भारतीय वन्यजीव संस्थान
Wildlife Institute of India

ASSESSMENT OF HABITAT USE BY BLACK-NECKED CRANE (*Grus Nigricollis*)

AND EFLOWS OF
NYAMJANG CHU
HYDROELECTRIC
PROJECT IN
TAWANG DISTRICT,
ARUNACHAL PRADESH

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C O N T

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Photo credits
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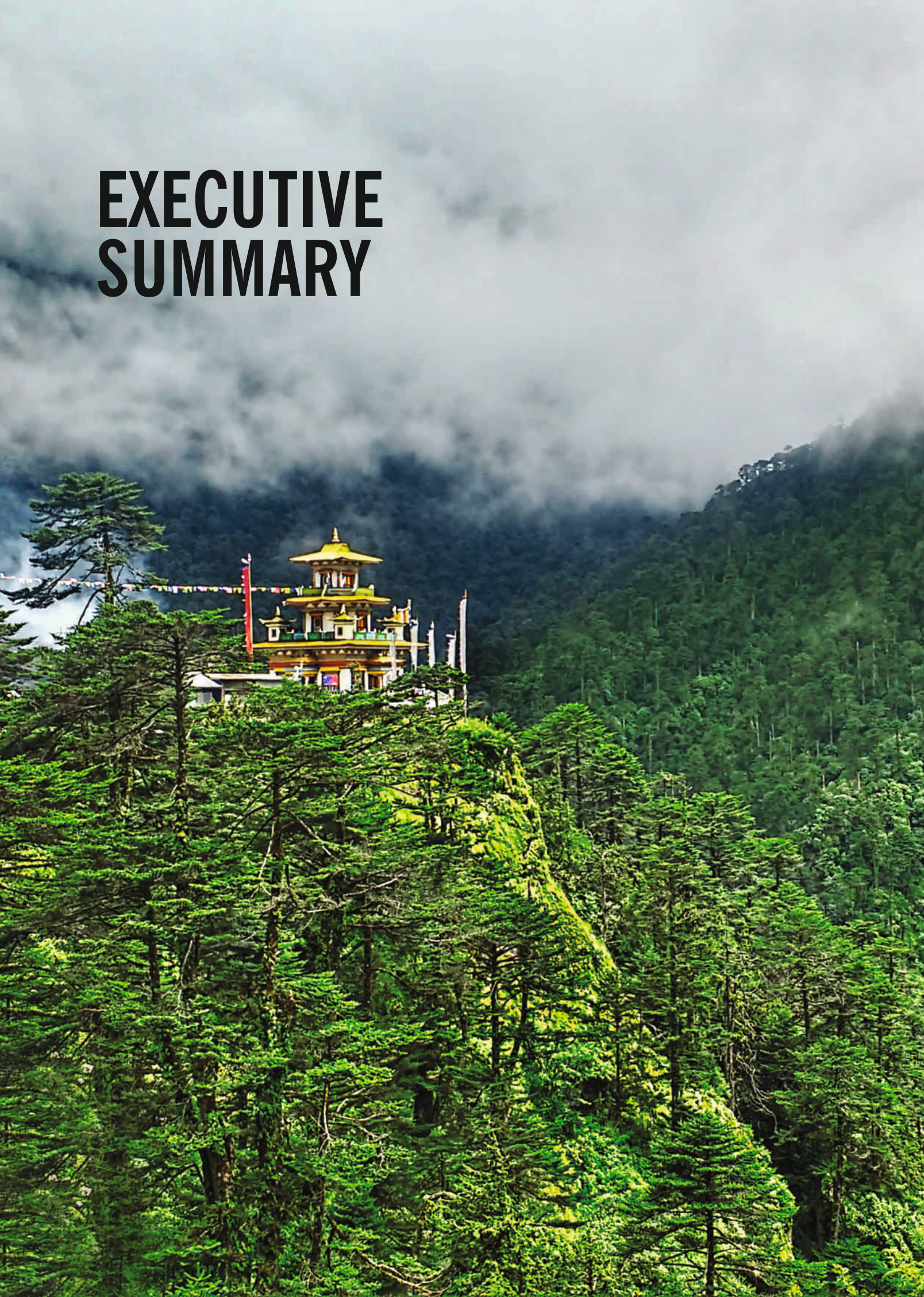
E N T S

EXECUTIVE SUMMARY



Nyamjang Chu River flowing in Zemithang Valley of Tawang District, Arunachal Pradesh is one of the only two known Black-necked crane wintering sites in India. In 2006, The Government of Arunachal Pradesh awarded the development of a hydropower project in the Nyamjang Chu River at Zemithang Valley to Bhilwara Energy Limited (BEL). On behalf of BEL, WAPCOS Limited and RS Envirolink Technologies Private Limited carried out the EIA and prepared EMP for the proposed project. However, the EIA and EMP were strongly opposed and challenged by many scientific as well as social institutions. Citing flaws in the methods adopted for floral and faunal studies, the baseline setting for the ecological aspects and prediction of impacts on the wildlife, habitat and environment of the region. Recently, the Honourable National Green Tribunal (NGT) observed gross errors in the EIA and EMP, such as omission of key, rare and threatened species such as the Black-necked crane (*Grus nigricollis*) in the report and ordered that the Wildlife Institute of India (WII) to conduct a detailed study in this regard. The primary scope of the WII study was to assess the habitat requirements of the Black-necked crane and assess the environmental flows requirement for protection and conservation of Black-necked crane habitats at the proposed Nyamjang Chu Hydroelectric Project site in Zemithang Valley.

A field study was carried out at the proposed barrage site, Zemithang Valley, Nyamjang Chu River for seven months (July 2017 to February 2018), a period covering monsoon and the wintering period of the Black-necked crane to assess the potential impact of the proposed hydroelectric power accurately. During the field study, habitat and vegetation structure of the area was studied; details of rare and endangered animals found in the region were collected using camera traps; bird diversity of the region was assessed; river depth and velocity were measured; and distribution pattern of vegetation of different types near the proposed barrage site were assessed. Finally, field deta was interpreted using remote sensing (RS) and GIS techniques and various software packages were used to analyse and interpret the habitat requirements of the Black-necked crane and estimated environmental flows that is suitable for the longterm conservation of the Black-necked crane and how the proposed barrage will affect the existing habitat.

The study found that the area is rich in terms of faunal diversity. A rich mammalian species assemblage was documented with a total of 31 species, of these 18 are of global conservation importance. The Arunachal Macaque (*Macaca munzala*), Red Panda (Ailurus fulgens), Alpine Musk Deer (*Moschus chrysogaster*) and Asiatic Wild Dog (*Cuon alpinus*) found here are in the IUCN's Endangered list. A total of 159 species of birds belonging to 54 families were documented in the project area. Intense vegetation sampling in the proposed barrage site, covering an area of 95.30 ha was carried out. More than 112 species of plants were recorded in this limited area. This reveals the rich biodiversity of the project area. *Alnus sp*. was found to be the most dominant tree species here followed by *Erythrina sp*. Among the herbs, the highest density was that of *Kummerowia sp*. and *Pennisetum sp*. *Hippophae sp*. and *Elaeagnus sp*. were very common shrubs of the study area. Apple orchards and agricultural fields were also found within the study area.

The land use land cover (LULC) of the proposed barrage site was mapped using field-collected GPS locations and November data from Sentiel-2. Altogether 12 LULC classes were identified within the extent of 95.034 ha of study area. River occupied the greatest area (20.873 ha), followed by Low Grassland (15.989 ha), Mixed (15.706 ha), Seasonal Sandbars (13.492 ha), *Hippophae* Patch (8.004 ha), *Alnus* (7.378 ha), House and Farmland (4.494 ha), Highland Grassland (4.474 ha), Shrubland (2.757 ha), Farmland (0.832 ha), Stream (0.739 ha) and Apple Orchard (0.296 ha).

Local peoples' perceptions towards the construction of the dam was documented using questionnaire survey. It was found that no one was in favour of constructing a barrage at Zemithang. To further confirm the visits of the Black-necked crane in the valley a questionnaire survey was conducted among the local villagers. Seventeen people responded that they had seen the cranes for last 1-10 years, 11 people for 10-20 years and 14 people for 20-60 years. Seven senior citizens responded that they had seen them for more than 60 years in their lifetime. We documented that the seasonal sandbars, shallow river areas and low grasslands were the primary habitats used by the Black-necked crane in the valley for roosting and foraging. We termed these as "critical habitats" of the Black-necked cranes. Further, it was found that the people of Zemithang Valley and the Monpas in general have a strong

compassion towards wildlife. Hunting or fishing is strictly banned in the Zemithang area by traditional customary laws. The Black-necked crane occupies a special place for the people of Zemithang. The people consider the cranes as *norbu* (meaning a sign of fortune) as per the Tibetan Buddhist culture. People believe that arrival of the birds augurs well for the crops and is a sign of good hope for the region.

Alteration of the existing ecological character and environmental settings will become inevitable if the proposed HEP is implemented. However, the degree of impacts depends on the quantity of the water storage and the management plan. The proposed barrage location is exactly on the critical habitat of the Black-necked crane. The barrage will alter the existing natural ecosystem and it will adversely affect and jeopardise the critical habitat of Black-necked cranes. Further, the upstream area will be converted into a lake or pond ecosystem, and the downstream section will be at the mercy of the barrage management authority. It was calculated that during the minimum drawn down level (MDDL) an extent of approximately 33.251 ha and at full reservoir level (FRL) an area of approximately 39.393 ha will be submerged under water. At FRL, 63% of total upstream areas, more than 91% of the *Hippophae* area and 85% of the seasonal sandbars will be submerged, leaving only 15% of the foraging grounds for the Black-necked crane in the valley.

An attempt was also made to understand the reasons for the Black-necked cranes to choose Nyamjang Chu River in Zemithang Valley. The weighted overlay method, SRTM DEM-derived slope and elevation data from the literature survey were used. To assign the relative suitability, variables from established Black-necked crane wintering site from Bhutan was collected from available literature to see the relative suitability of its habitat type in Zemithang valley. It was found that Zemithang valley has the same suitability value that Bhutan had. Moreover, all the established wintering sites in Bhutan appear to lie on a straight line and that of Zemithang valley, which also lies on an extension of the same line.

The average depth of the Nyamjang Chu river ranged between a minimum of 0.43 m and a maximum of 1.42 m, and the average velocity was between 0.36 m s^{-1} and 0.67 m s^{-1}. The average winter discharge of the Nymajang Chu River was found to be 14.778 cumecs. The maximum area under water was observed at cross-section 3, with a width of 44 m, and the narrowest cross-section had a width of 32 m. In order to understand the impact of altered flow on Black-necked crane habitat, physical habitat simulation method (PHABSIM) was used to predict the eflow. Six cross-sectional data containing depth and velocity at every 2m interval were generated at the Black-necked crane habitat. Based on the previous records and field observations, depth and velocity suitability curves were generated for Black-necked crane. The depth suitability curves inferred that, from 0 to 30 cm water depth and no flow region (0 flow) to

slow flowing region (<0.2 m/s) are suitable habitats for Black-necked cranes. Further, the cross-sectional information and suitability data were simulated at different level of discharge in PHABSIM. The result of habitat simulation using combined suitability index showed that at discharges between 10 to 20 cumecs produces more than 40% open area available for Black-necked cranes and at 40 cumecs simulation the open habitat available reduced to more than 75%. At 20 cumecs discharge, it was predicted that 53.34% of the channel area would be under water and Black-necked crane habitat decreases steadily beyond 20 cumecs discharge. Further, the predicted 53.34% habitat area at 20 cumecs is more or less matching with percentage water area (52.2%) available during the lean season (winter months). Thus, it is recommended that 20 cumecs e-flow should be maintained in Nyamjag Chu river between section 1 and 6 at Zemithang region during winter months (November to February) in order to maintain available open and shallow habitat for Black-necked crane.

The Black-necked cranes are a wetland habitat-dependent species mainly choosing the seasonal sandbars, lentic water areas, shallow areas of the river and some portions of marshy areas along the river banks. Black-necked cranes are highly sensitive to any kind of disturbances to their habitats including river flow. Construction of the proposed dam will eventually submerge the whole habitat, leaving no space for the Black-necked crane leading to local extinction in Zemithang Valley. As a result of the gradual process of construction, an upsurge of people from outside, construction of roads for access and pollution caused by labour camps will cause the entire habitat to collapse. We recommend the "Existing Natural Flow" as the "Required Environmental Flow" to retain the habitat of Black-necked cranes in the valley. We could not find any alternate flow other than retaining the 20 cumecs i.e the natural flow of the river during the winter when Black-necked cranes uses this habitat. Any change in the water level (i.e. at higher side) due to dam would completely submerge the Black-necked cranes habitat in the valley. Thus this study strongly recommends that the proposed HEP not to be constructed in this ecologically rich area and the valley should be made free from major anthropogenic disturbances.

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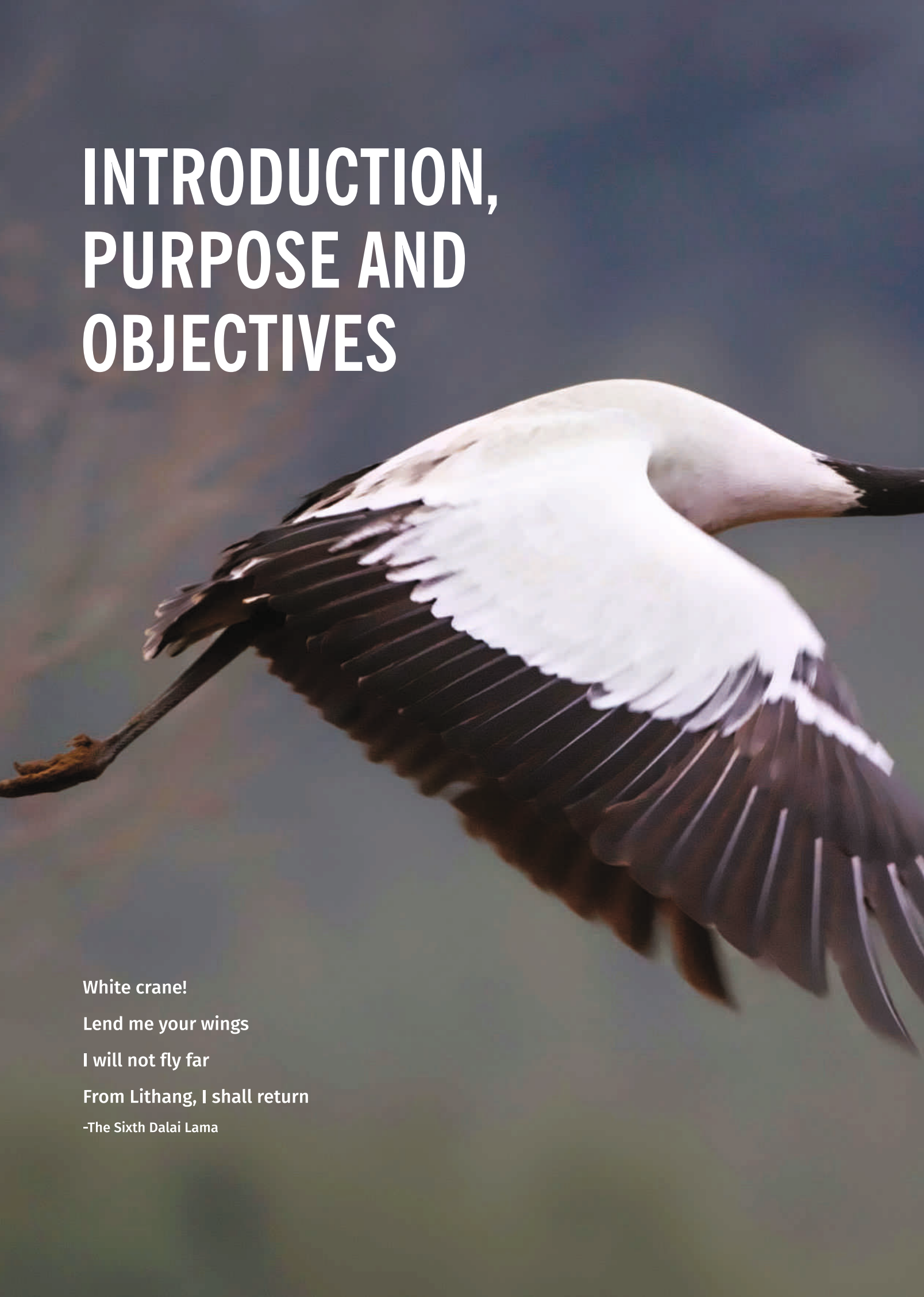
Thank you all!

- Project Team

INTRODUCTION, PURPOSE AND OBJECTIVES



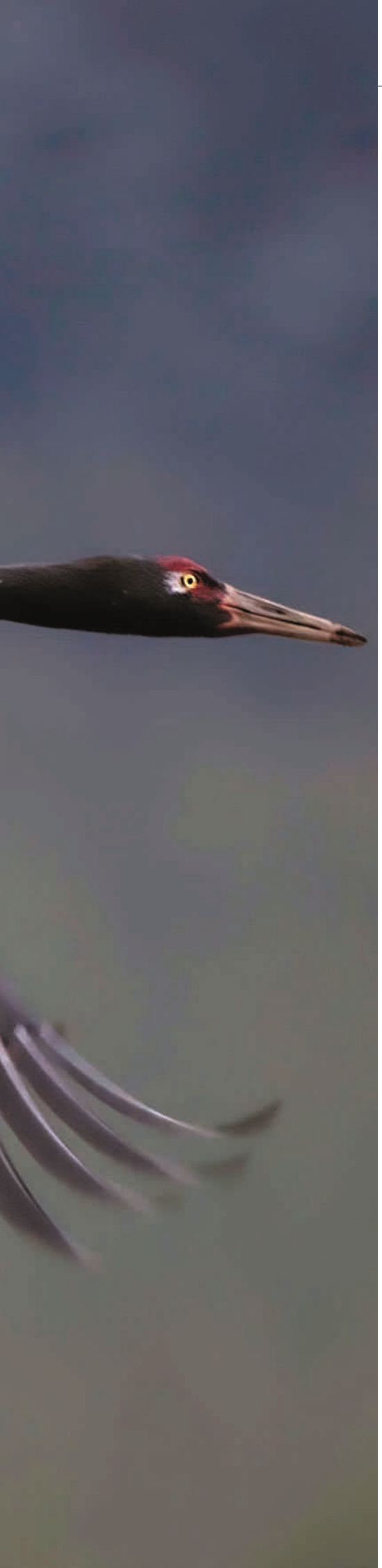
White crane!

Lend me your wings

I will not fly far

From Lithang, I shall return

-The Sixth Dalai Lama



Acknowledging the powerful flight of cranes, His Holiness the Sixth Dalai Lama expresses his desire to don their wings and travel from Lhasa to Lithang County, to the southwest of Garzê Tibetan Autonomous Prefecture, Sichuan, China, covering more than 800 km. Throughout the world there are 15 species of cranes (Chandan et al. 2005) and cranes are amongst the tallest of flying birds (Archibald 1981). They are characterised by their long necks and long legs. Their plumage is compact. They manage seasonal changes quite successfully by migrating from one place to another (Chandan et al. 2005).

The Black-necked crane (*Grus nigricollis*) is one among 15 crane species found worldwide. It is the only high-altitude crane and has the most restricted distribution of the family Gruidae (Harris & Mirande 2013). Its home range falls within latitudes 28° and 38° north and longitudes 78° and 104° east, stretching from the Altun and Kunlun mountain ranges east to the Qilian and Wumeng mountain ranges and south to the Himalaya. It can survive temperatures as low as -30°C. Maybe due to the geographical inaccessibility of its home range, the Black-necked crane was the last of the world's cranes to be discovered by the scientific community (Chandan *et al*. 2005). It was first sighted by the Russian naturalist Count Przewalski near Lake Koko Nor, in north-eastern Tibet, in 1876.

The Black-necked crane is a tall bird, with an average height of 139 cm and wingspan of about 235 cm. Both the sexes are almost of the same size, sometimes the male is slightly bigger than the female. The upper portion of the long neck, head, primary and secondary flight feathers and tail are completely black, and the body plumage is pale grey/whitish. A conspicuous red crown adorns the head. The bill is greenish, and the legs and feet are black. The juveniles have a brownish head and neck, and the plumage is slightly paler than that of the adult.

In India, Black-necked crane was first reported from Ladakh in 1919 by the naturalist F. Ludlow at Tsokar (Ludlow 1920). Till now, few studies have been conducted on the Black-necked crane habitat, ecology, counts, etc. in India. Chandan *et al*. (2005, 2014) studied the status and distribution of the

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Black-necked crane in India and reported its presence in wetlands of Ladakh and Sikkim during the breading season. Chandan *et al*. (2014) reported a maximum of 112 sightings in 2014 from 22 wetlands in Ladakh and a maximum of two sightings in 2013 from the Yum Tso wetland, in Sikkim.

Distribution Status

Country	Status
Bhutan	B,W
India	B,W (rare)
Myanmar	W ?
Vietnam	X (W)

kingdom	Animalia
Phylum	Chordata
Class	Aves
Order	Gruiformes
Family	Gruidae
Genus	*Grus*
Species	*nigricollis*
Author	Przevalski, 1876
IUCN Status	Vulnerable

Figure 1.1: Picture record of Black-necked crane obtained in 2017 on the bank of the Nyamjang Chu River, Zemithang (credit: Pemba Tsering Romo) [B, present during breeding season; W, present during winter; X, extirpated: (w) as a wintering species (source: Bishop (1996)]

In India, wintering populations of the Black-necked crane have been recorded only in small pockets of Arunachal Pradesh. The earliest record of a Black-necked crane wintering population was that of Betts, in 1955. The first record of the Black-necked crane in Arunachal Pradesh was from Apatani Valley. However, a later study conducted by Chandan et al. (2014) found that the cranes had abandoned Apatani Valley, mainly due to an increased level of disturbance and the possession of firearms by locals. Sangti Valley and the Zemithang area of Pangchen Valley are two other well-established BNC wintering sites in Arunachal Pradesh. They are both in western Arunachal. Currently, Zemithang and Sangti Valley are the only known areas in India where small wintering populations of the Black-necked crane are found (Chandan et al. 2014).

The Convention on Conservation of Migratory Species (CMS), or Bonn Convention, came into force in 1979 and aims to conserve migratory species throughout their ranges. India has been a signatory to the convention since 1983. During COP 10, India was also nominated a member of the Standing Committee of the Convention with support from various countries in Asia. During the COP, the Ministry of Environment and Forests, WWF-India, Wetlands International and Bombay Natural History Society (BNHS) jointly organised a side event on the Black-necked crane. Cooperation among the range states for the conservation of this unique species that is found in the Himalayan high-altitude wetlands was urged. It is our obligation as a signatory body, to uphold our commitment and conserve the existing wintering habitats of the BNC in the country.

Scope and purpose

The Hon'ble National Green Tribunal (NGT) has recently suspended the environmental clearance (dated 19 April 2011) accorded to the 780 MW Nyamjang Chu hydroelectric project in the Tawang River Basin, which was allotted to Bhilwara Energy Limited (BEL), based at Noida. The NGT has ordered that a fresh study to be conducted for grant of environmental clearance as the EIA and EMP prepared and submitted by WAPCOS Limited and RS Envirolink Technologies Private Limited has been challenged by the Save Mon Region Federation (SMRF), a Tawang-based group spearheaded by Buddhist lamas opposing the grant of the environmental clearance. The EIA and EMP had some serious flaws. One such gross error is the omission of **key, rare and threatened species such as the Black-necked crane (*Grus nigricollis*) in the report.** The NGT has also ordered that the Wildlife Institute of India (WII) to take up a detailed study of the habitat requirements of the Black-necked crane vis-à-vis the environmental flows at the Nyamjang Chu project barrage site. This was also mentioned in the Perspective Plan for Development of Tawang River Basin (Barik et al. 2015). Following this, the Ministry of Environment, Forests and Climate Change (vide its letter no. L-11011/20/2012-IA-1 dated 6 June 2016) requested WII to take up a study as suggested by the basin study (Barik, 2015) and the order of NGT dated 7 April 2016. The primary scope of the WII study was to assess the habitat requirements of the Black-necked crane and the environmental flows requirement for the protection and conservation of Black-necked crane habitats in the proposed Nyamjang Chu hydroelectric project site in Zemithang, Tawang River Basin.

Objectives

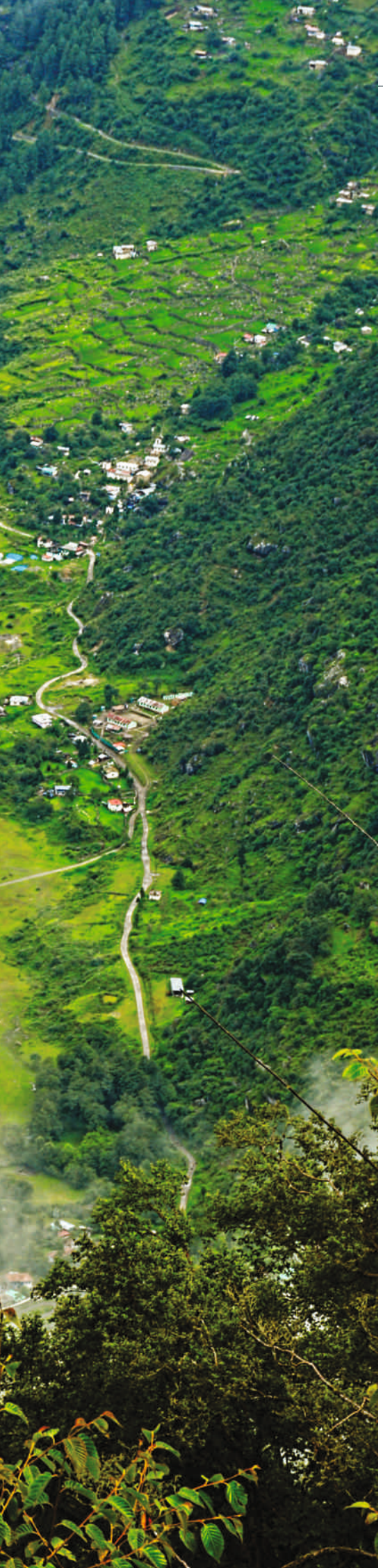
1

To assesss the habitat requirement of Black-necked crane in the Nyamjang Chhu project site.

2

To assess the e-flow in Nyamjang Chhu river and e-flow requirement for conservation of threatened Black-necked crane habitats and aquatic biodiversity in Nyamjang Chu HEP site in Tawang river basin.

STUDY SITE



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The project site is located at an elevation of 2115 m on the Nyamjang Chu River in montane sub-tropical, temperate and sub-alpine climatic zones. The vegetation types within a 10 km radius of project site are the following.

1. **East Himalayan sub-tropical broad-leaved forest (2000-3000 m):** Oak-dominated forests were found mostly below 3000 m. Other tree species included *Rhododendron*, and *Acer*. Most of the forests were degraded due to human use, as most of the villages in the region lie within this altitudinal zone. The tree branches are often moss covered. These forests are used for grazing cattle, mithun and cattle-mithun hybrids. People also collect oak leaf-litter for manure and extract bamboo and timber from these forests.

2. **Eastern Himalayan sub-alpine conifer forests (3000-4000 m):** This forest type was variable in species composition and appearance, ranging from open Fir (*Abies densa*)-*Juniperus* patches to closed, homogenous stands of Fir. While Fir was the predominant conifer, other species included *Larix, Tsuga, Picea, J. recurva* and *J. indica*. The understorey features a rich community of colourful rhododendrons, including *Rhododendron hodgsonii, Rhododendron barbatum, Rhododendron campylocarpum, Rhododendron campanulatum, Rhododendron fulgens* and *Rhododendron thomsonii*. *Pinus wallichiana* occurred in drier areas. The understorey included species of bamboo, *Daphne* and *Rubus* and several ferns. The tree branches were covered with a thick mat of moss. Bamboo and the fruit of *Illicium griffithi* are collected and timber (mainly Fir, but also some *Juniperus*) is extracted from these forests.

3. **Alder forest (1800-2200 m) and Hippophae forest (3500-3750 m):** With a few exceptions, alders are deciduous, and the leaves are alternate, simple and serrated. The flowers are catkins, with elongate male catkins appearing on the same plant as the shorter female catkins, often before the leaves appear. They are mainly wind-pollinated but are also visited by bees to a small extent. Alders are commonly

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found near streams, rivers and wetlands. The Sea Buckthorn (*Hippophae*) is a deciduous, thorny, willow-like plant species native to Europe and Asia. It is a pioneer species and prefers to grow in low humid, alluvial gravel, wet landslips and riversides. It has brown rusty-scaly shoots (Lu 1992). It is also a multipurpose fast-growing species that is used in biodiversity conservation and soil conservation measures and provides medicines, food, fodder and fuelwood. For farmers in mountains, the Sea Buckthorn offers the opportunity to maintain a sustainable livelihood by providing healthy foods and a variety of medicines and protecting their land from soil erosion (Lu 1992; Ansari 2003). Most of the area covered in the submergence zone of the study area was full of *Hippophae* vegetation. *H. rhamnoides* subsp. *turkestanica*.

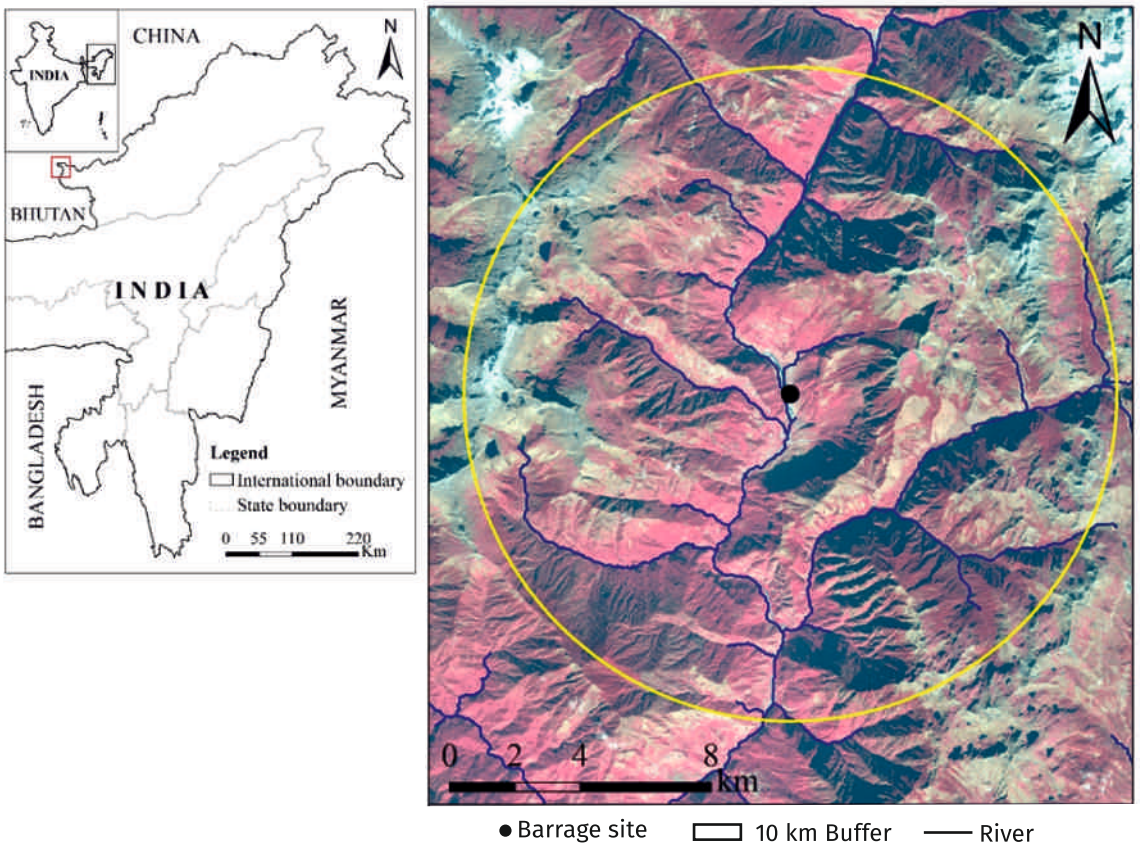


Figure 2.1: Location of the proposed Nyamjang Chu river HEP barrage site, 10 km radius buffer FCC and Nyamjang chu river.

The location of the proposed barrage site, the 10-km radius False colour composite (FCC) and the Nyamjang Chu River are shown in Figure 2.1. The Tawang Basin report by Barik et al. (2015) gives details of the floral and faunal diversity in and around the proposed Nyamjang Chu River HEP. A total of 165 plant species belonging to different groups were recorded from the barrage and powerhouse sites and the catchment area. Three fish species, viz. *Mystus vittatus*, *Amblyceps mangois* and *Exostoma berdmorei* have been recorded at the barrage site, 20 species of butterfly belonging to 19 genera and five families, three mammalian species of conservation significance, including the Arunachal Macaque (*M. munzala*), Capped langur (*Trachypithecus pileatus*) and Red Panda (*A. fulgens*), and 86 species of bird belonging to 64 genera and 33 families were reported. Most of the birds are residents (57 species) 18 are breeding visitors and 11 are winter visitors. The construction of the barrage would lead to submergence of the habitat of the highly threatened BNC. Further, the barrage site has also been identified as an Important Bird Area and Endemic Bird Area (Rahmani et al. IBA India. 2016).

