DISTRIBUTION, ABUNDANCE AND HABITAT INTERACTION OF HIMALAYAN PHEASANTS WITH THEIR RESPONSE TO CLIMATE CHANGE IN KHANGCHENDZONGA BIOSPHERE RESERVE, SIKKIM, INDIA

Thesis Submitted to the University of North Bengal
For the Award of Doctor of Philosophy in Zoology

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UNIVERSITY OF NORTH BENGAL
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This is to certify that Mr. Bijoy Chhetri, M.Sc., has prepared the thesis entitled "DISTRIBUTION, ABUNDANCE AND HABITAT INTERACTION OF HIMALAYAN PHEASANTS WITH THEIR RESPONSE TO CLIMATE CHANGE IN KHANGCHENDZONGA BIOSPHERE RESERVE, SIKKIM, INDIA" for the award of Ph.D. Degree in Zoology of the University of North Bengal, under my supervision. The thesis is based on the original investigations done by him and that neither this thesis, nor any part of it has been submitted for any other Degree or any other academic award anywhere before.

Mr. Bijoy Chhetri had carried out the work at both the Aquaculture & Limnology, Department of Zoology, University of North Bengal and G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Govt. of India, Sikkim Unit. Mr. Chhetri has fulfilled the requirements of the Degree of Doctor in Philosophy in Science (Zoology) of the University of North Bengal.

Dated: 11th December, 2018

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DECLARATION

I declare that the thesis entitled "DISTRIBUTION, ABUNDANCE AND HABITAT INTERACTION OF HIMALAYAN PHEASANTS WITH THEIR RESPONSE TO CLIMATE CHANGE IN KHANGCHENDZONGA BIOSPHERE RESERVE, SIKKIM, INDIA" has been prepared by me under the guidance of Dr. Sudip Barat, Professor, Department of Zoology, University of North Bengal and Dr. Hemant K. Badola, Formerly Scientist 'G' & Scientist In-Charge of G.B. Pant National Institute of Himalayan Environment and Sustainable Development, Sikkim Unit, and presently, Advisor-Biodiversity, Hon'ble Chief Minister's Office, Govt. of Sikkim, Gangtok. No part of this thesis has formed the basis for the award of any Degree or Fellowship previously.

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Dedicated to my Parents

Shri. Bhirav Bahadur Chhetri
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ABSTRACT

Current rates of climate change will affect the structure and function of community assemblages on Earth. However, the long-term ramifications of these changes remain opaque. In recent decades, advances in modelling techniques, like MaxEnt (Maximum Entropy Modelling), can illuminate the answers to many management queries including threatened and sensitive taxa such as Himalayan Pheasant in biodiversity hotspots like Himalaya. Using MaxEnt prediction distribution model, an attempt was given to better understand the potential distribution of Himalayan Pheasants of Khangchendzonga Biosphere Reserve (Blood Pheasant, *Ithaginis cruentus*; Himalayan Monal, *Lophophorus impejanus*; Kalij Pheasant, *Lophura leucomelanos*; and Satyr Tragopan, *Tragopan satyra*) in Eastern Himalaya, Sikkim Himalaya, and Khangchendzonga Biosphere Reserve, respectively.

A total geo-reference datasets of the point location of the Himalayan Pheasant was identified based on primary and existing records (133 point locations of the Blood Pheasant, 106 for the Himalayan Monal, 75 for the Kalij Pheasant, and 91 for the Satyr Tragopan) reflects the current distribution point locations of the species in the Eastern Himalayas. Then study modelled potential distribution of the Himalayan Pheasants in the Eastern Himalayas, Sikkim Himalaya, and KBR by selecting potent environmental predictors using Principal Component Analysis and quantified the potential habitat area of the Pheasants.

For projecting distribution of the Blood Pheasant, among the environmental predictors, the Climatic parameter (44.2%) had the highest contribution to the model followed by Physical parameter (41.5%), Biophysical parameter (8.5 %), Topography (5.6%), and Human-modified mosaic landscape (0 %). Similarly, the Climatic parameter (46.5%) had the highest contribution to the model for Himalayan Monal followed by Physical parameter (32.7%), Bio-physical (15.7), Topography (4.5%), and Human-modified mosaic landscape (0.4%). The Physical parameter (39.7%) had the highest contribution to the model for Kalij Pheasant followed by Climatic parameter (37.2%), Bio-physical parameter (17 %), Topography (3.1%), and Human-modified mosaic landscape (2.8%). Among the environmental predictors, the Biophysical parameter (34.1%) had the highest contribution to the model for Satyr Tragopan followed by Topography (24.7%), Climatic parameter (20.4%), Physical parameter (18.1%), and Human-modified mosaic landscape (2.6%). The results showed that the Himalayan pheasants are found in very limited pockets of most of the high slope mountain regions of the landscape.

The Himalayas provide high altitudinal gradients and extreme slopes which may cause rapid changes in the climatic zone over a small distance which reflects noticeable alterations in the forest community composition structures, which may affect the habitats of the Himalayan Pheasants. Study identified and analyzed various aspects of forest community composition with the effect of climate variables and altitudes in the Khangchendzonga Biosphere Reserve (the core zone, Khangchendzonga National Park was recently inscribed by the UNESCO as world heritage site in July 2016), taking two altitudinal transects (c. 1800-4300 m asl altitudinal gradient) covering western (Yuksom-Black Kabru transect) and northern parts (Tholung-Kisong transect) of the biosphere reserve.

A total of 107 and 95 woody species were encountered in Yuksom-Black Kabru and Tholung-Kisong transects, respectively. Based on the Importance Value Index (IVI), the forests of Khangchendzonga Biosphere Reserve are classified broadly into as sub-tropical mixed broad-leaved forest, warm temperate Oak- broad-leaved forest, cold temperate coniferous-broadleaved forest, subalpine, and alpine forest. The entire forest reflected a dominance of young trees and the species richness of forest which showed a negative correlation with the altitude.

Climatic variables (Actual evapotranspiration, Potential evapotranspiration, and Moisture index) are the measures of available environmental energies which drive the final shape of forest community structure. The study revealed that these forces showed a significant relationship with woody species richness and altitude of the forest.

Himalaya is considered as data deficient region. For the first time, attention was given to the details of ecological interaction and community-level ramifications of the Himalayan pheasants especially focusing upon the Khangchendzonga Biosphere Reserve. Based on the study carried out during the period of 2014-2017, around 3 successive years, covering an altitudinal gradient c. 1700 -5000 m asl, the overall density and encounter rate of the Himalayan pheasant were assessed (for Blood Pheasant, density =11.07/sq. km, encounter rate = 0.78±0.14 /km; Himalayan Monal, density= 1.5±0.33/ sq.km, encounter rate= 0.10± 0.20/ km; Kalij Pheasant, density=1.6±0.45/ sq. km, encounter rate=0.14±0.033/km; Satyr Tragopan, density=0.79±0.35/ sq. km, encounter rate=0.079±0.02/km) in the biosphere reserve, by using Distance software 0.7 version.

Climate change is the burning issue all across the globe and predicted to alter species distributions, life histories, community composition, and ecosystem function, which adds fuel to various conservation directives. The recent advances in modelling techniques have illuminated the potential effects of various climatic scenarios on biodiversity hotspots, like Himalaya. These methods were utilized to test the effects of Representative Concentration Pathways (RCPs) AR5-2050 based on future greenhouse gases emission trajectories of climate change scenario/year combination.

Abstract

Examining the Himalayan Pheasants, current Bioclimatic variables, Miroc-esm, Hadgem2-AO and Gfdl-cm3 as future climate change scenario models, were used to predict its future distribution and gain-loss of future habitat area in the Eastern Himalayas, Sikkim Himalayas, and Khangchendzonga Biosphere Reserve. The results indicate the future climatic conditions may significantly affect the future distribution of the Himalayan Pheasants. Regions of high risk under climate change scenarios based GIS toolkit, SDM projection of gain and loss of habitat suitability areas of the Himalayan Pheasants were identified. The predicted trend of habitat shifting of the Himalayan pheasants will gradually become more prominent with climate warming boost up.

Indigenous people are closely related with the natural rhythms and processes of their ecosystem. Therefore, their perception of changing ecosystem with the time is crucial for understanding the ongoing biodiversity process and pattern, and climate change trends of the landscape. Based on perception tool, people felt that climate change is more prominent in and around the Khangchendzonga Biosphere Reserve. The factors of range shift significantly influence the overall range of the Himalayan pheasants as revealed by the data obtained from the respondents. This is the first attempt to use the advanced modelling, field study along with perception tool for quantitatively justifying management strategies for the pheasants in the Himalayas.

PREFACE

Himalaya is considered as data deficient region which generally lacks quantitative analysis needed to impact conservation and management policies for Avian Biology including Himalayan Pheasants. Although, monitoring on the Himalayan Pheasants are largely ignored for their conservation and habitat management due to their narrow habitats, mostly confined to mountain landscape having with severe climate and difficult topography to carry out the study. Taking this challenge, I worked on recent advances in modelling techniques and field studies and utilized existing records, which should help in improving conservation and habitat management of the Himalayan Pheasant in Eastern Himalaya.

This is significant because the prediction distribution model helps in finding the possibilities of new populations of vulnerable/threatened species in new projected areas, where no scientific exploration has been reached so far. Also, there are possibilities of the relocation of the sensitive species in newly predicted areas which may further help to strengthen in their conservation. Climate change model predicts how species will respond to global climate change under the present and future scenarios and provides useful clues of climate change threats on biodiversity in future. These ecological and climate change modelling techniques will help conserve the threatened and the climate-sensitive species before their valuable genetic assets plunge to extinction.

Considering habitat assessment crucial to understand conservation status of the Himalayan Pheasants, the analysis is done for woody species dominance, basal cover, regeneration pattern, ecological indices with the effect of climatic variables of the region in Khangchendzonga Biosphere Reserve. The forces of climate variable such as Potential evapotranspiration (PET) Actual evapotranspiration (AET) and Moisture Index (MI) showed a significant correlation with the species richness and altitudinal gradient of the study area. The study helps to weigh up the effect of geometric constraints and environmental factors in giving shape to the present structure of forest community composition in the biosphere reserve.

For population assessment of the Himalayan Pheasants in the biosphere reserve, the analysis is done on the present status of their availability along with density, encounter rate and seasonal's diversity in the altitudinal gradient. The conceptual frameworks of the impact of climate change on Himalayan Pheasants have given emphasis, based on local people's perception, because indigenous people are closely related with the natural rhythms and processes of their ecosystems. This study will help to identify the most priority conservation areas and sensitive habitat areas for the Himalayan Pheasant in the region and provide distribution data as the geo-referenced database of the Himalayan Pheasants in Eastern Himalaya.

These data can help conservation directives in addressing the conservation strategies and habitat management planning for Himalayan Pheasants, including associated climate sensitive native organisms of Himalaya.

Bijoy Chhetri

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LIST OF ABBREVIATIONS

&	and
AET	Actual evapotranspiration
AIC	Akaike's Information Criteria
AUC	Area under the receiving operator curve
BC	Before Christ
BH	Behaviour
BTS	Barlett test of sphericity
CC	Climate change
CFSR	Climate Forecast System Reanalysis
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
D&F	Diet and Feeding
De	Deforestation
ESW	Effective strip width
EVI	Enhanced Vegetation Index
GBIF	Global Biodiversity Information Facility database
GIS	Geographic Information System
GBNPIHESD	G.B. Pant National Institute of Himalayan Environment and Sustainable Development
GCMs	General Circulation Models
HB	Habitat disturbance
IHR	Indian Himalayan Region

IVI	Important Value Index
IUCN	International Union for Conservation of Nature and Natural Resources
IPCC	Intergovernmental Panel on Climate Change
KBR	Khangchendzonga Biosphere Reserve
KNP	Khanchendzonga National Park
LULC	Land use and land cover
MaxEnt	Maximum Entropy Modelling
KMO	Kaiser-Meyer-Olkin test
M&C	Mangement and conservation
MI	Moisture Index
N	Number of sample size
NDVI	Normalised Difference Vegetation Index
Oth	Others
PAs	Protected areas
PCA	Principal Component Analysis
PET	Potential evapotranspiration
PS	Population studies
RCP	Representative Concentration Pathways
SC	Scarcity of food
SDM	Spatial distribution model
SE	Standard error

List of Abbreviations

Sq.km	Square Kilometer
SS&HS	Status survey & habitat studies
SV	Shifting vegetation
UNESCO	United Nations Educational, Scientific, and Cultural Organisation
VI	Vegetation Index
vs.	Versus
WII	Wildlife Institute of India

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"Each and every animal on earth has as much right to be here as you and me"

-Anthony Douglas Williams

CHAPTER 01

INTRODUCTION

Chapter 01

INTRODUCTION

1.1. Pheasant

Pheasants represent the most distinctive bird family due to their charismatic features, act as bio-indicators for owing to their sensitivity to habitat degradation and climate change, and indicate habitat quality of forest, vulnerability to human exploitation and central position in the food web (Kaul, 1989; Fuller & Garson, 2000; Chhetri et al., 2018). They are large-bodied, brightly coloured, ground-dwelling birds, exhibiting greater sexual dimorphism in both size and plumage, and belonging to the taxonomic order Galliformes and family Phasianidae. The pheasants are recognized by a total of 51 species (excluding one extinct species Double-banded Argus, *Argusianus bipunctatus,* IUCN, 2007) under 16 genera (Ghose, 1999). Out of the total, 50 species of pheasants are Asian in origin and found in wide range of area occupying a diversity of habitats, which range from lowland tropical rainforest (e.g. Crested Fireback, *Lophura ignita*) to alpine meadows (e.g. Chinese Monal, *Lophophorus ihuysii*). For long, many biologists have pursued studies relating to the distribution and abundance of birds to their natural environment, knowledge of abiotic clues, and its influence on the birds and interactions (Gaston, 1980; Davidson, 1981; Chettri, 2000; Basnet & Badola, 2010). Such pieces of evidence have provided a better understanding of the distribution patterns of birds in natural ecosystems (Gaston, 1980; Chettri, 2000). Nevertheless, habitat destruction and loss of biodiversity due to anthropogenic factors and climate changes are considered to be the most important influencing forces towards sustainability of the pheasants. However, other factors such as social, economical and political also play a crucial role is enhancing biodiversity loss (Machilis & Forester, 1996; Badola & Aitken, 2010).

1.2. Environment and Climate change

1.2.1. Role of the Habitats

The interaction between plants and animals is directly associated within and between the ecosystems and their external environmental variables, which play a significant role to balance the ecosystem stability, is a priority area of research in the present scenario for on-going biodiversity conservation theme (Chhetri et al., 2017). Worldwide, the biodiversity is under tremendous environmental and anthropogenic pressures, which apply equally to its natural elements including floral and faunal components. This might be driven by the risk of vulnerability as some species show the extremely poor level of adaptation to altered habitat (Lovejoy, 1986; Vermeij, 1986), which may result in some species fall under the risk of extinction (Terborgh & Winter, 1980; Slobodkin, 1986). In Sikkim Himalaya, many threatened birds species are found (Acharya &Vijayan, 2010) and most of which are confined to restricted elevation range (Acharya et al., 2011) for their possible specific ecological niche requirements (Chhetri et al., 2017). Due to anthropogenic pressure and habitat fragmentation, these birds are becoming more sensitive within their restricted range. Therefore, the immediate task is needed for their improved conservation and management practices in protected areas (Basnet & Badola, 2012; Chhetri et al., 2017). Baseline data are needed from wildlife protected areas on the availability of birds. Scientific data are required on the ecological status, distribution, diversity of bird species and associated habitats, which may offer vital clues on the disturbance level for the effective implementation of conservation management of the same (Chettri, 2000; Nawaz et al, 2000; Basnet & Badola, 2012; Klerka et al., 2004; Fernández-Juricica et al., 2004). Greater focus has been paid on the high biodiversity areas and the accelerated rate of deforestation (Myers, 1988). Biodiversity loss has also been associated with specific - land use changes, such as urbanisation (Leidy & Fiedler, 1985), colonisation adjacent to protected areas (Neuman & Machilis, 1989), and the fragmentation of forest due to resource exploitation (Harris, 1984). The comparative studies in this field are insufficiently available, and predictive ability is inadequate; hence there is a gap left to understand better the relationship between anthropogenic actions, habitat alternation, and biodiversity loss (Machilis & Forester, 1994). Therefore, it is imperative to have ecologically inter-related studies on the pheasants' diversity and abundance, along with understanding on their habitat relationships as part of complete quality research assessment (Chhetri et al., 2017).

