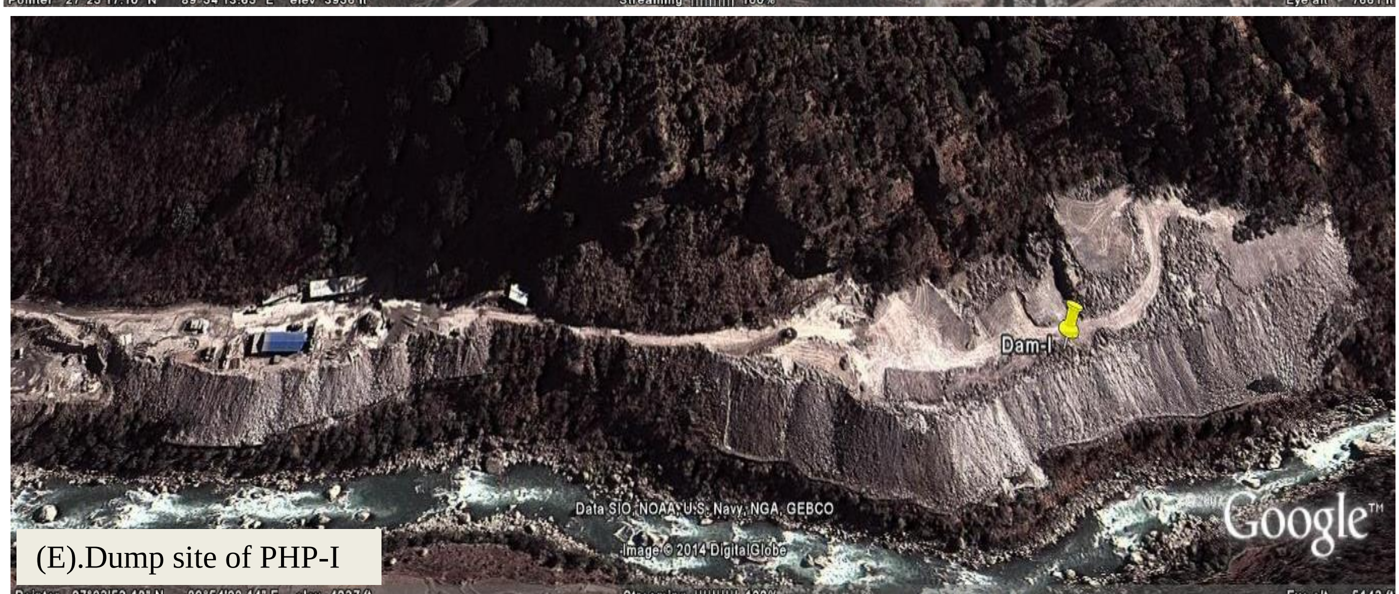


(B). Area generation by marking boundary

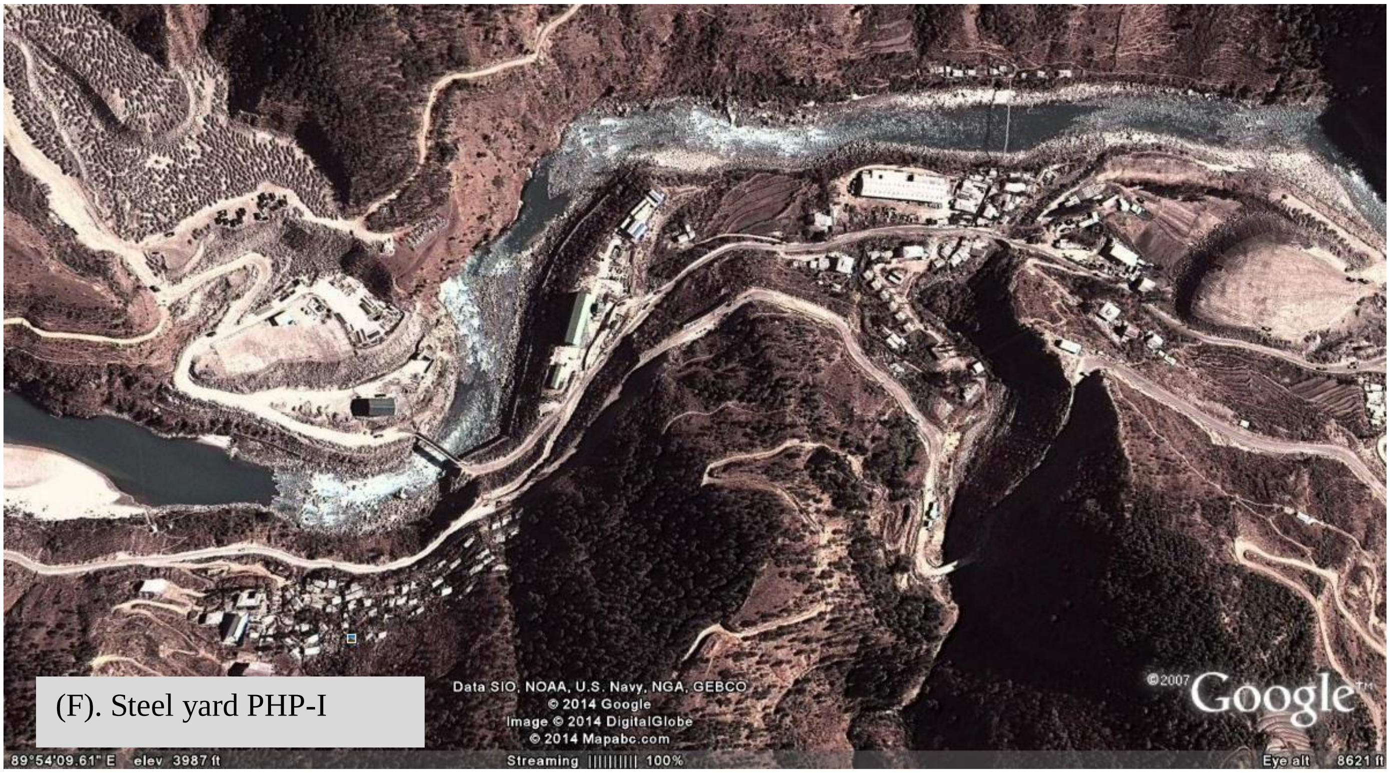


(C). Area generation by marking boundary

(D). Land use change at PHP Dam-I



(E).Dump site of PHP-I



(F). Steel yard PHP-I

(G). After river diversion


(H). Tunnel construction


(I). Clearance of vegetation


(J). Land use change