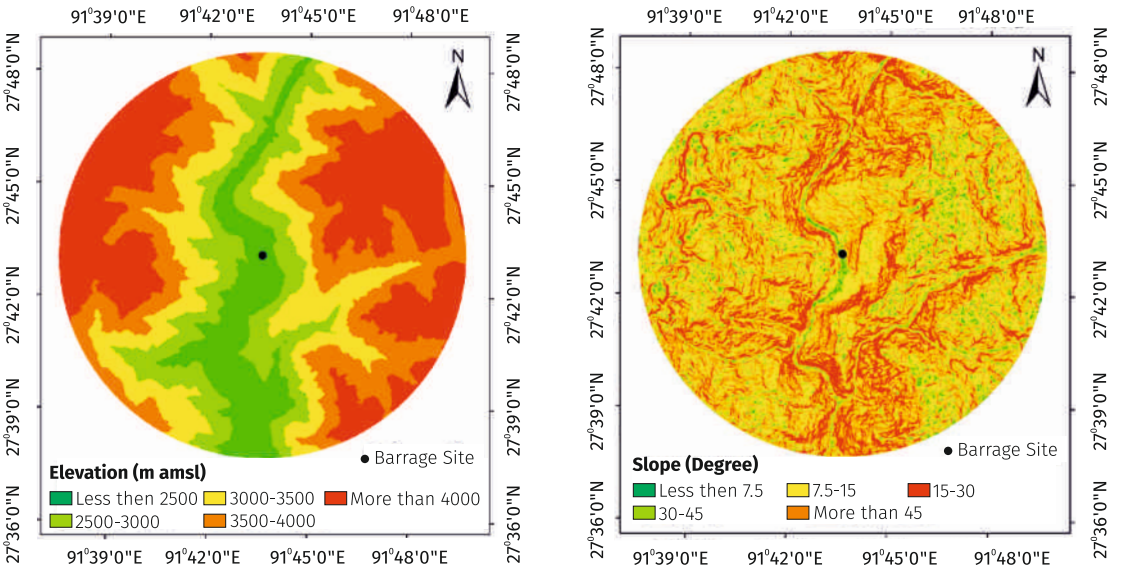


Figure 2.2: Elevation and slope of Nyamjang Chu hydroelectric project (HEP) barrage site

The Nyamjang Chu River originates in Tibet and flows in a nearly north-south direction into India in the Zemithang region. This river is one of the vital perennial rivers of the Tawang River Basin. Several important tributaries, viz. Gomkang Rong Chu, Sumta Chu and Taksang Chu, drain into the Nyamjang Chu River. The Nyamjang Chu merges with the Tawang Chu near Lumla, and the resultant river flows into Bhutan, where it is known as Gamri Chu.

The Nyamjang Chu hydroelectric project (HEP) has been designed as a run-of-the river project to harness the hydropower potential of the Nyamjang Chu River. The Nyamjang Chu HEP is located along the Nyamjang Chu in Zemithang and Lumla. The diversion site is located near Zemithang (27°43'06" N, 91°43'37" E), and the powerhouse is located near the confluence of Nyamjang Chu and Tawang Chu (27°31'16" N, 91°41'12" E). A total of 780 MW of power will be generated in an underground powerhouse. An 11 m high barrage, 175 m in length, and a tunnel of length around 23.45 km will divert the water to the powerhouse, downstream near Lumla. The extent of the area within a 10 km radius of the Nyamjang Chu HEP site is 31,443.93 ha. Most of the area is covered with forests (50.33%), followed by scrubland (32.78%). Cropland covers only 0.02%, water bodies constitute around 11.15%, and grasslands occupy only 0.30% of the total area. The area occupied by snow and ice and the built-up area together make up 5.42%.

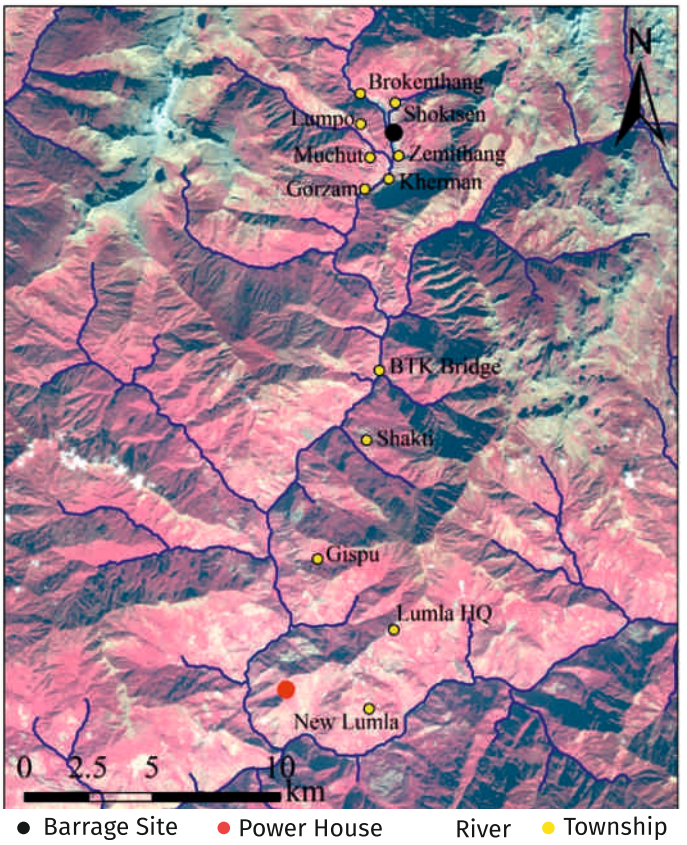


Figure 2.3: Locations of barrage, powerhouse and major townships

The proposed HEP will require a total extent of 276.6 ha for the different project components to be constructed in. About 89.5271 ha of the forest land will be diverted for construction purposes, and about 10 ha is of private land, which which will be acquired from 47 project-affected families in five hamlets/villages. Most of the land to be acquired is community land.

The present study was confined to the barrage site. The study was carried out inside the periphery, following the roads as boundary between Zemithang Bridge and Brokenthang Bridge. The black boundary in Figure 2.4 shows the exact area of this study. The study area has an extent of around 95.03 ha and comprises vegetation of different types. *Hippopahe* forest, grassland, seasonal sandbar and *Alnus* forest were some of the major land cover types found within the study area. Details of the different vegetation types and land use land cover are provided in Chapter 3.

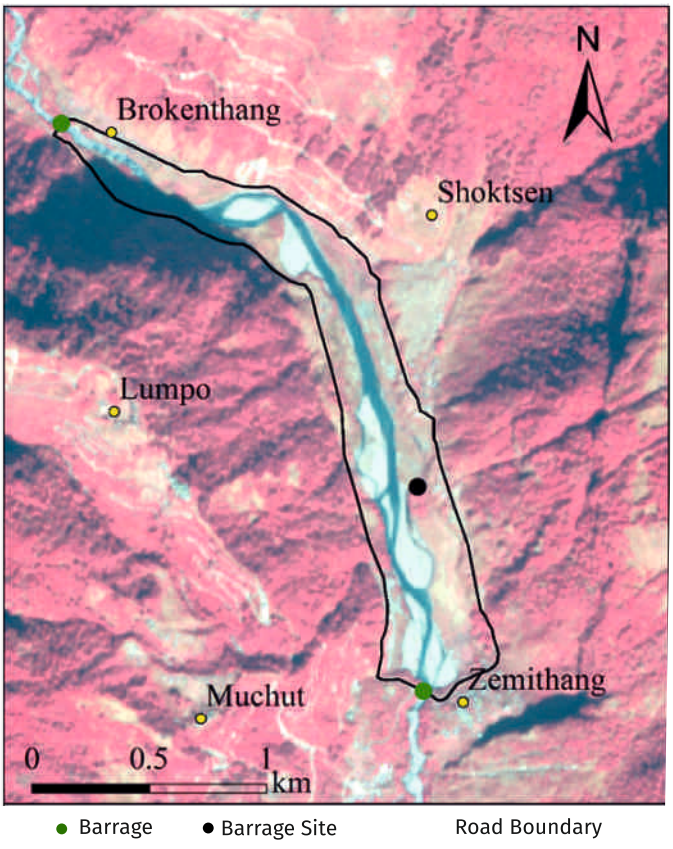
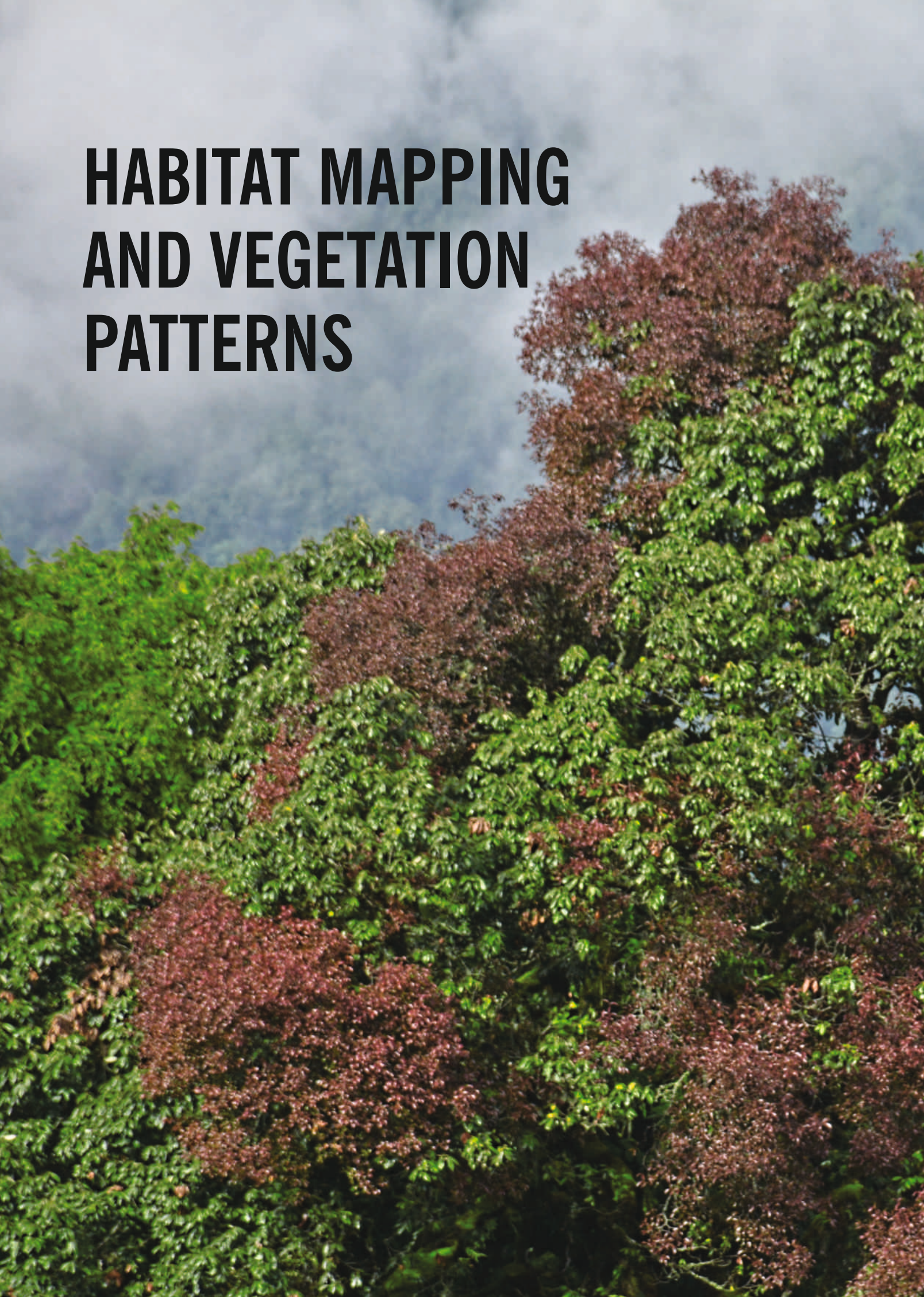


Figure 2.4: Black-necked crane habitat of Zemithang, Arunachal Pradesh

Figure 2.5: Study site, Nyamjang Chu River Valley (Photo: Malyasri Bhattacharya)

HABITAT MAPPING AND VEGETATION PATTERNS



Introduction

The study area had a mosaic of vegetation types dominated by *Alnus* and apple (*Pyrus malus*) trees. The apple orchards are situated on the riverbanks. The farmlands are mostly agricultural lands under local authorities in which millet or wheat is grown. They are found as certain patches near the riverbank. The highland grassland areas are mainly at a certain elevation from the riverbank, and they are mostly dominated by *Cosmos* sp. and *Artemesia* sp.. The highland grasslands are also used as agricultural lands in a few places. The *Hippophae* patches are mainly *Hippophae*-dominated areas along the riverbanks. Quadrats of size 5 m × 5 m were laid for estimating the number of shrubs in the area. The houses and farmland were areas in which there were both agricultural lands and settlements. They were located close to the river. These settlements were mainly temporary settlements. Most of the area is covered with lowland grassland patches. There were a few mixed forest areas near the riverbanks. The seasonal sandbars were mainly temporary vegetative zones that are seen during the lean season. There were few streams in the study area. The area was largely dominated by shrubs and herbs, but there were also a few patches of trees in the region. Seabuck thorn, which is significant for its medicinal and nutritional potential, also dominated the area. There were two sacred groves near the river.

Hippophae rhamnoides, commonly known as Seabuck Thorn, is a valuable plant. It grows in wild along Nyamjang Chu at the HEP site.This has been found to be covering an area of 8.0ha. Seabuck Thorn is a thorny nitrogen-fixing deciduous shrub of cold, arid regions. It has recently gained worldwide attention mainly for its medicinal and nutritional potential (Dwivedi et al. 2006a; Stobdan et al. 2010). It is currently grown in several parts of the world, including India, for its nutritional and medicinal properties. Biochemical evaluation (Dwivedi et al. 2006b) and propagation (Stobdan et al. 2013) of the species have been carried out. In India, DRDO has developed technologies for producing different Seabuck Thorn products, which have been received well by different stakeholders, including industries, NGOs and local entrepreneurs (Stobdan et al. 2013).

3

CHAPTER

Mapping the land use land cover of the barrage site

The terms *land use* and *land cover* are often used interchangeably, but each term has its unique meaning. *Land cover* refers to the characteristics and surface cover of the Earth, as represented by natural elements such as the vegetation, water, bare earth and physical features of the land, whereas *land use* refers to the activity, intended use or management strategy employed in the land cover by humans. Land management and land planning require knowledge of the current state of the landscape. Understanding the current land cover and how it is being used provide us baseline information about the area/vegetation that is going to be affected/altered by any developmental project. Using remotely sensed imagery and manual digitisation or semi-automated classification methods provides a cost-effective and accurate means of deriving land resource information of a region.

To quantify and understand the spatial arrangement of the different land use and land cover (LULC) of the study area, SENTINEL-2 imagery of 10 m resolution of November 2017 was downloaded from https://earthexplorer.usgs.gov/. False colour composite images were visually interpreted along with the field information and GPS location as the area of interest was not large. The vegetation types and different LULC types present in the study site were broadly categorised in the 12 classs listed in Table 3.1. River/water body occupied the maximum extent in the area of interest, followed by lowland grassland, with an area of 20.87 ha. The third greatest extent was that of seasonal sandbar, with an area of 13.49 ha, the prime attraction for the wintering BNC. Within the study area, there were also houses and farmland. The extent of the human managed-area was 05.32 ha.

The study area was divided into 30-m grids using Landsat-8 OLI data for vegetation sampling. On the basis of the pixel signature, a total of 178 grids were selected (Figure 3.2). Grids were selected on the basis of vegetation type/LULC class, and quadrats were laid in selected grids for vegetation sampling. A map showing the vegetation types and LULC classes of the entire study area (project site) was prepared.

LULC class	Area (ha)	LULC class	Area (ha)
Alnus	7.378	Lowland grassland	15.989
Apple orchard	0.296	Mixed	15.706
Farmland	0.832	River	20.873
Highland grassland	4.474	Seasonal sandbars	13.492
Hippophae potential area	8.004	Shrub dominated	2.757
House and farmland	4.494	Stream	0.739
Grand total = 95.03 ha			

Table 3.1: LULC classes of the proposed Nyamjang Chu HEP site

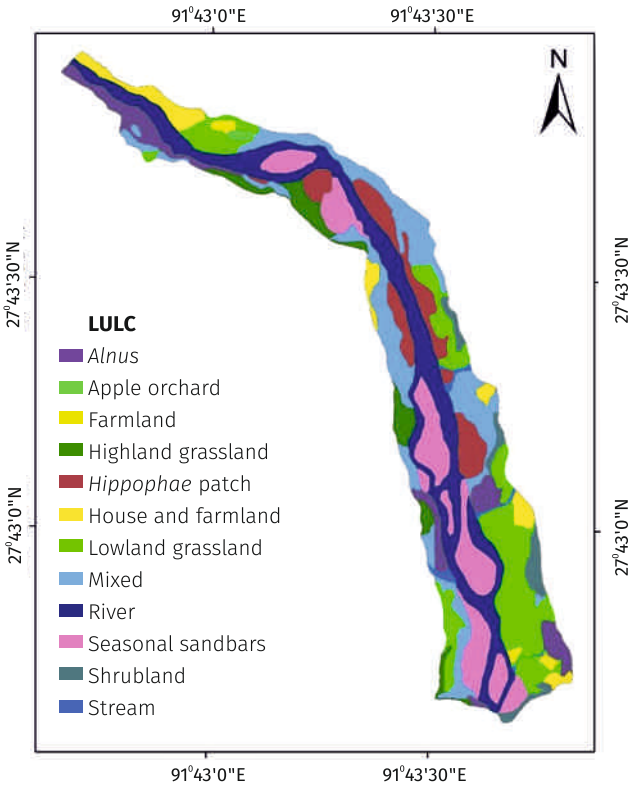


Figure 3.1: Land use and land cover of proposed Nyamjang Chu HEP barrage site

Floral inventory and vegetation communities

River damming leads to strong hydro-morphological alterations of the watercourse, consequently affecting a river's vegetation pattern (Ceschin et al. 2015). Some studies have focused on the effects of dams on the upstream river stretches, among which the most important are the increase in water level, with subsequent flooding of the surrounding riparian lands (Crivelli et al. 1995; Nilsson & Berggren 2000; New & Xie 2008) and the reduction in the velocity of the water in the river, with the formation of sub-lacustrine habitats (Nilsson & Jansson 1995; Jansson et al. 2000a, 2000b; Evans et al. 2007; Franchi et al. 2014).

Methodology

The vegetation structure and composition of the Black-necked crane habitat in the proposed Nyamjang Chu HEP site, was assessed using the Global Positioning System (GPS). GPS coordinates were collected from both former (on the basis of information from local people) and current roosting and foraging habitats in the study area. Ground-based field surveys were carried out by the team along the 3-km river stretch through the wintering season to understand the habitat use pattern of Black-necked cranes.

Various habitat characteristics were recorded in the identified grid. The traditional method was used for vegetation sampling. Twenty 1 m × 1 m quadrats were laid for the ground layer (herbs and grasses), 10 quadrats (5 m × 5 m) were laid for the shrub layer, and 10 quadrats (10 m × 10 m) were laid for the tree layer in each habitat. Standard vegetation quantification techniques were followed to measure various parameters such as the density, frequency, total basal area, Importance Value Index (IVI) (Misra 1968), diversity and evenness (Magurran 1988, 2004).

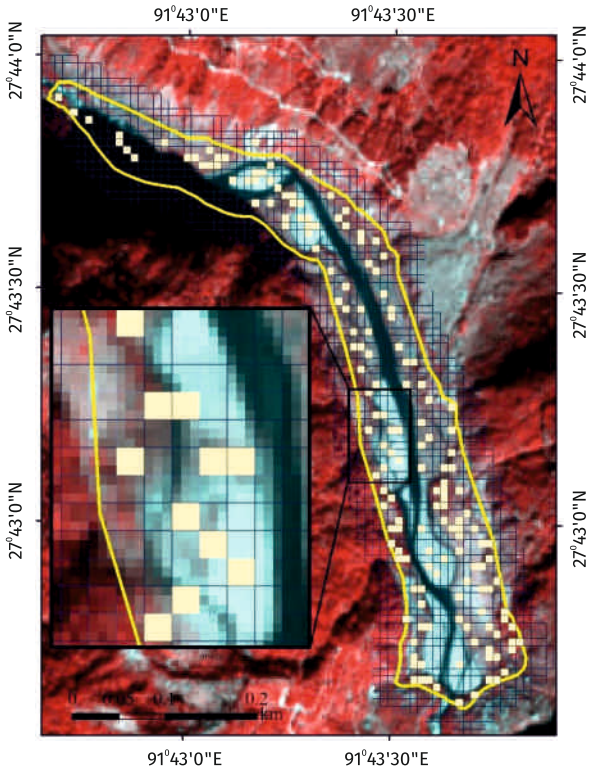


Figure 3.2: Grids selected for vegetation sampling

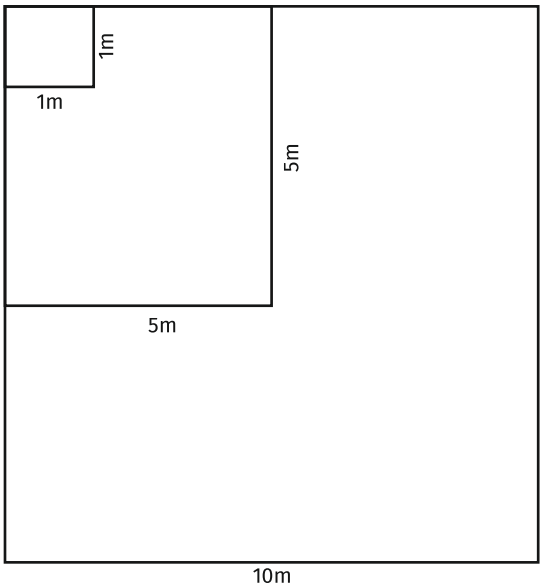


Figure 3.3: Schematic diagram of nested quadrats for tree, shrub and herb layers

Table 3.2: Details of classes, sites and quadrats in vegetation mapping

Class	Sites	Quadrats
Alnus	5	29
Apple orchard	1	2
Farmland	1	0
Highland grassland	7	6
Hippophae patch	5	20
House and farmland	7	2
Lowland grassland	6	39
Mixed forest	9	33
River	1	4
Seasonal sandbar	9	26
Shrubland	3	11
Stream	1	0
Total	**55**	**172**

Results

Twelve habitats/LULC classes, viz. seasonal sandbar, lowland grassland, highland grassland, shrubland, *Hippophae* potential area, mixed forest, *Alnus* forest and apple orchard, were identified in the project site. The total area of the site was 95.03 ha, the various LULC types, in decreasing order of area were: lowland grassland (17%) > mixed forest (16%) > seasonal sandbar (14%) > *Alnus* and *Hippophae* forests (each 8%) > highland grassland and house and farmland (each 5%) > shrubland (3%) > farmland (1%) > apple orchard (0.3%).

Detailed descriptions of these habitat types/classes are as follows:

1. Seasonal Sandbar

The total density of trees in seasonal sandbar was 414 trees ha^{-1}, of which 21% was contributed by *Salix* sp., 18% by *yayoong* (local name) and 12% by *Alnus nepalensis*. The total basal area (TBA) is 19.2 m^2 ha^{-1}, of which 49% is contributed by *Salix* sp., 30% by *Alnus nepalensis* and 21% by *yayoong* (and, respectively). The IVI value was highest for *Salix* sp. (189), followed by *yayoong* (59) and *Alnus nepalensis* (53).

The total density of shrubs was 1466 individuals ha^{-1}, of which 73% was contributed by *Hippophae rhamnoides* and 27% by *Elaeagnus umbellata*. The highest frequency was that of *Hippophae rhamnoides* (64%), followed by *Elaeagnus* sp. (36%). All the species were randomly distributed.

The total density of the herbaceous layer was 38 individuals m^{-2}, with the highest contribution being that of *Pasplaum paspaloides* (43%), followed by *Artemisia* sp. (19%) and *Calamagrostis scabrescens* (15%). The contributions of the other species were relatively small (0.1-2%). The highest frequency was that of *Artemisia nilagirica* (16%), followed by *Artemisia* sp. (13%), *Erianthus sikkimensis* (10%) and *Calamagrostis scabrescens*, *Eragrostis tenuifolia* and *Pennisetum clandestinum* (each 6%). The others contributed 3%. The distribution patterns were contiguous for most of the species, except *Artemisia nilagirica*, which was randomly distributed.

2. Lowland grassland

The total density of shrubs was 8450 individuals ha^{-1}, of which 97% was contributed by *Elaeagnus* sp., followed by *Boehmeria* sp. (2%). The highest frequency observed was that of *Elaeagnus umbellata*. (75%), followed by *Boehmeria* sp. (13%). The distribution pattern was contiguous for all the species.

The total density of the herbaceous layer was 626 individuals m^{-2}, the greatest contribution to which was that of *Kummerowia striata* (7%), followed by *Pennisetum clandestinum* (5%) and *Oplismenus* sp.

(3%), while the contributions of the others were very small (0.01-2%). The highest frequency observed was that of *Pennisetum clandestinum* (9%) and the frequencies of the others were very low (1-4%). The distribution patterns were contiguous for all the species.

3. Highland grassland

The total density of the herbaceous layer was 288 individuals m^{-2}, and the highest contributions were those of *Kummerowia striata* and *Pennisetum clandestinum* (25% each), followed by *Schizachyrium delavayi* (12%), *Smithia ciliata* (7%) and others (0.1-3%). The highest frequency was that of *Artemesia* sp. (16%), which was followed by *Equisetum* sp. (8%). The distribution patterns were contiguous for most of the species, except *Artemisia* sp. and *Cosmos bipinnatus*, which were randomly distributed.

4. Shrubland

The total density of trees in the shrub-dominated area was 617 trees ha^{-1}. 43% was contributed by *Alnus nepalensis,* followed by *Erythrina variegata*. (27%), *Salix* sp. (11%) and *Prunus* sp. (8%). The TBA was 21.8 m^2 ha^{-1}, of which 74% was contributed by *Alnus nepalensis*, followed by *Erythrina variegata*. (11%), *Salix* sp. (6%) and *Prunus* sp.(4%). The IVI was greatest for *Alnus nepalensis* (150), followed by *Erythrina* sp.(55), *Salix* sp. (33) and *Prunus* sp. (28).

The total density of shrubs was 2293 individuals' ha^{-1}, with 79% being contributed by *Elaeagnus* sp. and 16% by *Hippophae rhamnoides*. The contributions of the others were relatively small (1-2%). The highest frequency observed was that of *Elaeagnus* sp. (72%), followed by *Debregeasia longifolia* (11%) and others (*Hippophae rhamnoides, Lindera neesiana* and *Zanthoxylum armatum*, 6%). The distribution patterns were contiguous for all the species.

The total density of the herbaceous layer was 3 individuals m^{-2}. The greatest contribution was that of *Cannabis sativa* (43%), followed by those of *Pteris* sp. (30%), *Pteridium aquilinum* (20%) and others (only 3%). The highest frequency was that of *Cannabis sativa* and *Pteris* sp.(each 42%), while those of the others (*Ambrosia artemisiifolia, Erianthus sikkimensis* and *Pteridium aquilinum*) were each 5%. The distribution patterns were contiguous for most of the species, except *Cannabis sativa* and *Pteris* sp. it was regular.

5. Hippophae patch

The total density of trees in the *Hippophae* patches was 575 trees ha^{-1}. 52% was contributed by *Erythrina variegata*. *Menchen* and *bhaber* (local names) contributed 26% and 13%, respectively. The TBA was 9.6 m^2 ha^{-1}, with 44% being contributed by *Erythrina variegata*. *Menchen* and *bhaber* and contributed 25% and 18%, respectively. The IVI was highest for *Erythrina variegata*. (134), followed by *menchen* (76) and *bhaber* (44). *Salix* sp. had the lowest IVI (21).

The total density of shrubs was 4047 individuals' ha^{-1}, with the contribution of *Hippophae rhamnoides* being 75% and that of *Elaeagnus umbellata*. 22%. The others contributed very little (*Debregeasia longifolia*, 2%; *Debregeasia velutina*, 1%). The highest frequency observed was that of *Hippophae rhamnoides* (56%), which was followed by *Elaeagnus umbellata*. (37%). The distribution patterns were contiguous for all the species.

The total density of herbaceous layer was 45 individuals m^{-2}, with the greatest contribution being that of *Artemesia* sp.(31%), followed by those of *Arthraxon* sp. (27%), *Kummerowia striata* (15%) and *Axonopus affinis* (10%). The others contributed 0.1-4%. The highest frequency observed was that of *Cannabis sativa* (28%) followed by that of *Girardina macrophylla* (10%). The frequencies of the others very very small (3-5%). The distribution patterns were contiguous for most of the species, except *Girardina macrophylla* and *Cannabis sativa*, which were randomly and regularly distributed, respectively.

6. Mixed forest

The total density of trees in mixed forests was 600 trees ha^{-1}, with *Alnus nepalensis* contributing 30%, *Erythrina variegata*. 28%, *menchen* 20% and *Salix* sp. 11%. The TBA was 21.9 m^2 ha^{-1}. 49% was contributed by *Erythrina variegata*., 30% by *Alnus nepalensis*, 11% by *menchen* and 6% by *Salix* sp. The others contributed very little (1-2%). The IVI of *Erythrina variegata*. was highest (101), followed by those of *Alnus nepalensis* (84), *menchen* (59) and *Salix* sp.(29).

The total density of tree saplings was 300 saplings ha^{-1}, with 67% contributed by glangma and 33.3% by *Erythrina variegata*. The frequencies of the two species were similar. The distribution pattern of glangma was contiguous and that of *Erythrina* sp. was random. However, there were no seedlings of tree species at the site.

The total density of shrubs was 2320 individuals' ha^{-1}, with 76% contributed by *Elaeagnus* sp., 18% by *Hippophae rhamnoides* and 1-2% by others. The highest frequency observed was that of *Elaeagnus* sp. (60%), which was followed by *Hippophae rhamnoides* (22%) and *Debregeasia longifolia* (4%). The distribution patterns were contiguous for all the species, except *Elaeagnus* sp., which was randomly distributed.

The total density of the herbaceous layer was 22 individuals m^{-2}, with the greatest contribution being that of *Fimbristylis* sp. (72 %), which was followed by that of *Schizachyrium delavayi* (13%). The highest frequency observed was that of *Cannabis sativa* (18%), followed by those of *Artemisia nilagirica*, *Pteris* sp. and *Xanthium strumarium* (each 11%), *Periploca calophylla* (9%) and *Pteridium aquilinum* (7%). The distribution patterns were contiguous for most of the species, except *Artemisia nilagirica, Cannabis sativa* and *Xanthium strumarium*, which were randomly distributed.

7. Alnus forest

The total tree density of the *Alnus* forests was 807 trees ha^{-1}, of which 83% was contributed by *Alnus nepalensis*, 6% by *Salix* sp. and 4% by *Lyonia ovalifolia*. The TBA was 41.1 m^2 ha^{-1}, with 89% contributed by *Alnus nepalensis* and 2% by *Erythrina* sp. and *Salix* sp. (each 2%). The highest IVI was that of *Alnus* (232), which was followed by *Salix* sp. (17), others (11-12) and *Lindera neesiana* (3).

The total density of tree saplings was 253 saplings ha^{-1}, with 82% contributed by *Alnus nepalensis* and others (*Erythrina* sp., *Prunus* sp. and *Celtis* sp.) contributing much less (3-5%). The frequency of *Alnus nepalensis* was the highest (93%). The distribution patterns were contiguous for most of the species, except *Alnus nepalensis*, which was regularly distributed. However, there were no seedlings of tree species at the site.

The total density of shrubs was 900 individuals ha^{-1}, with 81% contributed by *Eleagnus umbellata*. and 15% by *Hippophae rhamnoides*. The highest frequency recorded was that of *Eleagnus umbellata*. (92%), which was followed by *Hippophae rhamnoides* (25%). The distribution pattern of *Elaeagnus* sp. was regular and random for *Hippophae rhamnoides*.

The total density of the herbaceous layer was 79 individuals m^{-2}, with the highest contribution being that of *Axonopus affinis* (54 %), followed by those of *Luzula* sp. (29%) and *Utricularia* sp. (11%). The highest frequency was that of *Xanthium strumarium* (20%), followed by that of *Periploca calophylla* and *Artemisia nilagirica* (each 13.3%). The distribution patterns were contiguous for most of the species, except *Artemisia nilagirica, Periploca calophylla* and *Xanthium strumarium,* which were randomly distributed.