1.2.2. Role of the Climate change

Climate change issues are topical all across the globe and predicted to alter species distributions, life histories, community composition, and ecosystem functions (McLaughlin et al., 2002). In particular, population loss, altering distribution and abundance of many species are caused by climate change threaten both species diversity and the delivery of critical ecosystem services (Guisan & Zimmermann, 2000; McLaughlin et al., 2002; Malcolm et al., 2006; Peh, 2007; Velasquen-Tibata et al., 2012). Predictions of climate-induced population extinctions are supported by correlational evidence that numerous species are shifting their ranges in response to climatic warming. Nevertheless, few mechanistic studies have linked extinctions to recent climate change (Pounds, et al., 1999). Furthermore, most climate change research and forecast focus on shifts in climatic means. Global climate models also predict changes in climatic variability, but biotic impacts of those increases have received less attention. It has been documented that varieties of species (both fauna and flora) have recently changed their elevation and latitudinal distribution and many species may be pushed to higher elevations, effectively shrinking their distributions as the climate warms (Grabherr et al., 1994; Parmesan et al., 1999; Bakkenes et al., 2002; Peh, 2007; Seimon et al., 2007; Chen et al., 2009, 2011). Various field studies and predictive spatial modelling have provided strong proof that these species range shifts is due to climate change (Root, 1988; Parmesan, 1996; Pounds et al., 1999; Chhetri et al., 2018). Current scenario of global changes in climate has aroused considerable interest in the field of distributional patterns and conservation strategies for native species (Parmesan, 1996; Pounds et al., 1999). Strong evidence of significant relationships between climate and the distribution patterns of birds have been studied (Ashmole, 1963; Root, 1988; Currie, 1991; Peh, 2007; Velasquen-Tibata et al., 2012). There are recent studies available from Indian Himalayan Region, suggesting the early flowering phenomena due to climate change, improving understanding level of the effect of the climate change on species (Badola, 2010; Gaira et al., 2011, 2014). Such consequences possibly synchronize the habitat dynamism and the pheasant diversity in Himalaya could be susceptible to such changes. Climate change is not the lone factor for the distribution of birds but is also affected by the availability of suitable habitats, which in turn, may be influenced by the climate change (Matthews, 2004; Acharya et al., 2011).

1.3. Himalayan pheasants

Amongst all the mountain systems of the world, Himalaya is one of the highest and youngest, which extends over 2400 km from northwest to southeast and covers 150 to 250 km in width (Devan, 1988). The Himalayan mountain range is considered to be one of the most significant bio-geographical zones in India because it is a hub of three bio-geographical realms viz., Palaearctic, Africo-tropical and Indo-Malayan (Mani, 1974). Due to this unique feature, varieties of wildlife species freely move from different faunal realms into Himalaya. Out of 51 pheasant species in the world, 20 (39%) are endemic to Himalaya, some of which includes the genera of *Ithaginis* (Blood Pheasant), *Tragopan* (Tragopans or Horned Pheasants), *Lophophorus* (Monal Pheasants), *Lophura* (Kalij Pheasant), *Pucrasia* (Koklass Pheasant), *Catreus* (Cheer Pheasant), *Crossoptilon* (Eared Pheasant) and *Polypectron* (Peacock-Pheasant). Indian Himalaya is represented by 16 species, which occupy various vegetation and altitudinal gradients (Ramesh et al., 1999). The severe climatic condition has been controlling the life of the Himalayan pheasant population. However, the large size and heavily built plumage in pheasants are possibly due to the physiological requirements to withstand the typical climate, terrain, and low-atmospheric pressure in high altitudes. As a result, the winter season in this region plays a vital role in their survival. During winter, when the ground is snow-covered and very little resources are available, pheasants are compressed to move to lower elevations where they face inter and intra-specific competition for resources and also get easily poached for meat and plumage by people. However, a recent study showed migratory movements of some pheasants along elevation gradients, offering newer findings (Nawang et al., 2013), suggesting strongly more studies in the Himalayan region.

1.3.1. Indian Himalayan Region (IHR)

Out of the 17 pheasant species in India, 16 species (94%) occur in Himalaya, except for the endemic Grey Junglefowl, *Gallus sonneratii*, which is confined to the Peninsular of India, however, five pheasant species are listed as 'threatened' (Sathyakumar & Sivakumar, 2007). In terms of species diversity, Eastern Himalaya of India represents 11 species as compared to eight in Western Himalaya of Indai, whereas, four species, namely Satyr Tragopan, Himalayan Monal, Kalij Pheasant, and Red Junglefowl are common across the two regions. In Western Himalaya (India), eight of the species of pheasants found, five species are recorded from the Great Himalayan National Park. They are the Western Tragopan (*Tragopan melanocephalus*), Koklass Pheasant (*Pucrasia macrolopha*), Himalayan Monal (*Lophophorus impejanus*), Cheer Pheasant (*Catreus wallichii*), and Kalij Pheasant (*Lophura leucomelana*) (Ramesh et al., 1999). Out of the eleven pheasant species found in Eastern Himalaya, four are recorded in Khangchendzonga Biosphere Reserve. They are the Blood Pheasant (*Ithaginis cruentus*), Satyr Tragopan (*Tragopan satyra*), Himalayan Monal (*Lophophorus impejanus*), and Kalij Pheasant (*Lophura leucomelana*) (Sathyakumar et al., 2011; Badola & Subba, 2012). Comparing both Great Himalayas National Park and Khangchendzonga Biosphere Reserve, it seems that two species of pheasants are widely scattered in both regions that is Himalayan Monal (*Lophophorus impejanus*), and Kalij Pheasant (*Lophura leucomelana*).

1.4. Description of the study species

1.4.1. Taxonomy

Phylum: CHORDATA

Class: AVES

Order: GALLIFORMES

Family: PHASIANIDA

1.4.2. Biology and Ecology

1.4.2.1. Blood Pheasant (*Ithaginis cruentus* Hardwicke)

Morphological Features: Crested head, and red orbital skin and legs/feet. Male has a blood-red throat, grey upperparts streaked with white, and greenish underparts and plumage is splashed with red (Figure 1.1).

Figure1.1: Male Blood Pheasant in the field.

Female has grey crest and nape, rufous-orange face, dark brown upper part and black on head (Figure 1.2). Both sexes are 38 cm in length. They sound like a repeated chuck and aloud, grating kzeeuk-cheeu-cheeu-chee (Grimmett et al., 2011). Blood Pheasant, *Ithaginis cruentus* is only single species of genus *Ithaginis*.

Distribution: Blood Pheasant is a resident and fairly common pheasant that is distributed in the Central and Eastern Himalaya (Sikkim and Arunachal Pradesh) [Figure 1.3].

Figure 1.2: Female Blood Pheasant in the field.

Habitat: The species mainly dwells the alpine areas but is also seen in the sub-alpine habitats of the area. The species is the state bird of Sikkim and found to occur in groups of up to 70-80 individuals.

Breeding: Breeding season probably occurs in April-May as small chicks have been seen in June and early July (WPA- India, 2008).

Threats: It is found in high altitude region. Although, it is not under human pressure, hunting for local consumption by shepherd and poachers during and after monsoon cannot be ignored (Yonzon & Lelliott, 1980).

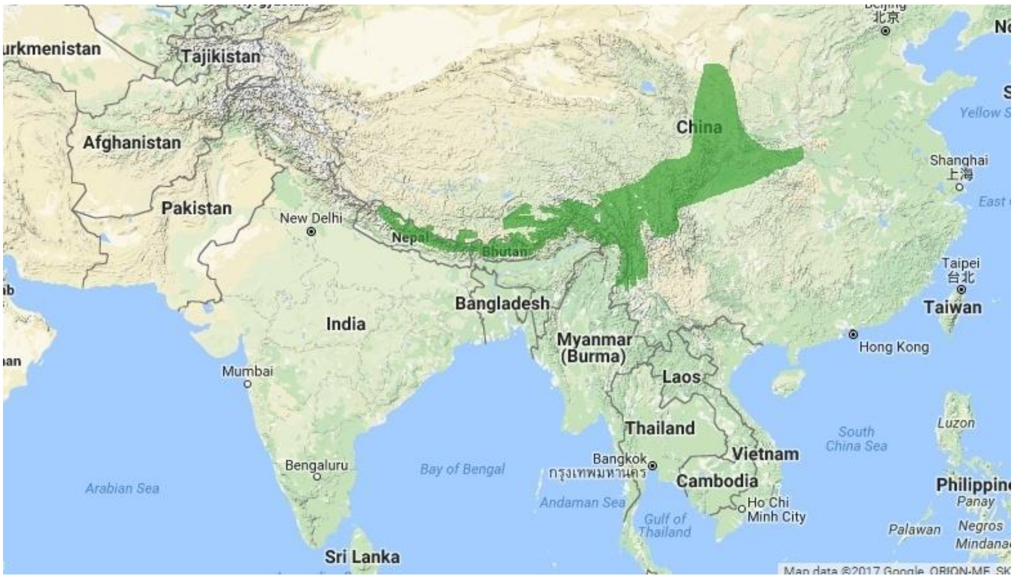

Figure 1.3: Global geographical distribution of Blood Pheasant
(Source: BirdLife International, 2017).

1.4.2.2. Himalayan Monal (*Lophophorus impejanus* Latham)

Morphological Features: Male is iridescent green, copper and purple, with small white patch on back and cinnamom-brown tail, and spatulate-tipped crest (Figure 1.4), female has pale streaking on under parts, prominent white throat, short crest and bright blue orbital skin (Figure 1.5). The size of a male is 70 cm and a female is 63.5cm in length. They sound like a series of upward-inflected whistles, kur-leiu or kleeh-vick, alternated with kwick-kwick (Grimmett et al., 2011).

Figure 1.4: Male Himalayan Monal in the field.

Distribution: Himalayan Monal is a resident and fairly common pheasant that is distributed in Bhutan, China, India, Myanmar, Nepal, and Pakistan. Its distribution in Afghanistan is uncertain (Birdlife International, 2016) [Figure 1.6].

Habitat: It occupies upper temperate oak-conifer forests interspersed with open grassy slopes, cliffs, and alpine meadows.

Figure 1.5: Female Himalayan Monal in the field.

Figure 1.6: Global geographical distribution of Himalayan Monal (Source: BirdLife International, 2017).

Breeding: Breeding season starts from May-June (WPA –India, 2008). Their nest is a simple scrape, often under the shelter of a bush, a rock, or in the hole of some large tree (Johnsgard, 1986)

Threats: The main threats to the species from poaching during winter for local consumption and its plumage, when the bird descends to the lower altitude (Yonzon & Lelliott, 1980).

1.4.2.3. Kalij Pheasant (*Lophura leucomelanos* Latham)

Morphological Features: Both sexes have red facial skin and down curved tail. Male has blue -black upperparts and variable amounts of white on rump and under parts (Figure 1.7). Female varies from dull brown to reddish -brown, with greyish -buff fringes producing scaly appearance (Figure 1.8).

Figure 1.7: Male Kalij Pheasant in the field.

Subspecies variation marked with males varying in colour of crest and under parts and extent of pale barring to upperparts. The size of a male is 65-73cm in length and a female is 50-60 cm in length. They make a loud sound like whistling chuckle or chirrup; guinea pig –like squeaks and chunckles when flashed (Grimmett et al., 2011).

Distribution: Mainly found in the Himalayan foothills, from the Indus River to western Thailand. The Kalij Pheasant is distributed in the northwestern, western, central and eastern Himalayas (Jammu & Kashmir, Himachal Pradesh, Uttarakhand, Sikkim, Arunachal Pradesh and north-west Bengal) usually < 2,700 m and in the hills of north east India (Assam, Meghalaya, Manipur, Mizoram, Nagaland and Tripura)[Figure 1.9].

Figure 1.8: Female Kalij Pheasant in the field.

Habitat: It inhabits all types of forest with dense undergrowth and thickly overgrown steep gullies, usually not far from water (Sathyakumar & Kaul, 2007). The species inhabits the temperate habitat of the study area.

Breeding: Breeding season starts from February to October but mainly in April-May (Johnsgard, 1986).

Threats: They found close to the village and they are easily the victim of local hunting (WPA- India, 2008).

Figure 1.9: Global geographical distribution of Kalij Pheasant
(Source: BirdLife International, 2017).

1.4.2.4. Satyr Tragopan (*Tragopan satyra* Linnaeus)

Morphological features: Male has red underparts with black -bordered white spots and olive -brown colouration to upper parts including rump and upper tail -coverts. Facial skin is blue (Figure 1.10). Female varies from rufous-brown to ochraceous -

brown in colouration; wings, tail and underpart are generally brighter and more rufescent (Figure 1.11). The size of a male is 67-72cm in length and a female is 57.5 cm in length. They make sound like a repeated deep, wailing drawn-out call wah! Oo-ah! Oo-aaaa! Ising in volume and becoming more protracted; alsoa wah, wah (Grimmett et al., 2011).

Figure 1.10: Male Satyr Tragopan in the field.

Threats: Major threats to the species include hunting for local consumption as well as habitat clearance and degradation due to timber harvesting, fuelwood and fodder collection and livestock grazing (Madge & McGowan, 2002).

Habitat: It is found in the moist evergreen forest with the dense undergrowth bamboo of cold temperate and sub-alpine forests.

Figure 1.11: Female Satyr Tragopan in the field.

Figure 1.12: Global geographical distribution of Satyr Tragopan
(Source: BirdLife International, 2017).

Distribution: The Pheasant is found in the Himalayan reaches of India, China, Nepal, and Bhutan. It is a resident and rare pheasant that is distributed in the Western, Central and Eastern Himalaya (Figure 1.12).

Breeding: Breeding season starts from May-June (Madge & McGowan, 2002). The species is partial arboreal; nest have been seen in trees an also on the ground (Johnsgard, 1986).

CHAPTER 02

REVIEW OF LITERATURE

Chapter 02

REVIEW OF LITERATURE

2.1. Background

2.1.1. Genesis of Research on Pheasants

Pheasants have been closely associated with humans for long, right from 500 BC, the time Red Junglefowl was domesticated as the progenitor of the domestic fowl (Wood-Gush, 1959). The first modern investigation on Pheasants was made by William Beebe (1922) and Jean Delacour (1951 & 1977) in the mountains and jungles of Asia to gather information on the pheasants' diversity and distribution. Their works captured in 'A monograph of Pheasants' (Beebe, 1922) and 'The Pheasant of the world' (Delacour, 1951 & 1977) are classic examples. Serious scientific status on Pheasants did not begin until 1957, when Howman and Mirza were censuring pheasants in Pakistan (Howman, 1977; Mirza et al., 1980 a, b, & c). Since then, a few studies, mainly limited to census and re-introduction of Cheer Pheasant (Severinghaus, 1979; Gaston, 1979; Gaston, 1980) emerged from Pakistan and India. The previous studies did not include the differences in the survival rates of pheasants between genetic groups, although different subspecies have indicated their specific ecological requirements (Schwartz & Schwartz, 1951). The first International Pheasant Symposium in Kathmandu, November 1979 gave a platform for researchers on Himalayan pheasants. Around this time, many publications appeared on this subject (Gaston, 1980; Lelliott & Yonzon, 1980; Mirza, 1980 a, b, & c; Shrestha & Nepali, 1980; Zeliang, 1980; Krauss et al., 1987).