8. Apple orchard

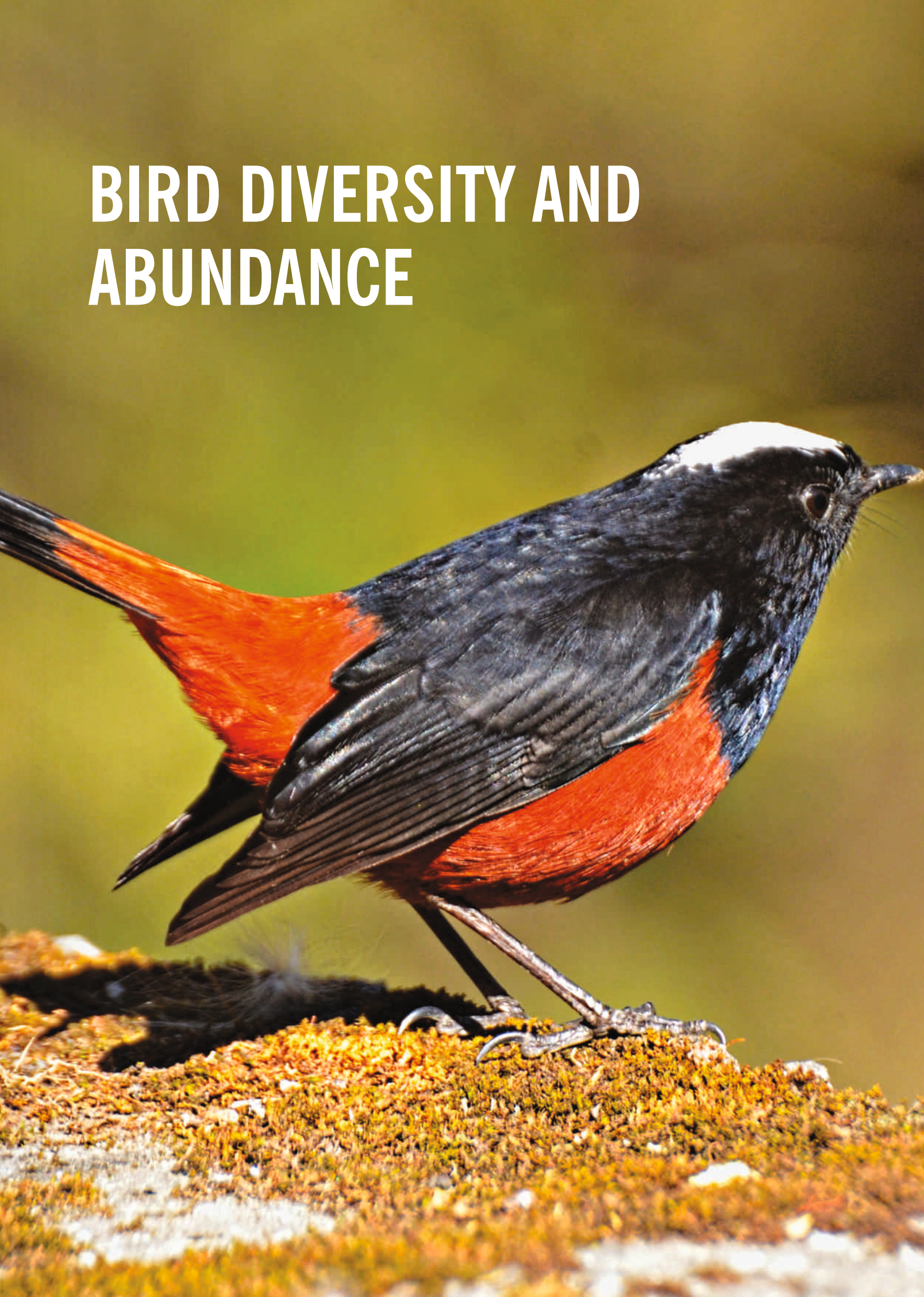
Only apple saplings were measured in the apple orchards. The total density of *Pyrus malus* was 450 saplings ha^{-1}, with a frequency of 100% and a random distribution. However, seedlings of tree species were absent at the site.

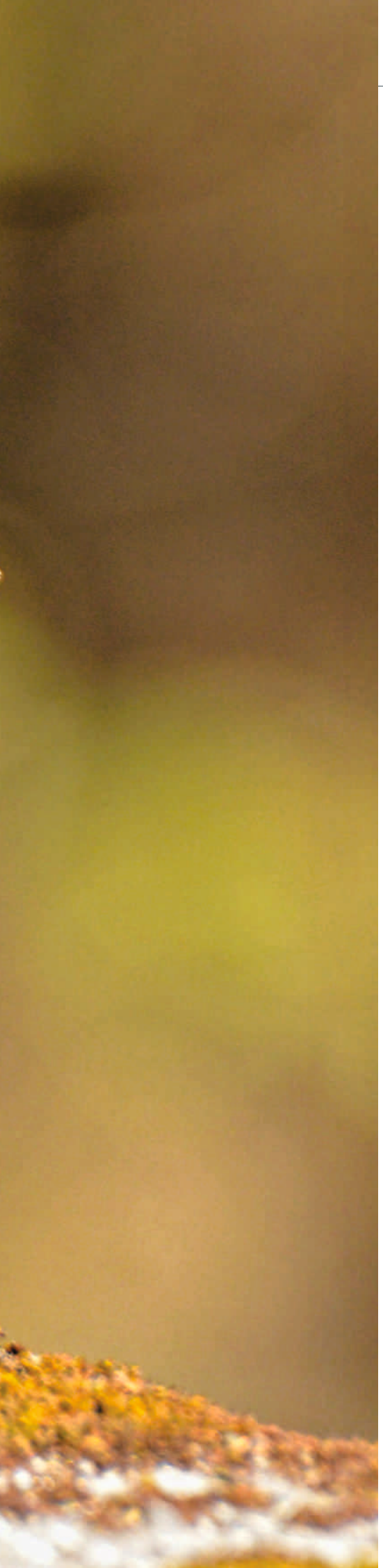
Discussion

The Nyamjang Chu, flowing through the study area, constituted 22% of the total study area, with the few streams that drain into it from both the sides. The proposed dam site will submerge all the lowland vegetation as well as the sacred grove in the area. According to SRTM DEM, at full reservoir level (FRL), the total upstream study area will be submerged by 63%, submerging more than 91% of the *Hippophae* area and 85% of the seasonal sandbars, leaving only 15% of the foraging ground of the Black-necked crane.

The luxuriant growth of *Alnus* and *Hippophae* may lead to dense forests near the riverine area in the near future, which may have adverse impacts on the use of the habitat by the Black-necked crane. Therefore, harvesting of selected shrubs and trees sustainably may be considered, without compromising the habitat requirements of Black-necked crane.

BIRD DIVERSITY AND ABUNDANCE





Introduction

Modifications to natural landscapes by hydroelectric projectsstations interfere with the distribution and abundance of species by altering the quality of habitats (Benchimol & Peres 2015). The occurrence of bird species is related to the vegetation structure (Roth 1976; Finch 1989, 1991). Therefore, the presence and absence of birds in relation to vegetation have affected the diversity and richness of those areas. Abundance is an ecological concept referring to the relative representation of a species in a particular ecosystem. It is usually measured as the number of individuals found per sample. Abundance is contrasted with, but typically correlates to, incidence, which is the frequency with which a species occurs in a sample. When high abundance is accompanied by low incidence, there is a case of local or sporadic abundance.

The study area, which falls in the Zemithang-Nelya area, is listed as an Important Bird Area (IBA code INAR-28), in which several bird species are listed as Vulnerable and Near Threatened by the IUCN (Islam & Rahmani 2004). These include species such as the Satyr Tragopan (*Tragopan satyra*), Wedge-Billed Wren-Babbler (*Sphenocichla humei*) and Ward's Trogon (*Harpactes wardi*), which are categorised as Near Threatened, while species such as the Black-necked crane (*Grus nigricollis*) are Vulnerable. However, due to the topography, climate and difficulty of access of this area, the avifauna is poorly documented (Srinivasan et al. 2010).

4

CHAPTER

Methods

Three transects of 2 km each were selected around the study area. Variable-width point count surveys were carried out fortnightly for 10 minutes at 12 randomly selected points at 200 m apart along each of the three transects. The surveys were conducted from 0500 hours to 1000 hours. During the count, the time of observation, number of individuals, name of the species, and distance from the point and height of sighting of birds were measured using a range finder. Birds were counted within a 10-minute of each point count. Calls and flying birds were also recorded within the scheduled 10-minute observational point counts. Twelve points count were done in each of the three transects. The fixed-point count method as described by Buckland *et al*. (2001) and Bibby *et al*. (2000) was used to estimate the density of the birds. Transects that were suitable for point counts were selected all around the proposed hydroelectric power project construction area.

The entire study area, from Zemithang to Brokenthang, was covered, including the submergence zone. Seven replications of each of the three transects were carried out for each 12 point counts. The relative abundance of the birds in the study site is shown in appendix 4. The total number of birds (for example, in a pair or a flock) seen or heard by the observer, of each species, during the point counts in each fragment were also used for statistical calculations. The abundance, density and diversity of different bird species were calculated using Distance (version 6.2). The results are discussed in the following section.

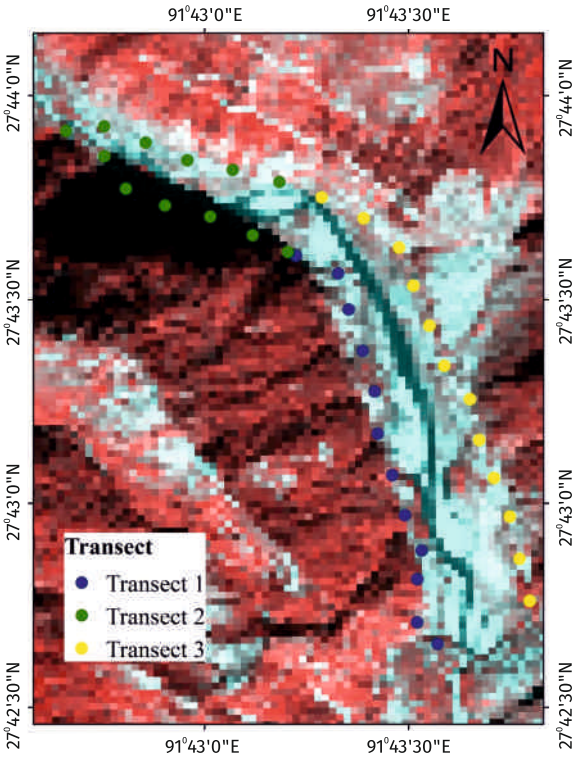


Figure 4.1: Bird count transects along Nyanjang Chu River

Results

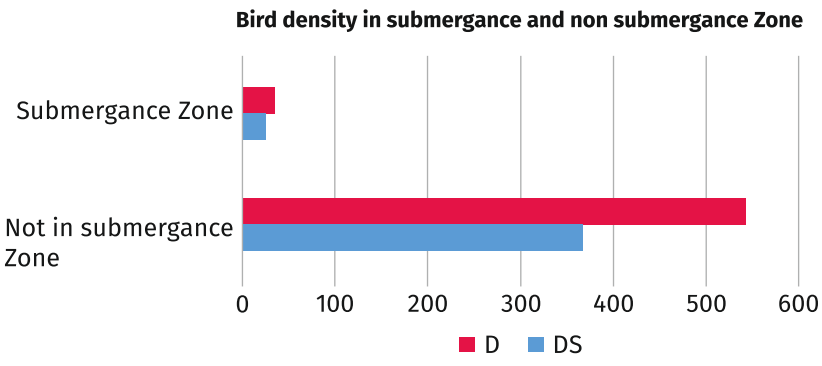
The study area was observed to have a rich diversity of birds, as reported by many researchers (Mishra et al. 2004; Maheswaran 2013; Chakraborty et al. 2018). The highest relative densities and relative abundances were those of the Russet Sparrow (*Passer cinnamomeus*), Spotted Dove (*Spilopelia chinensis*) and Yellow-Breasted Greenfinch (*Chloris spinoides*), and the lowest values were those of the Black-Throated Sunbird (*Aethopyga saturata*), Blue-Winged Minla (*Minla cyanouroptera*) and Ruddy Shelduck (*Tadorna ferruginea*). The highest bird density recorded was in the forest patches, followed by the *Artemesia* grassland. Though most of the species were recorded in the non-submergence zone, but few important species were also recorded in the submergence zone, including the Ibisbill (*Ibidorhyncha struthersii*), Goosander (*Mergus merganser*), Tufted Duck (*Aythya fuligula*) and Ruddy Shelduck (*Tadorna ferruginea*).

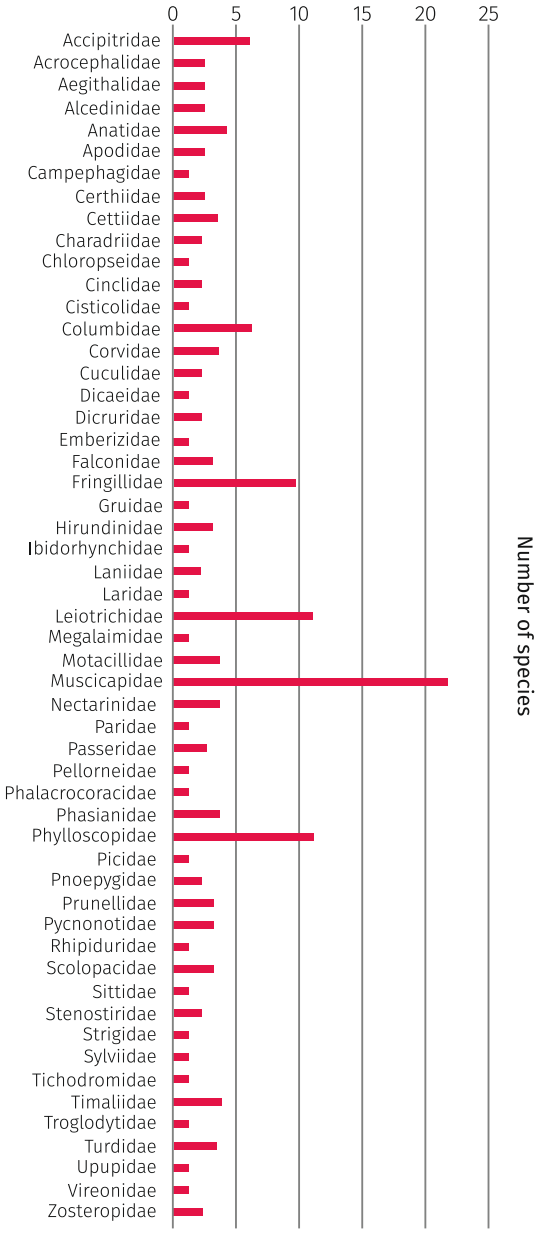
Table 4.1: Details of bird diversity in the study area

Sl. No.	Parameter	Transect 1	Transect 2	Transect 3
1	Total number of individuals	725	910	277
2	Dominance_D	0.07738	0.1438	0.05811
3	Simpson_1-D	0.9226	0.8562	0.9419
4	Shannon_H	3.097	2.626	3.157
5	Evenness_e^H/S	0.4098	0.3005	0.5875
6	Richness per site	54	46	40

Figure: 4.2 Bird densities in submergence and non-submergence zones

The maximum diversity was recorded in Transect 3 where species like the Tawny Fish Owl (*Ketupa flavipes*) was sighted. The highest richness value was that of Transect 1. This transect had a rich avifauna because there were fewer settlements on that side of the river.





From the point count data 54 species have been reported. However a total of 159 bird species in 54 families were found from the whole Zemithang area. The family Muscicapidae had the largest number of species.

Figure 4.3: Number of species by family from the point counts and daily bird surveys.

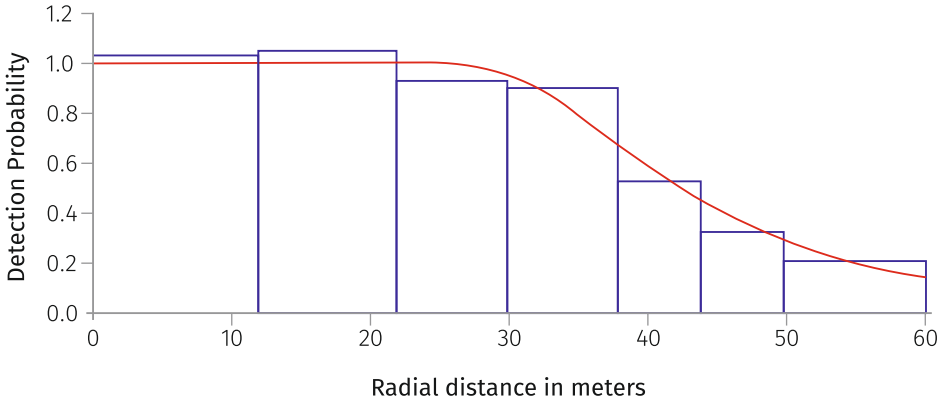


Figure:4.4: The graph shows how the detection probability changes with radial distance from each point.

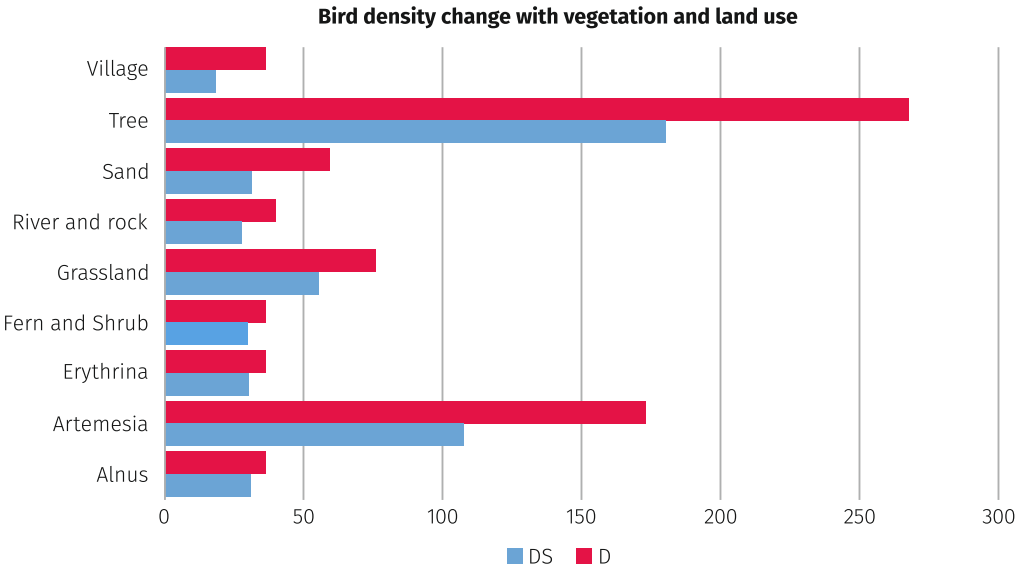


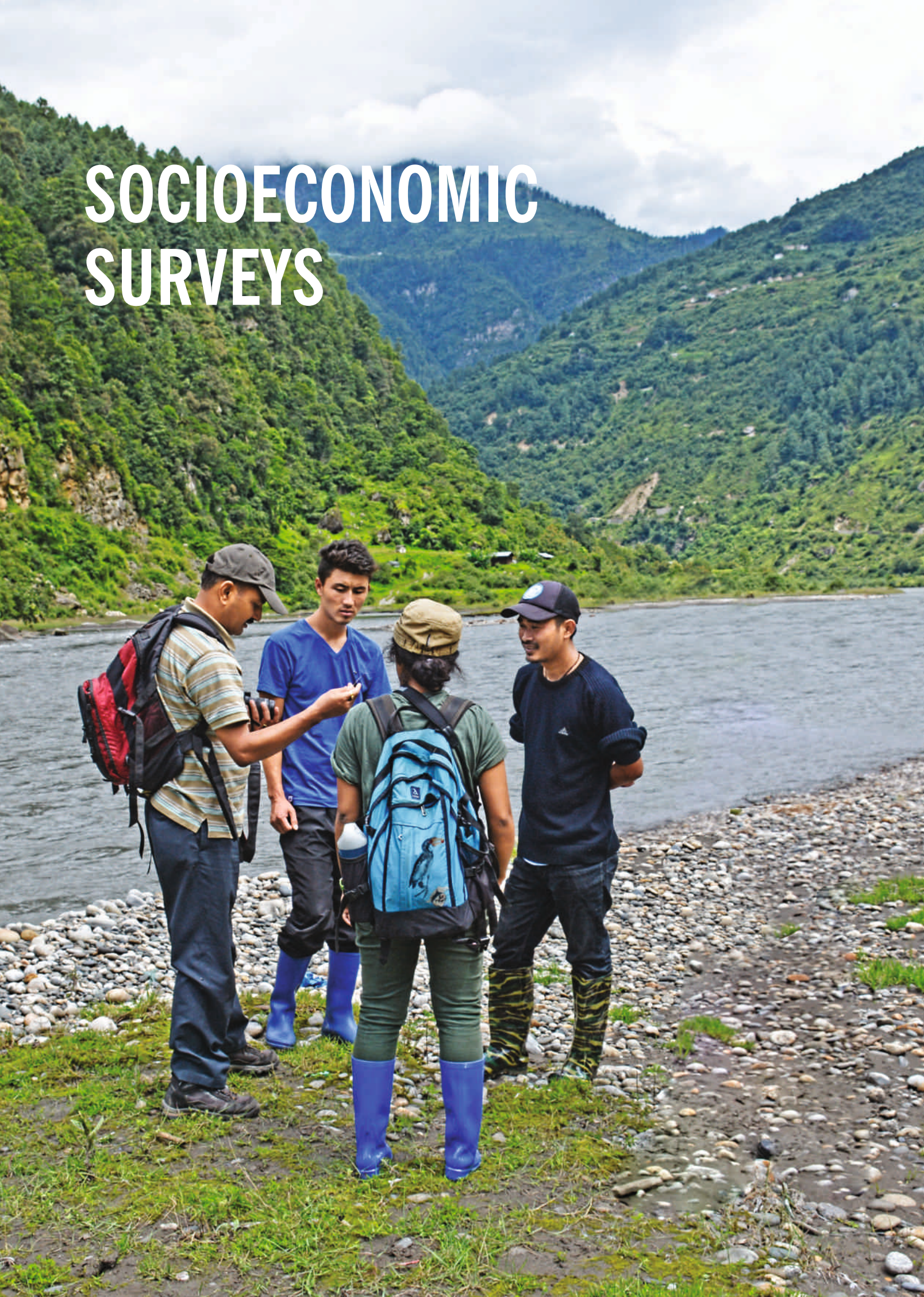
Figure: 4.5: Bird densities in different vegetation layers. D, estimate of density of clusters; DS, estimate of density of bird species

Discussion

A total of 159 bird species were found during the survey. Other than the Vulnerable Black-Necked Crane, the study area had a rich diversity of birds. Among the bird species found were the Near Threatened Satyr Tragopan (*Tragopan satyra*) and Himalayan Griffon (*Gyps himalayensis*). The present checklist includes a rare member of the Strigiformes (owls) that was recorded for the first time in the region, the Tawny Fish Owl (*Ketupa flavipes*). The Zemithang-Neyla area has been declared as an Important Bird Area (IBA code INAR-28). This IBA has many bird species that are listed as Vulnerable and Near Threatened by the IUCN (Islam & Rahmani 2004). These include species such as the Wedge-Billed Wren-Babbler (*Sphenocichla humei*) and Ward's Trogon (*Harpactes wardi*), which are categorised as Near Threatened. The site is included in the Eastern Himalaya Endemic Bird Area (Stattersfield et al. 1998). Species such as the White-Naped Yuhina (*Yuhina bakeri*), Ludlow's Fulvetta (*Alcippe ludlowi*), Broad-Billed Warbler (*Tickellia hodgsoni*), Hoary-Throated Barwing (*Actinodura nipalensis*) are some of the important endemic species have been observed in this area. This site is also important for biome-restricted species. Interesting species found in this IBA include the Snow Partridge (*Lerwa lerwa*), Ibisbill (*Ibidorhyncha struthersii*), Snow Pigeon (*Columba leuconota*), Gray-Backed Shrike (*Lanius tephronotus*) and Blood Pheasant (*Ithaginis cruentus*).

Figure 4.6: Goosander (*Mergus merganser*) in Nyamjang Chu River

SOCIOECONOMIC SURVEYS



Introduction

Humans have been building dams for over 5000 years, but the pulse of dam-building in the last century has altered riverine ecosystems more extensively than has any other anthropogenic activity, leaving two-thirds of the world's large rivers fragmented by dams (Nilsson *et al*. 2005). If mismanaged, the indirect effects following dam construction have the potential to profoundly affect regional biodiversity in the absence of effective government command and control. Once construction contracts are terminated, the suddenly-unemployed construction workers often join other migrants and resort to exploitative activities such as illegal deforestation (Fearnside 2008).

The major indiegenous community in the study area are Monpas. They are predominantly Buddhist, inhabiting the high-altitude Himalayan grasslands (10,000-15,000 feet) in Tawang and parts of West Kameng District, of Arunachal Pradesh. Subsistence forms of agricultural and high-altitude pastoralism are two of the most widespread forms of economic activities traditionally practised among them.

One of the larger pastures of Tawang District, Zemithang Valley is mainly home to the Monpas. Pastoralism is what had traditionally underpinned their economy and culture. The Monpas arrived between 500 BC and 600 AD, during the reign of the Monyul kings, and since then they have been permanent inhabitants of this region. Grazing is still an important socioeconomic activity among the Monpas. Although most of the other Monpas in different parts of Tawang and West Kameng have discontinued traditional livestock rearing and grazing activities, the people in Zemithang Valley still practice these activities because they have strong religious connections with the Tawang Monastery, which has played an institutional role for the community. In 1969, the Zemithang Circle was recognised under the Lumla Subdivision, which was traditionally known as Pangchen Dingduk (Norbu 2008). Pangchen Dingduk consists of six villages: Lumpo, Kharmen, Khelengteng, Upper and Lower Socktsen and Muchut.

The total population of Zemithang Circle (according to the 2001 census report) is 2805 since it consists of 12 villages, including Sirdhi, Khobleteng, Shakti and Thiksi), and each village has a population of 200-900, with 50 to over 100 houses per village.

But today, the Monpas have politically, economically and socially drifted to the mainstream economy. Many of them are engaged in commercial farming, horticulture or government jobs, and most of them are engaged as daily wage labourers, building roads for the PWD, the BRO and private companies. Thus, their socioeconomic situations and living are undergoing a rapid transformation

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(Farooque & Rao 2001). Despite their rich history and complex connection to the national economy, the popular image of the Monpas as remote people in a pristine mountain environment influences the way governments shape and implement policies that affect them and how conservationists approach the Himalaya as a region in critical need of environmental protection (Farooque & Rao 2001; Fratklin 1997; Goodall 2004; Sureja 2006).

Unlike some other parts of the world, where traditional hunting is one of the major issues that heightens the conflict between conservationists and the local community, Zemithang Valley does not have that problem. The valley itself has restrictions over hunting practices. In West Kameng District, where most of the people are Dirang Monpas, Buddhism is a religion that was not introduced to them for long.

Unlike Dirang the first settlement was of a Buddhist Tibetan population, and so there was not much acculturation until recently. The second reason why people of Zemithang Valley do not hunt or hunting is banned in Zemithang is the social side of the community. As mentioned earlier, since pastoralism is the main livelihood activity that people are dependent on, the social dimensions and food habits revolve around pastoralism. Also, other than pastoralism, small-scale agriculture is practiced in the region, and the main crop that is widely grown here is *moruwa* (millet). Due to the rugged terrain and temperature, millet is a kind of crop that grows well (Michaelraj & Shanmugam 2013).

Having a variety of socioeconomic status within a small geographic area presents opportunities for disparity in impacts of environmental changes. Dams are a primary example of large infrastructure projects that present opportunities for economic development, while they also engender environmental changes that consequentially feed back to the social and economic values of communities downstream. With highly valued ecosystems and people who rely on the land closely for their livelihoods, it is important to take all possible impacts into account. Most communities, from villages to cities, are located adjacent to bodies of water. As global energy production shifts away from fossil fuels, domestic production of energy is increasingly desired. Decision-makers are revisiting hydroelectric dams as a means of increasing energy security and supporting economic growth and development ("Modern hydropower," 2007a).

Methodology

Socioeconomic impact analysis can be completed with a variety of tools. A questionnaire is the most efficient option. It allows a broad sample size to be covered, in a minimal time period, and generates uniform results (Saris & Gallhofer 2007). The use of a questionnaire allowed the research project to evaluate the perceived socioeconomic impacts on the local community, gather participant demographics and examine factors that determine the perceived level of impact within the target population.

Questionnaire surveys were conducted among 46 people in the study area. Out of the 46 people, seven were from Brokenthang, 21 from Kelaktang, 12 from Shoktsen, four from Kharman and one each from Zemithang and Gorzam. Most of the people who participated in the survey were labourers. Only two farmers and one headmaster were involved. Most of the people earned Rs.350 per day as their wages. A few were government officials.

Results

Question 1: Do you want the construction of the dam or not?

Yes/No

Results: 100% were against the construction of the dam.

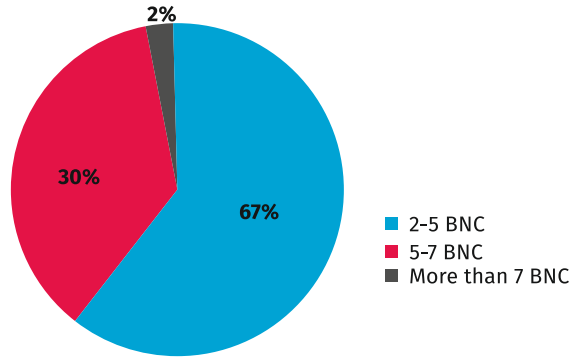
Discussion: All of them who were interviewed were aware of the construction of the dam. Not a single person agreed to the construction of the dam. This is because the construction of the dam will nearly submerge a large part of the area, including settlements of the people and a 13th century stupa, Gorzam Chorten, which has great cultural and historical significance.

Question 2: How many Black-necked crane have you seen?

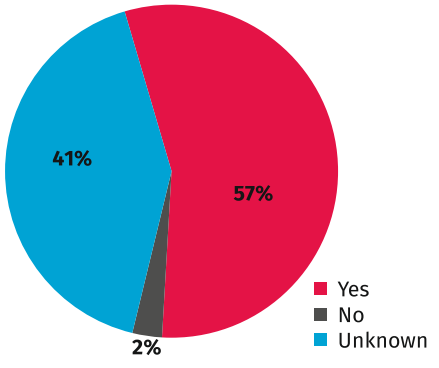
Results: Among the sample group, 67% had seen 2-5 Black-necked cranes in the study area, 14% had seen 5-7 Black-necked cranes; however, only 2% had seen more than seven cranes, that is, only one senior person from Shoktsen had seen 18-19 cranes. He had been seeing cranes for the past 65 years (as told by the person).

Discussion: It is clear from the views expressed that the Black-necked cranes come to Zemithang Valley in small numbers. However, there are certain reports were they have been seen flying in huge numbers above the valley, but there is no direct evidence of the birds landing in the valley.

Number of Black-necked cranes seen in the valley



Number of Black-necked cranes declined from the past



Question 3: Is there any decline in the number of Black-necked cranes over the years? Yes/No

Results: Within the sample group most of the people (around 26) had observed a decline in the number of Black-necked cranes in Zemithang Valley. However, many of them preferred not to answer the question as they had not noticed the cranes regularly.

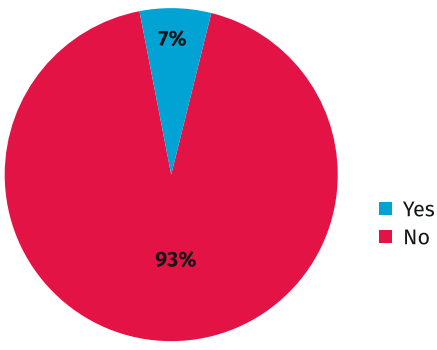
Discussion: Most of the people observed a decline in their numbers. This can be due to the continuous habitat destruction due to sand mining and road construction near the riverbank, as well as loss of agricultural fields, of which there were many near the riverbanks previously.

Question 4: Have you seen any hunting of Black-necked crane by humans or animals?

Results: Three out of the 46 people had heard about the death of one Black-necked crane, which was killed by some people from outside who came to hunt in Zemithang. There is no direct evidence of any other threat in Zemithang so far other than sand mining.

Discussion: The people were quite aware about the fact that hunting is not allowed in this particular habitat due to the local religious belief of the Monpas living there. They had also never seen any carnivores that would hunt the cranes. Only a few of the people had heard about one death, which had been caused by some outsiders.

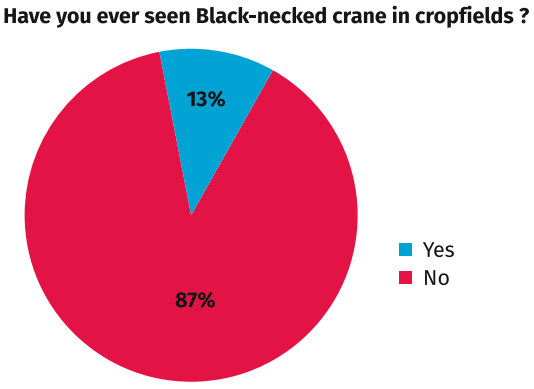
Have you seen any hunting of Black-necked crane ?



Question 5: Have you ever seen Black-necked cranes in crop fields?

Results: Almost none of the people had ever observed Black-necked cranes in crop fields. However, six people had seen cranes in the areas, mainly in the *marwa* (millet) fields near Dung and Nergong Basti, in Zemithang Circle.

Discussion: The people had practically never observed cranes in other agricultural fields as they had been constantly watching the crane for consecutive years in the Nyamjang Chu River bed area (the study area). However, some of them had observed them in the *marwa* fields, which clearly shows that their habitat preference includes farmlands. A study at Caohai quantified the selection of winter foraging habitat by Black-necked cranes. Sedge meadows were preferentially selected, followed by grasslands and farmlands (Li 1999). The cranes also generally avoided grasslands, preferring farmland, marshes and water. This is probably because of the different levels of food availability in the four habitats and possibly because of other physiological requirements (Jun et al. 2011).



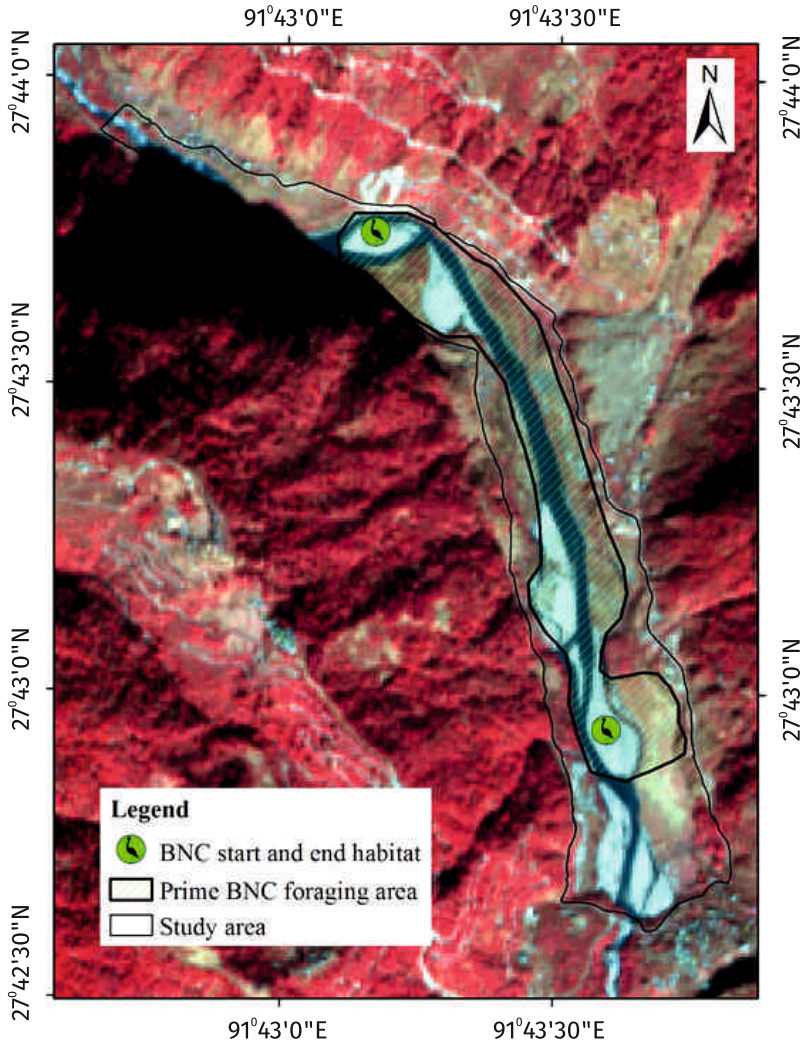
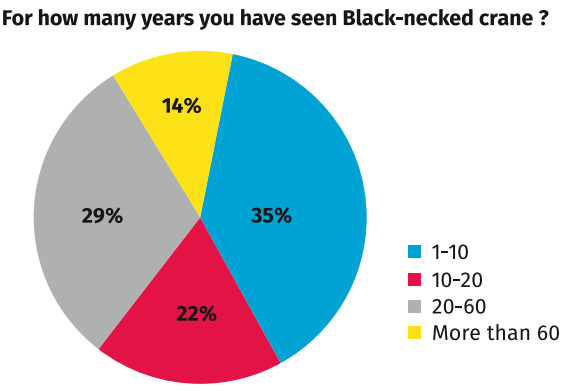


Figure 5.1: Habitat of Black-necked crane in Zemithang, Nyamjang Chu HEP barrage site

Question 6: For how many years are you seeing Black-necked crane?

Results: Seventeen people were observing the cranes for 1-10 years. Eleven were seeing them for 10-20 years, and 14 had been sighting them for 20-60 years. However, only seven people had seen them for more than 60 years in their lifetime.

Discussion: The sample group consisted mostly of young or middle-aged people who had been observing the cranes only from the recent past. But a few of the elders had answered about their presence from the early 20th century. This shows that the area has been used by the Black-necked crane as a critical wintering site for a very long period of time.



Discussion

The survey showed that a large number of people were aware about the construction of the dam and that no one wanted the dam to be constructed as a vast area of their land will be submerged after the construction. When the dam was first proposed in 2006, a majority of the people in the region were enthusiastic about the proposed plan. Since the country's hydropower sector had planned for long-term development, promises were made by private companies and the state to improve the region's living conditions through new ventures, job opportunities and overall development. But now the people can understand the negative effects of the dam to be constructed. At the same time they were all aware about the Vulnerable Black-necked crane visiting Nyamjang Chu Valley. The people have a lot of knowledge and respect for the flora and fauna of the region as well as a religious attachment with the Black-necked crane. The survey showed that they had knowledge and ideas about the species to be conserved. Also most of the Monpas in the region are Buddhists and have a strong religious attachment with the Monastery (Srivastava & Ramchandra 2016). The area is one of the pillars of ancient Buddhism, and the Gorsam Stupa, which is nearly 800 years old, is located close to the proposed dam site and might be adversely affected by construction activities such as blasting and tunnelling. The people were well aware about the effects the dam would have on the stupa, and no one agreed to the construction of the dam there.

Figure 5.2: Questionnaire survey of locals

CAMERA TRAP RECORDS AND FAUNAL ASSEMBLAGE

Introduction

The Nyamjang Chu River Valley area from Zemithang to Brokenthang is an important habitat for the survival of different animals. The area has different types of vegetation and provides a foraging ground and cover for different animals. Barking Deer, Eurasian Otter, Himalayan Crestless Porcupine, Yellow-Throated Marten, Arunachal Macaque, Capped Langur, Orange-Bellied Squirrel, Pika and Bhutan Striped Squirrel can be seen here. A survey carried out in 2004 by ecologists from the Nature Conservation Foundation reported 35 mammal species from six areas in Tawang and West kameng districts. (Lower Nyamjang Chu, Upper Nyamjang Chu Valley, PTSO, Mukto, Mago Chu and the high altitude areas of West kameng). While 35 species were confirmed from the entire area, at least 21 mammal species (including three Endangered and four vulnerable species) were recorded either through direct sightings or reliable local evidence in the Lower and Upper Nyamjang Chu Valley (Mishra *et al*. 2004, 2006). Even though the rest of the species were not confirmed, most of these species are likely to occur in the Nyamjang Chu Valley. The Monpa people living in this area have banned hunting and fishing (Mishra *et al*. 2006; Aiyadurai *et al*. 2010). They fear that with the influx of a huge migrant population there will be greater pressures on forest resources and increased poaching and fishing. Due to the prohibition of fishing practices we could not sample the fish fauna of the area. The valley is also home to other Schedule 1 species such as the Red Panda (*Ailurus fulgens*, found in the Zemithang- T-Gompa area), the Snow Leopard (*Panthera uncia*, in the Nelya-T Gompa area), Musk Deer (*Moschus* sp.) and Takin (*Budorcas taxicolor*) (both in the higher reaches) and the Arunachal Macaque (*Macaca munzala*, a newly described primate species in the area) (Sinha *et al*. 2005). There are several troops of the Arunachal Macaque in the Zemithang Valley, which is one of the primary habitats of this species (Kumar *et al*. 2007; Mendiratta *et al*. 2009).

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Methods

Regular surveys were carried out in the area from Zemithang to Brokenthang village, in the Nyamjang Chu Valley, from August 2017 to February 2018. Areas close to the Nyamjang Chu river (Lumpo, Muchut, Shoktsen, Kelaktang and Kharman) were also surveyed for mammals. We conducted extensive field surveys in the region with the assistance of local guides. We scanned the slopes from vantage points for large vertebrate wildlife, using binoculars. Sighting records of all mammal and bird species were maintained, including the location, altitude and habitat type.

Camera trapping was done in the submergence zone. Ten cameras were set in different regions near the submergence zone of the Nyamjang Chu River, and the cameras were kept in position for 62 camera trap nights. Cameras are usually set 30-40 cm above the ground to accommodate the height of the target species. Mammals can be active during the day or night, and therefore camera traps are programmed to take pictures 24 hours per day. In locations with low traffic, camera traps are typically checked only once every 10-14 days, whereas they are checked every 2 or 3 days at sites with high traffic, in order to avoid running out of film. Pilot surveys are useful for determining the frequency with which cameras and film need to be checked and replaced, as well as for determining the optimum sites for photographing animals (Rosas-Rosas 2006).

Digital infrared camera traps (Cuddeback Color Model 1279) equipped with 8 GB SD cards (SanDisk Western Digital Technologies, USA) were used. Each camera was attached to the nearest tree at an angle that minimised the duration during which direct sunlight fell on the camera lens and on the infrared sensors. We programmed each camera to record a video of 10 seconds when the infrared sensor was triggered. The time delay for activation is usually between 30 seconds and 5 minutes, but in places with high traffic of non-target species/objects (e.g., roads with trucks, trails or salt licks with people or wildlife), a longer time delay was used. We defined a 1-minute interval between two consecutive videos, and the sensor sensibility was set to medium.

The technique does not have to be based on a random sampling of the area. Rather, cameras are set up systematically in a pattern designed to maximise capture the probability for all the animals in the sampled area (Silver 2004).

Results

Camera trap records:

1. Himalayan Crestless Porcupine (*Hystrix brachyura*), Least Concern
2. Barking Deer (*Muntiacus muntjac*) Schaller and Rabinowitz (2004): Least Concern. *M. vaginalis* at high altitudes in Arunachal Pradesh, with one direct sighting at 3000 m asl near Tawang, and there may therefore be significant local variations in the upper altitudinal limit.
3. Leopard Cat (*Prionailurus bengalensis*) (Kerr, 1792), Least Concern
4. Wild Boar (*Sus scrofa*) Linnaeus, 1758, Least Concern
5. Arunachal Macaque (*Macaca munzala*) Madhusudan & Mishra, 2005, Endangered

Figure 6.1: Arunachal Macaque (*Macaca munzala*) in Zemithang

Direct sightings (photographic evidence/direct sightings):

1. Arunachal Macaque (six troops)
2. Capped Langurs (two troops; one near Brokenthang ,one near Gorzam)
3. Yellow-Throated Martens
4. Eurasian Otter
5. Barking Deer
6. Himalayan Goral
7. Chinese Goral
8. Sambar
9. Himalayan Striped Squirrel
10. Orange-Bellied Himalayan Squirrel

Indirect records (reported/previous sightings):

Musk Deer, Himalayan Serow, Blue Sheep, Snow Leopard, Common Leopard, Himalayan Black Bear, Slow Loris, Takin, Wild Dog, Himalayan Marmot, Large-Eared Pika

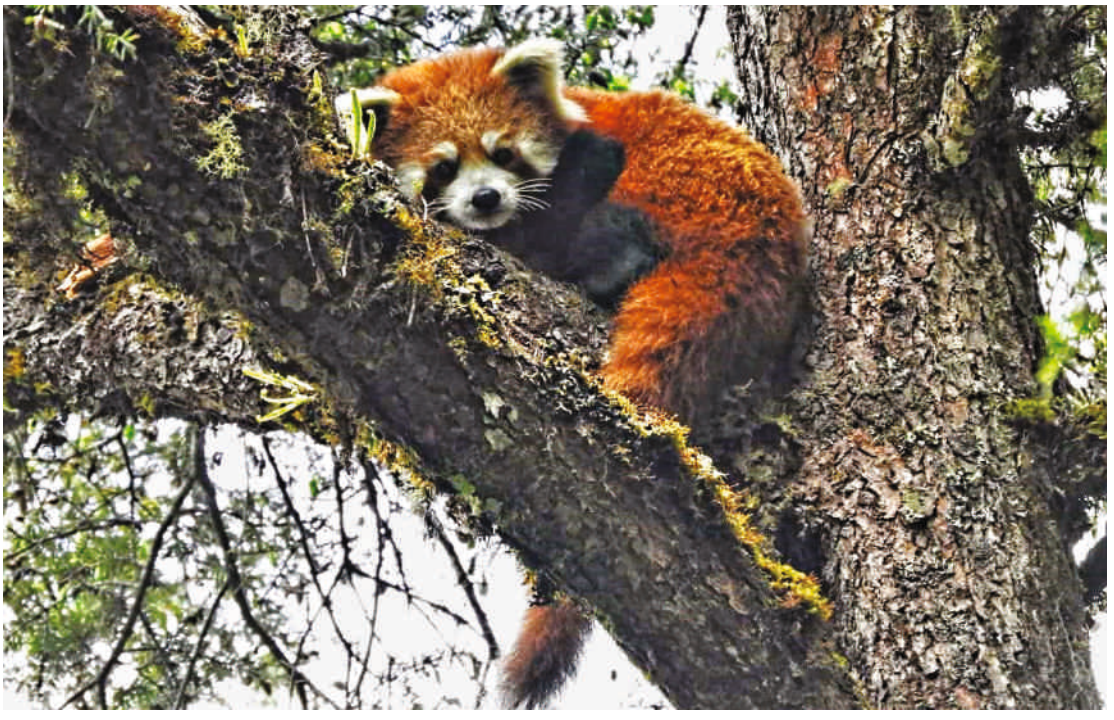


Figure 6.2: Red Panda (*Ailurus fulgens*) in Pangchen Valley (photo: Degin Dorjee)

Table 6.1: List of direct and indirect sightings of mammals

Species	Scientific name	IUCN status	Direct evidence		Indirect evidence
			Camera trap	Direct sightings	
Himalayan Crestless Porcupine	*Hystrix brachyura*	Least Concern	+	+	Quills
Barking Deer	*Muntiacus muntjac*	Least Concern	+	+	Reported/previous sightings
Leopard Cat	*Prionailurus bengalensis* (Kerr, 1792)	Least Concern	+	--	Reported/previous sightings
Wild Boar	*Sus scrofa Linnaeus*, 1758	Least Concern	+	+	Droppings

Species	Scientific name	IUCN status	Direct evidence		Indirect evidence
			Camera trap	Direct sightings	
Capped Langur	*Trachypithecus pileatus* Horsfield, 1851	Vulnerable	--	+	–
Yellow-Throated Marten	*Martes flavigula* (Boddaert, 1785)	Least Concern	--	+	Reported/previous sightings
Himalayan Goral	*Naemorhedus goral* (Hardwicke, 1825)	Near Threatened	--	+	Reported/previous sightings
Himalayan Serow	*Capricornis thar* Hodgson, 1831	Near Threatened	--	--	Reported/previous sightings
Eurasian Otter	*Lutra lutra* (Linnaeus, 1758)	Near Threatened	--	+	Reported/previous sightings
Smooth-Coated Otter	*Lutrogale perspicillata* (Geoffroy Saint Hilaire, 1826)	Vulnerable	--	+	Reported/previous sightings
Chinese Goral	*Naemorhedus griseus* Milne-Edwards, 1871	Vulnerable	--	+	Reported/previous sightings
Himalayan Striped Squirrel	*Tamiops macclellandii* (Horsfield, 1840)	Least Concern	--	+	Reported/previous sightings
Hodgson's Giant Striped	*Petaurista magnificus* (Hodgson, 1836)	Least Concern	--	+	–
Masked Palm Civet	*Paguma larvata* (Hamilton-Smith, 1827)	Least Concern	--	--	Reported/previous sightings (Barik 2015)
Orange-Bellied Himalayan Squirrel	*Dremomys lokriah* (Hodgson, 1836)	Least Concern	--	+	Reported/previous sightings
Asiatic Golden Cat	*Catopuma temminckii* (Vigors & Horsfield, 1827)	Near Threatened	–	+	-
Indian Sambar	*Rusa unicolor* (Kerr, 1792)	Vulnerable	--	+	Reported/previous sightings
Red Panda	*Ailurus fulgens* F.G. Cuvier, 1825	Endangered	--	--	Droppings
Himalayan Serow	*Capricornis thar* Hodgson, 1831	Near Threatened	--	--	Reported/previous sightings
Alpine Musk Deer	*Moschus chrysogaster* (Hodgson, 1839)	Endangered	--	--	Reported/previous sightings
Bharal	*Pseudois nayaur* (Hodgson, 1833)	Least Concern	--	--	Reported/previous sightings
Snow Leopard	*Panthera uncia* (Schreber, 1775)	Vulnerable	--	--	Reported/previous sightings
Himalayan Black Bear	*Ursus thibetanus* G. [Baron] Cuvier, 1823	Vulnerable	--	--	Reported/previous sightings
Takin	*Budorcas taxicolor* Hodgson, 1850	Vulnerable	--	--	Reported/previous sightings
Asiatic Wild Dog	*Cuon alpinus* (Pallas, 1811)	Endangered	--	--	Reported/previous sightings
Himalayan Marmot	*Marmota himalayana* (Hodgson, 1841)	Least Concern	--	--	Reported/previous sightings

Species	Scientific name	IUCN status	Direct evidence		Indirect evidence
			Camera trap	Direct sightings	
Chestnut White-Bellied Rat	*Niviventer fulvescens* (Gray, 1847)	Least Concern	+	+	Reported/previous sightings
Large-Eared Pika	*Ochotona macrotis* (Günther, 1875)	Least Concern	--	+	Reported/previous sightings
Common Leopard	*Panthera pardus* (Linnaeus, 1758)	Vulnerable	--	--	Reported/previous sightings
Slow Loris	*Nycticebus coucang* (Boddaert, 1785)	Vulnerable	--	--	Reported/previous sightings
Total species	31				
Direct sightings of all species	16				
Species of global importance	18				
Indirect evidence	26				

Source of previous sightings: Mishra et al. (2006), Chakraborty & Upadhyay 2015, Medhi et al. (2014)

Figure 6.3: Leopard Cat in the submergence zone of the river (photo: camera trap image)

Documented reptiles:

A few reptiles were also documented during the study period.

Direct sightings

Jerdon's Pit Viper, *Protobothrops jerdonii* Günther, 1875)

Mountain Pit Viper, *Ovophis monticola* (Günther, 1864))

Large-Eyed False Cobra, *Pseudoxenodon macrops* (Blyth, 1855)

Figure 6.4: Jerdon's Pit Viper in Zemithang Valley (photo: Malyasri Bhattacharya)

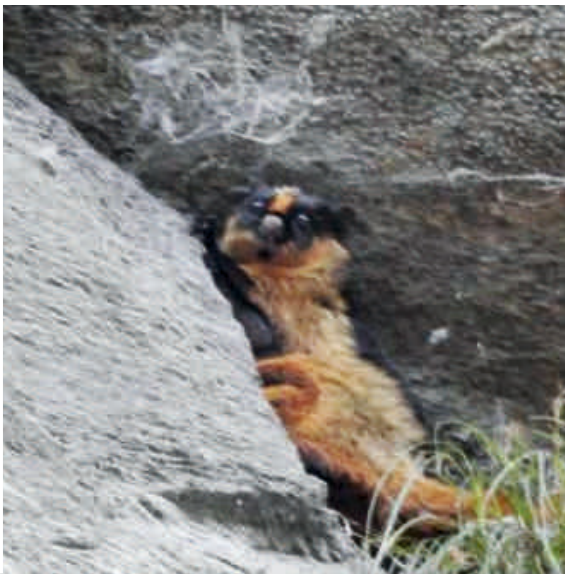
Discussion

This study has established the presence of a rich mammalian assemblage in Nyamjang Chu Valley, including 16 species of global importance. The density of the mammalian fauna of the survey region, including the probable submergence zone of the river, was high. Eight species were found in the submergence area. The Eurasian Otter *Lutra lutra* (Linnaeus, 1758) was recorded for the first time from the district. The Barking Deer, Yellow-Throated Marten and Eurasian Otter were seen directly in Nyamjang Chu Valley. The sand mining in the river valley is a serious threat for the wildlife. Previous surveys also established the presence of the endangered Snow Leopard in the region. The proposed hydroelectric power project will not only submerge the habitat of this rare mammal in the Nyamjang Chu River Valley but also will affect the whole forest area adjoining the valley. Because of the upcoming dam, the accessibility to the area will increase with the construction of roads, which can increase anthropogenic pressures, leading to impacts on the terrestrial ecosystem by the destruction of a vast extent of the habitat. It is also evident from the survey that during the dam construction phase, waste disposal, noise levels, increased vehicular movement and an influx of a migrant labour population can have various kinds of negative impacts on the faunal diversity, both short-term and long-term.

Eurasian Otter (*Lutra lutra*)

Indian Muntjac (*Muntiacus muntjak*)

Yellow-Throated Marten (*Martes flavigula*)



Hodgson's Giant flying squirrel (*Petaurista magnificus*)

Figure 6.5: Mammals from Zemithang Valley (photos: Malyasri Bhattacharya)

Himalayan Goral (*Naemorhedus goral*)

DIRECT IMPACT OF BARRAGE (SUBMERGENCE)

The Nyamjang Chu River HEP is proposed to construct a barrage of length of 151.0 m with an embankment length of 89.0 m. The average river bed level is 2106.20 m amsl, and the proposed bridge deck level is 2116.40 m amsl, meaning that a raised embankment barrage of 10.20 m is available for storage of water (DPR-Bilwara Private Limited). For continuous generation of power, the said project aims to store water up to a maximum level of 2114.9 m asl, meaning the depth will be 8.7 m at full reservoir level (FRL), and the minimum draw down water level (MDDL) will 2112.20 masl, meaning there will be 6 m of water above the average river bed level throughout the year. Construction of the proposed barrage will have a direct impact on the existing wetland ecosystem by partitioning the existing ecosystem. The upstream area will be converted into a lake/pond ecosystem, and the downstream area will be at the mercy of the barrage management authority (which aims to generate power continuously) and the rainfall/water availability. The downstream area will be dry during the lean season and will have an altered as well as fluctuating water level during the rainy season.

7

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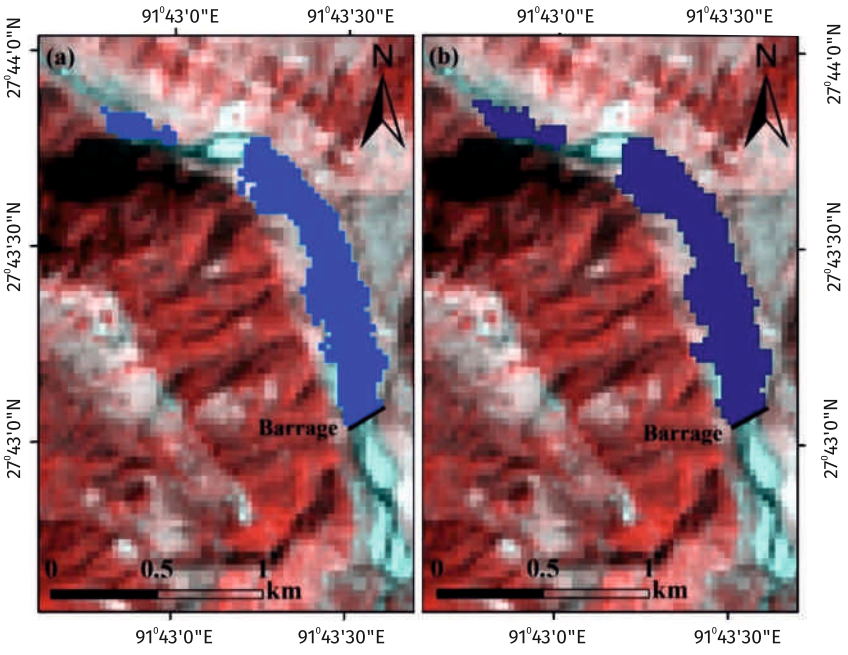

Figure 7.1: Area of submergence (a) at MDDL 2112 m and (b) at FRL 2115 m

Storage of water for generation of power will lead to submergence of most of the valley. To determine the submergence area, SRTM DEM data with 30 m spatial resolution were used, and the submergence areas at FRL and MDDL were worked out in a GIS platform using ArcGIS 10.1. The accuracy of these DEM cannot match a DEM or contour developed using field measurements. Hence the submergence area estimate may differ by a little from that made on the ground. The submergence at a water level of 2112.20 m (MDDL) was worked out for 2112 m due to the information limitation of the SRTM DEM. The area that will be submerged at 2112 was estimated at 33.251 ha (Figure 5(a)). Similarly, the submergence area at 2114.9 m (FRL 2115 m) was estimated to be 39.393 ha (Figure 5(b)).

To quantify the submergence area of different LULC classes, area statistics were worked out using the LULC and submergence layer in the ArcGIS platform. At FRL, the maximum percentage change will take place in the *Hippophae* habitats (91.78% will be submerged). About 44% of the land under the mixed and high grassland classes will also be submerged. About 18.3% of the low grassland class will be submerged. The house and farmland classes will also be affected (14%). The expected change in each LULC class at MDDL and at FRL is given in Tables 7.1 and 7.2.

LULC	Present (ha)	Unchanged (ha)	Submerged (ha)	Change (%)
Alnus	7.378	6.314	1.065	14.432
Apple orchard	0.296	0.296		0.000
Farmland	0.832	0.832		0.000
High grassland	4.474	3.295	1.179	26.352
Hippophae potential area	8.004	1.076	6.928	86.556
House and farmland	4.494	4.063	0.431	9.590
Low grassland	15.989	13.727	2.261	14.143
Mixed	15.706	10.358	5.348	34.052
River	20.873	10.713	10.159	48.673
Seasonal sandbar	13.492	8.253	5.240	38.835
Shrub-dominated	2.757	2.605	0.152	5.527
Stream	0.739	0.575	0.164	22.233
Total	**95.034**	**62.106**	**32.928**	**34.649**

Table 7.1: LULC changes in the entire study area at MDDL

Table 7.2: LULC changes in the entire study area at FRL

LULC	Present (ha)	Unchanged (ha)	Submerged (ha)	Change (%)
Alnus	7.378	5.847	1.532	20.757
Apple orchard	0.296	0.296	-	0.000
Farmland	0.832	0.739	0.093	11.169
High grassland	4.474	2.488	1.986	44.398
Hippophae potential area	8.004	0.658	7.346	91.780
House and farmland	4.494	3.852	0.641	14.272
Low grassland	15.989	13.062	2.926	18.302
Mixed	15.706	8.716	6.991	44.508
River	20.873	9.925	10.948	52.452
Seasonal sandbar	13.492	7.909	5.583	41.382
Shrub-dominated	2.757	2.557	0.200	7.259
Stream	0.739	0.575	0.164	22.233
Total	**95.034**	**56.623**	**38.411**	**40.418**

As the Black-necked crane habitat was confined to the upstream of the proposed barrage, the LULC changes at FRL and MDDL were also worked out. At FRL, 54% of the total upstream area will be submerged, including 86% of the *Hippophae* area and 80% of the seasonal sandbars, which are the prime foraging ground of the Black-necked crane. Details of the LULC changes upstream at FRL are given in Table 7.2.

Figure 7.2: Black-necked crane on seasonal sandbars of Zemithang, Nyamjang Chu HEP barrage site, Aruncahal Pradesh (picture: Pemba Tsering Romo)

Table 7.3: LULC changes in the area upstream of the proposed barrage site at MDDL

LULC	**Present (ha)**	**Unchanged (ha)**	**Submerged (ha)**	**Change (%)**
Alnus	4.035	2.971	1.065	26.387
Apple orchard	0.296	0.296	0.000	0.000
Farmland	0.360	0.360	0.000	0.000
Highland grassland	3.636	2.457	1.179	32.423
Hippophae potential area	8.004	1.076	6.928	86.556
House and farmland	3.316	2.885	0.431	12.997
Lowland grassland	4.998	2.737	2.261	45.242
Mixed	13.194	7.846	5.348	40.535

LULC	Present (ha)	Unchanged (ha)	Submerged (ha)	Change (%)
River	15.102	4.943	10.159	67.271
Seasonal sandbar	6.534	1.295	5.240	80.187
Shrub-dominated	1.053	0.901	0.152	14.470
Stream	0.239	0.075	0.164	68.669
Total	**60.768**	**27.840**	**32.928**	**54.186**

When the water level is increased to FRL, 63% of upstream part of the study area that will be submerged including more than 91% of the Hippophae area and 85% of the seasonal sandbars, leaving only 15% of the foraging grounds for the BNC. Detail of the LULC changes in the upstream section at FRL are given in Table 7.4.

Figure 7.3: BNC in low grassland (near *Alnus* patch) of Zemithang, Nyamjang Chu HEP barrage site, Arunachal Pradesh (picture: Pemba Tsering Romo)

Table 7.4: LULC changes in the upstream part of the study area of the proposed barrage site at MDDL

LULC	Present (ha)	Unchanged (ha)	Submerged (ha)	Change (%)
Alnus	4.035	2.504	1.532	37.953
Apple orchard	0.296	0.296		0.000
Farmland	0.360	0.267	0.093	25.811
Highland grassland	3.636	1.650	1.986	54.627
Hippophae potential area	8.004	0.658	7.346	91.780
House and farmland	3.316	2.675	0.641	19.341
Lowland grassland	4.998	2.072	2.926	58.547
Mixed	13.194	6.204	6.991	52.982
River	15.102	4.205	10.948	72.495
Seasonal sandbar	6.534	0.951	5.583	85.447
Shrub-dominated	1.053	0.853	0.200	19.006
Stream	0.239	0.075	0.164	68.670
Total	**60.768**	**22.409**	**38.411**	**63.209**

SUITABILITY OF BARRAGE SITE FOR BLACK-NECKED CRANE

Reason why we need to conserve this particular ecosystem

Black-necked cranes are migratory birds wintering in Zemithang. During the questionnaire survey, a senior villager revealed that for more than 50 years the Black-necked crane has been a regular winter visitor to Zemithang, Nyamjang Chu River. Further discussions with the villagers indicated that confirmed sightings were confined to Zemithang and Brokenthang Bridge. An attempt was made to understand the reasons for the Black-necked crane to chose this particular location, using a simple weighted overlay method and the elevation, slope and proximity to the river.

To establish a sound reason, through literature, well known Black-necked crane wintering site of Bhutan were selected to find out the suitable habitat condition (slope & altitude). Bhutan was selected considering its proximity and geographic similarity to Zemithang. Some of the well-established Black-necked crane wintering sites in Bhutan, where large number of Black-necked cranes are seen every year and reported, are listed in Table 8.1.

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Sl. no.	Latitude (°N)	Longitude (°E)	Location	Elevation from DEM (m)
1	27.48361	90.68636	Kawdang Singma	2905
2	27.5115	90.64936	Sagfog Singma	2970
3	27.63681	90.84642	Tandigang	2963
4	27.59269	90.88431	Pralang	2696
5	27.61786	90.69319	Sikjarthan	3051
6	27.47251	90.17547	Phobjikha and Khotokha	2848
7	27.47105	90.17608	Phobjikha and Khotokha	2834
8	27.48787	90.15781	Beyta	2905
9	27.43156	89.99166	Khotokha	2594
10	27.67553	91.44003	Dowaling	1886

Table 8.1: Black-necked crane wintering sites in Bhutan (source: Namgay & Wangchuk 2016)

To find the reason why the Black-necked crane chooses these particular sites and whether there are any similarities between the sites in Bhutan, a weighted overlay technique was applied to the Bhutan data. An SRTM DEM of all of Bhutan was downloaded for the purpose, and the weighted overlay was worked out using only the elevation and slope. The vegetation type, which can also play a vital role in the wintering of the Black-necked crane, was not considered due non-availability of data. In general, there is a higher chance of having stagnant water where there is a gentle slope, which will support more wetland formation, and with increasing slope the possibility of water running off increases. Therefore, the possibility of the BNC choosing areas with greater slopes as wintering grounds is less. Similarly, as the elevation increases, the possibility of the Black-necked crane choosing a location as a wintering ground decreases. With increasing altitude/elevation the temperature drops. Under normal atmospheric conditions the average atmospheric lapse rate results in a temperature decrease of 6.4°C/km altitude. During our stay we found (base camp at 2120 m amsl) that the winters are cold but there is no snowfall at elevations less than 3000 m amsl; when the elevation is greater than 3000 m amsl, the chances of the ground being covered with snow either partially or temporally are higher. When the elevation is greater than 4000 m amsl, the probability of the Black-necked crane wintering there can get reduced. Keeping this in mind, the influence of slope class with relative suitability and elevation class with relative suitability are shown in Table 8.2 and Table 8.3.

Slope class (°)	Relative suitability
Less than 7.5	5
7.5-15	4
15-30	3
30-45	2
More than 45	1

Table 8.2: Relative suitability ranking of slope classes

Elevation class (m)	Relative suitability
0-1000	1
1000-1500	2
1500-2000	4
2000-3000	5
3000-3500	4
3500-4000	3
4000-5000	2
5000-6000	1

Table 8.3: Relative suitability ranking of elevation classes

The weighted suitability was obtained by multiplying the relative suitability reclassified slope and elevation layers. The steps of the overlay analysis of this study are shown in Figure 8.4. The possible suitability values will be {1, 2, 3, 4, 5, 6, 8, 9, 10, 12, 14, 16, 20 and 25}. Finally the obtained suitability map was re-classed into four class viz., 1-10 = 10; 11-16 = 16; 20 = 20; and 25 = 25. Pixels with value 10 represent areas where the slope is high and the elevation is very high or very low, those with value 16 represent areas of moderate slope and moderate elevation, those with value 20 represent areas where the slope is less than 15° and the elevation is between 1500 m and 3500 m, and those with value 25 represent areas with slope less than 7.5°, with the elevation between 2000 m and 3000 m, the last being most suitable as wintering sites for Black-necked crane, such as those found in Bhutan (Table 8.1).

To analyse the weighted suitability obtained, the Black-necked crane wintering points in table 8.1 and the water/drainage system generated using Arc-SWAT were overlaid upon the weighted suitability layer. It was found that all the Black-necked crane wintering points were in clusters where the suitability value was highest (i.e., 25) and in very close proximity to streams. In other words, the slope was less than 7.5°, the elevation was between 2000 and 3000 m amsl and the location was very close to the river, were preferred most by Black-necked cranes.