2.1.1.2. Overview of pheasant studies in native area (Asia)

Asia is the native home of Pheasants. In Asia, most of the earlier work on pheasants was documented by British sportsman in the nineteenth century famous among these were Hodgson (1846), Hume and Marshall (1879), and Osmaston (1935). They did not work specifically on the pheasants but dealt with birds of the subcontinent in general. Their findings were very anecdotal but provided valuable details about the distribution of these birds at that time and some information on their habitats. An observation was captured by Beebe in his 'Monograph of the Pheasants' (1922), considered archetypal work on the pheasants, is based mainly on his first-hand investigations. After Beebe, several other researchers published work on the Himalayan Pheasants but these were mostly based on Beebe's work (e.g. Baker, 1935; Bates & Lowther, 1952; Ali & Ripley, 1969; Delacour, 1977; Johnsgard, 1986).

2.1.1.3. Overview of pheasant studies in non-native area (America and Europe)

Asia is the native home of Pheasants. After a successful introduction of pheasants in European and American continents, nowadays, they are found in a good feral population. The natural range of the two species, the Common Pheasant (*Phasianus colchicus*) and the Japanese Green Pheasant (*Phasianus versicolor)* now are extended over the temperate regions of Europe and North America, the Hawaiian Islands, New Zealand, Chile, St. Helena, King Island, Rottnest Island and Tasmania (Hill & Robertson, 1988).

In England, the pheasant *Phasianus colchicus* is reported to be introduced before the 14^{th} century, probably by the Normans and breeds in the wild during the late 15^{th} century, whereas later on other species and subspecies were also introduced

(Kathait, 2008). The pheasant became the most popular game birds which widely breeds in England (Sharrock, 1976). The pheasants were brought to Europe from Asia by over 1000 years ago (Long, 1981), and nowadays they are found all over Europe and USA. In England the pheasants are widely hunted for sport; they are released from hand-reared stock ensuring their high densities for shooting (Hill & Robertson, 1988; Robertson & Dowell, 1990). In America, several attempts were made to introduce pheasants during the 18^{th} -19^{th} centuries. The first successful introduction and establishment of the pheasant *Phasianus colchicus* were in the Willamette Valley, Oregan in 1882 (Hill & Robertson, 1988), and subsequent release was done by the year 1900, after that the pheasants have spread over most of the United States of America (USA). After the year 1900, with the high rate of stocking and release, hunting seasons became common in the USA by 1920 (McAtee, 1945; Allen, 1985). During 1904-1933, 40,000 pheasants were released from the State-owned game farms in Missouri, USA, and between 1940-1950, over 600,000 small game hunters practised hunting by taking nearly one million rooster pheasant annually (Missouri Conservation Department, 1985). In 1986, the State of Missouri made an arrangement for shipment of 30 Black-necked sub-species of Chinese Ring-necked and 1000 eggs for the introduction in its State farms (Kathait, 2008). Following that, many researchers were attracted towards the Ring-necked Pheasants for their ecological and behavioural aspects (Carroll, 1988).

2.2. Formulation of review of literature

This review of literature is based on the compilation, analysis, and interpretation of the baseline information for the pheasants all over the world in various forms of published documents such as journal articles, books, booklets, book chapters, reports, conference proceedings, management and development plans, and Ph.D. thesis. The publications were gathered from internet, libraries, and other primary sources. A total of 159 articles on pheasants were gathered from the years 1846-2018; about 172 years of scientific records were captured in this review. It is accepted that this is not complete work on the pheasants but this review should provide a baseline analysis examining the available research gaps and identify future priorities. Using 159 available articles of pheasants, this analysis is made on different aspects of study on pheasants including accumulation curve of the year of publication, native and non-native area of international level, national level, and regional level. The available articles chronologically listed in a Microsoft Excel Spreadsheet (Microsoft Corporation, Redmond, WA, USA) and categorized into three ways:

1. The first category is based on parts of representative native and non-native areas in the international level where the particular studies were carried out.

2. The second category is based on date(s) of publications, which further grouped for 10 years intervals from 1846-2018; this enabled understanding the research trends and patterns.

3. The third category is based on the different aspect of studies' focus on the pheasants.

2. 2.1. Geographical distribution of publications

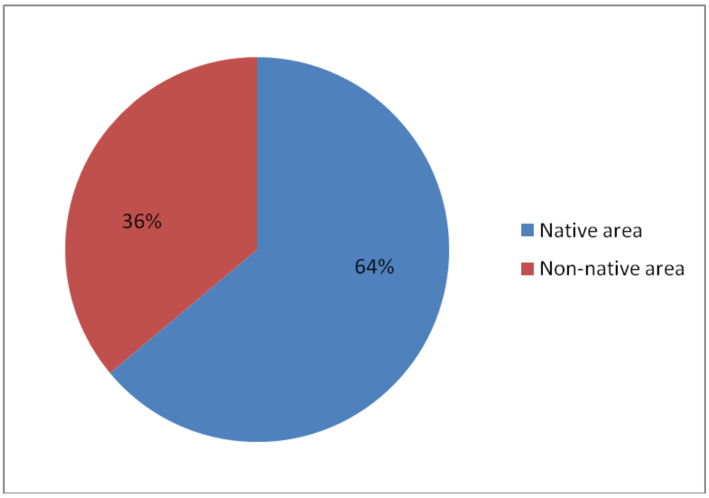

Figure 2.1: Studies on pheasants in the native areas and non-native areas, based on available literature.

The geographic distribution of the publications is noted with regard to the native and non-native areas where the research was carried out (Figure 2.1). Based on 159 articles, reviewed, majority research appeared in the native area, i.e. Asia (64%) and 36% from the non-native area (America & Europe). In the native area, the majority of studies were done in India (49.38%) followed by China (20.98), Pakistan (17.28%), Nepal (6.17%), Malaysia (3.70%), Taiwan (1.23%), and Philippines (1.23%). In national level, the maximum publications appeared from Uttarakhand (38.09%) state, followed by Himachal Pradesh (28.57%), Jammu & Kashmir (14.28), Mizoram (7.14%), Sikkim (4.76%), Arunachal Pradesh (2.38%), and Uttar Pradesh (2.38%). It seems that the native area is more explored for pheasant study compared to non-native area.

2.2.2. Temporal pattern of publications

The temporal pattern of publications on the pheasants is depicted in figure 2.2. This study reveals that the first attention was given on pheasant for the scientific community as early as the 1840s (e.g. Hodgson, 1846), which offered a catalogue of the specimens and drawings of mammals and birds (including pheasants) of Nepal and Tibet. For the catalogue, the specimens were collected by Hodgson during his residency in Nepal and the catalogue of the specimens as described in various scientific papers, deposited in the British Museum collection, and the duplicate set was distributed in series and sent to various British and continental collections.

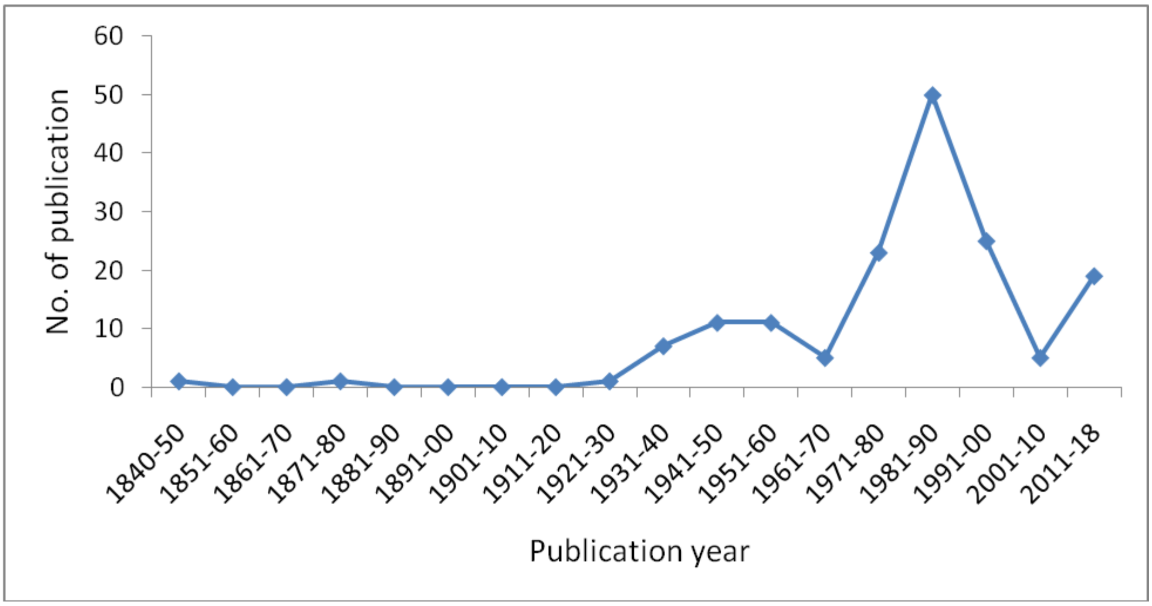

Figure 2.2: Temporal pattern of publications on pheasants collected from the worldwide sources.

Nonetheless, a more modern scientific investigation was made by William Beebe (Beebe, 1922) and Jean Delacour (Delacour, 1951 & 1977) in the mountains and jungles of Asia. This result based on the temporal pattern of publications indicates from the extensive works on pheasants was started from 1920s-1950s, which intensified during the 1970s and reached the highest peak in 1980s (Figure 2.2). After that sharp decreased from the 1980s to 2010, and onwards 2010, fair studies are going on pheasants.

2.2.3. Studies by different aspects in non-native areas

Out of 36% studies appeared for the non-native areas, the maximum entries emerged on population studies (33%), followed by behaviour (29%), management and conservation (15%), status survey and habitat studies (13%), and diet/feeding (10%), see figure 2.3.

2.2.3.1. Status survey and habitat studies

The first extensive field study was made on the distribution pattern of Ring-necked Pheasant in Wisconsin during winter by using a collar (Gates & Hale, 1974). The broods roosted of the pheasant mainly in oats and hay (Warner, 1979). They used mixed and deciduous woodland fields sown with winter and spring corn as their habitats and feeding grounds (Hill & Ridely, 1987). A female Ring-necked Pheasant prefers the food patches and bushes and avoids pastures and croplands (Gatti et al., 1989). During the 1980s, more researchers also focused on this aspect on Ring-necked Pheasant, for example, by Robertson (1985) and Meyers et al. (1988).

2.2.3.2. Population studies

During 1865 and 1932 other pheasants, *Lophura nycthemerus* and Golden Pheasant, *Chrysolophus pitus* were introduced as game birds and liberated from the game farm in Oahu. Similarly, in between 1907 and 1914, Copper Pheasant, *Syrmaticus soemmerriingii* (Temminck), was introduced to Oahu, Maui, and Kauai islands. But only the Lady Amherst's pheasant, *Chrysolophus samherstiae* was recorded for liberation in 1932 in Oahu and 1933 in Hawaii. Unfortunately, all these species failed to survive (Caum, 1933). In this context, the initiative was taken for understanding population ecology and management of Ring-necked pheasant during a period from 1946 to 1961, which suggested the possible mechanisms and causes of short-term fluctuations, population balance, and determination of long-term mean density in any given area (Wagner et al., 1965). Many researchers published their finding on pheasants on this related aspect. An extensive study was carried out in 1937 by Errington & Hammerstrom on Ring-necked Pheasant based on the nest loss and juvenile mortality. After the 1940s, various related publications appeared on population studies in different parts of non-native areas (Eklund, 1942; Bach 1944; Errington, 1945; Carlson, 1946; Buss, 1946; Kimball, 1949; Schwartz & Schwartz, 1951).

2.2.3.3. Behaviour

In the non-native area the first-time study on the behaviour of pheasant was published when some incidental observations on breeding behaviour and territoriality of pheasant came across (Baskett & Thomas, 1947). Later, more extensive work on breeding of Ring-necked Pheasant started. This study covered many aspects of breeding biology, namely the pre-breeding, breeding courtship behaviour, spring dispersal and increase in the testes weights of cocks, breeding vocalization, harem formation, territoriality, and incubation of the pheasant (Taber, 1949). Subsequently, many researchers inspired and gave their scientific contribution on pheasants' behaviour (Gondahl, 1953; Anderson, 1964; Stokes & Williams, 1972; Gates & Hale, 1975; Dumke & Pils, 1979; Ninov, 1979; Goranson, 1980; Trautman, 1982; Ridley, 1983; Snyder, 1984; Koubek & Kubista, 1990; Ligon & Zwartjes, 1995).

2.2.3.4. Diet/Feeding

The first study focused on the diet of pheasants in relationship to their winter survival (Green, 1938). Following this, various research publications appeared on different aspects on diet/ feeding of pheasants such as food habitat, prioritization of food for their juveniles, etc. (Dalke, 1943; Loughery & Stinson, 1955; Scwartz & Scwartz, 1951; Hill, 1985).

2.2.3.5. Management and conservation

Changes in land use pattern, climate, and impacts of anthropogenic pressures due to various reasons adversely affect pheasants' populations. While considering conservation and management of pheasants, studies revealed well-managed area attracts more pheasants' populations than in the unmanaged area (Robertson, 1986; Robertson et al., 1988).

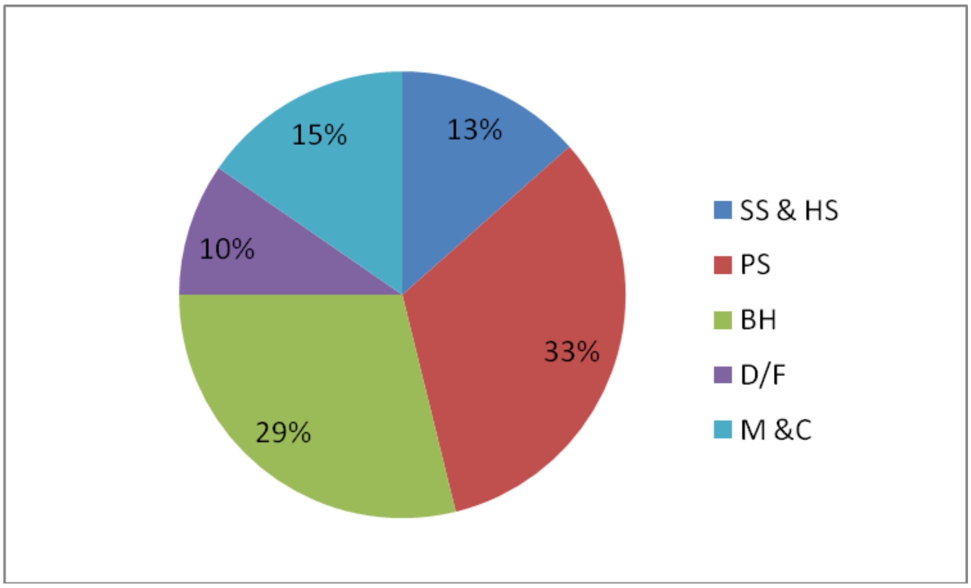

Figure 2.3: Percentage of studies on different aspects of pheasants in non-native areas [Status survey & habitat studies (SS&HS), Population studies (PS), Behaviour (BH), Diet & Feeding (D&F), and Management & Conservation (M&C)] based on available literature.