Figure 8.1: Steps of the weighted overlay analysis of this study

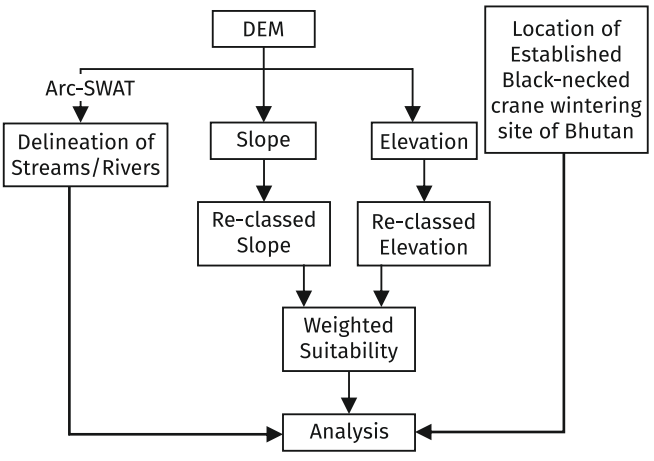
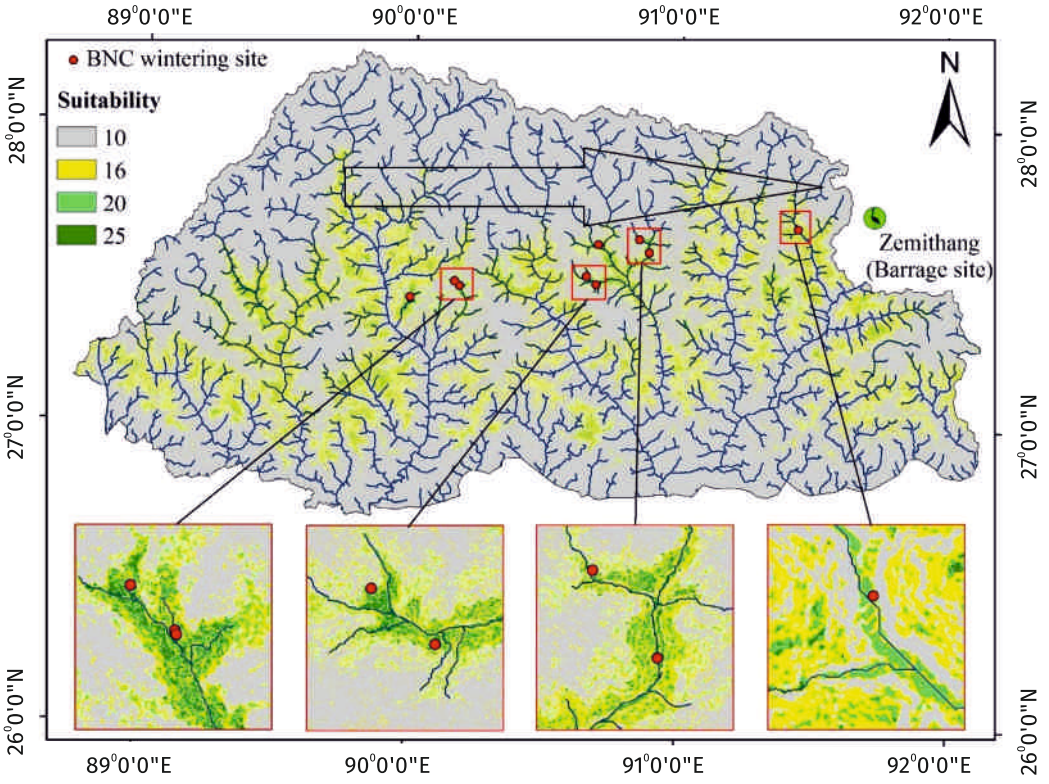


Figure 8.2: Weighted suitability map of Bhutan, Black-necked crane wintering sites and Nyamjang Chu HEP site



At one glance (Figure 8.5), without much science, we can say that all the Black-necked crane wintering sites in Bhutan lie on a straight line and that the proposed Nyamjang Chu HEP barrage site can be seen as an extension of that line, forming a clear migration route. To check the resemblance of Nyamjang Chu HEP site with the Black-necked crane wintering site in Bhutan, we followed the same method as given in Figure 8.1 in the area covering 10 km radius from the proposed barrage site location. (DPR by Bilwara Private Limited.). Surprisingly, the same conditions (i.e., areas with slope less than 7.5° and elevation between 2000 m and 3000 m) were found exactly at the proposed HEP site only (see Figure 8.3). The suitable area was restricted to just a few metres upstream and downstream of the location of the barrage.

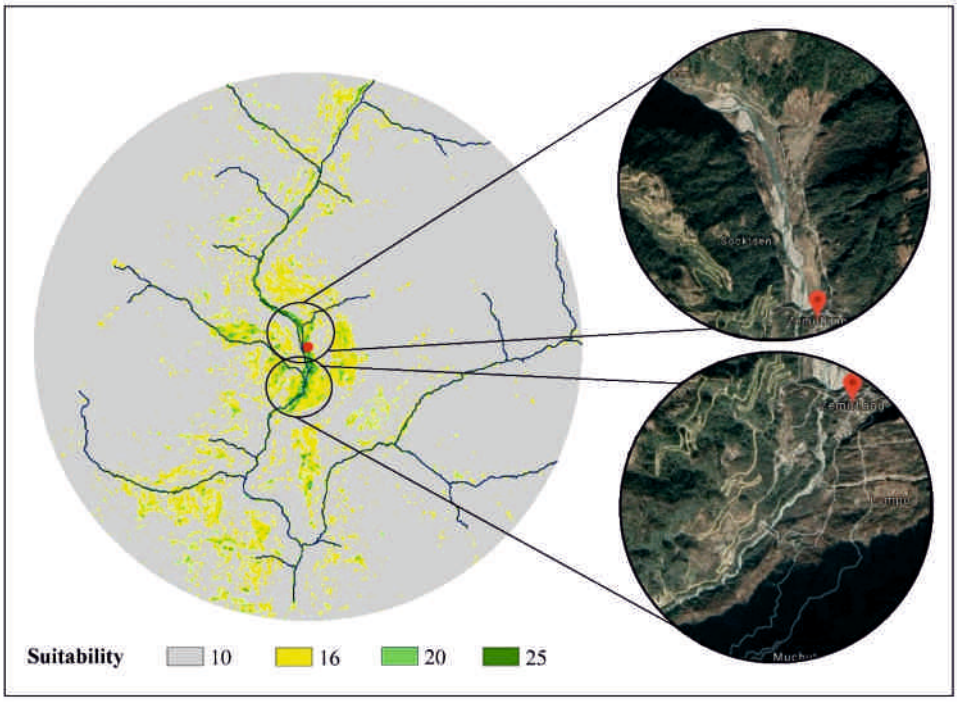


Figure 8.3: Weighted suitability map of 10-km buffer of Nyamjang Chu HEP

Further, to get a deeper insight into the suitable area as determined using the weighted overlay method, the areas upstream and downstream of the proposed barrage site were examined using Google Earth. Google Earth images showed that there were narrow rivers downstream of the barrage. There was level ground (potential Black-necked crane wintering areas), flat highlands, elevated more than 20 m above the river and disconnected from any water bodies, forming a totally different ecosystem. The upper right circle in Figure 8.6 clearly shows that the area adjoins the Nyamjang Chu River, with its open sandbars, which are preferred by the Black-necked cranes. From our analysis, it can be said that within a 10 km radius of the Nyamjang Chu HEP site, the proposed barrage site is the only available habitat of the Black-necked cranes in the region.

Therefore, if we wish to retain the suitable habitat for the migratory Black-necked crane in the Nyamjang Chu, of Zemithang valley, there is no alterative than to reject the proposed HEP.

ENVIRONMENTAL FLOW

Introduction

Environmental flows are necessary to maintain the ecological integrity of water bodies, including rivers, flood plains and wetlands (mangroves, sea-grass beds and estuaries). Since flowing water is one of the important determinants of the health of a river, a large reduction of the flow can cause many adverse impacts, including degrading river ecosystems (Bunn *et al*. 2002; Poff *et al*. 2010). The flow is considered the master variable because it has great impacts on aquatic habitats, river morphology, biotic life, river connectivity and water quality (Karr *et al*. 1995). On the basis of the hypothesis that the health of a river progressively deteriorates as more and more water is withdrawn, and it significantly falls if the flow is below some threshold value, the concept of minimum flows in rivers came into existence in the 1970s. Subsequent studies have shown that all the elements of a flow regime, including high, medium and low flows, are important from the ecosystem point of view. (Richter *et al*. 1997). Specifically, high flows are necessary for channel flushing and maintaining floodplain connectivity and riparian vegetation. Medium flows help fish growth and migration, and low flows are important for river connectivity (Acreman *et al*. 2009). A perennial flow of water is the best evidence that a river exists.

According to the Brisbane Declaration 2007, environmental flows are the quantity, timing, duration, frequency and quality of flows required to sustain freshwater, estuarine and near-shore ecosystems and the human livelihoods and well-being that depend on them. Note that besides the amount, one should also specify the temporal pattern of the flows. Exact values of Environmental flows can be established for a project using detailed hydrological data, the river cross-sections and the channel morphology, as well as the quantitative water needs of the aquatic life and the sensitivity of the aquatic life to reductions in the river flow, combined with knowledge of the preferences of all the stakeholders (Acreman *et al*. 2004).

Consumption of energy is increasing globally at about 2% per year. Currently, renewable energy sources meet 17% of the global primary energy requirements, and this could increase to between 30% and 75% by 2050. Renewables offer many benefits, such as environment protection, mitigation of climate change and sustainability of use.

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Hydropower has the best efficiency of all energy sources and a very high energy payback ratio. Hydropower dams provide society substantial benefits, but if they are poorly planned, designed or operated, they can also have serious consequences for the ecological health of rivers and the economic and social well-being of communities dependent upon the goods and services provided by healthy rivers (Krchnak *et al*. 2009). India is currently facing huge shortages in base and peak electricity. As of 2014, the country has 255 GW of installed generation capacity, of which 40.8 GW is contributed by hydropower plants (http://www.cea.nic.in). Among the renewable sources, hydropower is the most attractive, but these projects are facing stiff opposition in India because of displacement of the population, submergence of forests and perceived adverse impacts on river ecosystems and the surrounding environment. The EF requirements of a river depend on the properties of the aquatic ecosystem, development stage of the area and societal requirements. Long-term implementation, a high-flow regime and a discharge value between 0% and 10% for the environmental flows promote biodiversity and improve ecosystem services around the world, particularly in river wetlands.

Methods

Assessment of environmental flow is a challenging task. Over 200 scientific methodologies exist that have been used across 44 countries (Tharme 2003). These methods can be grouped under the following categories: hydrological, hydraulic rating, habitat simulation and holistic methodologies. Environmental flow studies in India are still in developmental stage and very few studies addressed eflow with reference to hydropower development (Rajvanshi *et al*. 2012, Johnson *et al*. 2017). In this background, the present study was conducted to assess the minimum ecological flow (e-flow) requirement of Black-necked crane based on its habitat preference. In this study the PHABSIM model was used, as it incorporates species habitat suitability criteria for estimating ecological flow (PHABSIM 2001; Johnson et al. 2017).

The present study was carried out between November 2017 and February 2018 in Nyamjang Chu River at Tawang District of Arunachal Pradesh. The stretch from Zemithang Bridge to Brokenthang Bridge over the Nyamjang Chu River was divided into six sections. Six representative cross-sections were established in the submergence zone area of the proposed dam site. The downstream part of the river was much wider and had a rocky bed. The riverbed was mostly sandy or rocky. There were very little riparian vegetation on both the banks; mostly rocky patches. The cross-sectional surface, depth and width of each point were measured, and the discharge was recorded using an environmental flows meter.

At each transect, the flow, the depth and the width were recorded at 2-m intervals along the river. The river depth was recorded using a wooden stick marked with a measurable tape. A floating tube was used to carry out the survey. Measurements were taken across the river by fastening a rope on one side of the river and floating on the tube with a environmental flows meter. The water column velocity was recorded at 40% depth from the water surface (at the middle of the water column). The water velocity was measured using a water current meter (Global Water Flow Probe Meter, USA) with a digital recorder. All the measurements were taken by moving the tube back and forth.

i) Generation of cross-sectional data

Six cross-sectional data were generated between downstream and upstream of Black-necked crane habitats covering a length of about 200m river. At each cross section points, a marked rope was fixed across the channel and depth and velocity profile was carryout at every 2m interval (Figure 9.1). Depth was recorded using sonar based depth recorder (Hondex digital sounder: model PS-7) and graduated measuring road. Similarly, the flow at every 2 m interval was recorded using hand held-flowmeter (Global Water Flow Probe Meter, USA). In addition, river dry bed width and wetted width also recorded directly from the marked rope. All measurements were repeated during all winter months (November to February) at same points.

ii) Generation of Habitat suitability curves(HSCs) for BNC

Habitat suitability curve of the species is one of the most important inputs in the PHABSIM model. Based on the suitability curve, the model stimulates the availability of suitable area for the species concern. Though, the Black-necked crane is not a flow dependent species, they use wadeable habitats in the channel for foraging (Birdlife international, 2017). Further, they use dry and open area between wetted channel and riverbanks as resting and roasting ground (Kong et al., 2008; King, 2008; Phutsho and Tshering 2014) during winter months in India (November to February).To describe the habitat suitability curve of the Black-necked crane, multiple location data on Black-necked crane foraging and roasting sites were collected from historical records (Appendix 1 and Pemba Tsereing Romoper. obs., Zemithang) and local knowledge. Based on the habitat use by Black-necked crane and available river channel the HSC for Black-necked crane was prepared according to the procedure outlined by Bovee (1982) and Johnson *et al.* (2017).The depth distribution in the channel was categorised in to nine classes (depth class: 0.1, 0.3, 0.6, 1.0, 1.2, 1.5, 1.8, 2.0;<2.0 m) and velocity measurements was classified into seven classes (velocity class: 0.2, 0.3, 0.5, 0.6, 0.9, 1.2;<1.2 m/s) as described in Johnson *et al.* (2017). At each class, the frequencies of observed available habitat (from the cross-sectional data) and use by Black-necked crane was generated. Then the preference for each class interval of the measured

variables was calculated from the estimated relative frequencies of utilization and availability as Pi = Ui/Ai.Where -Pi - is the relative preference value of Black-necked cranes for a specific interval of the measured variable; Ui - is the proportion of utilization of a specific interval of the measured variables and Ai - is the proportion of a specific interval of the measured variables in the studied river sector. The information on depth and flow suitability, Habitat Suitability Curves were generated for Black-necked crane.

iii) Flow simulation and estimation of Habitat suitability using PHABSIM model

The Physical Habitat Simulation or PHABSIM model is part of a broad conceptual and analytical framework for addressing stream/ river flow management issues known as Instream Flow Incremental Methodology (IFIM) (Stalnaker *et al* 1995). These tools were developed aids for instream flow decision making. This technique also used in quantifying the incremental differences in a stream habitat that result from proposed alternative stream flow regimes (PHABSIM, 2001). PHABSIM estimates changes in physical microhabitat as a function of flow and translates them into an estimate of the quality and quantity of microhabitats for aquatic organism. Incremental changes in stream flow are used to produce relationships between simulate depth and velocity values, measured microhabitat value known as Weighted Usable Area for target species (PHABSIM, 2001).

In the present study PHABSIM model was used in Nyamjang Chu HEP area to stimulate the habitat suitability criteria for Black-necked cranes. Considering the watering period and availability of wadeable habitat and open area between river and riverbanks, the base flow during the winter was considered as bench-mark flow for Black-necked cranes. In the habitat simulation model, six cross sectional data and depth and flow suitability curves were provided as inputs for the model. Further, different flow scenarios (10, 20, 30, 40, 50, 60, 70 and 80 cumecs) were simulated to understand the availability of weighted usable area for Black-necked crane. The value of weighted usable area generated were plotted against different simulated discharge.

Results

i) Condition of river discharge and Habitat availability

River properties of six cross-sections (hereafter section) at the Nyamjung Chu Hydro-electric project site are is presented in Table 9.1. It was observed that the hydrological and hydraulic properties varied from location to location. The average depth ranged between 0.43 m and 1.42 m, and the average velocity was between 0.36 ms-1 and 0.67 ms-1. The average winter discharge of the Nymajang Chu River was between 19.56 cumecs and 12.28 cumecs. The maximum area under water was observed at cross-section 3, which had a width of 44 m, and the narrowest section was 32 m at section 1 & 4. Further, to determine the overall frequency of occurrence of different velocities and depths in the Black-necked crane habitat, all the sections were clubbed and analysed using standard class intervals. The total number of observations and the depth and velocity profiles at every 2 m intervals in the Black-necked crane habitat are given in Figure 9.2.

The proportion of different categories of water depth and water flow available during winter months are presented in Figure 9.3 and 9.4. The proposition of depth classes ranges from 1 cm to 30 cm (shallow habitat) was about 0.15 and high proportion of depth ranged from 60cm to 1 m was observed during the study period. In the case of flow, low flow (0 to 0.2 ms^{-1}) had relatively high proportion (0.24) next to high flow region (0.9 ms^{-1}).

Figure 9.1: Field measurement of velocity and depth at 2-m intervals

Table 9.1: River properties at different cross-sections at the Nyamjang Chu HEP site

Section	Wetted width (m)	Average depth (m)	Average velocity (ms^{-1})	Average discharge (cumecs)
1	32	1.17	0.52	19.56
2	34	0.90	0.48	14.58
3	44	0.43	0.67	12.78
4	38	1.42	0.36	16.49
5	32	0.80	0.40	12.28
6	24	0.81	0.67	12.98

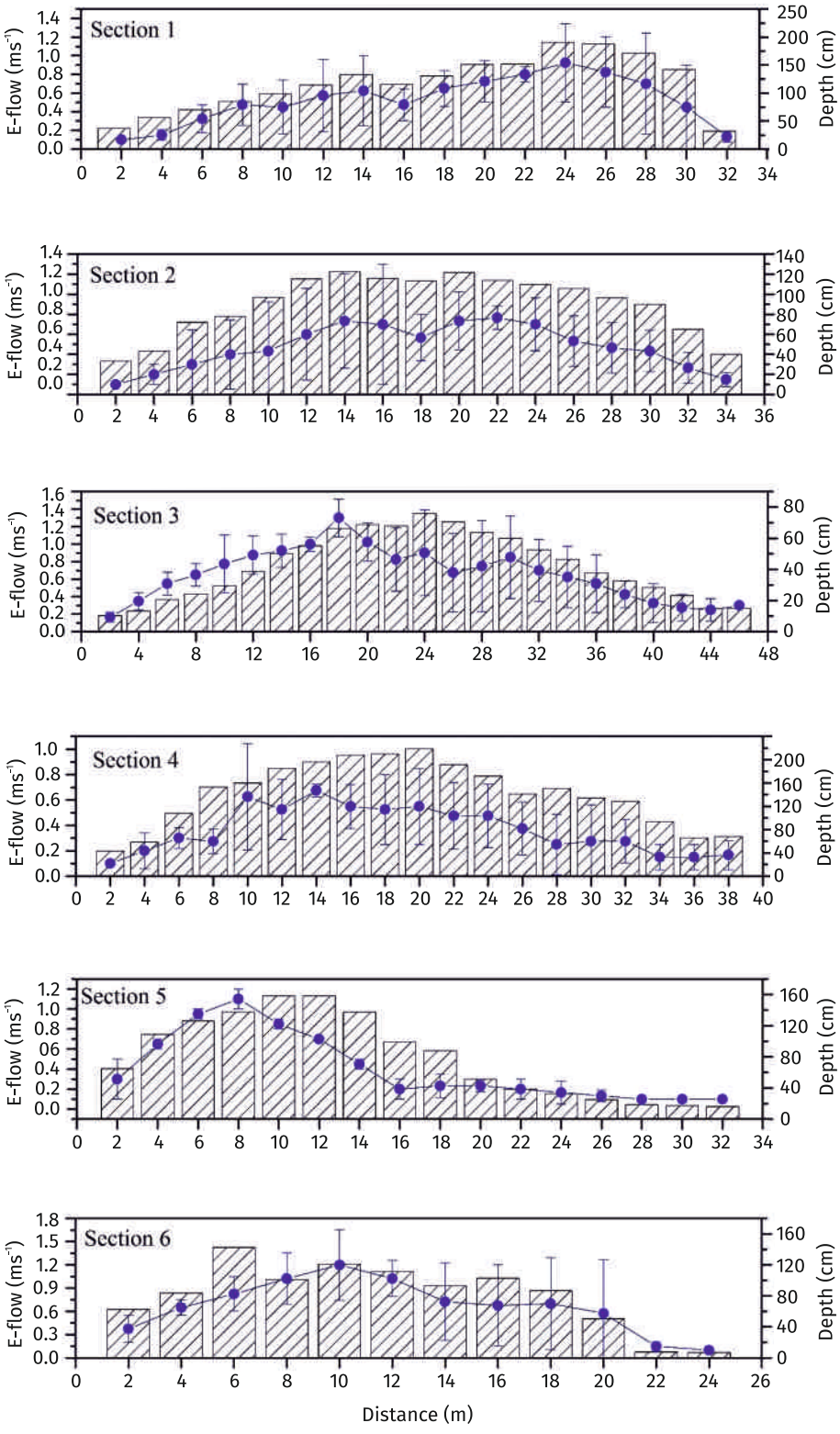


Figure 9.2: Depth and velocity profiles of different cross-sections at Nyamjang Chu HEP in winter months

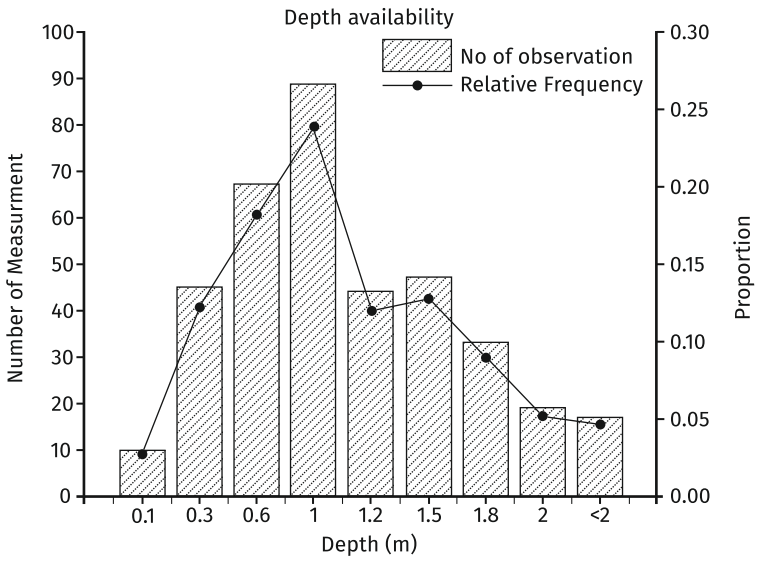


Figure 9.3: Proportion of depth at availability at Nyamjang Chu River at HEP site

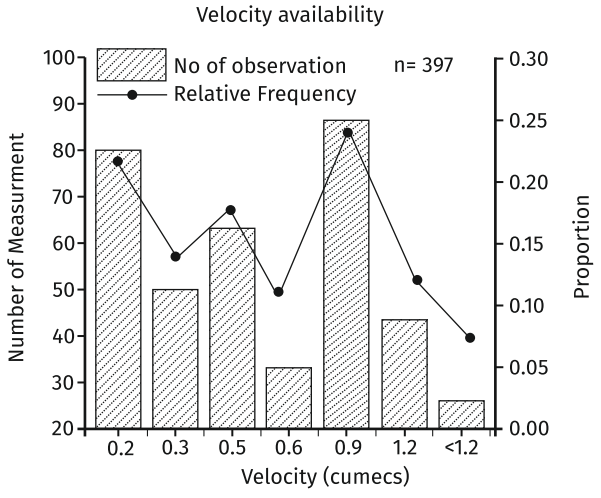


Figure 9.4: Proportion of velocity availability in deferent flow categories in the Nyamjang Chu River at the HEP site

ii) Habitat Suitability Curves

Based on Black-necked crane roosting and foraging site observation data, the depth and flow habitat suitability curves were generated for Black-necked crane and the curves are presented in Figure 9.5. Since the Black-necked crane uses non-water, open area and shallow region of the river channel, therefore non-water areas (0 depth) and shallow water areas (1 to 30cm) of the River are considered as Black-necked crane habitat. The depth suitability curve of Black-necked crane depicted that the depth ranged from 0 to 30cm water depth in the channel is suitable habitat for Black-necked crane (Figure 9.5). Similarly, velocity suitability curve indicated that the channel area with no flow region (0 flow) to slow flowing region (<0.2 ms^{-1}) are suitable habitat for Black-necked crane (Figure 9.5).

iii) Habitat Suitable Area for Black-necked crane

In this section describes cross-section wise information on available combined suitability area (combined suitability area were generated based on depth and velocity suitability of Black-necked crane) generated in PHABSIM model at different flow scenarios.

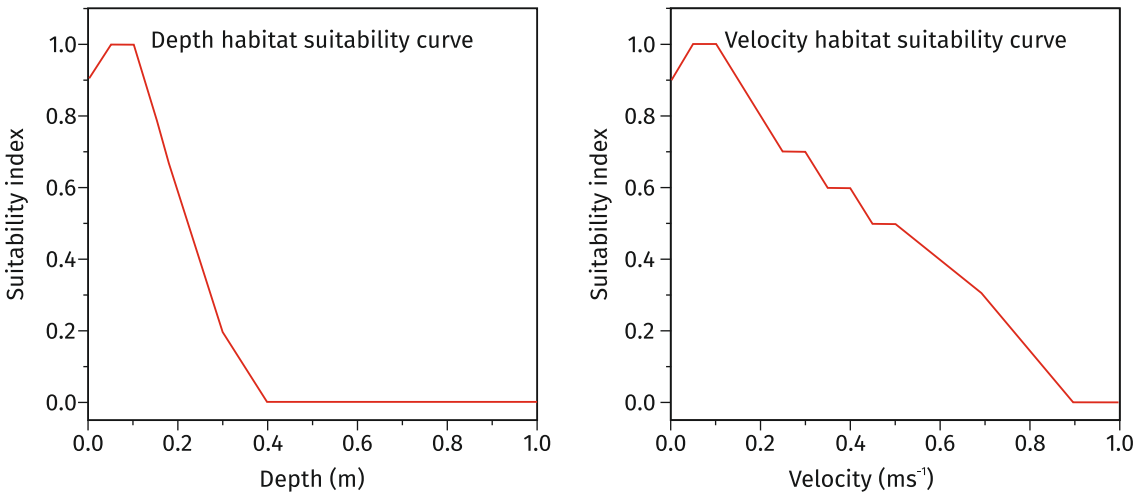


Figure 9.5: Depth and velocity habitat suitability curves of the BNC

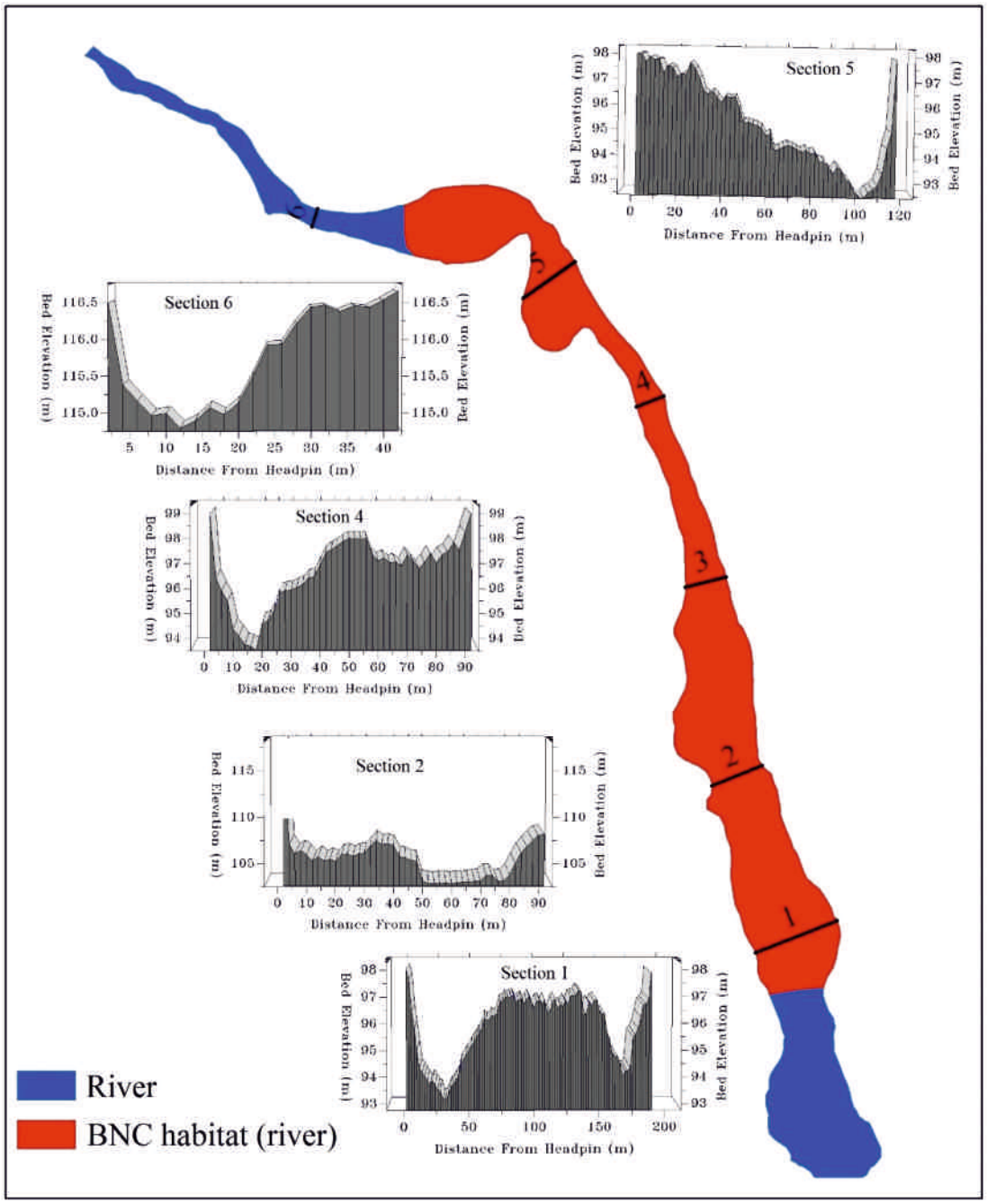


Figure 9.6: Locations of the cross-sections and the relative depth profiles

Section 1 and Section 5 are two important sections (Figure 9.6). Section 1 marks the start of the Black-necked crane habitat, whereas Section 2 represents the end of the Black-necked crane habitat area (Figure 9.6). These two sections are also where the river cross-section was widest, with the greatest number of open sandbars during winter. Section 1 was approximately 190 m wide, and it represents one of the best foraging grounds of the Black-necked crane. At a width of just 42 m, Section 6 was the narrowest among all the cross-sections measured. Where the Nyamjang Chu River enters the study area, it is narrow but has a high flow velocity. It gets broader and less turbulent as it reaches Section 5, than shrinked by Section 4. The river gets calmer and broader by Section 2 and Section 1, before it exits the study area through a narrow rapid waterfall, exactly beneath the Zemithang Bridge.

Section 1

Out of the full width 190 m of the section, the wet length of Section 1 was only 50.00 m, i.e. 140.00 m of the cross-section was available to Black-necked cranes as open sandbars for foraging. To check the area availability under different discharge conditions, simulations were carried out in the PHABSIM model by assigning different discharge values. First, 10 cumecs, and then 10 cumecs, was added in every subsequent simulation until the entire cross-section came under water. At 10 cumecs, more of the cross-section area will be available compared with the present condition. As the discharge value increases, the area under water increases, and at around 40 cumecs, 50% of the cross-section is filled with water. When the discharge value reaches 70 cumecs, the entire cross-section will be filled with water. Table 9.2 gives estimates of the lengths of the open area and area under water at different discharge values:

Table 9.2: Section 1 length of river and different discharge values

Section 1. 190 (m) Section length (m) at different discharge values (cumecs)								
	Present	10	20	30	40	50	60	70
Open ground	140	164	137.22	124	106	20	2	2
Under water	50	26	52.78	66	84	170	188	188

The results of the habitat suitability simulation for Section 1 are shown in the following Figure 9.7. Different colours indicate different suitability values. Open ground is suitable for Black-necked cranes.

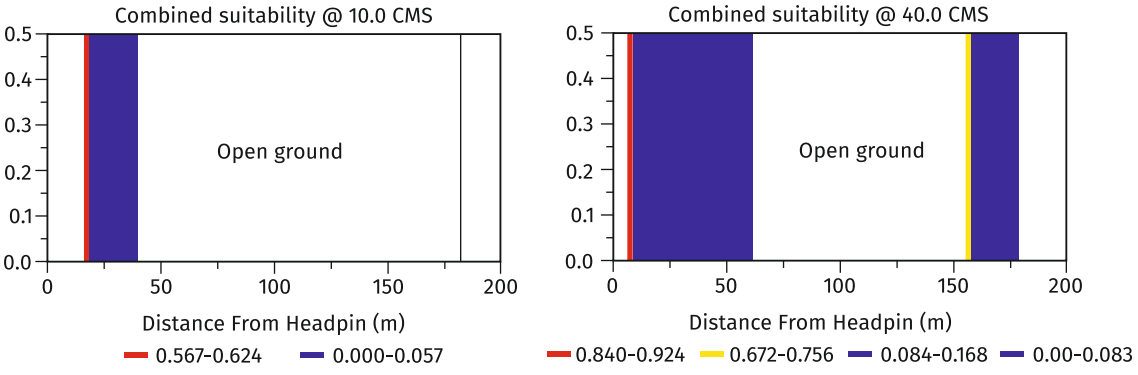


Figure 9.7: Black-necked crane combined habitat suitability index of Section 1 at 10 cumecs and 40 cumecs

During the simulation it was observed that at 70 cumecs the entire cross-section comes under water. However, in some portions of the cross-section the discharge velocity was not very high. If only the velocity suitability criteria of Black-necked crane are considered, some portions of the cross-section would still be Black-necked crane habitat (Figure 9.8). But when the depth parameter was considered as defining the suitable area for the Black-necked crane, all portions of the cross section were deeper than 0.4 m, making it impossible for the Black-necked crane to use it as a habitat. So the resultant combined suitability index became zero (Figure 9.9).