From 1959 onwards, the server population decline of pheasants in the USA as compared to the year 1940's -1950s (Missouri Conservation Department, 1985) added the fuel for many research works on good management and conservation areas of Pheasants (Robertson et al., 1993; Erickson et al., 1951; Dale, 1951 &1952). Concerned about their conservation, experiments were conducted to understand the factor affecting pheasants' mortality (Kabat et al., 1956; Ohlsson & Smith, 2001).

2.2.4. Studies on different aspects of pheasants in native Areas

Out of 64% studies on different aspects on pheasants covered in native areas, the maximum number of publications appeared on status survey and habitat investigation on pheasants (45%), followed by population study (26%), behaviour (15%), management and conservation (9%), and diet and feeding (5%), see figure 2.4.

2.2.4.1. Status surveys and habitat studies

The work of Collias and Collias (1967) from India was amongst the earlier references on pheasants, which focused on the Red Junglefowl in the adjacent forests of Dehradun. Even, an earlier study was conducted by Bump and Bohl (1961) on Red Junglefowl and Kalij in the same general area. Similarly, in Pakistan, a survey was conducted on pheasants which recorded five species (Mirza et al., 1978). A remarkable study of pheasants carried out by Lelliott (1981) was considered as the first survey of pheasants in Nepal. His research area was on the slope of Annapurna, north of Pokhara based on the four species of pheasants. Based on his extensive work on the pheasants in Pipar and its surrounding areas, Nepal Government declared that area as a sanctuary. In China, the study on the habitat requirement of Chinese Monal, *Lophophorus Ihuysii* revealed that this pheasant uses the alpine scrub, subalpine, alpine pastures and exposed rocks and cliff of Mountains as their preferable habitats

(Hen Fen-qi et al., 1988). Subsequently, several studies were conducted on the similar aspects in the different parts of native areas (Roberts,1970; Severinghaus, 1979; Lelliott, 1981; Islam, 1982 & 1985; Islam & Crawford, 1987; Severinghaus & Severinghaus, 1989; McGowan et al., 1991; Young et al., 1991; Bland & Han Lixiang, 1993; Li Xiang-toa, 1995; Ding-Change Quing & Zhang-Guang-mei (1993); Shi Hai-tao et al., 1996; Singh et al., 2011; Shah et al., 2014).

2.2.4.2. Population studies

In Pakistan population study of pheasants suggested the dwindling number of pheasants (Roberts, 1970). The first-time estimation of the density of Chinese Monal was highlighted from China (He Fen-qi et al., 1988). Several studies were made on populations in different regions in Asia (Howman, 1977; Mirza et al., 1978; Gaston & Singh 1980; Zhang & Zhang, 1989; Li & Lu, 1989; Duke, 1989; Islam & Crawford, 1993).

2.2.4.3. Behaviour

It is documented that the first partial descriptions of the breeding behaviour of pheasants started by Beebe, (1931) and Kozlowa, (1947). Later, in India (Dehradun), an extensive study on Red Jungle Pheasant was conducted for male vocalization and its territorial boundaries (Collias & Collias, 1967). Similarly, in China, first-time the breeding behaviour of Hume's Pheasant was highlighted, which indicated the breeding period between February-June and the grounds with dense cover used for nesting by the bird. Studies on the courtship behaviour of the pheasants of Malaysia are also reported (Davison, 1981 & 1982). Later on, many researchers showed their interest on the behaviour of pheasants (Zhengje, 1989; Severinghaus & Severinghaus, 1989; Li, 1995; Zhang & Zheng, 1989; Awan & Buner, 2014).

2.2.4.4. Diet/ Feeding

Studies on the diet of the pheasants in the wilderness are few in Asia. Although a diet of Crested-fireback Pheasant was highlighted from Malaysia, which was mostly found in invertebrates' laden moist areas of the forests (Davison, 1981). Likewise, in China, the study on the diet composition of Cobot's Pheasant (Li & Lu, 1989) and Hume's Pheasant (Liu et al., 1989) revealed that the species is to be vegetarian. It was reported that 83% food of Ring-necked Pheasant comprised of plant materials and the species considered being vegetarian (Zhengje, 1989). A difference in foraging patterns between male and female Temminck's Tragopan (*Tragopan temminckii*) was studied at Padmaja Naidu Himalayan Zoological Park, Darjeeling under captivity (Mitra & Jha, 2015).

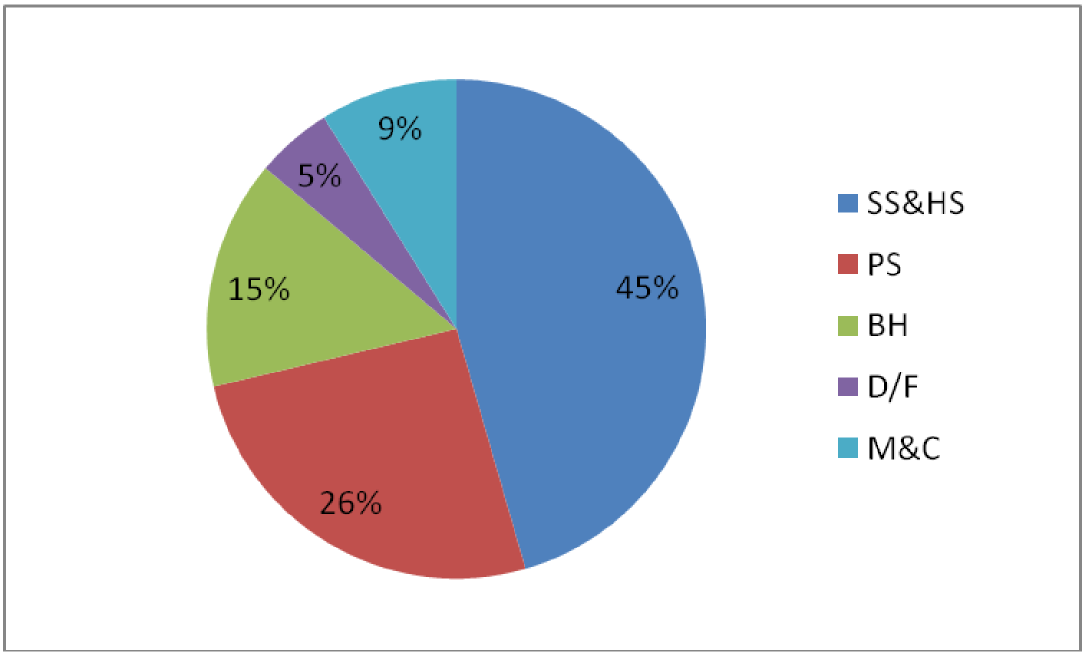

Figure 2.4: Percentage of studies on different aspects of pheasant in native areas [Status survey & habitat studies (SS&HS), Population studies (PS), Behaviour (BH), Diet & Feeding (D&F), and Management & Conservation (M&C)], based on available literature.

2.2.4.5. Management and Conservation

In 1976, Cheer pheasant, *Catreus wallichii* was declared extinct from the Margali hills in Pakistan (Hussain, 1986). Subsequently, several studies were focused on the management and conservation aspects of pheasants. Despite the global biological significance, the region faces numerous challenges for biodiversity conservation and sustainable development which affect the pheasants' resilience. Most of the challenges for pheasants are anthropogenic, like human encroachment, habitat fragmentation, and poaching (Tai-chun et al., 1986; Poudyal et al., 2011; Hilaluddin et al., 2012; Lalthanzara et al., 2014). Hypothetical models were developed to access suitable habitat of pheasants, based on conservation and management aspects (Dunn et al., 2016; Cai et al., 2018; Chhetri et al., 2018).

2.3. Overview of pheasant studies in India

State-wise, the majority of studies on the pheasants appeared from Uttarakhand (35.71%), followed by Himachal Pradesh (28.57%), Jammu & Kashmir (14.28), Mizoram (7.14%), Sikkim (4.76%), Arunachal Pradesh (2.38%), Uttar Pradesh (2.38%), West Bengal (2.38), and Haryana (2.38). Similarly, the maximum number of studies appeared on the pheasants' status survey and habitat (50%) followed by population study (22.5%), behaviour (17.5%), management and conservation (7.5%), and diet and feeding (2.5%) aspects. In India, oldest references on the pheasants' researches credit to studies of Collias and Collias (1967) on the Red Junglefowl, and by Bump and Bohl (1961) on Red Junglefowl and Kalij Pheasant in the same general area. While studying vocalization pattern in pheasants, Collias and Collias (1967) studied divulge that the crowing in males was used by the dominant male to advertise territorial rights and assert dominance. They further concluded that the breeding behaviour and vocal repertoire of the Red Junglefowl in nature were very similar to those of the domestic fowl and considered the Red Junglefowl to be its ancestor. Subsequently, several studies were conducted on different aspect on pheasants by various researchers in regional level in India, such as censuring pheasants (Gaston & Singh, 1980; Gaston et al., 1981; Garson, 1983; Lamba et al., 1982; Gaston et al., 1983a & b; Kaul, 1986; Narang, 1992; Sailo et al. 2013), habitat requirements (Young & Kaul, 1987; Bisht et al., 1989; Garson et al., 1992; Sathyakumar et al., 1993; Kukreti, 2015), behaviour (Young et al., 1987; Hussain & Sultana, 2013), population (Ahmed & Musavi, 1993; Pandey, 1993; Khaling, 1998) diet/feeding (Mitra & Jha, 2015), and conservation and management (Hilaluddin et al., 2012; Lalthanzara et al., 2014; Eliza & Sharma, 2016).

2.4. Overview of pheasant studies in Sikkim

Hitherto, Himalayan pheasants, however, are largely ignored for their conservation management, as most of them are found in high elevation habitats, it is often very difficult to monitor them (Chhetri et al., 2017). Except general observations made by the WII (Satyakumar et al., 2011) and ecological study of Satyr Tragopan by Chhetri et al. (2017) in the Khangchendzonga Biosphere Reserve, there is no substantial published or other work available in public domain. The current review assessment will help in providing a substantial scientific understanding and fulfil the disparity of information on various aspects of pheasants, including, the distribution, abundance, and habitat interaction of Himalayan Pheasants with their response to climate change in Sikkim, particularly the Khangchendzonga Biosphere Reserve, Sikkim, India

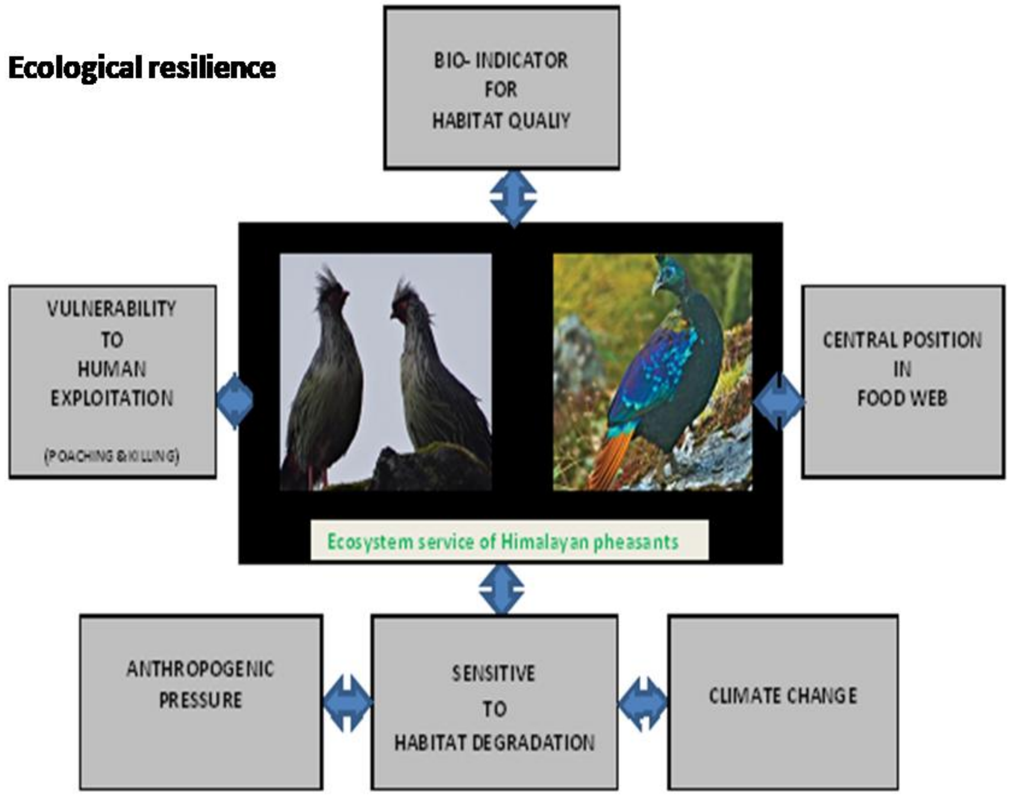

Plate 01: pictorial representation of a flowchart of the ecosystem service of Himalayan Pheasants.

CHAPTER 03

RATIONALE & OBJECTIVES

CHAPTER 03

RATIONALE & OBJECTIVES

3.1. Rationale of the study

Definition of the problem

In the recent decade, the studies of Himalayan pheasants have gained immense importance in India and abroad for their role in ecosystem services; this is because they act as bio-indicator for habitat quality. Amongst the top ten -megadiversity countries, India's enhancement is to have 1,40,000 sq. km protected forest areas, out of a total of 640,000 sq. km. Indian Himalaya is considered as an exceptional area in the world due to its biodiversity and cultural richness, expanded from the east to west in the country. For having a rich base of natural resources and ecosystem services, this region offers tremendous significance to humankind. However, the Himalayan region comes under the influence of anthropogenic threats due to overexploitation of biodiversity by the people for their survival as well as for commercial purposes. Existing conflicts between conservation and human dependency on natural resources have remained a big challenge for governmental agencies. Local people in the Himalayan region need appropriate strategies, back-upped with provisions of supporting and strengthening levels of their income, health, and education. Moreover, the sustainable use of native biodiversity and improved area management is equally important. Or else, over-exploitation of natural resources may result in alteration of the habitat of certain faunal diversity including Himalaya pheasants, which are threatened for their high sensitivity towards degradation of their habitats. Conserving biodiversity is one of the top priorities for protected and sensitive areas today;

to meet the same, appropriate initiatives are urgently required. Research to explore the potential of existing populations of sensitive and threatened species of Himalayan pheasants, including their diversity, distribution, and determination of their habitat requirements are mandatorily required, especially under the on-going threat of climate change, besides their susceptibility to poaching and habitat degradation. Himalayan pheasants, however, are hitherto, largely ignored for their conservation management and researches, as most of them are found in high elevation habitats, it is often very difficult to monitor them.

In India, some good studies on Himalayas Pheasants are available especially in the Great Himalayan National Park in Western Himalaya; whereas, in Khangchendzonga Biosphere Reserve pheasants are insufficiently explored, especially for their population and habitat ecology and climate change point of view. Nevertheless, inadequate studies are available on the pheasants of Sikkim Himalaya, except for fewer generalized observations by few researchers.

Importance of the pheasants

Pheasants have been associated with the social and religious status of people living in Asia and Europe (Poudyal, 2008). Over a long time, pheasant feathers were used to make headgear, earring, and also were used to decorate weapons, spears, helmets, garments, and other in different parts of the world. Consequently, this fashion brought a serious threat to pheasants, especially of rare and endangered species, as 100 male pheasants were required to make a headgear (http:///www.greecetravel.com). For their beauty, pheasants became the jewels of the high altitudes, especially the Himalayan region. The brightly coloured plumage and well-featured crests have been attracting people towards its beauty since time immemorial. About 300 species of Galliformes around the world (26%) are under risk (WPA, 2008); 21 species of pheasants are globally threatened and 12 species are near threatened. Three pheasants are endangered and 18 are vulnerable under the IUCN category (IUCN, 2007). CITES lists 17 species of pheasants in Appendix I, whereas, 08 species are included in Appendix II and 04 in Appendix III (CITES, 2008). These birds are threatened because of high human activities in their natural habitats. Many pheasant species are likely to become extinct within the next 100 year if overexploitation and habitat destruction continue (Ramesh, 2003).