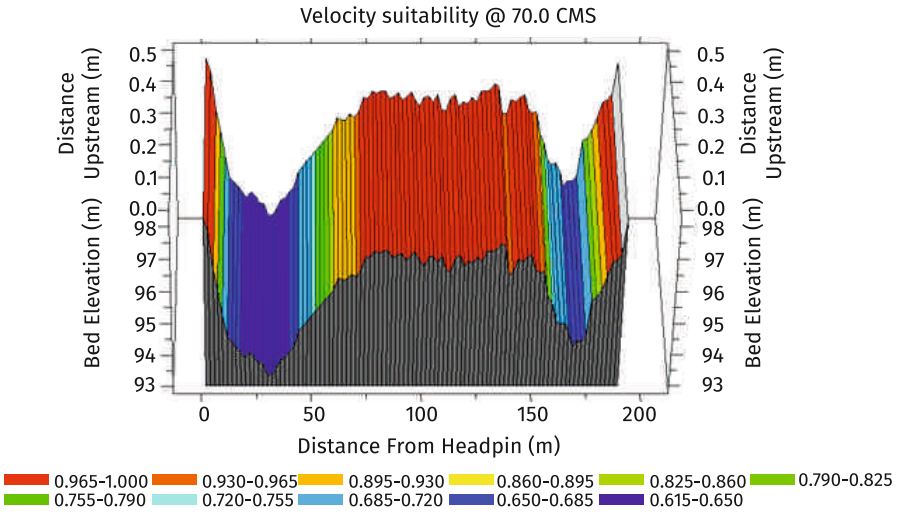


Figure 9.8: Velocity suitability index at 70 cumecs for Section 1

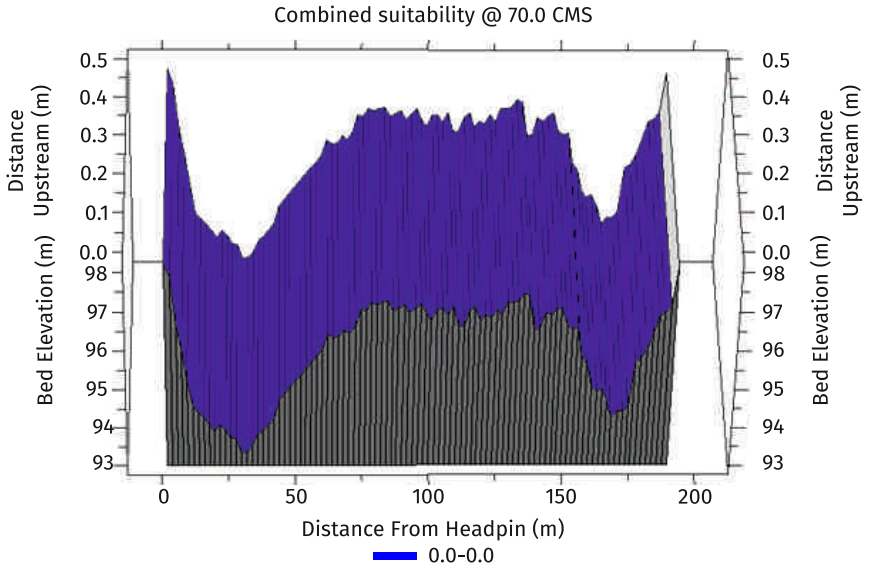


Figure 9.9: Complete submergence and zero combined habitat suitability index at 70 cumecs for Section 1

Section 2

This section has a cross-section length of 92 m, and during our study only 18 m of the cross-section was with water. The cross-section had a narrower and smoother river bed profile compared with Section 1. At 10 cumecs, 40 m will be open ground, and by 40-50 cumecs, 90 m (out 92 m) will be under water. Simulated area statistics of the open ground and the part under water at different discharge values are given in table 9.3. The results of simulation indicated that at 10 cumecs, discharge section 2 had maximum percentatge of open ground (40%), whereas at 40 cumencs predicted that 90% of the area will be filled with water. When combined suitability index was considered, at 10 cumecs generated more open area than 20 cumecs simulation (Fig 9.10). At 50 cumecs simulation more that 90% of the Black-neced crane habitat will be inundated with water (Fig 9.12). However, if only velocity index was considered, some habitat (Zero flow areas) may be suitable for Black-necked crane (Fig 9.11).

Section 2. 92 (m) Section length (m) at different discharge values (cumecs)

	Present	10	20	30	40	50
Open ground	18	40	18	6	2	2
Under water	74	52	74	86	90	90

Table 9.3: Section 2 length of river and different discharge values

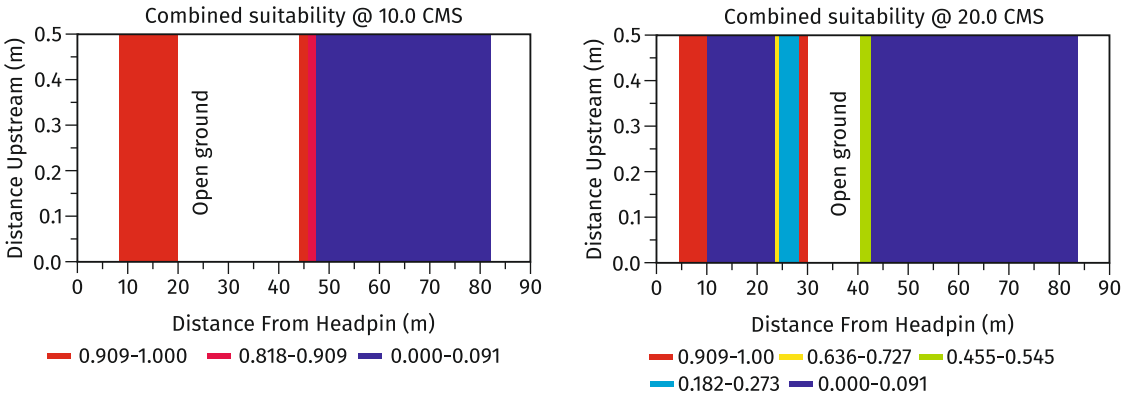


Figure: 9.10 BNC combined habitat suitability index of Section 2 at 10 cumecs and 20 cumecs

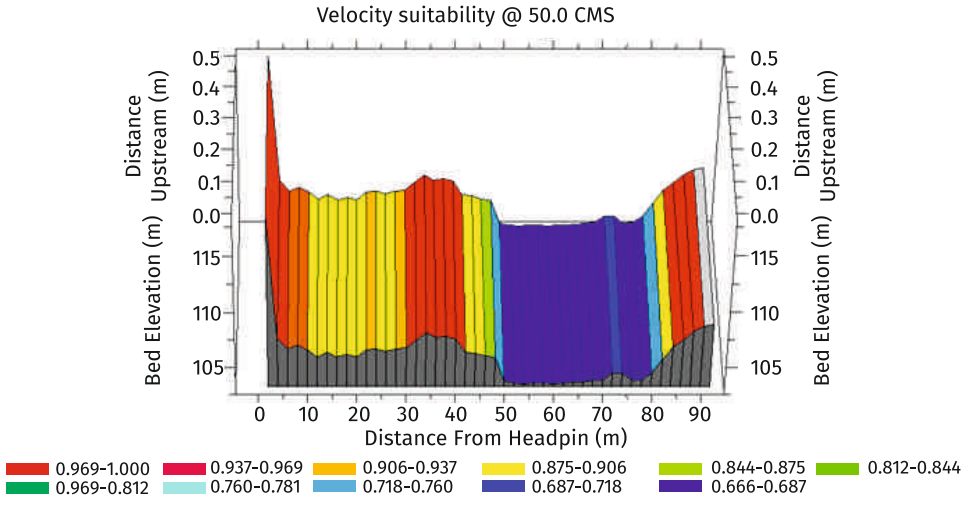


Figure:9.11 BNC velocity habitat suitability index of Section 2 at a discharge of 50 cumecs

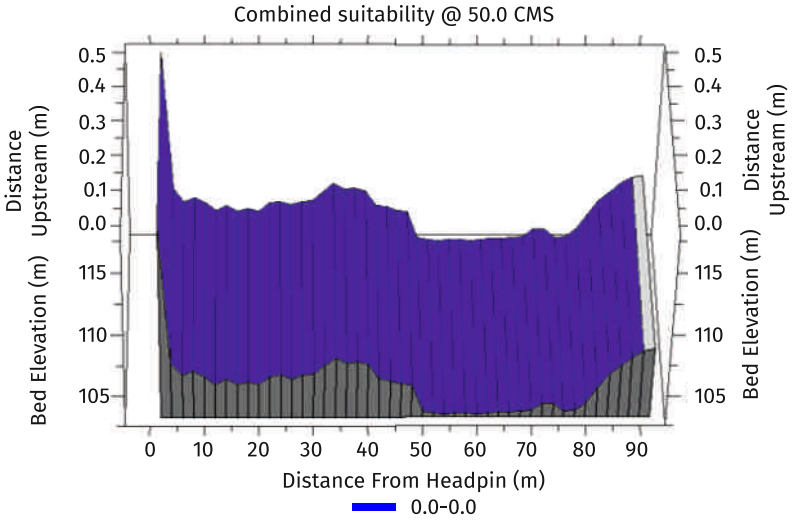


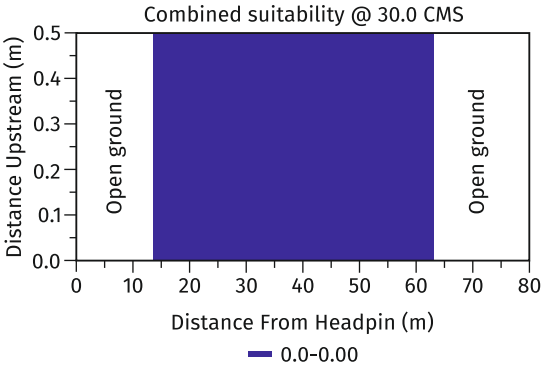
Figure:9.12 Complete submergence and zero combined habitat suitability at 50 cumecs for Section 2

Section 3

The section had a cross-section length of 82 m. During the study, 58.53% of the total length was under water, i.e. only 34 m out of the 82 m of the cross-section was open ground. At 10 cumecs, the open sandbar area increased to 28.48 m. By 40 cumecs, almost the entire cross-section would be under water, leaving just an 0.86 m length of open ground 9Table 9.4). When this cross section was subjected to simulation, at 10 cumecs generated more open ground (Fig 9.13). This suitability area was generated using combined depth and velocity suitable index. As the discharges increases (at 30 cumecs) the open habitat in river channel would be reduced considerably (Fig 9.13) and at 40 cumecs discharge, the entire channel will be completely filled with water (Fig 9.14), which is not suitable for Black-necked cranes.

Section 3. 82 (m) Section length (m) at different discharge values (cumecs)						
	Present	10	20	30	40	50
Open ground	34	66	34	30	2	2
Under water	48	16	48	52	80	80

Table 9.4: Section 3 length of river and different discharge values



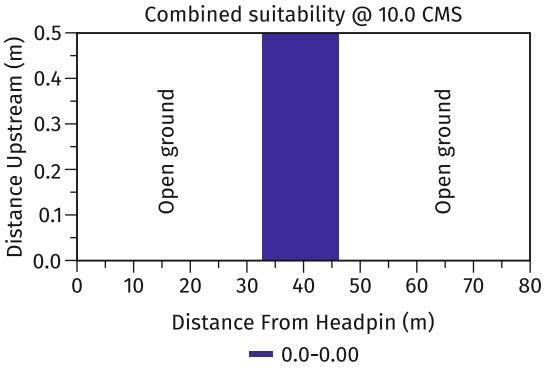


Figure 9.13: Combined habitat suitability index of Section 3 at 10 and 30 cumecs

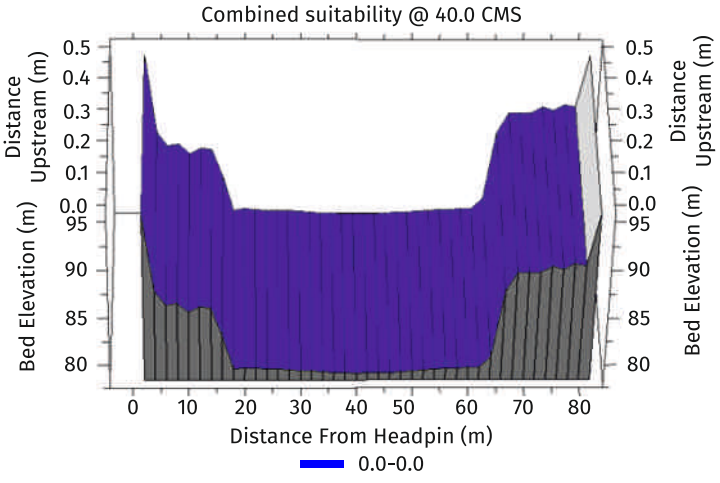


Figure 9.14: Complete submergence and zero combined habitat suitability at 40 cumecs for Section 3

Section 4

The full width of Section 4 was 92 m. During the study, 48 m was under water, leaving 44 m as open sandbars. At 10 cumecs, 38 m would be under water, and the available open area will be 54 m. When the discharge value reaches 40 cumecs, more than 63% of the total cross-section would be covered by water. Only 2 m of the entire cross-section would be open ground when the discharge value exceeds 70 cumecs. The simulated open ground and under water extents at different discharge values are given in table 9.5:

Section 4. 92 (m) Section length (m) at different discharge values (cumecs)									
	Present	10	20	30	40	50	60	70	80
Open ground	44	54	50	34	24	12	4	2	2
Under water	48	38	42	58	68	80	88	90	90

Table 9.5: Section 4 length of river and different discharge values

Figure 9.15 shows the simulated cross-sectional suitable habitat available for BNCs at 25 cumecs and 50 cumecs. At 25 cumecs, around 50% of the cross-section remains suitable habitat for BNCs. Even at 50 cumecs, some of the middle portion of the cross-section will remain above water, and a small section of area near the bank would remain shallow, with a low velocity, and will be suitable for BNCs. When the discharge value reaches 80 cumecs, almost the entire length of the cross-section would be submerged, leaving just 2 m on the right bank, and the combined suitability index would become zero (Figure 9.16).

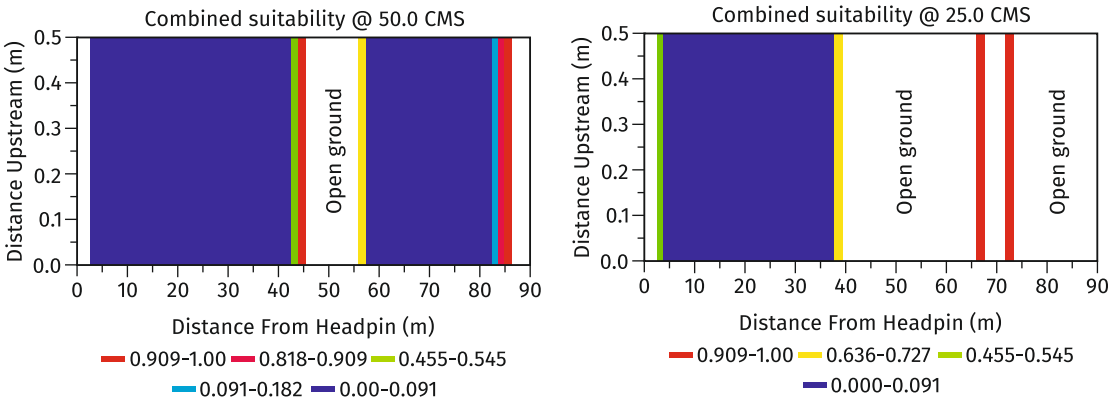


Figure 9.15: Combined habitat suitability index of section 4 at 25 and 50 cumecs

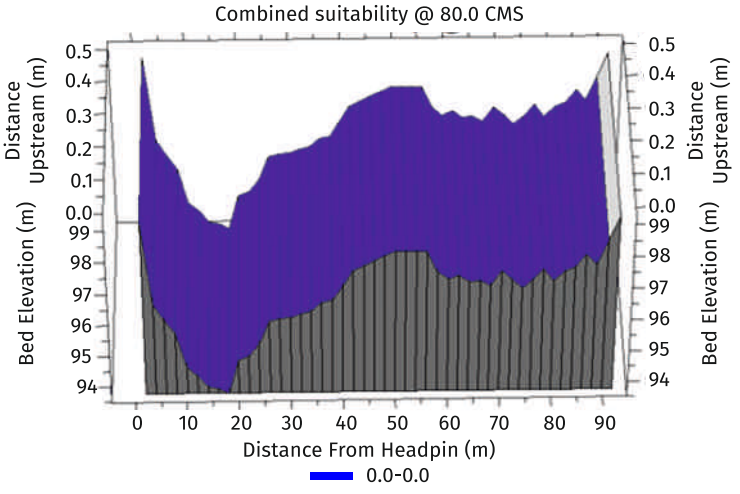


Figure 9.16: Complete submergence and zero combined habitat suitability of Section 4 at 80 cumecs

Section 5

This section is one of the two most important cross-sections in the entire study area. It lies at the end of the Black-necked crane habitat in Zemithang, Nyamjang Chu HEP site. The full length of Section 5 was 118 m. During the present study (winter), only 33.89% of the length was under water, leaving 78 m of open sandbars. At 10 cumecs, more sandbar area would open up, and the sandbar length would increase to 86 m. At around 40 cumecs, 55% of the total cross-section would be filled by water. The cross-section would be almost filled by water when the discharge value reaches 80 cumecs. Details of the open ground and the part under water at different discharge values are given in Table 9.6. During the simulation it was observed that at 70 cumecs discharge the entire cross section was covered under water when combined habitat index was used (Fig 9.19). However, if velocity suitability index alone was used for simulation at 70 cumecs, it produced some suitable habitat for Black-necked cranes (Figure 9.19). In contrast, more open ground was observed at low discharge at 10 cumecs (Figure 9.19). The availability of suitable habitat for Black-necked cranes (Open grounds) decreases when eflow discharge increased from 10 cumecs to 50 cumecs (Figure 9.17).

Table 9.6 : Section 5 length of river and different discharge values

Section 5. 118 (m) Section length (m) at different discharge values (cumecs)										
	Present	10	20	30	40	50	60	70	80	90
Open ground	78	86	64	52	46	30	16	4	2	2
Under water	40	32	54	66	72	88	102	114	116	116

Simulated habitat suitability index values at different discharges are given in the Figures 9.20.

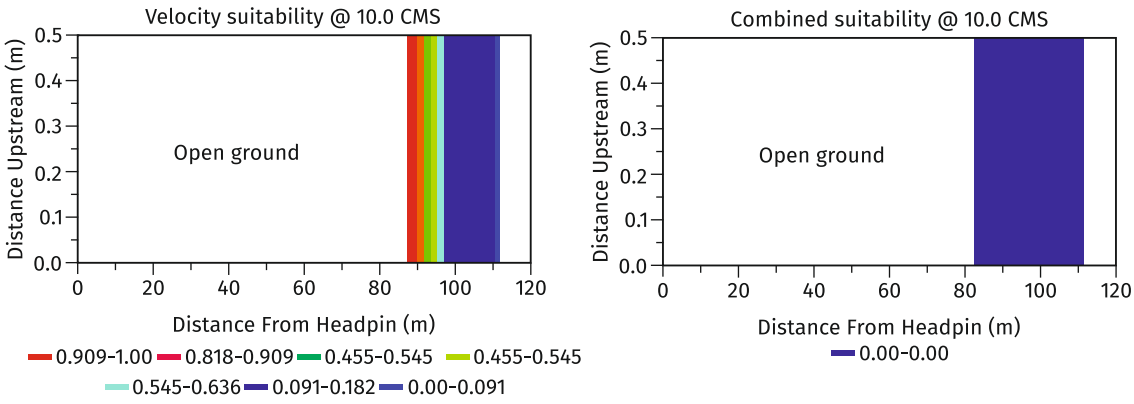


Figure 9.17: Velocity and combined habitat suitability index of Section 5 at a discharge of 10 cumecs

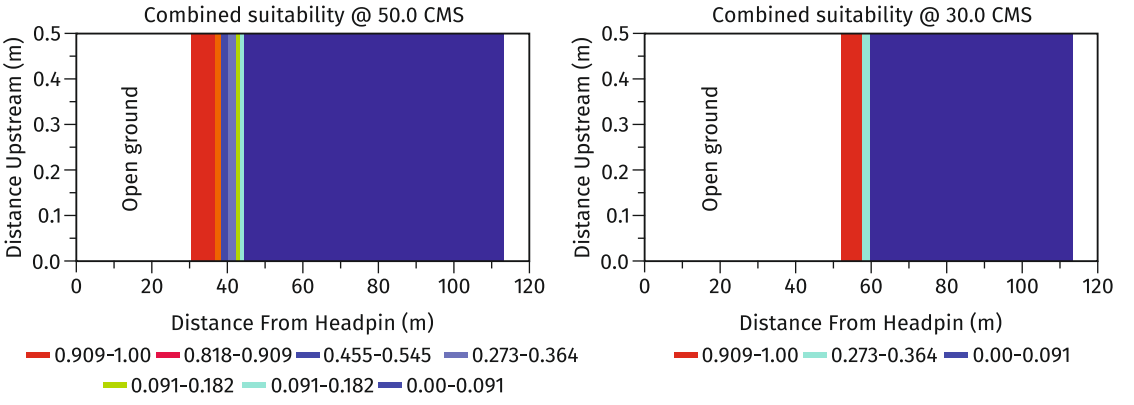


Figure 9.18: Combined habitat suitability index of Section 5 at discharges of 30 cumecs and 50 cumecs

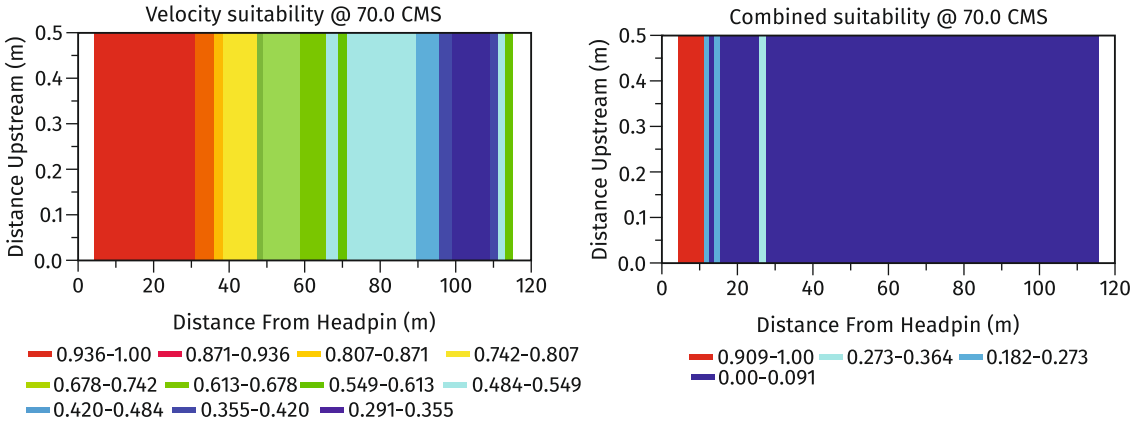


Figure 9.19: Velocity and combined habitat suitability index of Section 5 at discharge of 70 cumecs

Section 6

This section was the narrowest of all the sampled/measured sections. It lies just before the start of the Black-necked crane prime habitat, and the full width of channel was 42 m. Approximately 61% of the width was under water during winter. At discharges of 10 cumecs and 20 cumecs, the area under water remained the same. When the discharge increases to 30 cumecs, the area under water would increase to 66.66%. By 50-60 cumecs, 40 m would be covered by water, leaving just 2 m of the cross-section open. The extents of the cross-section open and under water at different discharge values are given in Table 9.7. The result of habitat simulation using combined suitability index at 10 cumecs, 20 cumecs, 30 cumecs, 40 cumecs and 60 cumecs are presented in Figure 9.20 to 9.22. More suitable habitat was observed at low discharges between 10 to 20 cumecs (40% open area available). At 40 cumecs simulation the open habitat available reduced drastically and completely ceased at 60 cumecs discharge (Figure 9.22).

Table 9.7: Extents of open ground and parts under water in Section 6 at different discharge values

Section 6. 42 (m) Section length (m) at different discharge values (cumecs)								
	Present	10	20	30	40	50	60	70
Open ground	16	16	16	14	4	2	2	2
Under water	26	26	26	28	38	40	40	40

Figure 9.20: Combined habitat suitability index of Section 6 at discharges of 10 cumecs and 20 cumecs

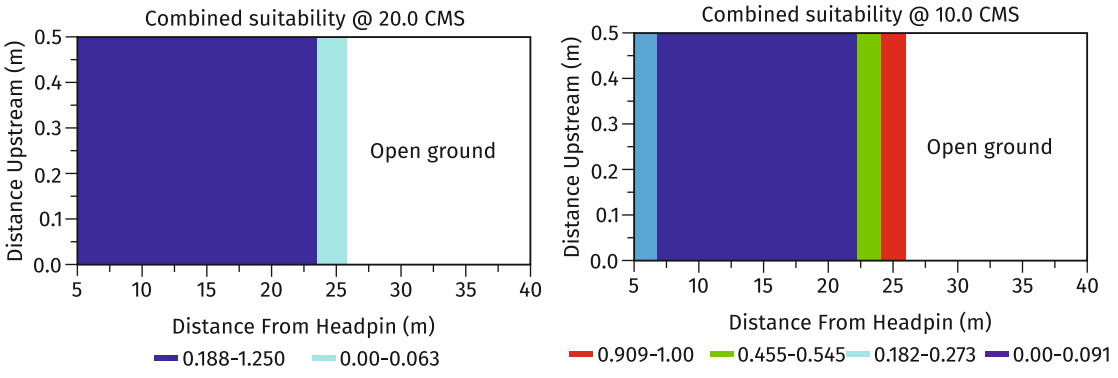


Figure 9.21: Combined habitat suitability index of Section 6 at discharges of 40 cumecs and 30 cumecs

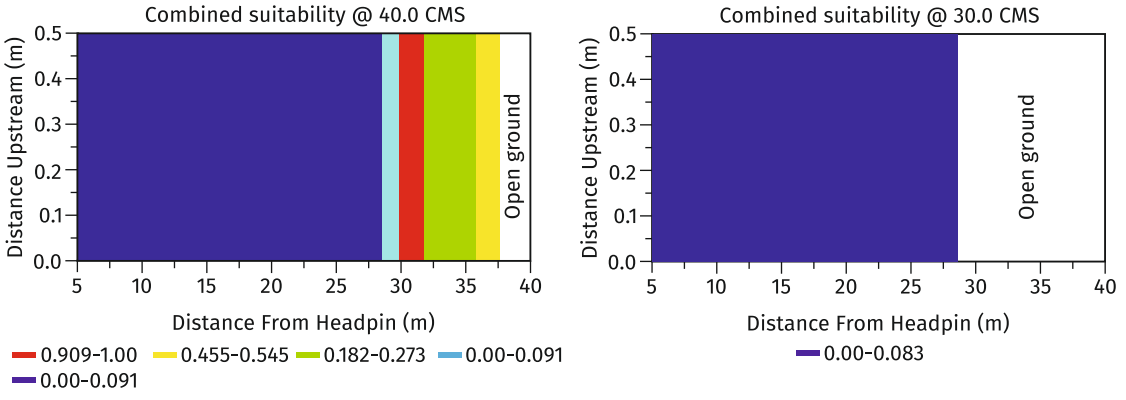
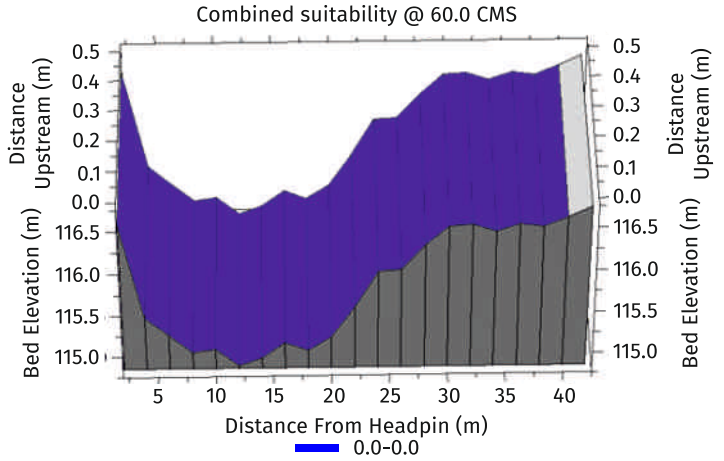


Figure 9.22: Submergence and zero combined habitat suitability index of Section 6 at 60 cumecs



Defining environmental flows of Black-necked crane

The present observation shows that the Black-necked crane uses open sand bars, dry channel area and shallow wadeable riverian habitat. The Nyamjang Chu river at Zemithang region provide such suitable habitats during lean flow season (i.e., November to February). However, the proposed HEP at Zemithang region will bring adverse impact on Black-necked crane habitat due to flow alteration and habitat modification. In order to predict the flow condition up to which the existing habitat can continue to support foraging and roasting habitat for Black-necked crane during winter, a target was set whereby at least 50% of the existing open sandbar areas (average open area) between section 1 and section 6 should remain above the river channel at any given flow discharge. The cross-section 1 to 5 are wider channel with more sandbar areas and important habitat for Black-necked crane (Figure 9.6). In the present study, habitat simulation model PHABSIM was used to generate suitable habitat available in river channel at different discharge. Summary of percentage of area under water in different section of river at different discharge are given in Table 9.8. Similarly, the percentage of river sections under water against different discharge levels is plotted in graph for easy interpretation (Figure 9.23).

From the table 9.8, the areas under water in Section 1 are 13.68%, 27.78%, 34.74%, 44.21%, 89.47% and 98.95% at 10, 20, 30, 40, 50 and 60 cumecs, respectively. In the 40-50 cumecs range, there is a change in the percentage area under water from 44.21% to 89.47%. Hence, for Section 1, 40 cumecs should be the maximum discharge level for maintaining at least 50% of the area as open sandbars. In Section 5, the areas under water at 10, 20, 30, 40, 50, 60, 70 and 80 cumecs are 27.12%, 45.76%, 55.93%, 61.02%, 74.58%, 86.44%, 96.61% and 98.31%, respectively. At 30 cumecs 55.93% of Section 5 will be filled with water. Further, from the Figure 9.23, we can see that at 30 cumecs, 55.93% of the area is under water but 6 m of the cross-section has a combined suitability index value greater than 0.8, which brings the available part close to 50% of the total cross-section. Hence, for Section 5 the maximum flow regime can be set at 30 cumecs.

Section no.	River bank width (m)	Percentage section under water at different discharge values (cumecs)								
		Present	10	20	30	40	50	60	70	80
1	190	26.32	13.68	27.78	34.74	44.21	89.47	98.95	98.95	98.95
2	92	80.43	56.52	80.43	93.48	97.83	97.83	97.83	97.83	97.83
3	82	58.54	19.51	58.54	63.41	97.56	97.56	97.56	97.56	97.56
4	92	52.17	41.30	45.65	63.04	73.91	86.96	95.65	97.83	97.83
5	118	33.90	27.12	45.76	55.93	61.02	74.58	86.44	96.61	98.31
6	42	61.90	61.90	61.90	66.67	90.48	95.24	95.24	95.24	95.24
	Average	**52.21**	**36.67**	**53.34**	**62.88**	**77.50**	**90.27**	**95.28**	**97.33**	**97.62**

Table 9.8: Percentage of area under water at different discharge levels

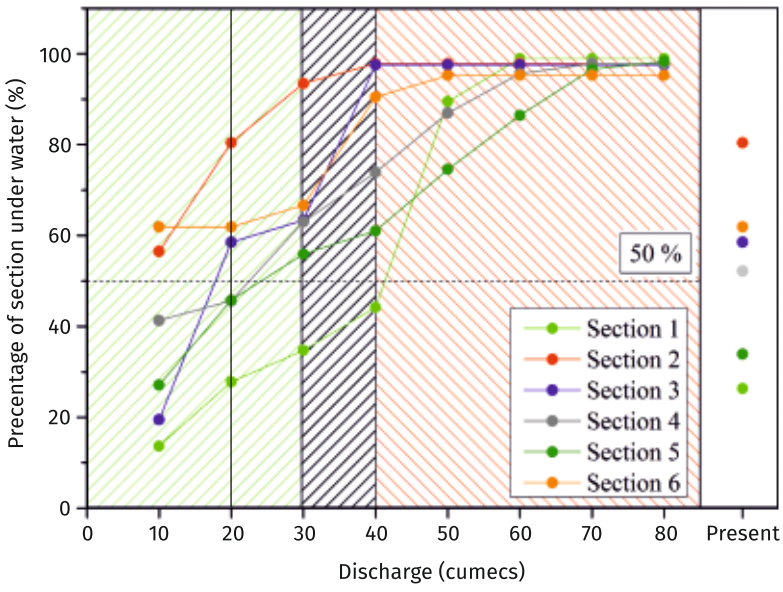


Figure 9.23: Percentage of river sections under water at different discharge volumes and natural (present) flow. The green portion represents the suitable discharge value, the black portion represents the buffer discharge value zone, and the red portion represents the discharge value that will potentially destroy the existing BNC wintering habitat at Zemithang, at the proposed Nyamjang Chu HEP barrage site.

E-flow Recommendation

To sum up, the average habitat to be under water (submerged) varied from 36.67% at 10 cumecs to 97.62% at 80 cumecs. At 20 cumecs, the percentage area under water would increase to 53.34% and the percentage area of water increases and Black-necked crane habitat area decreases steadily beyond 20 cumecs discharge. Further, the predicted 53.34% habitat area at 20 cumecs is matching with present natural condition with percentage area under water of 52.2% (Table 9.8) that is available during the lean season (i.e. winter months). Hence, it is recommended that 20 cumecs e-flow (equal to existing normal flow) should be maintained in Nyamjag Chu river between section 1 and 6 at Nyamjag Chu river (Figure 9.6) during winter months (November to February). Altering flow above 20 cumecs at Zemithang region will drastically reduce the habitat available for Black-necked cranes.

DISCUSSION

The Black-necked crane (*Grus nigricollis*), with its declining population, is a vulnerable species. So far very few studies have been carried out on the habitat requirements of the Black-necked crane or the causes of the decline of its population. The Black-necked crane population is estimated at 10,070-10,970 individuals globally (Birdlife International 2012), and the species is classified as Vulnerable under the IUCN Red List classification (IUCN 2009).

The Black-necked crane usually breeds in Ladakh in India and China. However, very little is known about the wintering population. In India, only two wintering sites from Arunachal Pradesh are known, Sangti, in West Kameng and Zemithang, in Tawang District, of Arunachal Pradesh. The earliest records, from 1946 (Betts 1955), show that the species was present in Apatani Valley, Arunachal Pradesh, which was subsequently abandoned due to anthropogenic disturbances. Two to six Black-necked cranes visited Sangti, West Kameng from the early 1990s. According to published reports, Black-necked cranes first arrived in Zemithang in 2009. Three to nine individuals were recorded. However, local people have reported that the species visited Zemithang valley since time immemorial.

Because of the Buddhist culture in most of the areas where Black-necked cranes are found in India, this species has been protected for a long time (Betts 1955; Chandan et al. 2006; Gole 1981). During our study period, we observed that at many locations the Indian Army and Indo Tibetan Border Police (ITBP) units are also helping with the conservation of these birds. These military and paramilitary forces further need to be encouraged so that they can take adequate measures for the protection of these birds. The study area has two recently established community-conserved areas (CCAs) that have been set aside and are being protected by the community with assistance and advice from WWF in Nyamjang Chu Valley (also known as Pangchen Valley). Community-based conservation practices are important for encouraging conservation-friendly practices among the local community. Conservation awareness programmes are required in schools. Such programmes are also needed for politicians, bureaucrats, the judiciary and the army for long term conservation of biodiversity in the region.

CHAPTER

Significant resources and manpower need to be made available to the forest department, with a clear mandate of wildlife conservation and implementation of wildlife laws. The forest department also needs to devise means of regulating timber felling, medicinal plant collection and the cutting and burning of forests and sand mining practices that continue in the Nyamjang Chu Valley but it should be done in consultation with local communities..

The development of the dam will eventually submerge the entire habitat of the vulnerable Black-necked crane in Zemithang. The cranes use Zemithang Valley as a critical wintering site during the season of heavy snowfall, from November to February. Continued sand mining practices also imposes a threat to the habitat of the Black-necked crane, and the presence of human can compel the Black-necked crane to avoid the area during its winter migration. The death of one crane in January 2007 in Sangti due to the presence of high tension wires in the crane habitat indicates that there is a major threat to the species (Bishop et al. 2012). Bird reflectors need to be fixed on this wire immediately to prevent further killing of birds.

The construction of the dam will be critically damaging for the region, not only for the vulnerable Black-necked crane habitat but also for the fishes, mammals and reptiles as well as the livelihoods and agriculture that is dependent upon the river ecosystem. Furthermore, the construction will lead to the submergence and possible flooding of a large area including the habitat of the Black-necked crane. The area also serves as an Important Bird Area (IBA code: INAR-28), from where several Vulnerable and Near Threatened species have been reported (Islam & Rahmani 2004). The Near Threatened Satyr Tragopan (*Tragopan satyra*), reported from the region, is very sensitive to disturbance. Undisturbed areas are needed to conserve this bird in the area. Important fishes such as the Snow Trout (*Schizothorax* spp.) and Mahseer (*Tor* spp.) that are also endemic to the Himalaya that occur in the area are listed as Vulnerable in the IUCN Red List of threatened species. The migration of these fishes will be severely affected by the construction of the dam. From the socioeconomic survey carried out during our study, it is clearly seen that not a single person wanted the dam to be constructed in Zemithang. So we recommend a strong refusal for the construction of the dam. At the same time, in our opinion, the area, having a very rich biodiversity, can be considered to be declared a protected area i.e community reserve.

Proposal of establishing a community reserve

The areas adjoining Nyamjang Chu river and the high-altitude area of this district together harbour the richest mammalian assemblage. The species richness of this area is only marginally lower those of the two important wildlife reserves of Arunachal Pradesh, the low-elevation Pakke Tiger Reserve and the low- to mid-elevation Namdapha Tiger Reserve. The area will protect a great number of globally important animal as well as plant species. The area will be the only existing wildlife reserve in the world to harbour all three species of goral and the only wildlife reserve in Arunachal Pradesh affording protection to high-altitude species such as the Snow Leopard, the Red Panda, the Chinese Goral and the Himalayan Marmot. Hence, this area may be considered to be declared as a community reserve with due consultations with the local communities.

Figure 10.1: Blood Pheasant (*Ithaginis cruentus*) in Pangchen Valley, Photo: Malyasri Bhattacharya

APPENDIX 1

Numbers of Black-Necked Cranes wintering in Arunachal Pradesh

Sl. no.	Number of BNCs	Year	Place	References
1	27	1946-1947	Apatani	Betts (1955)
2	2	1990	Sangti	Awati (1994)
3	3	1991-1992	Sangti	Singh (2000) and Awati (1994)
4	1	1992-1993	Sangti	Singh (2000) and Awati (1994)
5	6	1993-1994	Sangti	Singh (2000)
6	3	1994-1995	Sangti	Singh (2000)
7	1	1995-1996	Sangti	Singh (2000)
8	1	1996-1997	Sangti	Singh (2000)
9	0	1997-1998	Sangti	Singh (2000)
10	3	1998-1999	Sangti	Singh (2000)
11	11	2005-2006	Sangti	Chandan et al. (2014)
12	6	2006-2007	Sangti	Chandan et al. (2014)
13	4	2007-2008	Sangti	Chandan et al. (2014)
14	0	2008-2009	Sangti	Chandan et al. (2014)
15	3	2009-2010	Zemithang	Chandan et al. (2014)
16	7	2010-2011	Zemithang	Chandan et al. (2014)
17	4	2011-2012	Zemithang	Chandan et al. (2014)
18	2	2012-2013	Zemithang	Chandan et al. (2014)
19	5	2013-2014	Zemithang	Chandan et al. (2014)
20	7	November 2014	Zemithang	Chakraborty and Upadhaya (2018)
22	9	2015	Zemithang	Chakraborty & Upadhaya (2018)
23	5	2016	Zemithang	Chakraborty & Upadhaya (2018)
24	Only seen flying	2017	Zemithang	Chakraborty & Upadhaya (2018)

Source: References

One crane was seen flying over the Nyamjang Chu Valley on 12 January 2018 according to locals.No crane landed in the Zemithang Valley due to severe disturbances caused by sand mining operations in the river bed.

APPENDIX 2

A report on the impacts of disturbance on the critical Black-necked crane habitat

1. **Impacts of sand mining in the Black-necked crane habitat**
   Nyamjang Chu river in Zemithang Valley faces a continuous threat due to ongoing sand mining in the river bed. Previously, sand mining was halted in a small stretch during the wintering months of the Black-Necked Crane (November-January) with the help of WWF and the local Gaon Bura. But in 2017 due to the lack of awareness of the local communities, the mining took long to halt for few months (28 November, 2017-February 28, 2018). Locals as well as outside officials indulge in these sand mining practices without concern for the critical crane habitat. The sand mining process not only alters the habitat by affecting the natural vegetation but also pollutes the area. The disposal of varieties of waste (including plastic bags) left behind by the labourers creates waste pollution in the river bed of the habitat of the crane. At the same time, due to the accessibility of the river bed by road, continuous vehicle traffic affects the normal peace of the valley.

2. **Impacts of non-biodegradable waste from China side in the Nyamjang Chu River**
   Huge amounts of non-biodegradable plastic waste disposed in the Nyamjang Chu River come from the China side as the area is close to the border with China. The large number of plastic bags creates a huge pile near the river bed of the valley, which is a serious threat to the aquatic and terrestrial fauna of the area.

3. **Impacts due to the upcoming hydroelectric power project Prediction of impacts of increased human interference on terrestrial flora**
   During the various construction phase disturbances (movement of machinery and large number of workers, blasting, noise and siting of equipment, godowns, labour and construction camps) the terrestrial flora of the region will be highly disturbed. The total area including the submergence zone has a rich mammalian as well as avifauna. The habitat will be extensively damaged due to the construction work. At the same time only the submergence area consists of Eurasian otters, Porcupine, Barking deer, Arunachal Macaque as well as Leopard cat as reported will be critically in danger.

4. **Impacts of acquisition of forest land during the construction phase on the biological environment**
   The area has a number of important medicinal plants (Choudhury 1996; Choudhury et al. 2007; Namsa et al. 2011) and is rich in various species of alpine herb, rhododendron and orchid (Chowdhury 1998; Paul et al. 2005). From our study it is evident that the variety of the trees and the vegetation in the submergence zone is quite rich. This will be affected by the construction of the dam.

5. **Impacts on migratory routes**
   Important fishes like the Snow Trout (*Schizothorax* spp.) and Mahseer (*Tor* spp.) that are endemic to the Himalaya and are listed as Vulnerable in the IUCN Red List of Threatened Species occur in the area. The proposed dam may obstruct the migratory route of the Mahseer and Snow Trout, which migrate upstream along the Nyamjang Chu River in summer and the monsoon (May-June) for breeding and come downstream in winter.

6. **Impacts on avifauna**
   The project area and its surrounding area have a rich avifauna. The area is the natural habitat of sub-tropical, temperate and alpine bird species and not necessarily only water birds. The area is a critical wintering habitat for the vulnerable Black-necked crane as well as the Ibisbill. It also harbours a few migratory species such as the Mallard, Little Grebe, Tufted Duck and Goosander as well as some rare birds such as the Satyr Tragopan, Blood Pheasant and Himalayan Griffon. The construction phase will vastly affect their habitat.

7. **Construction phase: Impacts due to excavation of construction material from river bed and impacts due to discharge of sewage from labour camp/colony**
   Continuous excavation of materials from the river may cause floods in the area as well. At the same time, there will be very heavy pollution and use of explosives.

8. Impacts on socioeconomic environment: Impacts on cultural/religious/historical monuments

Zemithang is one of the significant areas of ancient Buddhism, and the Gorsam Stupa, which is nearly 800 years old, is located close to the proposed dam site and might be adversely affected by the construction activities, such as blasting and tunnelling. There are also some small monasteries in the area and other areas of cultural/religious significance to the Buddhist Monpa community. The proposed dam site encompasses community land/common property grounds where events such as Republic Day, Independence Day and local festivals have been celebrated for a long time, and these celebrations would be hampered if the project is allowed to progress. Nearly 60 km of roads needs to be constructed during the construction of the hydel project. This construction would destroy the forest area and result in increased soil erosion during the monsoons.

As a whole, from the considerable disturbanceexpected, the local people are all against the construction of the dam, which will affect their belief, their tradition the ecology of the region.

Figure 11: Illegal sand mining in Nyamjang Chu Valley

APPENDIX 3

A checklist of the birds of Zemithang, Arunachal Pradesh from bird surveys

Serial number	Common name	Scientific name	Family
1	Alpine Accentor	*Prunella collaris*	Prunellidae
2	Ashy Drongo	*Dicrurus leucophaeus*	Dicruridae
3	Ashy-Throated Warbler	*Phylloscopus maculipennis*	Phylloscopidae
4	Asian House-Martin	*Delichon dasypus*	Hirundinidae
5	Banded Bay Cuckoo	*Cacomantis sonneratii*	Cuculidae
6	Barn Swallow	*Hirundo rustica*	Hirundinidae
7	Barred Cuckoo-Dove	*Macropygia unchall*	Columbidae
8	Bhutan Laughingthrush	*Trochalopteron imbricatum*	Leiotrichidae
9	Black Bulbul	*Hypsipetes leucocephalus*	Pycnonotidae
10	Black Drongo	*Dicrurus macrocercus*	Dicruridae
11	Black Eagle	*Ictinaetus malaiensis*	Accipitridae
12	Black Redstart	*Phoenicurus ochruros*	Muscicapidae
13	Black-Browed Tit	*Aegithalos bonvaloti*	Aegithalidae
14	Black-Faced Laughingthrush	*Trochalopteron affine*	Leiotrichidae
15	Black-Faced Warbler	*Abroscopus schisticeps*	Cettiidae
16	Black-Throated Prinia	*Prinia atrogularis*	Cisticolidae
17	Black-Throated Sunbird	*Aethopyga saturate*	Nectariniidae
18	Black-Throated Tit	*Aegithalos concinnus*	Aegithalidae
19	Blood Pheasant	*Ithaginis cruentus*	Phasianidae
20	Blue Whistling-Thrush	*Myophonus caeruleus*	Muscicapidae
21	Blue-Capped Rock-Thrush	*Monticola cinclorhyncha*	Muscicapidae
22	Blue-Fronted Redstart	*Phoenicurus frontalis*	Muscicapidae
23	Blue-Winged Minla	*Minla cyanouroptera*	Leiotrichidae
24	Blyth's Leaf Warbler	*Phylloscopus reguloides*	Phylloscopidae
25	Blyth's Reed Warbler	*Acrocephalus dumetorum*	Acrocephalidae
26	Brown Dipper	*Cinclus pallasii*	Cinclidae
27	Black-Headed Gull	*Chroicocephalus ridibundus*	Laridae
28	Buff-Barred Warbler	*Phylloscopus pulcher*	Phylloscopidae
29	Chestnut-Bellied Rock-Thrush	*Monticola rufiventris*	Muscicapidae
30	Chestnut-Crowned Bush Warbler	*Cettia major*	Cettiidae
31	Chestnut-Crowned Laughingthrush	*Trochalopteron erythrocephalum*	Leiotrichidae

Serial number	Common name	Scientific name	Family
32	Chestnut-Crowned Warbler	*Seicercus castaniceps*	Phylloscopidae
33	Chestnut-Headed Tesia	*Cettia castaneocoronata*	Cettiidae
34	Chestnut-tailed Minla	*Minla strigula*	Leiotrichidae
35	Clamorous Reed Warbler	*Acrocephalus stentoreus*	Acrocephalidae
36	Collared Grosbeak	*Mycerobas affinis*	Fringillidae
37	Common Kingfisher	*Alcedo atthis*	Alcedinidae
38	Common Merganser	*Mergus merganser*	Anatidae
39	Common Sandpiper	*Actitis hypoleucos*	Scolopacidae
40	Crested Kingfisher	*Megaceryle lugubris*	Alcedinidae
41	Crimson-Breasted Woodpecker	*Dryobates cathpharius*	Picidae
42	Dark-Breasted Rosefinch	*Procarduelis nipalensis*	Fringillidae
43	Dark-Rumped Rosefinch	*Carpodacus edwardsii*	Fringillidae
44	Dark-Sided Flycatcher	*Muscicapa sibirica*	Muscicapidae
45	Daurian Redstart	*Phoenicurus auroreus*	Muscicapidae
46	Eurasian Hoopoe	*Upupa epops*	Upupidae
47	Eurasian Jay	*Garrulus glandarius*	Corvidae
48	Eurasian Kestrel	*Falco tinnunculus*	Falconidae
49	Eurasian Nutcracker	*Nucifraga caryocatactes*	Corvidae
50	Eurasian Tree Sparrow	*Passer montanus*	Passeridae
51	Eurasian Woodcock	*Scolopax rusticola*	Scolopacidae
52	Eurasian Wren	*Troglodytes troglodytes*	Troglodytidae
53	Fire-Breasted Flowerpecker	*Dicaeum ignipectus*	Dicaeidae
54	Fire-Tailed Sunbird	*Aethopyga ignicauda*	Nectariniidae
55	Gold-Naped Finch	*Pyrrhoplectes epaulette*	Fringillidae
56	Gould's Sunbird	*Aethopyga gouldiae*	Nectariniidae
57	Gray Bushchat	*Saxicola ferreus*	Muscicapidae
58	Gray Wagtail	*Motacilla cinerea*	Motacillidae
59	Gray-Backed Shrike	*Lanius tephronotus*	Laniidae
60	Gray-Cheeked Warbler	*Seicercus poliogenys*	Phylloscopidae
61	Gray-Headed Canary-Flycatcher	*Culicicapa ceylonensis*	Stenostiridae
62	Gray-Hooded Warbler	*Phylloscopus xanthoschistos*	Phylloscopidae
63	Gray-Winged Blackbird	*Turdus boulboul*	Turdidae
64	Great Barbet	*Psilopogon virens*	Megalaimidae
65	Great Cormorant	*Phalacrocorax carbo*	Phalacrocoracidae
66	Greater Spotted Eagle	*Clanga clanga*	Accipitridae
67	Green Imperial-Pigeon	*Ducula aenea*	Columbidae
68	Green Sandpiper	*Tringa ochropus*	Scolopacidae
69	Green-Backed Tit	*Parus monticolus*	Paridae

Serial number	Common name	Scientific name	Family
70	Greenish Warbler	*Phylloscopus trochiloides*	Phylloscopidae
71	Green Shrike-Babbler	*Pteruthius xanthochlorus*	Vireonidae
72	Green-Tailed Sunbird	*Aethopyga nipalensis*	Nectariniidae
73	Hen Harrier	*Circus cyaneus*	Accipitridae
74	Himalayan Beautiful Rosefinch	*Carpodacus pulcherrimus*	Fringillidae
75	Himalayan Bluetail	*Tarsiger rufilatus*	Muscicapidae
76	Himalayan Bulbul	*Pycnonotus leucogenys*	Pycnonotidae
77	Himalayan Griffon	*Gyps himalayensis*	Accipitridae
78	Himalayan Monal	*Lophophorus impejanus*	Phasianidae
79	Hodgson's Redstart	*Phoenicurus hodgsoni*	Muscicapidae
80	Hodgson's Treecreeper	*Certhia hodgsoni*	Certhiidae
81	Ibisbill	*Ibidorhyncha struthersii*	Ibidorhynchidae
83	Kalij Pheasant	*Lophura leucomelanos*	Phasianidae
84	Kentish Plover	*Charadrius alexandrines*	Charadriidae
85	Large-Billed Crow	*Corvus macrorhynchos*	Corvidae
86	Large-Billed Leaf Warbler	*Phylloscopus magnirostris*	Phylloscopidae
87	Lesser Cuckoo	*Cuculus poliocephalus*	Cuculidae
88	Lesser Kestrel	*Falco naumanni*	Falconidae
89	Little Bunting	*Emberiza pusilla*	Emberizidae
90	Little Forktail	*Enicurus scouleri*	Muscicapidae
91	Long-Billed Plover	*Charadrius placidus*	Charadriidae
92	Long-Tailed Shrike	*Lanius schach*	Laniidae
93	Ludlow's Fulvetta	*Fulvetta ludlowi*	Sylviidae
94	Mallard	*Anas platyrhynchos*	Anatidae
95	Maroon-Backed Accentor	*Prunella immaculate*	Prunellidae
96	Nepal House-Martin	*Delichon nipalense*	Hirundinidae
97	Olive-Backed Pipit	*Anthus hodgsoni*	Motacillidae
98	Orange-Bellied Leafbird	*Chloropsis hardwickii*	Chloropseidae
99	Oriental Magpie-Robin	*Copsychus saularis*	Muscicapidae
100	Oriental Turtle-Dove	*Streptopelia orientalis*	Columbidae
101	Pale Blue Flycatcher	*Cyornis unicolor*	Muscicapidae
102	Peregrine Falcon	*Falco peregrines*	Falconidae
103	Plumbeous Redstart	*Phoenicurus fuliginosus*	Muscicapidae
104	Pygmy Cupwing	*Pnoepyga pusilla*	Pnoepygidae
105	Red-Billed Leiothrix	*Leiothrix lutea*	Leiotrichidae
106	Red-Headed Bullfinch	*Pyrrhula erythrocephala*	Fringillidae
107	Red-Tailed Minla	*Minla ignotincta*	Leiotrichidae
108	Red-Vented Bulbul	*Pycnonotus cafer*	Pycnonotidae
109	Rosy Pipit	*Anthus roseatus*	Motacillidae
110	Ruddy Shelduck	*Tadorna ferruginea*	Anatidae

Serial number	Common name	Scientific name	Family
111	Rufous-Backed Sibia	*Heterophasia annectens*	Leiotrichidae
112	Rufous-Bellied Niltava	*Niltava sundara*	Muscicapidae
113	Rufous-Breasted Accentor	*Prunella strophiata*	Prunellidae
114	Rufous-Breasted Bush-Robin	*Tarsiger hyperythrus*	Muscicapidae
115	Rufous-Fronted Babbler	*Stachyridopsis rufifrons*	Timaliidae
116	Rufous-Throated Fulvetta	*Alcippe rufogularis*	Pellorneidae
117	Rufous-Vented Yuhina	*Yuhina occipitalis*	Zosteropidae
118	Russet Sparrow	*Passer cinnamomeus*	Passeridae
119	Rusty-Cheeked Scimitar-Babbler	*Pomatorhinus erythrogenys*	Timaliidae
120	Rusty-Flanked Treecreeper	*Certhia nipalensis*	Certhiidae
121	Satyr Tragopan	*Tragopan satyra*	Phasianidae
122	Scaly-Breasted Cupwing	*Pnoepyga albiventer*	Pnoepygidae
123	Scarlet Minivet	*Pericrocotus speciosus*	Campephagidae
124	Shikra	*Accipiter badius*	Accipitridae
125	Slaty-Blue Flycatcher	*Ficedula tricolor*	Muscicapidae
126	Slender-Billed Scimitar-Babbler	*Pomatorhinus superciliaris*	Timaliidae
127	Snow Pigeon	*Columba leuconota*	Columbidae
128	Speckled Wood-Pigeon	*Columba hodgsonii*	Columbidae
129	Steppe Eagle	*Aquila nipalensis*	Accipitridae
130	Streak-Breasted Scimitar-Babbler	*Pomatorhinus ruficollis*	Timaliidae
131	Striated Laughingthrush	*Garrulax striatus*	Leiotrichidae
132	Tawny Fish-Owl	*Ketupa flavipes*	Strigidae
133	Tibetan Blackbird	*Turdus maximus*	Turdidae
134	Tibetan Serin	*Spinus thibetanus*	Fringillidae
135	Tickell's Leaf Warbler	*Phylloscopus affinis*	Phylloscopidae
136	Tufted Duck	*Aythya fuligula*	Anatidae
137	Ultramarine Flycatcher	*Ficedula superciliaris*	Muscicapidae
138	Verditer Flycatcher	*Eumyias thalassinus*	Muscicapidae
139	Wallcreeper	*Tichodroma muraria* (Linnaeus, 1766)	Tichodromidae
140	Wedge-Tailed Pigeon	*Treron sphenurus* (Vigors, 1832)	Columbidae
141	Whiskered Yuhina	*Yuhina flavicollis* Hodgson, 1836	Zosteropidae
142	Whistler's Warbler	*Seicercus whistleri* Ticehurst, 1925	Phylloscopidae
143	White Wagtail	*Motacilla alba* Linnaeus, 1758	Motacillidae
144	White-Capped Redstart	*Phoenicurus leucocephalus* (Vigors, 1831)	Muscicapidae
145	White-Collared Blackbird	*Turdus albocinctus* Royle, 1840	Turdidae

Serial number	Common name	Scientific name	Family
146	White-Crested Laughingthrush	*Garrulax leucolophus* (Hardwicke, 1815)	Leiotrichidae
147	White-Crowned Forktail	*Enicurus leschenaulti* (Vieillot, 1818)	Muscicapidae
148	White-Rumped Needletail	*Zoonavena sylvatica* (Tickell, 1846)	Apodidae
149	White-Spectacled Warbler	*Phylloscopus intermedius* (La Touche, 1898)	Phylloscopidae
150	White-Tailed Nuthatch	*Sitta himalayensis* Jardine & Selby, 1835	Sittidae
151	White-Throated Dipper	*Cinclus cinclus* (Linnaeus, 1758)	Cinclidae
152	White-Throated Fantail	*Rhipidura albicollis* (Vieillot, 1818)	Rhipiduridae
153	White-Throated Laughingthrush	*Garrulax albogularis* (Gould, 1836)	Leiotrichidae
154	White-Throated Needletail	*Hirundapus caudacutus* (Latham, 1802)	Apodidae
155	White-Winged Grosbeak	*Mycerobas carnipes* (Hodgson, 1836)	Fringillidae
156	Yellow-Bellied Fairy-Fantail	*Chelidorhynx hypoxanthus* (Blyth, 1843)	Stenostiridae
157	Yellow-Billed Blue-Magpie	*Urocissa flavirostris* (Blyth, 1846)	Corvidae
158	Yellow-Breasted Greenfinch	*Chloris spinoides* (Vigors, 1831)	Fringillidae
159	Black-Necked Crane	*Grus nigricollis* Przevalski, 1876	Gruidae

Figure 12: Black-Faced Warbler (*Abroscopus schisticeps*) (photo: Malyasri Bhattacharya)

APPENDIX 4

Bird density and abundance table

Bird species	Estimate	%CV	df	95% Confidence interval	
Stratum: Ashy Drongo					
Hazard/cosine					
DS	4.3062	40.32	35.97	1.96	9.4611
D	5.5365	46.04	39.37	2.2815	13.436
Stratum: Himalayan Beautiful Rosefinch					
Hazard/cosine					
DS	2.4607	59.95	35.43	0.79938	7.5746
D	9.2276	94.72	8.04	1.4604	58.306
Stratum: Bhutan Laughinthrush					
Hazard/cosine					
DS	8.6124	33.18	36.45	4.4731	16.582
D	18.455	42.89	44.99	8.0667	42.222
Stratum: Black Bulbul					
Hazard/cosine					
DS	12.919	26.32	37.34	7.6482	21.821
D	21.531	28.61	49.11	12.255	37.829
Stratum: Black Drongo					
Hazard/cosine					
DS	1.8455	56.26	35.49	0.63682	5.3483
D	1.8455	56.26	35.49	0.63682	5.3483
Stratum: Black Redstart					
Hazard/cosine					
DS	1.2303	69.85	35.32	0.34231	4.4221
D	1.2303	69.85	35.32	0.34231	4.4221
Stratum: Black-Throated Sunbird					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Blue Whistling Thrush					
Hazard/cosine					
DS	41.832	13.13	45.99	32.153	54.423
D	41.73	13.17	46.54	32.053	54.329
Stratum: Blue-Winged Minla					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381

Bird species	Estimate	%CV	df	95% Confidence interval	
Stratum: Blue-Fronted Redstart					
Hazard/Cosine					
DS	1.8455	56.26	35.49	0.63682	5.3483
D	1.8455	56.26	35.49	0.63682	5.3483
Stratum: Blyth's Reed Warbler					
Hazard/cosine					
DS	1.2303	69.85	35.32	0.34231	4.4221
D	1.2303	69.85	35.32	0.34231	4.4221
Stratum: Brown Dipper					
Hazard/cosine					
DS	2.4607	48.04	35.68	0.97626	6.2022
D	2.4607	48.04	35.68	0.97626	6.2022
Stratum: Chestnut-Crowned Laughinthrush					
Hazard/cosine					
DS	11.073	35.5	36.26	5.5068	22.266
D	20.109	39.02	48.2	9.4337	42.863
Stratum: Crimson-Breasted Woodpecker					
Hazard/cosine					
DS	1.8455	56.26	35.49	0.63682	5.3483
D	1.8455	56.26	35.49	0.63682	5.3483
Stratum: Darjeeling Woodpecker					
Hazard/cosine					
DS	1.2303	100.11	35.15	0.22674	6.6762
D	1.2303	100.11	35.15	0.22674	6.6762
Stratum: Dark-Breasted Rosefinch					
Hazard/cosine					
DS	3.0759	51.15	35.6	1.1566	8.18
D	4.3062	58.59	32.83	1.4256	13.007
Stratum: Daurian Redstart					
Hazard/cosine					
DS	9.8427	27.95	37.07	5.647	17.156
D	9.8427	27.95	37.07	5.647	17.156
Stratum: Eurasian Tree Sparrow					
Hazard/cosine					
DS	5.5365	46.36	35.73	2.2621	13.55
D	25.837	71.29	21.44	6.823	97.839
Stratum: Fire-Tailed Sunbird					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381

Bird species	Estimate	%CV	df	95% Confidence interval	
Stratum: Gray-Backed Shrike					
Hazard/cosine					
DS	5.5365	33.66	36.41	2.8495	10.757
D	7.9972	35.79	43.18	3.9709	16.106
Stratum: Gray Bushchat					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Gray-Hooded warbler					
Hazard/cosine					
DS	13.534	26.72	37.27	7.9504	23.038
D	17.225	28.27	45.53	9.8564	30.102
Stratum: Green-Backed Tit					
Hazard/cosine					
DS	27.067	18.21	40.17	18.792	38.987
D	35.701	19.73	53.83	24.128	52.825
Stratum: Gray-Hooded Canary Flycatcher					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	1.8455	100.11	35.15	0.34011	10.014
Stratum: Himalayan Bulbul					
Hazard/cosine					
DS	1.2303	100.11	35.15	0.22674	6.6762
D	1.2303	100.11	35.15	0.22674	6.6762
Stratum: Hodgson's Redstart					
Hazard/cosine					
DS	63.978	10.36	55.31	52.016	78.689
D	65.823	10.48	57.97	53.397	81.141
Stratum: Hodgson's Treecreeper					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Large-Billed Crow					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Little Bunting					
Hazard/cosine					
DS	3.0759	42.35	35.88	1.3495	7.0105
D	10.08	81.15	5.6	1.7152	59.24

Bird species	Estimate	%CV	df	95% Confidence interval	
Stratum: Little Forktail					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Long-Tailed Shrike					
Hazard/cosine					
DS	3.0759	42.35	35.88	1.3495	7.0105
D	3.691	45.51	39.38	1.5351	8.8749
Stratum: Maroon-Backed Accentor					
Hazard/cosine					
DS	3.691	44.97	35.78	1.5455	8.8148
D	3.691	44.97	35.78	1.5455	8.8148
Stratum: Mrs Gould's Sunbird					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Olive-Backed Pipit					
Hazard/cosine					
DS	13.534	24.22	37.79	8.3464	21.945
D	51.674	32.93	56.25	27.175	98.26
Stratum: Oriental Turtle Dove					
Hazard/cosine					
DS	13.534	22.39	38.3	8.6496	21.176
D	17.225	24.22	49.78	10.663	27.824
Stratum: Plumbeous Water Redstart					
Hazard/cosine					
DS	3.0759	51.15	35.6	1.1566	8.18
D	3.691	53.8	39.59	1.3319	10.229
Stratum: Red-Vented Bulbul					
Hazard/cosine					
DS	22.146	31.97	36.56	11.767	41.679
D	35.68	33.85	45.28	18.38	69.264
Stratum: Red-Billed Leothrix					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Red-Tailed Minla					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381

Bird species	Estimate	%CV	df	95% Confidence interval	
Stratum: Ruddy Shelduck					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Rufous-Breasted Accentor					
Hazard/cosine					
DS	12.919	23.51	37.97	8.0777	20.66
D	34.45	41.96	38.27	15.249	77.826
Stratum: Rufous-Flanked Treecreeper					
Hazard/cosine					
DS	1.8455	73.83	35.29	0.48388	7.0387
D	1.8455	73.83	35.29	0.48388	7.0387
Stratum: Rufous Sibia					
Hazard/cosine					
DS	10.458	30.18	36.76	5.7488	19.025
D	10.709	31.45	42.6	5.7629	19.899
Stratum: Russet Sparrow					
Hazard/cosine					
DS	6.7669	41.13	35.93	3.0351	15.087
D	74.436	48.84	44.53	29.313	189.02
Stratum: Spotted Dove					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Streak-Breasted Scimitar Babbler					
Hazard/cosine					
DS	1.2303	69.85	35.32	0.34231	4.4221
D	3.0759	92.08	5.27	0.42326	22.353
Stratum: Striated Prinia					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Striated Yuhina					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: Tickell's Leaf Warbler					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381

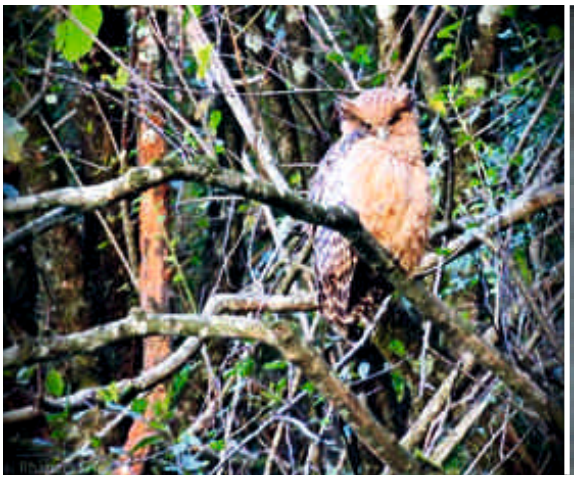
Bird species	Estimate	%CV	df	95% Confidence interval	
Stratum: Tytler's Leaf Warbler					
Hazard/cosine					
DS	4.3062	34.72	36.32	2.1727	8.5347
D	4.3062	34.72	36.32	2.1727	8.5347
Stratum: Verditer Flycatcher					
Hazard/cosine					
DS	4.3062	40.32	35.97	1.96	9.4611
D	4.3062	40.32	35.97	1.96	9.4611
Stratum: Wallcreeper					
Hazard/cosine					
DS	4.3062	40.32	35.97	1.96	9.4611
D	4.3062	40.32	35.97	1.96	9.4611
Stratum: Warbler sp.					
Hazard/cosine					
DS	7.382	31.97	36.56	3.9224	13.893
D	7.4174	32.32	38.12	3.9188	14.039
Stratum: Whiskered Yuhina					
Hazard/cosine					
DS	2.4607	48.04	35.68	0.97626	6.2022
D	4.3062	55.28	27.8	1.4947	12.406
Stratum: Whistler's Warbler					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381
Stratum: White Wagtail					
Hazard/cosine					
DS	7.9972	25.48	37.51	4.812	13.291
D	12.303	29.07	49.48	6.9422	21.805
Stratum: White-Capped Water Redstart					
Hazard/cosine					
DS	14.764	25.08	37.59	8.9525	24.348
D	14.764	25.08	37.59	8.9525	24.348
Stratum: White-Throated Laughingthrush					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	9.2276	100.11	35.15	1.7005	50.071
Stratum: Black-Throated Tit					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	0.61517	100.11	35.15	0.11337	3.3381