In the Himalayan context, pheasants are killed for food, feathers, and entertainment even though the pheasant hunting is banned by the national park and wildlife conservation Act 1973 in India. The male Himalayan Monal has been under heavy hunting pressure for its crest feathers, which are used in traditional hats in several regions of Nepal (Poudyal, 2008) and Himachal Pradesh, India.

The origin of the work

Sikkim is a part of Eastern Hindu-Kush Himalayas and global biodiversity hotspot (284-8586 m asl). However, climate change in Himalaya is proceeding at a rate of three times higher than the global average and has significantly affected its community assembles; however, many long-term species-level ramifications remain opaque because existing pieces of literature generally lack the quantitative analysis needed to impact conservation policies for avian biology including distribution pattern and habitat specificity of endemic and threatened species and impact of climate change. Based on this background present proposal originated to fulfil these disparities by studying "Distribution, Abundance and Habitat Interaction of Himalayan Pheasants with their response to climate change in Khangchendzonga Biosphere Reserve, Sikkim, India" because the Himalayan Pheasants are considered as a bio-indicator of habitat quality and adverse human impacts in high-altitude ecosystems. In Sikkim Himalaya, four Himalayan Pheasants are found (Blood Pheasant, IUCN Least Concern; Himalayan Monal, IUCN least Concern; Kalij Pheasant, IUCN Least Concern; and Satyr Tragopan, IUCN Near Threatned; their distributional range up to 5000 m asl). This study was aimed to identify the most priority conservation areas and the sensitive habitat areas of the Himalayan Pheasant in the Sikkim Himalayas through the advance climate change modelling approach.

The contribution of the work

Sikkim Himalayan ecosystems are facing threats from anthropogenic pressure, natural calamities (landslide), and climate change. So, an immediate task of biodiversity conservation is needed for various taxa which have a dearth of knowledge on their diversity and distribution which makes it difficult to formulate conservation strategies. Himalayan pheasants, however, are hitherto, largely ignored for their conservation management, as most of them are found in tough terrains in high elevation habitats, it is often very difficult to monitor them. This study was aided in providing a substantial scientific understanding of Himalayan Pheasants diversity, distribution pattern, and habitat interaction along the altitudinal gradient in the

Khanchendzonga Biosphere Reserve. Additionally, the niche and climate change modelling were used for identification of the most potential conservation priority areas and also the highly sensitive areas along with biodiversity threats of the Himalayan Pheasants in Khanchendzonga Biosphere Reserve, Sikkim, and Eastern Himalayas; such information generated from the study which will have immense help for conservation directives to formulate appropriate conservation strategies in the landscape. This study was aimed to understand the status, distribution pattern, and climate change impact on Himalayan Pheasants in the Sikkim Himalayas. Along with the distribution data, the data was used to prepare a database of geo-referenced of the Himalayan Pheasants in the Sikkim Himalayas. In view of the above and the importance of the target species, the proposed study was aimed to investigate diversity, abundance and the general ecological relationship between Himalayan pheasants and their habitat (including forest compositions) along with their potential elevation trails in Khangchendzonga Biosphere Reserve in Sikkim, India.

3.2. Objectives of the Study

1. **To assess the altitudinal distribution of pheasants and mapping of their habitat suitability**
2. **To study of the potential forest communities and habitat composition of Himalayan Pheasants along potential altitudinal gradients**
3. **To study seasonal variation on pheasants' diversity, abundance along habitats**
4. **To study the climate change impact on the distribution of pheasants and their associated elements, including using perception tools**

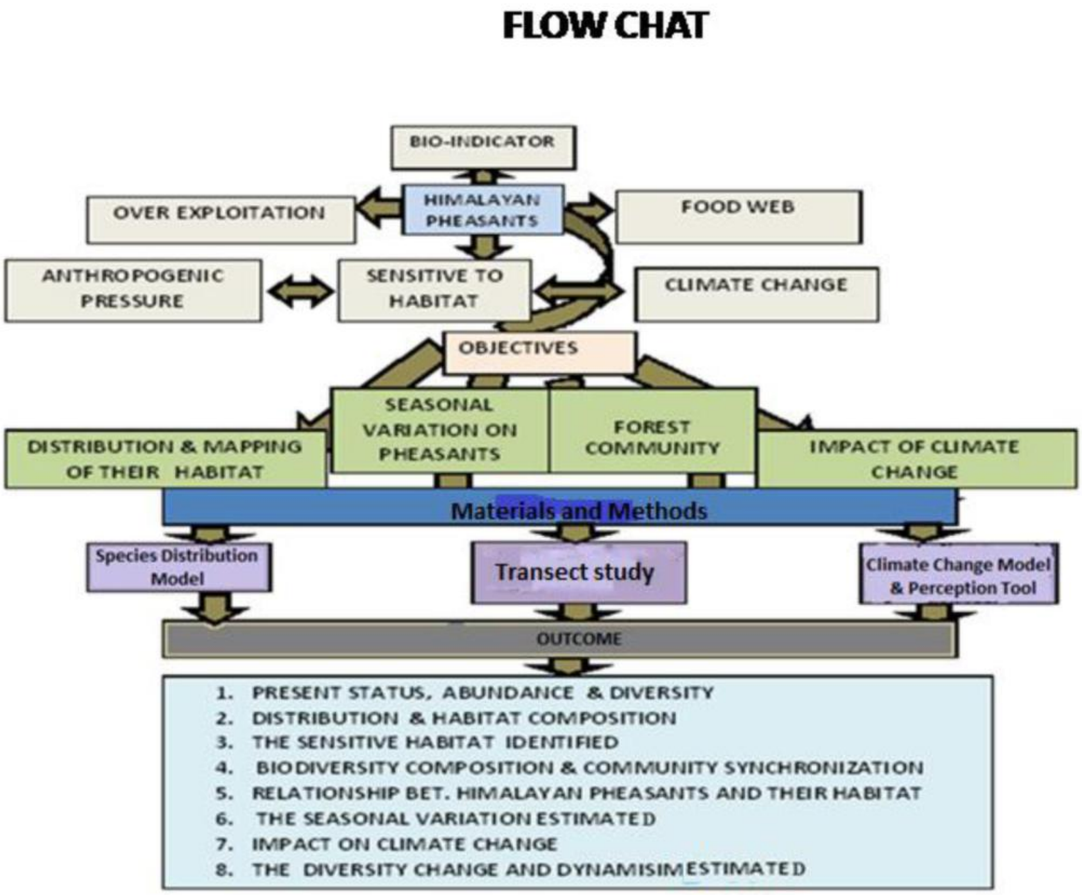

Plate 02: Pictorial representation of a flow chart of the research work.

CHAPTER 04

OBJECTIVE 01

To assess the altitudinal distribution of pheasants and mapping of their habitat suitability.

CHAPTER 04

OBJECTIVE 01

BACKGROUND

Chapter 04

Objective-01

To assess the altitudinal distribution of pheasants and mapping of their habitat suitability

4.1. Background

Conservation directives have historically focused on protecting individual, charismatic species using habitat suitability assessments (Wiens et al., 2009). Determining the geographical range of species is critical part of these endeavors (Mace et al., 2008; IUCN, 2011), as range-determining factors such as climate, dispersal, and suitable habitat availability, dictate where conservation management can be effectively employed (Rodrigues et al., 2006; Harris & Pimm, 2008). However, determining the suitable range for many species particularly uncommon species or those with limited distributions is difficult in many landscapes (Vidal-Garcia & Serio-Silva, 2011). For example, isolated mountain topographies are often under-surveyed or un-surveyed due to their tough geography. Along with the difficulties of exploring and assessing the status of actual populations and habitats (Badola & Pradhan, 2010a, b; Molano-Flores & Bell, 2012; Pradhan & Badola, 2015), prediction and mapping of potentially suitable habitats for the threatened species is crucial for biodiversity conservation approaches (Purvis, et al., 2000). Species distribution modelling tools are more popular these days in ecology, which widely relies on various ecological applications (Elith et al., 2006; Peterson et al., 2006, Sarma et al., 2015). These models are based on the relationships between the existences of species data and biophysical environmental variables in the study area. Although, numerous species distribution modelling methods are developed to predict the potential suitable habitat for a species (Guisan & Thuiller, 2005; Elith et al., 2006; Guisan et al., 2007a, b; Wisz et al., 2008), making clustered species for habitat modelling approaches shows difficulty (Kumar & Stohlgren, 2009). However, most of them are very sensitive to sample size (Wisz et al., 2008) and may not accurately predict the habitat patterns for the endangered and threatened species whose populations are very less in numbers. However, few predictive models of species distribution have been used for an endangered and threatened plant species (Engler et al., 2004; Kumar & Stohlgren, 2009). One of them, the Maximum Entropy modelling (MaxEnt) has accuracy in identifying the potential habitat distribution of threatened or rare species and is relatively insensitive to spatial errors associated with location data. This requires few locations to run useful models and to perform better than other modelling approaches (Elith et al., 2006; Hernandez et al., 2006; Phillips, et al., 2006). MaxEnt is based on a machine learning response that is designed to make prediction of habitat of a species using incomplete data and provides most uniform distribution approach estimate of sampling points compared to the background locations giving constraints derived from the data (Phillips et al., 2004; Phillips et al., 2006; Phillips et al., 2010). MaxEnt model has ability to avoid overfitting of predictors by running multiple replicates to get highly appropriate prediction maps.

CHAPTER 04

OBJECTIVE 01

MATERIALS & METHODS

4.2. Materials and Methods

4.2.1. Study Area

4.2.1.1. Eastern Himalaya

The geographical area of the Eastern Himalayan region is lying between 82.70°E and 100.31°E longitude and 21.95°N to 29.45°N latitude, covering a total area of 524,190 sq. km (Figure 3.1). The landscape forms a 1500 mile long barrier that separates the lowlands of the Indian subcontinent from the high, dry Tibetan plateau and extends from Kaligandaki Valley in central Nepal to northwest Yunnan in China, also encompassing Bhutan, the northeastern states, and north Bengal hills in India, southeastern Tibet, and parts of northern Myanmar (Chettri et al. 2010). There are at least 7,500 flowering plants, 700 orchids, 58 bamboo species, 64 citrus species, 28 conifers, 500 mosses, 700 ferns, and 728 lichens (Chettri et al. 2010). One hundred and seventy-five species of mammal and over 500 species of bird are known from the region (WWF & ICIMOD, 2001). Among these 175 vertebrates, 45 are threatened; of which 14 are endangered, 29 vulnerable, and two are critically rare (CEPF, 2005). Its grasslands are home to most important mammal species of the region such as Bengal tiger, Asian elephant, one-horned rhino, snow leopard, red panda, black bear, etc. The region is a rich cultural mosaic of Buddhists, Hindus, Christians, etc. all of whom lived in harmony with nature. The Eastern Himalayas are enlisted in the ‘crisis ecoregions'; ‘biodiversity hotspots'; ‘endemic bird areas'; endemic bird areas'; mega-diversity countries, and global 200 ecoregions'(Brooks et al., 2006). The landscape is also biogeographical realms of the Indo-Malayan, Palaearctic, and Sino-Japanese with diverse ecological and altitudinal gradients and an associated diversity of flora and fauna (CEPF, 2005; 2007). It contains parts of three of 34 global biodiversity hotspots; out of 39% of the Himalayan hotspot, 8% of the Indo-Burma hotspot, and 13% of the Mountains of southwest China hotspot. The complex topography and extreme altitudinal gradients from less than 300 m (tropical lowlands) to more than 8000 m asl (high mountains) have provided to unique biodiversity of a variety of vegetation patterns. The rivers of the landscape provide valuable goods and services along with healthy biodiversity. Geographically, the Eastern Himalaya is placed between the two densely populated countries of China and India, both of which have the highest dependency on its bio-resources (Beniston, 2003). The ecosystem fragmentation of the Eastern Himalaya is the main results of migration, urbanization, economic development, and population growth as well as from climate change faces (Beniston, 2003). The Eastern Himalayas are experiencing widespread warming at the rate of generally greater than 0.01˚C per year and it is prominent usual seasonal dichotomies, the highest rates of warming are in winter and the lowest, or even cooling, are in summer, and with areas higher than 4000 m asl experiencing the highest warming rates (Sharma et al., 2009). Threats to biodiversity especially endemic species that have a narrow and restricted range of distribution from climate change are experienced (Root et al., 2003). Based on the Intergovernmental Panel on Climate Change (IPCC), the current rate of climate change even the most stringent mitigation efforts would be ineffective in counteracting all the negative impacts of climate change (Pachauri et al., 2014). So far, there are hardly any concrete studies assessing the magnitude of future warming and its impact on biological resources in the Eastern Himalayas.

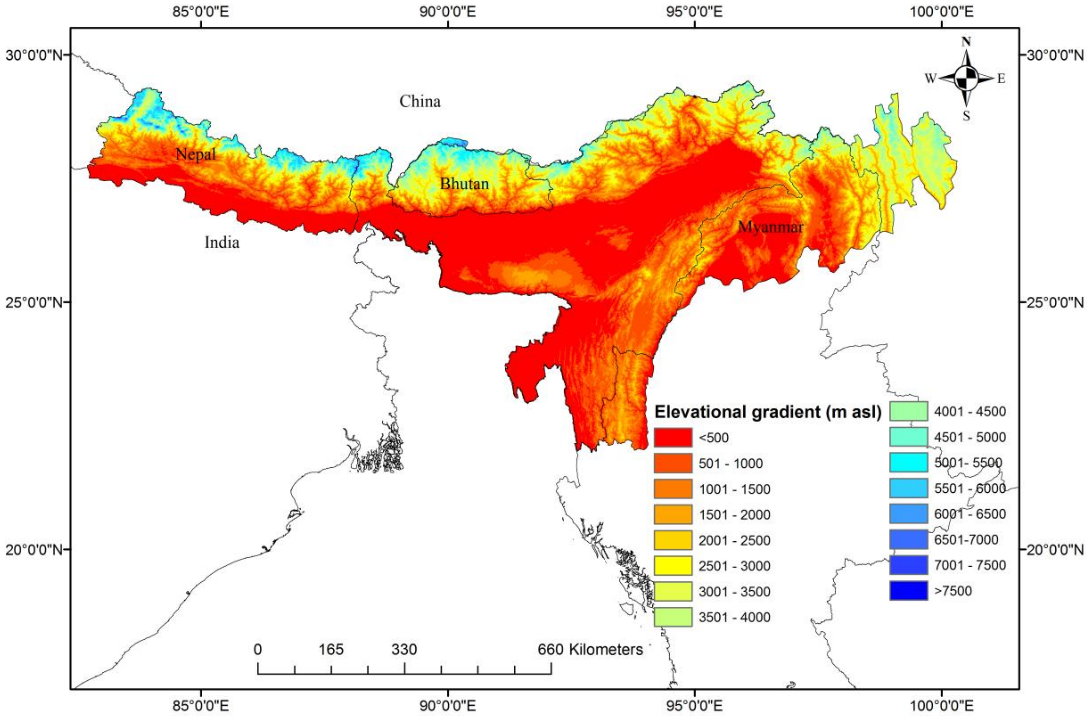

Figure 3.1: Digital elevation model of Eastern Himalaya.

4.2.1.2. Sikkim Himalaya

The geographical area of Sikkim Himalayan region is lying between 88˚3’40” to 88˚57’19” E longitude and 27˚3’47” to 28˚7’34” N latitude, covering a total area of 7096 sq.km, which forms just 0.02% of the total geographical area of the country (Figure 3.2). It is surrounded by Nepal on the west, by Tibet Autonomous Region (China, TAR) on the north, Bhutan, and TAR (China) on the east, and Darjeeling district of West Bengal on the south. Sikkim Himalaya is rich in cultural and biologically diversities; Lepchas, Bhutias, Nepalese, and Limbos are the main ethnic group of the state and they differ from each cultural, and traditional practices (Badola, 2017). The altitude gradient of Sikkim Himalayas ranges from 300 m asl to 8586 m asl (Mt. Khangchendzonga), which provides several ecological zones viz., subtropical, temperate, sub-alpine, and alpine. In such a small landscape sharp climatic differences observed in the ecological zones have promoted a rich gene pool of both faunal and floral elements. Forestry is the major land use pattern of the state and nearly 80% of the total area of the state is under the administrative control of the State Forest Department (Ganguli-Lachungpa et al., 2011), including 08 protected areas viz. Khangchendzonga National Park, Shingba Rhododendron Sanctuary, Barsey Rhododendron Sanctuary, Kyongnosla Alpine Sanctuary, Fambong Lho Wildlife Sanctuary, Maenam Wildlife Sanctuary, Pangolakha Wildlife Sanctuary, and Kitam Wildlife Sanctuary. The Sikkim Himalayas is enriched with biological diversity; flowering plants (4500), orchid (527), rhododendrons (36), bamboos (20), ferns and ferns allies (362), primulas (30), oaks (11), mammals (144), birds (550), butterflies (600+), fishes (48), etc. (Sikkim Biodiversity action plan, 2012). Like other Himalayan states, Sikkim Himalayan ecosystems are facing critical threats from anthropogenic pressure, natural calamities (landslide), and climate change along with deforestation, sporadic poaching of animals and extraction of plants and their parts, unregulated tourism, introduction and popularization of hybrids, etc.

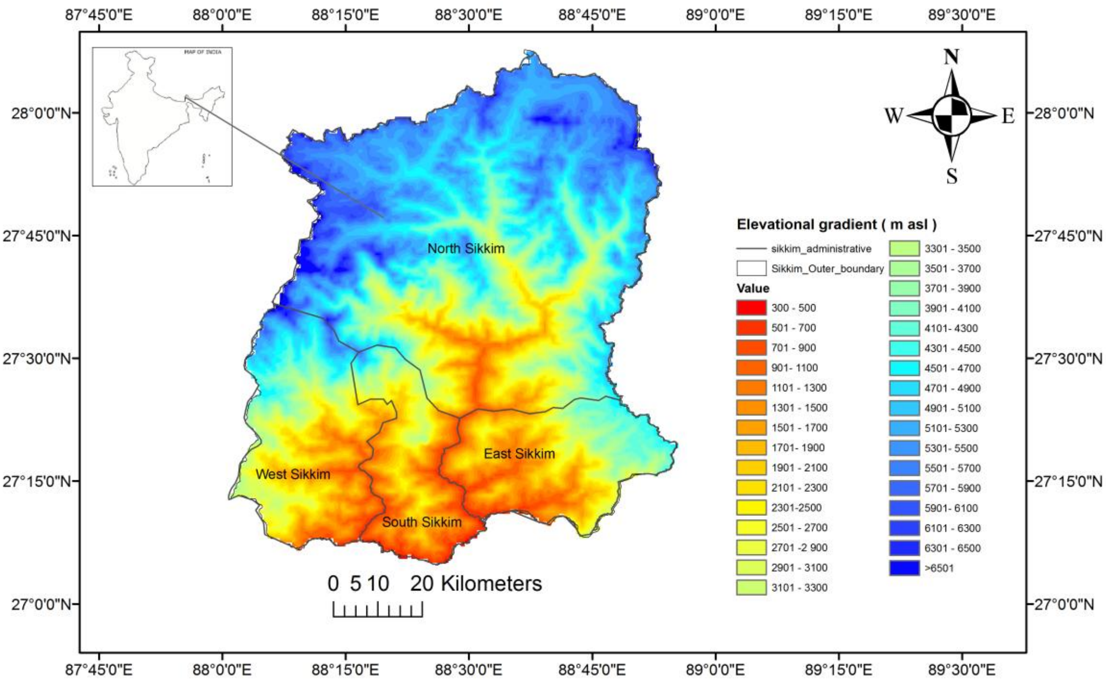

Figure 3.2: Digital elevation model of Sikkim Himalaya.

4.2.1.3. Khangchendzonga Biosphere Reserve

The Khangchendzonga National Park is the core zone of Khangchendzonga Biosphere Reserve (KBR), which recently inscribed as the World Heritage Site on 17 July 2016 by UNESCO (United Nations Educational, Scientific and Cultural Organization), with a geographical location of 27°15'-27°57' N latitude and 88° 02'-88°40' E longitude is an important protected area for the conservation of biodiversity, highly enriched flora and fauna, unique in its geographical terrains and with immense natural beauty in the Himalayan Region (Figure 3.3). KBR was notified initially by the Government of India on 07th February 2000 and subsequently, re-notified by the Government of Sikkim on 24th May 2010, with a separate transition zone identified with the support of GBPIHED-Sikkim Unit (Badola and Subba, 2012). The core zone of KBR, as the Khangchendzonga (High altitude) National Park, a major transboundary area, represents unique habitat zone and high endemic flora and fauna. A total area of the Khangchendzonga Biosphere Reserve is 2931.12 sq. km and is further divided into core zone (1,784.00 sq. km), buffer zone (835.92 sq. km) and transition zone (311.20 sq. km). The biosphere reserve falls in the North and West districts of Sikkim state in the north-eastern region of India, neighbouring Nepal in the west and China (Tibet) in the north-west (Badola & Subba, 2012). KBR is represented as one of the richest plant diversity centres in Himalaya for its unique geographical location covering from sub-tropical to arctic region. A wide range of physiographic and eco-climate gradients have fully expressed them for providing a rich gene pool of both wild and cultivated plants species. Many plant species from the neighbouring region and far off countries namely Nepal, Bhutan, China, Tibet, Myanmar, Malaysia and to a lesser extent to Peninsular Indian affinities as well as a good number of endemic species are met within this biosphere reserve and can be broadly classified in subtropical, temperate and alpine forest types (Badola & Subba, 2012). KBR is a protected area enriched with high biodiversity, found with a huge variety of birds, animals, trees and medicinal herbs and support different habitats, niches which are highly suitable for many rare and endangered taxa, these include snow leopards, clouded leopards, Tibetan sheep, Blue sheep, Himalayan thar, Red panda, musk deer, pheasants such as Himalayan Monal, Blood Pheasant, Satyr Tragopan and Khalij Pheasant and the relatively unexplored rich Rhododendrons reservoir (Badola & Pradhan, 2010a). The health of the ecosystem in the Eastern Himalayan forest (KBR) is greatly influenced by the availability of different species of Rhododendrons particularly for their specificity in maintaining long-lived evergreen leaves as important storage for good nutrients, which also supply suitable ecological niches to faunal communities (Badola & Pradhan, 2010b). These plants provide a favourable niche to several bird species, habitat for canopy lover insects and also playing important role in the ecological stability of ecosystems. KBR is listed as one of the world's most critical centres for biodiversity and endemic species (Badola & Subba, 2012) with a good assemblage of mammals (Sathyakumar et al., 2014) and birds (Chettri et al., 2001). The Khangchendzonga National Park and Biosphere Reserves experienced several policy level changes and modifications since the last 15 years, such as the exile of Yak herders from core area in western part of Khangchendzonga National Park, which largely have changed the livelihood practices of the local communities from traditional livestock herding to eco-tourism initiatives (Tambe & Rawat, 2009). Various studies suggested the Khangchendzonga National Park management through innovative co-management models, need safeguards and monitoring for vulnerable habitats, strengthen buffer zone management and focus conservation actions as mandatory for the long-term security of this unique mountain landscape (Badola & Subba, 2012, Tambe et al., 2012). Monitoring wildlife species in this landscape is useful because many species are excellent indicators of habitat quality and management interventions (Badola & Subba, 2012; Sathyakumar et al., 2014).

The Khangchendzonga Biosphere Reserve (KBR) is vital additional protected area network of India for wildlife management; it is the country's highest as well as world's third highest protected area having high altitude wildlife landscape covering 41.31% of the total geographical area (including transition zone) of the state of

Sikkim (Badola & Pradhan, 2013). KBR ranges from subtropical to arctic with an altitudinal gradient of between 1,200 to 8,586 m asl. Having such a treasure of biodiversity, very limited ecological studies and surveys on the faunal components of the Khangchendzonga National Park and Biosphere Reserve available (Chettri et al., 2001; Bhattacharya et al., 2010; Badola & Subba, 2012; Bashir et al., 2013 a, b; Bashir et al., 2014). However, vegetation studies are fairly good in numbers but largely focused on limited parts of KBR (Badola & Pradhan, 2010a, b; Tambe & Rawat, 2009).

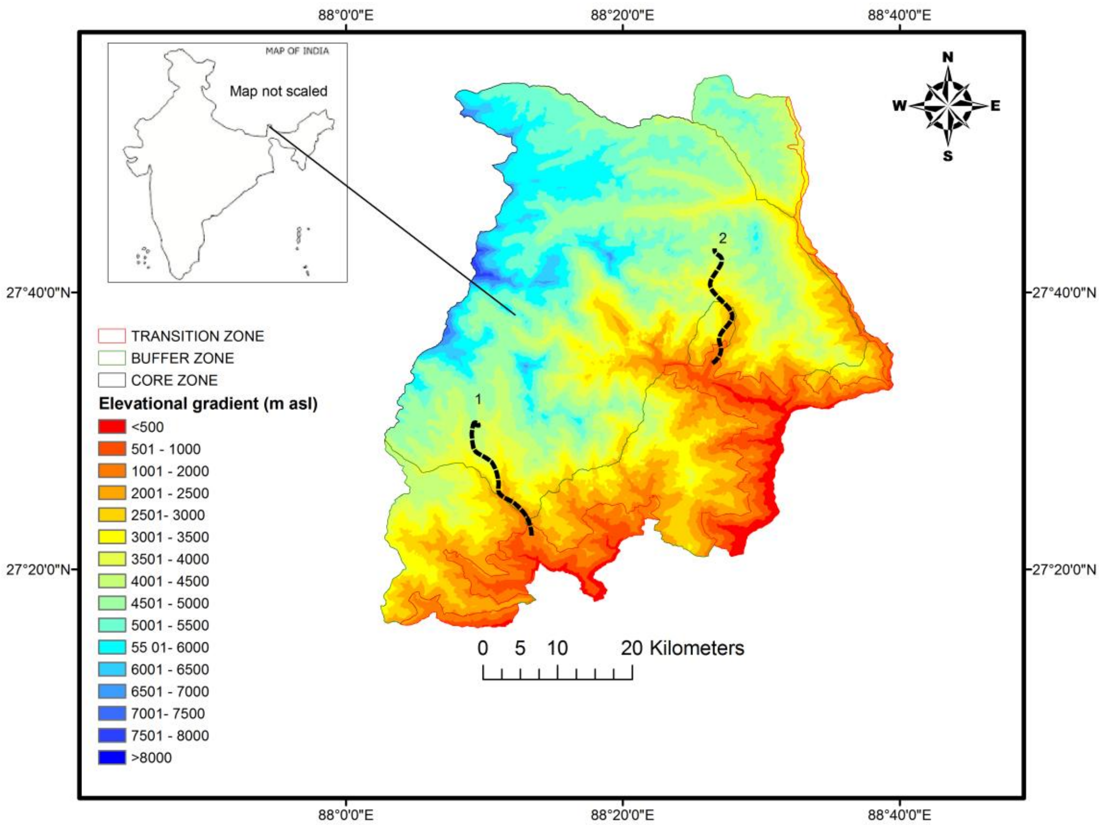

Figure 3.3: Digital elevation model of Khangchendzonga Biosphere Reserve (1 depicts Yuksom-Black Kabru (Dome) transect and 2 depicts Tholung-Kisong transect of the study area).

4.2.2. Spatial distribution model (SDM)

The potential distribution area of the Pheasants was predicted using MaxEnt software version 3.3.3k.d downloaded from www.cs.princeton.edu/ * schapire/MaxEnt/. By providing environmental variables and species existing data into MaxEnt software, the final potential area map of the pheasants was projected independently for Eastern Himalaya, Sikkim Himalaya, and Khanchendzonga Biosphere Reserve using ArcGIS 9.3. For the MaxEnt ecological habitat modelling of the Pheasants, the similar methodology of Phillips et al. (2006) was used.

4.2.2.1. Model species

Sikkim-Himalayan Pheasants: Blood Pheasant (*Ithaginis cruentus*), Himalayan Monal (*Lophophorus impejanus*), Satyr tragopan (*Tragopan satyra*), and Kalij Pheasant (*Lophura leucomelanos*)

4.2.2.2. Occurrence records and population assessments

The geo-reference records of primary and secondary nature of Sikkim-Himalayan Pheasants were collected from the Eastern Himalayas as a whole. The special focus was made on the primary records in Sikkim and Darjeeling Himalayas along the altitudinal gradients distribution assessment (C.1700-5000 m asl, during 2014-2017), using a standard methodology of open width point count along the transects (Bibby et al. 2000) and the secondary records from available literature. The historical species records were also reviewed using GBIF (Global Biodiversity Information Facility database) followed by the similar approaches of Mota-Vargas et al. (2016) and Wang et al. (2014), wherein the records of geo-reference of the Himalayan Pheasants are available in databases of Global Biodiversity Information

Facility (GBIF; www.gbif.org) then checked a set of occurrence point locations of the Pheasants with the GALLIFORM: Eurasian Database V.10 (http://dx.doi.org/10.5061/dryad.1464; Boakes et al., 2010), the IUCN distribution map of the species (BirdLife International, 2012) and geographical grid point location map of the species from status of Nepal Birds (Inskipp et al., 2016). Further, those point locations were excluded with a reported location inaccuracy and greater than 500 meters for the species (Friggens & Finch, 2015). Based on my knowledge of the distribution of the species, the datasets reflect the current distribution point locations of the species (the 133 point locations of primary and existing records for the Blood Pheasant, 106 for the Himalayan Monal, 91 for the Satyr Tragopan, and 75 for the Kalij Pheasant), in the Eastern Himalayas.

4.2.2.3. Current environmental predictors

Environmental parameters were used for the spatial distribution of the pheasants separately in the Eastern Himalaya, the Sikkim Himalaya, and Khagchendzonga Biosphere Reserve. The included Climatic parameter (19 variables of climatic envelope downloaded from www.worldclim.org), physical parameters (blue reflectance, Red reflectance and Sun zenith angle; downloaded from https://modis.gsfc.nasa.gov/), topography parameter (Altitude, Aspect and Slope downloaded from www.worldclim.org; Aspect and Slope also were generated by ArcGIS 9.3 version), Bio-physical parameter (NDVI, Normalised Difference Vegetation Index; EVI, Enhanced Vegetation Index; VI, Vegetation Index; downloaded from https://modis.gsfc.nasa.gov/), and Human-modified mosaic landscape (land use and land cover; downloaded from www.diva-gis.org/gdata).

These high-resolution environmental data were pre-processed at a spatial resolution of 30s latitude and longitude using ArcGIS 10.2.2 (around 1 km at ground level).