Bird species	Estimate	%CV	df	95% Confidence interval	
Stratum: White-Tailed Nuthatch					
Hazard/cosine					
DS	3.0759	42.35	35.88	1.3495	7.0105
D	3.0759	42.35	35.88	1.3495	7.0105
Stratum: Yellow-Bellied Fantail					
Hazard/cosine					
DS	3.0759	51.15	35.6	1.1566	8.18
D	3.0759	51.15	35.6	1.1566	8.18
Stratum: Yellow-Breasted Greenfinch					
Hazard/cosine					
DS	0.61517	100.11	35.15	0.11337	3.3381
D	46.138	100.11	35.15	8.5026	250.36

Figure 13: Birds of Zemithang, Photo: Malyasri Bhattacharya

Goosander (*Mergus merganser*)

Rufous-breasted bush robin (*Tarsiger hyperythrus*)



Tawny-fish owl (*Ketupa flavipes*)

Wallcreeper (*Tichodroma muraria*)

Yellow-bellied fantail (*Chelidorhynx hypoxantha*)

White-Throated Dipper (*Cinclus cinclus*)

Yellow-breasted greenfinch (*Chloris spinoides*)

White-Tailed Nuthatch (*Sitta himalayansis*)

Slender-billed scimitar babbler (*Pomatorhinus superciliaris*)

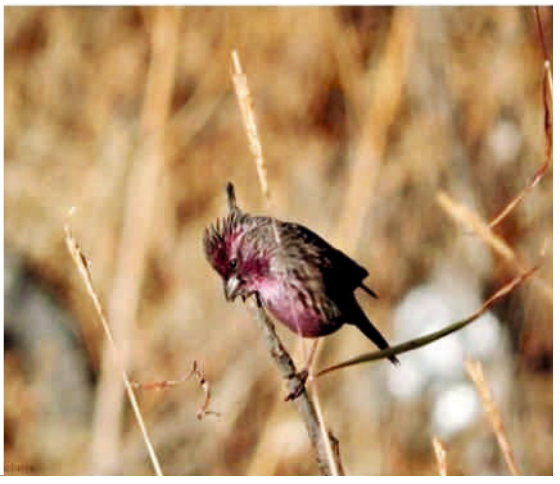
Crimson-breasted woodpecker (*Dryobates cathpharius*)

White-capped Water Redstart (*Phoenicurus leucocephalus*)

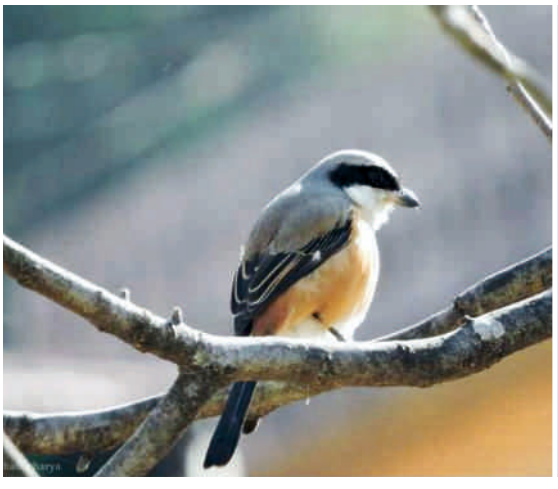
Figure 14: Birds of Zemithang (photos: Malyasri Bhattacharya)

Figure 15: Birds of Zemithang (photo: Malyasri Bhattacharya)

Lesser Kestrel (*Falco naumanni*)

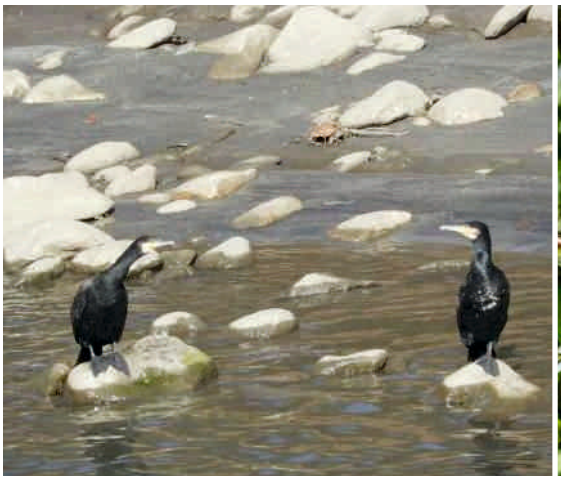


Himalayan beautiful rosefinch (*Carpodacus pulcherrimus*)

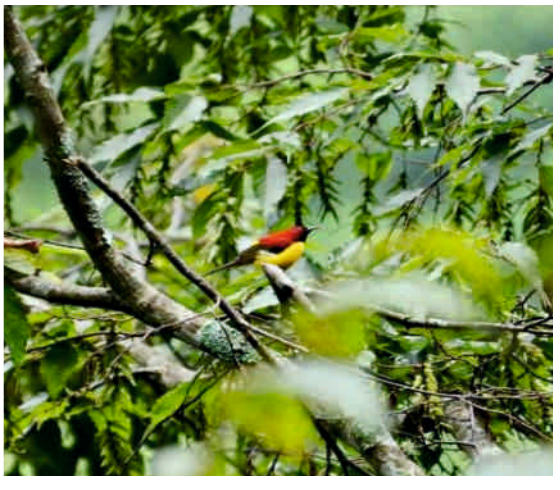


Long-Tailed Shrike (*Lanius schach*)

Himalayan Bulbul (*Pycnonotus leucogenys*)



Indian Cormorant (*Phalacrocorax fuscicollis*)



Mrs Gould's Sunbird (*Aethopyga gouldiae*)

Red-billed Leothrix (*Leiothrix lutea*)

Red-tailed Minla (*Minla ignotincta*)

Black-throated Prinia (*Prinia atrogularis*)

Green-tailed Sunbird (*Aethopyga nipalensis*)

Barn Swallow (*Hirudo rustica*)

Bhutan Laughingthrush (*Trochalopteron imbricatum*)

Figure 16: Birds of Zemithang (photos: Malyasri Bhattacharya)

APPENDIX 5

Density, frequency and IVI of tree species across different habitats

	TREE			
Layer	**Species**	**Density/ha**	**TBA**	**IVI**
Alnus	*Alnus nepalensis*	667.8	36.4	232.2
	Erythrina variegata	21.4	0.9	11.3
	Salix sp.	46.4	0.9	16.7
	Lyonia ovalifolia	28.6	0.5	11.3
	Lindera neesiana	3.6	0.1	2.8
	Jhalong	3.6	0.04	2.7
	Menchen	21.4	0.3	12.0
	Yayoong	14.3	2.0	11.1
Hippophae	*Erythrina variegata*	300.0	4.2	133.7
	Salix sp.	25.0	0.4	21.2
	Khusisang	25.0	0.8	25.4
	Menchen	150.0	2.4	75.8
	Bhaber	75.0	1.8	43.9
Mixed	*Alnus nepalensis*	179.0	6.6	84.0
	Erythrina variegata	168.4	10.8	101.1
	Lyonia ovalifolia	21.1	0.4	9.2
	Morus sp.	21.1	0.2	8.6
	Salix sp.	68.4	1.3	29.1
	Glangma	21.1	0.3	8.8
	Menchen	121.1	2.4	59.3
Seasonal sandbars	*Salix* sp.	171.4	9.3	188.8
	Alnus nepalensis	100.0	5.8	52.6
	Yayoong	142.9	4.1	58.6
Shrub-dominated	*Salix* sp.	66.7	1.3	33.4
	Alnus nepalensis	266.7	16.0	150.2
	Erythrina variegata	166.7	2.4	54.6
	Prunus sp. *(cherry blossom)*	50.0	0.8	28.4
	Menchen	66.7	1.3	33.4

APPENDIX 6

Densities and frequencies of saplings in different habitats

SAPLINGS OF TREE

Layer	Species	Density/ha	Frequency	Distribution pattern
Alnus	*Alnus nepalensis*	206.7	93.3	Regular
	Celtis sp.	6.7	6.7	Contiguous
	Erythrina variegata	13.3	6.7	Contiguous
	Prunus sp. (cherry blossom)	6.7	6.7	Contiguous
	Others (zezee, menchen)	10.0	6.7	Contiguous
Apple	*Pyrus malus* (apple)	450.0	100.0	Random
Mixed	Others (glangma)	200.0	50.0	Contiguous
	Erythrina variegata	100.0	50.0	Random

APPENDIX 7

Densities and frequencies of shrubs in different habitats

SHRUBS

Layer	Species	Density/ha	Frequency	Distribution pattern
Alnus	*Elaeagnus umbellata*	733.3	91.7	Regular
	Elaeagnus sp	33.3	8.3	Contiguous
	Hippophae rhamnoides	133.3	25.0	Random
Hippophae	*Debregeasia longifolia*	23.5	5.9	Contiguous
	Debregeasia velutina	94.1	5.9	Contiguous
	Elaeagnus umbellata	894.1	58.8	Contiguous
	Hippophae rhamnoides	3035.3	88.2	Contiguous
Lowland grassland	*Boehmeria* sp	200.0	12.5	Contiguous
	Elaeagnus umbellata	8200.0	75.0	Contiguous
	Elaeagnus sp.(Comirem)	50.0	12.5	Contiguous
Mixed	*Debregeasia longifolia*	40.0	6.7	Contiguous
	Elaeagnus umbellata	1760.0	90.0	Random
	Elaeagnus sp.(Comirem)	26.7	6.7	Contiguous
	Hippophae rhamnoides	426.7	33.3	Contiguous
	Lindera neesiana	26.7	3.3	Contiguous
	Philadelphus tomentosus	13.3	3.3	Contiguous
	Zanthoxylum armatum	13.3	3.3	Contiguous
	Others (lhangma)	13.3	3.3	Contiguous
Seasonal sandbars	*Elaeagnus umbellata*	400.0	44.4	Random
	Hippophae rhamnoides	1066.7	77.8	Random
Shrub dominated	*Debregeasia longifolia*	53.3	13.3	Contiguous
	Elaeagnus umbellata	1813.3	86.7	Contiguous
	Hippophae rhamnoides	373.3	6.7	Contiguous
	Lindera neesiana	26.7	6.7	Contiguous
	Zanthoxylum armatum	26.7	6.7	Contiguous

APPENDIX 8

Densities and frequencies of ground flora in different habitats

HERBS

Layer	Species	Density (/m²)	Frequency	Distribution pattern
Alnus	*Artemisia nilagirica*	0.3	25.0	Random
	Anaphalis sp.	0.1	12.5	Contiguous
	Axonopus affinis	42.1	12.5	Contiguous
	Bambusa sp.	0.1	12.5	Contiguous
	Cyperus kyllingia	2.5	12.5	Contiguous
	Kummerowia striata	0.3	12.5	Contiguous
	Luzula sp.	23.0	12.5	Contiguous
	Periploca calophylla	0.3	25.0	Random
	Utricularia sp.	8.9	12.5	Contiguous
	Xanthium strumarium	0.4	37.5	Random
	Others	0.9	12.5	Contiguous
Highland grassland	*Artemisia nilagirica*	0.1	14.3	Contiguous
	Artemisia sp.	3.3	85.7	Random
	Arthraxon hispidus	41.1	14.3	Contiguous
	Arthraxon sp.	10.9	14.3	Contiguous
	Bidens pilosa	0.1	14.3	Contiguous
	Cosmos bipinnatus	0.3	28.6	Random
	Crassocephalum crepidioides	0.1	14.3	Contiguous
	Cyanotis cristata	0.4	14.3	Contiguous
	Equisetum sp.	1.7	42.9	Contiguous
	Eragrostis tenuifolia	7.6	14.3	Contiguous
	Erigeron sp.	0.1	14.3	Contiguous
	Geranium sp.	1.1	28.6	Contiguous
	Hydrocotyle javanica	0.1	14.3	Contiguous
	Indigofera sp.	8.0	14.3	Contiguous
	Kummerowia striata	70.9	14.3	Contiguous
	Kyllinga brevifolia	0.4	14.3	Contiguous
	Myriactis nepalensis	1.4	14.3	Contiguous
	Oplismenus sp.	1.9	14.3	Contiguous
	Paspalum longifolium	0.1	14.3	Contiguous
	Pennisetum clandestinum	70.9	14.3	Contiguous
	Periploca calophylla	0.1	14.3	Contiguous
	Rumex nepalensis	1.6	14.3	Contiguous
	Rumex obtusifolius	0.6	14.3	Contiguous
	Sacciolepis indicus	3.1	14.3	Contiguous
	Schizachyrium delavayi	33.4	14.3	Contiguous
	Scleria sp.	1.9	14.3	Contiguous
	Setaria glauca	6.9	14.3	Contiguous
	Smithia ciliata	19.4	14.3	Contiguous
Hippophae	*Artemisia nilagirica*	0.1	11.8	Contiguous
	Ageratum conyzoides	0.1	5.9	Contiguous
	Anaphalis contorta	0.1	5.9	Contiguous
	Artemisia sp.	14.1	11.8	Contiguous
	Arthraxon sp.	12.3	5.9	Contiguous
	Axonopus affinis	4.5	5.9	Contiguous

Layer	Species	Density (/m²)	Frequency	Distribution pattern
	Bothriochloa intermedia	1.6	11.8	Contiguous
	Calamintha umbrosa	0.3	5.9	Contiguous
	Cannabis sativa	0.9	64.7	Regular
	Cyanotis cristata	0.6	11.8	Contiguous
	Fimbristylis sp.	0.7	5.9	Contiguous
	Girardinia macrophylla	0.2	23.5	Random
	Kummerowia striata	6.8	5.9	Contiguous
	Ophioglossum sp.	0.6	5.9	Contiguous
	Polygonum nepalense	0.1	5.9	Contiguous
	Pteris sp.	0.1	5.9	Contiguous
	Rubus sp.	0.9	5.9	Contiguous
	Stellaria media	0.7	5.9	Contiguous
	Verbascum thapsus	0.1	5.9	Contiguous
	Vernonia cinerea	0.5	5.9	Contiguous
	Xanthium strumarium	0.1	5.9	Contiguous
Lowland grassland	*Kyllingia nemoralis*	0.4	2.6	Contiguous
	Aconogonum molle	0.2	2.6	Contiguous
	Ambrosia artemisiifolia	0.0	2.6	Contiguous
	Anaphalis royleana	0.1	2.6	Contiguous
	Artemisia sp.	3.8	13.2	Contiguous
	Arthraxon hispidus	2.1	5.3	Contiguous
	Arthraxon sp.	1.9	2.6	Contiguous
	Axonopus affinis	8.8	18.4	Contiguous
	Axonopus sp.	15.3	7.9	Contiguous
	Bidens pilosa	0.2	2.6	Contiguous
	Bidens sp.	0.1	2.6	Contiguous
	Calamagrostise modensis	7.8	2.6	Contiguous
	Cannabis sativa	1.4	18.4	Contiguous
	Carex sp.	0.6	5.3	Contiguous
	Chenopodium sp.	0.8	5.3	Contiguous
	Chloris sp.	1.0	5.3	Contiguous
	Cirsium sp.	0.4	5.3	Contiguous
	Clinopodium umbrosum	0.1	2.6	Contiguous
	Cosmos bipinnatus	1.2	5.3	Contiguous
	Crassocephalum crepidioides	0.0	2.6	Contiguous
	Cyanotis cristata	0.0	2.6	Contiguous
	Cynodon dactylon	0.9	5.3	Contiguous
	Cyperus brevifolius	0.0	2.6	Contiguous
	Cyperus compressus	0.5	5.3	Contiguous
	Cyperus kyllingia	0.0	2.6	Contiguous
	Cyperus rotundus	0.9	2.6	Contiguous
	Cyperus sp.	0.1	2.6	Contiguous
	Drymaria cordata	6.5	21.1	Contiguous
	Drymaria diandra	0.3	5.3	Contiguous
	Duchesnea indica	0.0	2.6	Contiguous
	Equisetum sp.	0.5	13.2	Contiguous
	Eragrostis tenuifolia	1.3	13.2	Contiguous
	Erigeron bonariensis	0.4	2.6	Contiguous
	Erigeron sp.	0.3	5.3	Contiguous
	Eriocaulon sp.	0.8	2.6	Contiguous
	Fimbristylis dichotoma	1.0	13.2	Contiguous
	Fimbristylis sp.	1.3	10.5	Contiguous
	Galinsoga parviflora	0.0	2.6	Contiguous

Layer	Species	Density (/m²)	Frequency	Distribution pattern
	Geranium nepalense	0.6	2.6	Contiguous
	Geranium sp.	13.5	10.5	Contiguous
	Girardinia macrophylla	0.0	2.6	Contiguous
	Isachne albens	0.2	2.6	Contiguous
	Kummerowia striata	44.5	18.4	Contiguous
	Lespedeza sp.	0.0	2.6	Contiguous
	Murdannia nudiflora	0.4	2.6	Contiguous
	Ophioglossum sp.	0.7	2.6	Contiguous
	Oplismenus sp.	17.2	10.5	Contiguous
	Paspalum paspaloides	0.2	2.6	Contiguous
	Paspalum sp.	0.1	5.3	Contiguous
	Paspalum scrobiculatum	0.0	2.6	Contiguous
	Pennisetum clandestinum	32.0	42.1	Contiguous
	Pilea sp. (Urticaceae)	0.1	2.6	Contiguous
	Plantago ovata	0.6	7.9	Contiguous
	Poa sp.	4.7	10.5	Contiguous
	Polygala tatarinowii	0.1	2.6	Contiguous
	Polygonum nepalense	0.3	5.3	Contiguous
	Pteridium aquilinum	1.5	5.3	Contiguous
	Pteris sp.	0.2	10.5	Contiguous
	Ranunculus hirtellus	0.4	2.6	Contiguous
	Rorippa sp.	0.9	2.6	Contiguous
	Rubus sp.	5.0	10.5	Contiguous
	Selaginella sp.	0.9	2.6	Contiguous
	Solanum khasianum	0.0	2.6	Contiguous
	Sporobolus africanus	1.1	15.8	Contiguous
	Verbascum thapsus	0.5	7.9	Contiguous
	Vernonia cinerea	1.3	18.4	Contiguous
	Veronica sp.	0.8	2.6	Contiguous
	Cyprus sp.	11.2	5.3	Contiguous
	Others (nine species)*	1.6	3.2	Contiguous
Mixed	*Artemisia nilagirica*	0.2	21.7	Random
	Aconogonum molle	0.1	4.3	Contiguous
	Artemisia sp.	0.3	21.7	Contiguous
	Calamagrostis scabrescens	0.0	4.3	Contiguous
	Cannabis sativa	0.5	34.8	Random
	Cyanotis cristata	0.8	4.3	Contiguous
	Fimbristylis sp.	15.9	4.3	Contiguous
	Girardinia macrophylla	0.1	13.0	Contiguous
	Mentha sp.	0.0	4.3	Contiguous
	Periploca calophylla	0.2	17.4	Contiguous
	Pteridium aquilinum	0.4	13.0	Contiguous
	Pteris sp.	0.3	21.7	Contiguous
	Schizachyrium delavayi	2.9	4.3	Contiguous
	Xanthium strumarium	0.2	21.7	Random
	Cyprus sp.	0.0	4.3	Contiguous
Seasonal sandbars	*Artemisia nilagirica*	0.3	33.3	Random
	Artemisia sp.	7.3	26.7	Contiguous
	Bidens pilosa	0.1	6.7	Contiguous
	Calamagrostis scabrescens	5.5	13.3	Contiguous
	Cosmos bipinnatus	0.1	6.7	Contiguous
	Cynodon dactylon	1.3	6.7	Contiguous
	Cynodon transvaalensis	3.2	6.7	Contiguous

Layer	Species	Density (/m²)	Frequency	Distribution pattern
	Equisetum sp.	0.1	6.7	Contiguous
	Eragrostis tenuifolia	1.1	13.3	Contiguous
	Erianthus sikkimensis	0.3	20.0	Contiguous
	Kummerowia striata	0.9	6.7	Contiguous
	Paspalum paspaloides	16.3	6.7	Contiguous
	Pennisetum clandestinum	0.7	13.3	Contiguous
	Rubus ellipticus	0.1	6.7	Contiguous
	Rumex nepalensis	0.1	6.7	Contiguous
	Sigesbeckia sp.	0.6	6.7	Contiguous
	Vernonia cinerea	0.1	6.7	Contiguous
	Others (two species)*	0.0	6.7	Contiguous
Shrub dominated	*Ambrosia artemisiifolia*	0.1	9.1	Contiguous
	Cannabis sativa	1.2	72.7	Regular
	Erianthus sikkimensis	0.1	9.1	Contiguous
	Pteridium aquilinum	0.5	9.1	Contiguous
	Pteris sp.	0.8	72.7	Regular

* Others are average of the tota number of unidentified species found in the study area.

APPENDIX 9

Checklist of plants in the study area

	Scientific name	Family
1	*Artemisia nilagirica*	Asteraceae
2	*Aconogonum molle*	Polygonaceae
3	*Ageratum conyzoides*	Asteraceae
4	*Alnus nepalensis*	Betulaceae
5	*Ambrosia artemisiifolia*	Asteraceae
6	*Anaphalis contorta*	Asteraceae
7	*Anaphalis royleana*	Asteraceae
8	*Anaphalis* sp.	Asteraceae
9	*Artemisia* sp.	Asteraceae
10	*Arthraxon hispidus*	Poaceae
11	*Arthraxon* sp.	Poaceae
12	*Axonopus affinis*	Poaceae
13	*Axonopus* sp.	Poaceae
14	*Bambusa* sp.	Poaceae
15	*Bidens pilosa*	Asteraceae
16	*Bidens* sp.	Asteraceae
17	*Boehmeria* sp.	Urticaceae
18	*Bothriochloa intermedia*	Poaceae
19	*Calamagrostis emodensis*	Poaceae
20	*Calamagrostis scabrescens*	Poaceae
21	*Calamintha umbrosa*	Lamiaceae
22	*Cannabis sativa*	Cannabaceae
23	*Carex* sp.	Cyperaceae
24	*Celtis* sp.	Cannabaceae
25	*Chenopodium* sp.	Amaranthaceae
26	*Chloris* sp.	Poaceae
27	*Cirsium* sp.	Asteraceae
28	*Clinopodium umbrosum*	Lamiaceae
29	*Cosmos bipinnatus*	Asteraceae
30	*Crassocephalum crepidioides*	Asteraceae
31	*Cyanotis cristata*	Commelinaceae
32	*Cynodon dactylon*	Poaceae
33	*Cynodon transvaalensis*	Poaceae
34	*Cyperus brevifolius*	Cyperaceae

	Scientific name	Family
35	*Cyperus compressus*	Cyperaceae
36	*Cyperus kyllingia*	Cyperaceae
37	*Cyperus rotundus*	Cyperaceae
38	*Cyperus* sp.	Cyperaceae
39	*Debregeasia longifolia*	Urticaceae
40	*Debregeasia velutina*	Urticaceae
41	*Drymaria cordata*	Caryophyllaceae
42	*Duchesnea indica*	Rosaceae
43	*Elaeagnus* sp.	Elaeagnaceae
44	*Equisetum* sp.	Equisetaceae
45	*Eragrostis tenuifolia*	Poaceae
46	*Erianthus sikkimensis*	Poaceae
47	*Erigeron bonariensis*	Asteraceae
48	*Erigeron* sp.	Asteraceae
49	*Eriocaulon* sp.	Eriocaulaceae
50	*Erythrina* sp.	Fabaceae
51	*Fimbristylis dichotoma*	Cyperaceae
52	*Fimbristylis* sp.	Cyperaceae
53	*Galinsoga parviflora*	Asteraceae
54	*Geranium nepalense*	Geraniaceae
55	*Geranium* sp.	Geraniaceae
56	*Girardinia macrophylla*	Urticaceae
57	*Hippophae rhamnoides*	Elaeagnaceae
58	*Hydrocotyle javanica*	Araliaceae
59	*Indigofera* sp.	Fabaceae
60	*Isachne albens*	Poaceae
61	*Kummerowia striata*	Fabaceae
62	*Kyllinga brevifolia*	Cyperaceae
63	*Kyllingia nemoralis*	Cyperaceae
64	*Lespedeza* sp.	Fabaceae
65	*Lindera neesiana*	Lauraceae
66	*Luzula* sp.	Juncaceae
67	*Lyonia ovalifolia*	Ericaceae
68	*Pyrus malus* (apple)	Rosaceae
69	*Mentha* sp.	Lamiaceae
70	*Morus* sp.	Moraceae
71	*Murdannia nudiflora*	Commelinaceae
72	*Myriactis nepalensis*	Asteraceae

	Scientific name	Family
73	*Ophioglossum* sp.	Ophioglossaceae
74	*Oplismenus* sp.	Poaceae
75	*Paspalum longifolium*	Poaceae
76	*Paspalum paspaloides*	Poaceae
77	*Paspalum* sp.	Poaceae
78	*Paspalum scrobiculatum*	Poaceae
79	*Pennisetum clandestinum*	Poaceae
80	*Periploca calophylla*	Apocynaceae
81	*Philadelphus tomentosus*	Hydrangeaceae
82	*Pilea* sp. (Urticaceae)	Urticaceae
83	*Plantago ovata*	Plantaginaceae
84	*Poa* sp.	Poaceae
85	*Polygala tatarinowii*	Polygalaceae
86	*Polygonum nepalense*	Polygonaceae
87	*Prunus* sp. (cherry blossom)	Rosaceae
88	*Pteridium aquilinum*	Dennstaedtiaceae
89	*Pteris* sp.	Pteridaceae
90	*Ranunculus hirtellus*	Ranunculaceae
91	*Rorippa* sp.	Brassicaceae
92	*Rubus ellipticus*	Rosaceae
93	*Rubus* sp.	Rosaceae
94	*Rumex nepalensis*	Polygonaceae
95	*Rumex obtusifolius* (Large leaves)	Polygonaceae
96	*Sacciolepis indicus*	Poaceae
97	*Salix* sp.	Salicaceae
98	*Schizachyrium delavayi*	Poaceae
99	*Scleria* sp.	Cyperaceae
100	*Selaginella* sp.	Selaginellaceae
101	*Setaria glauca*	Poaceae
102	*Sigesbeckia* sp.	Asteraceae
103	*Smithia ciliata*	Fabaceae
104	*Solanum khasianum*	Solanaceae
105	*Sporobolus africanus*	Poaceae
106	*Stellaria media*	Caryophyllaceae
107	*Utricularia* sp.	Lentibulariaceae
108	*Verbascum thapsus*	Scrophulariaceae
109	*Vernonia cinerea*	Asteraceae
110	*Veronica* sp.	Plantaginaceae
111	*Xanthium strumarium*	Asteraceae
112	*Zanthoxylum armatum*	Rutaceae

ANNEXURES

F.No.-J-12011/13/2015-IA-1
Government of India
Ministry of Environment, Forest & Climate Change
(IA-1 Division)

Indira Paryavanaran Bhawan
Jor Bagh Road, New Delhi-3
Dated : 03.02.2016

To

The Chief Secretary
Government of Arunachal Pradesh
Itanagar, Arunachal Pradesh

The Secretary,
Ministry of Power
Government of India

The Secretary,
Ministry of Water Resources, River Development & Ganga Rejuvenation
Government of India

Subject: Cumulative Impact Assessment & Carrying Capacity Study of Tawang River Basin in Arunachal Pradesh for Development of Hydroelectric Power Projects (HEPs) - approved recommendations - Reg.

Sir,

The recommendations of the above study report, as explained in annexures have been approved by Ministry of Environment, Forest & Climate Change. The recommendations as accepted are required to be considered as road map for development of HEPs in Tawang River Basin. The report outlines recommended capacity, size, location of HEPs commensurate with the basin environmental carrying capacity conforming to the accepted cumulative impacts. However, EIA/EMP shall have to be carried out for individual projects as per provision of EIA Notification 2006 and its subsequent relevant amendments. Modification in design in HEPs or re-arrangements wherever recommended need to be incorporated. The major approved recommendations of the Study report as outlined below may kindly be considered for further necessary action for development of HEPs in Tawang River Basin by all concerned.

Major recommendations:

i. Eleven (11) proposed HEPs with cumulative installed capacity of 2802.20 MW have been considered in the basin. List of these projects is attached at **Annexure-I.**

No. L-11011/20/2012-IA-1
Government of India
Ministry of Environment, Forest and Climate Change
(IA-1 Division)

Indira Paryavaran Bhawan,
3rd Floor, Vayu Block
Jor Bagh Road,
New Delhi-110003
Dated: ~~May 2016~~
06/06/2016

To

Director,
Wildlife Institute of India,
Post Box #18, Chandrabani
Dehradun - 248001
Uttarakhand

Subject: Nyamjang Chu HEP (780 MW) Project in Tawang District of Arunachal Pradesh by M/s NJC Hydro Power Limited-Regarding.

Sir

It is to Inform that the Tawang River Basin study has been accepted by the Competent Authority and the same has been communicated to Govt. of Arunachal Pradesh on 03.2.2016. The basin study report clearly asks to carry out a detailed study on Black-necked Crane habitat requirement vis-à-vis E-flow at Nyamjang Chu project barrage site and overall conservation of Black-necked Crane. The executive summary of Basin study is enclosed herewith as **Annexure-I**.

2. Environmental Clearance (EC) given to the project of Nyamjang Chu HEP has been challenged in the NGT. The NGT vide order dated 7.4.2016 has been suspended the EC (Copy enclosed as **Annexure-II**) and directed the following:

a) The EC dated 19.4.2011, is suspended till the time the studies as directed are carried out, public consultation thereon done, the EAC considers outcome of such public consultation, carries out a fresh appraisal of proposal or grant of EC, makes recommendation to the MoEFCC and the MoEFCC act upon such recommendations in accordance with law.

b) The MoEFCC shall cause to be made a separate study of E-flow requirement for protection of habitat of the Black necked Crane and for conservation of the Black necked Crane through the Wildlife Institute of India, Dehradun, as expeditiously as possible and make such study report alongwith Tawang River Basin study available for 'Public consultation' in compliance of the aforesaid direction in accordance with law.

Gyanesh Bharti,
Joint Secretary

सत्यमेव जयते

भारत सरकार
पर्यावरण, वन एवं जलवायु परिवर्तन मंत्रालय
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE
इंदिरा पर्यावरण भवन, जोर बाग रोड,
नई दिल्ली-110 003
INDIRA PARYAVARAN BHAWAN, JOR BAGH ROAD,
NEW DELHI-110 003
Website : moef.nic.in

D.O. No. J-12011/20/2012-IA.I

Dated: 09.09.2016

Subject: Bearing of cost for Study on conservation of Black Necked Crane and e-flow requirement for their habitat in the proximity of Nyamjang Chu HEP

Dear

Kindly refer to the discussion held in the meeting under your chairmanship on 17.8.2016. In that meeting it was informed that a study is to be conducted on conservation of Black Necked Crane and e-flow requirement for their habitat in the proximity of Nyamjang Chu HEP, in District Tawang, Arunachal Pradesh. Wildlife Institute of India (WII), which is an institution under the administrative control of MoEF&CC has been requested to carry out this study. WII has informed that it would cost Rs. 36,86,900/- to carry out the same (copy of project proposal enclosed). It is requested that DONER may bear this expenditure and make the payment to WII, Dehradun.

With regards,

Yours sincerely,

Sd./-
(Gyanesh Bharti)

Shri Naveen Verma,
Secretary,
Ministry of Development of North Eastern Region,
Vigyan Bhawan Annexe,
New Delhi-110011

Copy to: Director, WII, Dehradun.

(Gyanesh Bharti)
Joint Secretary

भारतीय वन्यजीव संस्थान
Wildlife Institute of India

No. WII/ESM/GGV/NCHEP

Dated: 28 December, 2016

To,

Sh. Gyanesh Bharti,
The Joint Secretary,
Ministry of Environment, Forest and Climate Change,
Indira Paryavaran Bhawan,
Jor Bagh Road,
New Delhi – 110 003

Sub: Study on conservation of black necked crane and e-flow requirement for their habitat in the proximity of Nyamjan Chu – HEP

Ref: No. NEC/POW/511/2010-11/Vol-IV-5767 dated 21.09.2016

Sir,

The North Eastern Council (NEC) Secretariat vide their above cited reference has agreed in principle to fund the study as proposed by Wildlife Institute of India (WII). The NEC has requested WII to submit the project proposal to NEC routed through the Ministry of Environment, Forest and Climate Change, Government of India for further action at their end.

In view of the above, you are requested to kindly forward the attached project proposal directly to the Secretary, NEC with your recommendations.

Thanking you,

Yours faithfully

(G. S. Rawat)
Dean
Faculty of Wildlife Sciences

Encl: As above
Copy for kind information to:

1. The Secretary, North Eastern Council Secretariat, Government of India, Nongrim Hills, Shillong – 793003
2. The Director (NLCPR), Ministry of DoNER, Vigyan Bhawan Annexe, Maulana Azad Road, New Delhi – 11
3. The Principal Chief Conservatory of Forests and & Principal Secretary, Govt. of Arunachal Pradesh, Department of Environment and Forests, Itanagar – 791 111, (Arunachal Pradesh)

(G. S. Rawat)
Dean
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