4.2.2.4. Model validation for the prediction of potential habitats

The potent associated environmental variables were selected for the prediction of the present potential distribution of the Pheasants through Principal Component Analysis. The Principal Component Analysis (PCA) was applied to test the independence between each pair of environmental variables to reduce autocorrelation among the variables using the SPSS version 21, and the important property of obtained principal components of variables is their independence of each other, i.e. orthogonal (followed by similar approach of Afifi et al., 2012; Cruz-Cardenas et al., 2014). The variables were excluded from the analysis if their highest loading values were >± 0.7 and only variables were used for prediction distribution of the species whose loading values< ±0.7 as principal components in each parameter set which are considered as independent and non-correlated variables at 95% confidence level for the potential distribution model of the species. MaxEnt software version 3.3.3 was used for predicting the present distribution habitat of the pheasants by using the Jackknife validation methodology (adopted by Pearson et al., 2007), and the regularization multiplier value was set at 0.1 to avoid over fitting (Phillips et al., 2004). For the modelling of the Pheasants, the maximum number of background points was set at 1,000 along with the use of a threshold feature. The 10-percentile threshold rule was applied and provided 80% of the data for training and the remaining 20% for testing, and the total 3 replicates run was set in the software to avoid overfitting predictors for predicting accurate model (adopted by Flory et al., 2012). The AUC (area under the receiving operator curve) was used to test model's goodness-of-fit and a perfect model having an AUC of 1, when the AUC is >0.9 then performance is considered good (Swets, 1988). The final output map was divided into the five potential distribution areas that were reclassified with a range between 0-1 threshold class such as very low potential threshold (<0.10), low potential threshold (0.10-0.30), moderate potential threshold (0.30-0.50), high potential threshold (0.50-0.70) and very high potential threshold (>0.70), and in the final projected map, as a very low potential threshold class had covered the maximum area under consideration, it was excluded from the results as a suitable habitat area (adopted by Sarma et al., 2015).

CHAPTER 04

OBJECTIVE 01

RESULTS

4.3. Results

4.3. 1. Current Spatial Distribution Model (SDM) of the Himalayan Pheasants in Eastern Himalaya, Sikkim Himalaya, and Khangchendzonga Biosphere Reserve

4.3. 1. 1. Current habitat distribution model of Blood Pheasant

The result of the model calibration test for the Blood Pheasant (AUC $_{train}$= 0.997±0 and AUC $_{test}$=0.975±0.012) was found better than random (AUC=0.5).

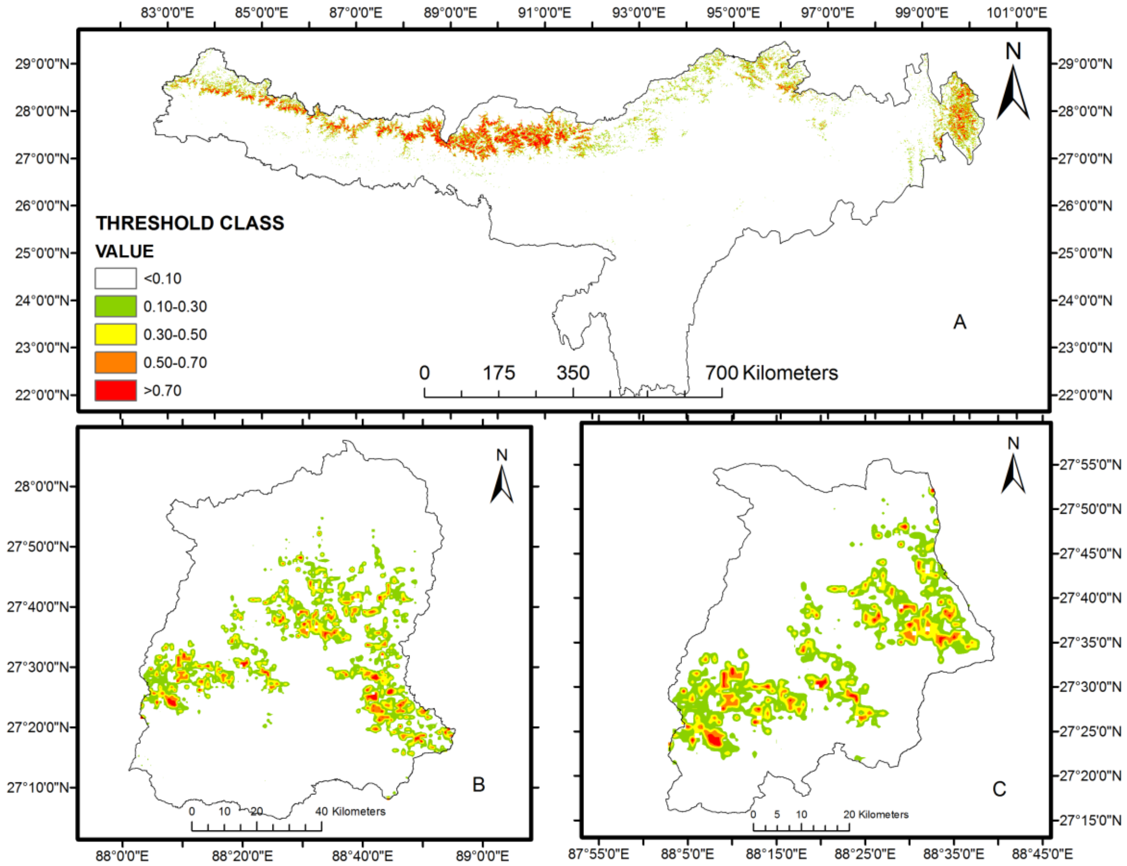

Figure 3.4: SDM of Blood Pheasant depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential suitability in Eastern Himalaya (A), Sikkim (B) and Khangchendzonga Biosphere Reserve (C).

Among the inputs as environmental predictors of different parameters, namely, Physical parameter, Topography parameter, Biophysical parameter, Climate parameter, and Human- modified mosaic landscape; the Climate parameter (44.2%) had highest contribution to the model followed by Physical parameter (41.5%), Biophysical parameter (8.5 %), Topography (5.6 %), and Human- modified mosaic landscape (0 %). Out of the targeted input variables, Blue reflectance (19.9%) was the highest performer for the prediction map followed by Bio-3 (16.2%), Solar Azimuth Angle (14.1%), Bio-9 (11.5%), Bio-11(6.6 %), and Normalized Difference Vegetation Index (5.5%) [Table 3.1].

The model demonstrates the currently suitable habitat of Blood Pheasant for which the habitat spans from moist, temperate broadleaved-coniferous-alpine meadow including the forest of Rhododendrons with dense undergrowth shrubberies to the grass of alpine meadow in the Eastern Himalaya, the Sikkim Himalayas, and the Khangchendzonga Biosphere Reserve (Figure 3.4). The potential habitat areas of the Blood Pheasant were quantified under four potential threshold categories, independently, in Eastern Himalaya, Sikkim Himalaya, and Khangchendzonga Biosphere Reserve, out of 524190 sq. km area of the Eastern Himalaya, the low potential threshold class (42504.75 sq. km) emerged as the highest area the model followed by the moderate potential (17364.32 sq. km), the high potential (7123.06 sq.km), and the very high (2710.04 sq.km). Similarly, out of 7096 sq. km area of Sikkim, the low potential threshold class (1052.83 sq. km) also emerged as highest one followed by the moderate potential threshold class (529.19 sq. km), the high potential threshold class (234.06 sq. km), and the very high potential threshold class (222.03 sq.km). Whereas, in the Khangchendzonga Biosphere Reserve, out of

2931.12 sq. km total area, the very high potential threshold class seemed as the lowest one (96.98 sq.km) followed by the high potential threshold class (120.22 sq.km), the moderate potential threshold class (242.86 sq. km), and the low potential threshold class (444.03 sq. km) [Figure 3.5].

Table 3.1: Environmental parameters and its associated variables used in the study and their percentage contribution to the prediction present Species Distribution Model (SDM) developed for potential habitat of Blood Pheasant in the Himalayas

Parameter	**Variable**	**Percent contribution**	**Permutation importance**
Physical	1. Red Reflectance	7.5	0.2
	2. Blue Reflectance	19.9	37
	3. Solar Azimuth Angle	14.1	1
	Sub-total	41.5	38.2
Topography	1. Altitude	2.8	0
	2. Slope	0.1	0
	3. Aspect	2.7	4
	Sub-total	5.6	4
Biophysical	1. NDVI (Normalized difference vegetation index)	5.5	1.5
	2. EVI (Enhanced vegetation index)	1.2	0
	3. VI (Vegetation index)	1.8	0
	Subtotal	8.5	1.5
Climate	Bio-2	2.1	9.6
	Bio-3	16.2	40.7
	Bio-4	0	0
	Bio-7	4	0
	Bio-9	11.5	3.7
	Bio-11	6.6	0
	Bio-14	2.3	2.3
	Bio-15	0.7	0
	Bio-17	0	0
	Bio-19	0.8	0
	Sub-total	44.2	56.3
Mosaic landscape	1. LULC (Land use and land cover)	0	0

[a]Above tabulated variables used in the modelling, selected through the multicollinearity test (PCA)

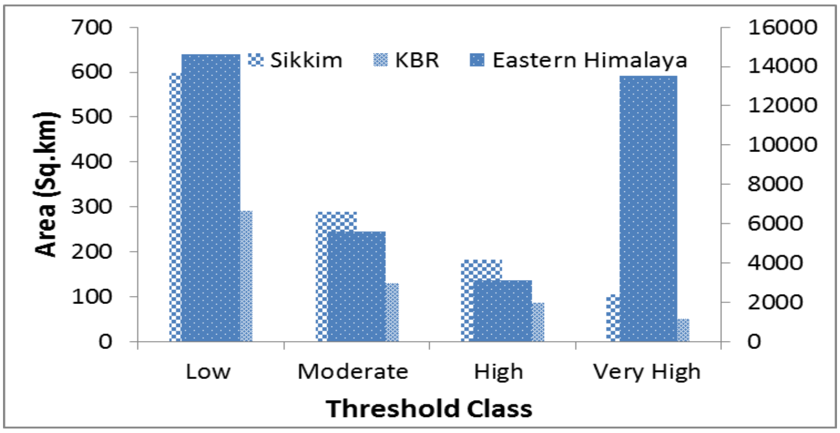

Figure 3.5: Area of potential threshold class of Blood Pheasant in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR).

4.3.1.2. Current habitat distribution model of Himalayan Monal

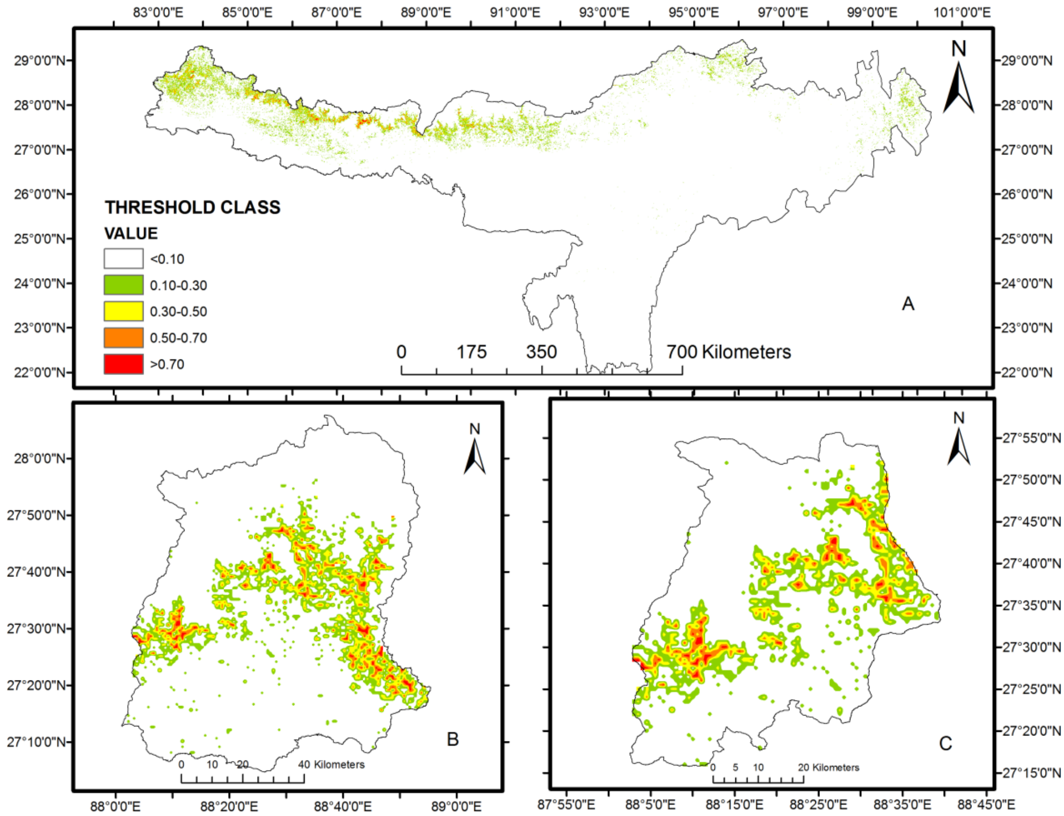

Figure 3.6: SDM of Himalayan Monal depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential suitability in Eastern Himalaya (A), Sikkim (B) and Khangchendzonga Biosphere Reserve (C).

The result of the model calibration test for Himalayan Monal (AUC $_{train}$= 0.997±0 and AUC $_{test}$=0.955±0.012) was found better than random (AUC=0.5). Among the inputs as environmental predictors of different parameters, namely, Physical parameter, Topography parameter, Biophysical parameter, Climate parameter, and Human- modified mosaic landscape, the climate parameter (46.5%) had highest contribution to the model followed by physical parameter (32.7%), Bio-physical (15.7), Topography (4.5%), and Human- modified mosaic landscape (0.4%) . Out of the input variables, Solar Azimuth Angle (16.6%) was the highest performer for the prediction map followed by Bio-3 (15.3%) Blue reflectance (13.6%), Bio-4 (11.5%), Vegetation index (9.3), and Bio-11(7.9%)[Table 3.2]. The model demonstrates the currently suitable habitat of Himalayan Monal in the Eastern Himalayas, Sikkim Himalayas, and Khangchendzonga Biosphere Reserve for which habitat falls in moist, cold temperate broadleaved-coniferous and rhododendron forest and scrubs to the alpine meadow (Figure 3.6). The suitable potential threshold area of the Blood Pheasant was quantified under four potential threshold categories in Eastern Himalaya, Sikkim Himalaya, and Khangchendzonga Biosphere Reserve, out of the total area of Eastern Himalaya, 524190 sq. km, the low potential threshold class (17533.58 sq.km) emerged as highest followed by the moderate potential (5620.55 sq.km), the high potential (2448.82 sq.km), and the very high (1304.15 sq.km). Similarly, out of 7096 sq. km area of Sikkim, the low potential threshold class also emerged as highest (787.00 sq.km) followed by the moderate potential threshold class (394.89 sq.km), the high potential threshold class (226.18 sq.km), and the very high potential threshold class (156.65 sq.km). In the Khangchendzonga Biosphere Reserve out of 2931.12 sq. km, the low potential threshold class (362.17 km) emerged as highest one followed by the moderate potential (164.67 sq.km), the high potential (92.38 sq.km), and the very high (69.88 sq.km) (Figure 3.7).

Table 3.2: Environmental parameters and its associated variables used in the study and their percentage contribution to the prediction present Species Distribution Model (SDM) developed for potential habitat of Himalayan Monal in the Himalayas

Parameter	**Variable**	**Percent contribution**	**Permutation importance**
Physical	1. Red Reflectance	2.5	0
	2. Blue Reflectance	13.6	22.7
	3. Solar Azimuth Angle	16.6	9.4
	Sub- total	32.7	32.1
Topography	1. Altitude	1.6	2.3
	2. Slope	2	0
	3. Aspect	0.9	0
	Sub- total	4.5	2.3
Biophysical	1. NDVI (Normalized difference vegetation index)	3.2	0.3
	2. EVI (Enhanced vegetation index)	3.2	3.4
	3. VI (Vegetation index)	9.3	1.1
	Sub-total	15.7	4.8
Climate	Bio-2	0.5	0
	Bio-3	15.3	35.8
	Bio-4	11.5	22.2
	Bio-7	4.9	0
	Bio-11	7.9	0
	Bio-14	1	0
	Bio-15	2.6	2.8
	Bio-17	0.7	0
	Bio-19	2.1	0
	Sub-total	46.5	60.8
Mosaic landscape	1. LULC (Land use and land cover)	0.4	0

[a]Above tabulated variables used in the modelling, selected through the multicollinearity test (PCA)

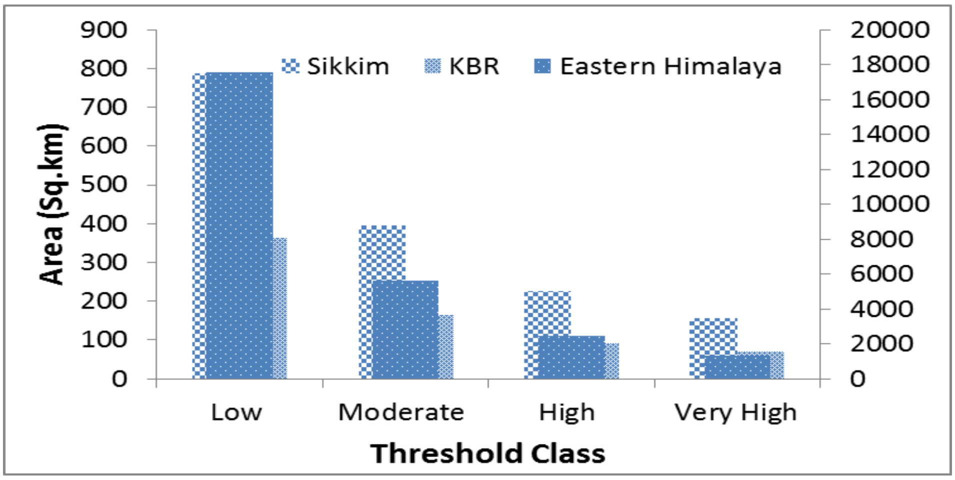

Figure 3.7: Area of potential threshold class of Himalayan Monal in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR)

4.3.1.3. Current habitat distribution model of Kalij Pheasant

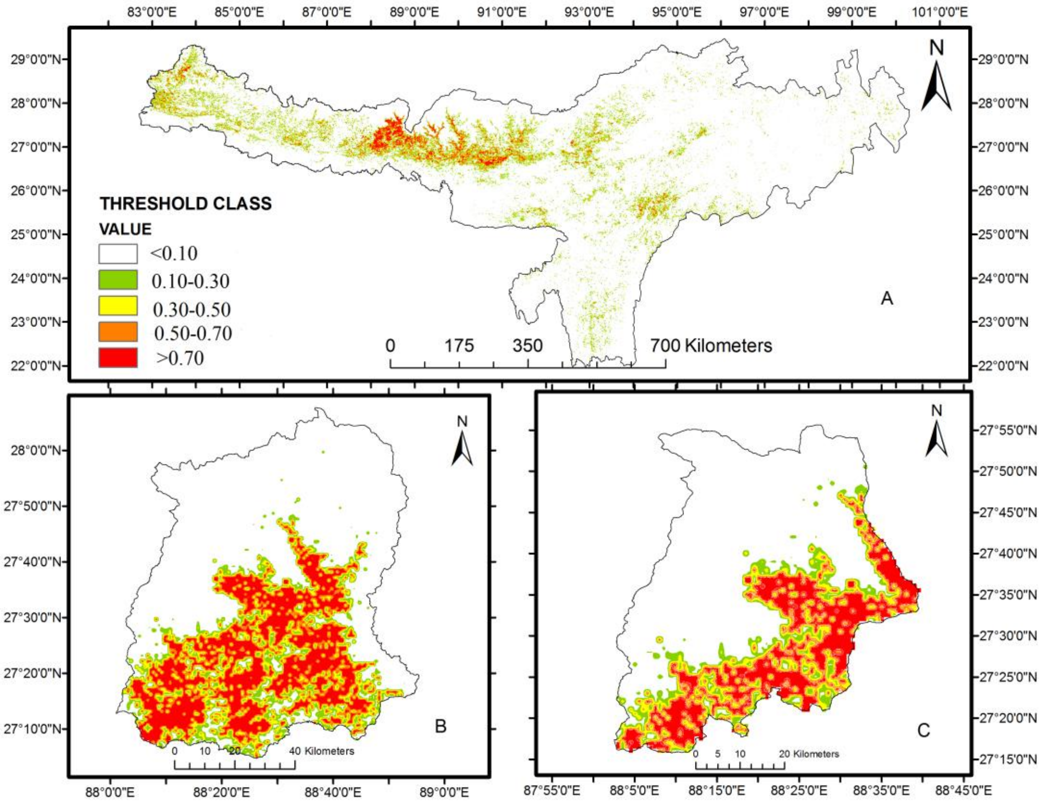

Figure 3.8: SDM of Kalij Pheasant depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential suitability in Eastern Himalaya (A), Sikkim (B) and Khangchendzonga Biosphere Reserve (C).

The result of the model calibration test for Kalij Pheasant (AUC $_{train}$= 0.997±0 and AUC $_{test}$=0.869±0.011) was found better than random (AUC=0.5). Among the inputs as environmental predictors of different parameters, namely, Physical parameter, Topography parameter, Biophysical parameter, Climate parameter, and Human - modified mosaic landscape, the Physical parameter (39.7%) had highest contribution to the model followed by Climate (37.2%), Bio-physical (17 %), Topography (3.1%), and Human –modified mosaic landscape (2.8%). Out of the input variables, Solar Azimuth Angle (22.4%) was the highest performer for the prediction map followed by Blue reflectance (11%), Bio-4 (10.5), Bio-7 (9.6), Enhanced vegetation index (8.7 %), and Red reflectance (6.3%) [Table 3.3].

Table 3.3: Environmental parameters and its associated variables used in the study and their percentage contribution to the prediction present Species Distribution Model (SDM) developed for potential habitat of Kalij Pheasant in the Himalayas

Parameter	Variable	Percent contribution	Permutation importance
Physical	1. Red Reflectance	6.3	0
	2. Blue Reflectance	11	9.8
	3. Solar Azimuth Angle	22.4	14.8
	Sub total	39.7	24.6
Topography	1. Altitude	1.1	0
	2. Slope	0.8	0
	3. Aspect	1.2	1.2
	Sub total	3.1	1.2
Biophysical	1. NDVI (Normalized difference vegetation index)	4.2	0
	2. EVI (Enhanced vegetation index)	8.7	2.5
	3. VI (Vegetation index)	4.1	14.8
	Sub-total	17	17.3

Climate	Bio-2	4.1	0
	Bio-3	0	0
	Bio-4	10.5	24.7
	Bio-5	3	27.2
	Bio-7	9.6	0
	Bio-14	1.6	0
	Bio-15	4.3	4.9
	Bio-17	1.7	0
	Bio-19	2.4	0
	Sub-total	37.2	56.8
Mosaic landscape	1. LULC (Land use and land cover)	2.8	0

[a]Above tabulated variables used in the modelling, selected through the multicollinearity test (PCA)

The model demonstrates the currently suitable habitat of Kalij Pheasant in the Eastern Himalayas, Sikkim Himalayas, and Khangchendzonga Biosphere Reserve for which the habitat spans from sub-tropical forest to moist, temperate broadleaved-coniferous forest (Figure 3.8). The potential habitat areas of the Kalij Pheasant were quantified into four potential threshold categories in the Eastern Himalaya, Sikkim Himalaya and Khangchendzonga Biosphere Reserve, the total area of the Eastern Himalaya (524190 sq.km), the low potential threshold class (32678.37 sq.km) was highest one followed by the moderate potential threshold class (9868.73 sq.km), the high potential (5900.22 sq.km), and the very high (13613.36 sq.km). Similarly, In Sikkim, out of the total area, 7090 sq. km, the very high potential threshold class (1981.96 sq.km) was emerged highest followed by the low potential threshold class (656.95 sq.km), the moderate potential threshold class (421.00 sq.km), and the high potential threshold class (300.71 sq.km). Whereas, in Khangchendzonga Biosphere Reserve, out of 2931.12 sq. km the total area of the Khangchendzonga Biosphere Reserve, the very high threshold class (637.2) was emerged highest followed by the low potential

(205.99 sq.km), the moderate potential (136.25 sq.km), and the high potential (96.18 sq.km)[Figure 3.9].

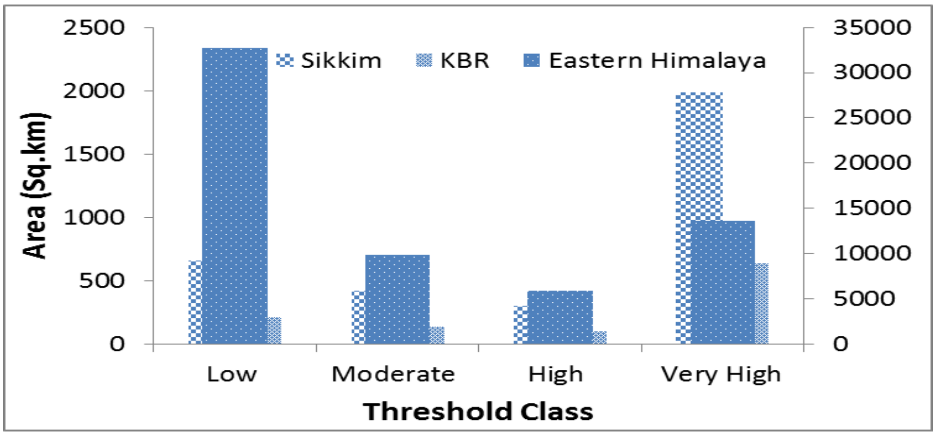

Figure 3.9: Area of potential threshold class of Kalij Pheasant in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR).

4.3.1.4. Current habitat distribution model of Satyr Tragopan

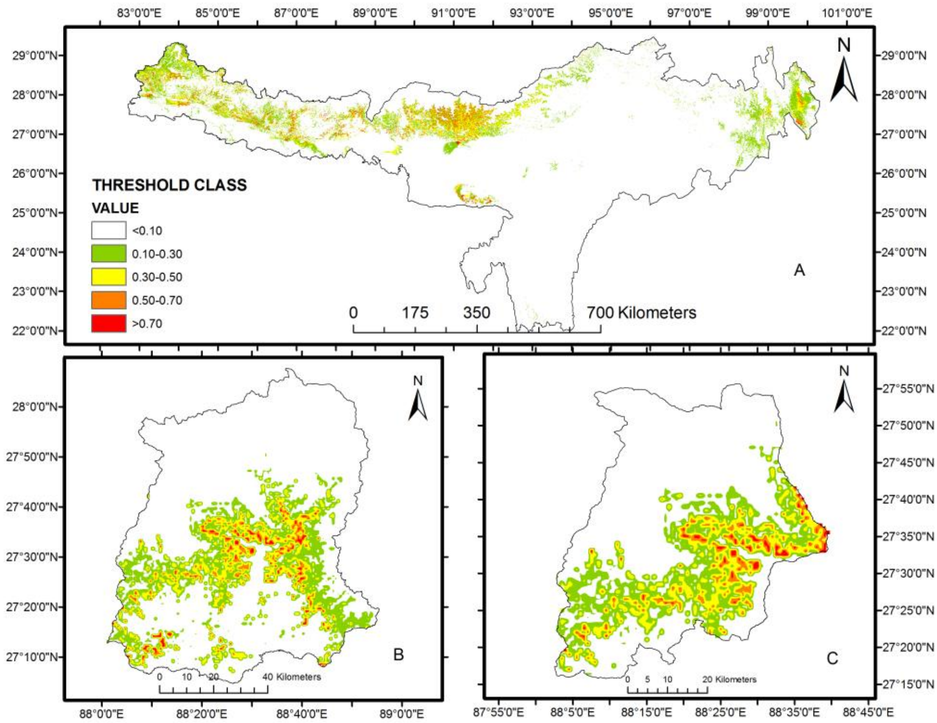

Figure 3.10: SDM of Satyr Tragopan depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential suitability in Eastern Himalaya (A), Sikkim (B) and Khangchendzonga Biosphere Reserve (C).

The result of the model calibration test for Satyr Tragopan (AUC $_{train}$= 0.997±0 and AUC $_{test}$=0.958±0.20) was found better than random (AUC=0.5).

Table 3.4: Environmental parameters and its associated variables used in the study and their percentage contribution to the prediction present Species Distribution Model (SDM) developed for potential habitat of Satyr Tragopan in the Himalayas

Parameter	Variable	Percent contribution	Permutation importance
Physical	1. Red Reflectance	2.5	1.9
	2. Blue Reflectance	2	2.8
	3. Solar Azimuth Angle	13.6	2.9
	Sub-total	18.1	7.6
Topography	1. Altitude	14.1	42.4
	2. Slope	4.9	0.2
	3. Aspect	5.7	4.1
	Sub-total	24.7	46.7
Biophysical	1. NDVI (Normalized difference vegetation index)	18.1	14.9
	2. EVI (Enhanced vegetation index)	13.1	3
	3. VI (Vegetation index)	2.9	0.5
	Sub-total	34.1	18.4
Climate	1. Bio2 (Mean diurnal range (mean of monthly (max temp - min temp))	2.5	6.7
	2. Bio3 (Isothermality (P2/P7) (*100))	4.5	5.6
	3. Bio4 (Temperature seasonality (standard deviation *100)	3.7	11.1
	4. Bio7 (Temperature annual range (P5–P6))	8.6	0.5
	5. Bio14 (Precipitation of driest month)	0.9	1
	6. Bio15 (Precipitation seasonality (coefficient of variation)	0.2	1.4
	Sub-total	20.4	26.3
Mosaic landscape	1. LULC (Land use and land cover)	2.6	0.8

[a]Above tabulated variables used in the modelling, selected through the multicollinearity test (PCA)

Among the inputs as environmental predictors of different parameters, namely, Physical parameter, Topography parameter, Biophysical parameter, Climate parameter and Human-modified mosaic landscape parameter, the Biophysical parameter (34.1%) had highest contribution to the model followed by Topography (24.7%), Climate (20.4%), Physical (18.1%), and Human- modified mosaic landscape (2.6%). Out of the applied input variables, Normalized Difference Vegetation Index (NDVI, 18.1%) was the highest performer for the prediction map followed by Altitude (14.1%), Solar Azimuth Angle (13.6%), Enhanced Vegetation Index (EVI, 13.1%) and Bio7 {Temperature annual range (Bio5-Bio6), 8.6%)} [Table 3.4]. The model demonstrates the currently suitable habitat of Saytr Tragopan individually in the Eastern Himalayas, Sikkim Himalayas, and Khangchendzonga Biosphere Reserve, where habitat spans from moist, temperate broadleaved-coniferous and rhododendrons forest with dense undergrowth including bamboo. The potential habitat area of the Satyr Tragopan was quantified into four potential threshold categories in the Eastern Himalayas, Sikkim Himalayas, and Khangchendzonga Biosphere Reserve (Figure 3.10). 0ut of 524190 sq.km area of the Eastern Himalayas, the low potential threshold class (42504.75 sq.km) was covered the maximum area in the model followed by the moderate potential threshold class (17364.32 sq.km), the high potential threshold class (7123.06 sq.km), and very high potential threshold class (2710.04 sq.km). Similarly, out of 7096 sq. km area of Sikkim Himalaya, the low potential threshold class emerged as the highest in the model (1052.83 sq.km) followed by the moderate threshold class (529.19 sq. km), the high potential threshold class (234.07 sq.km), and the very high potential threshold class (222.04 sq.km).

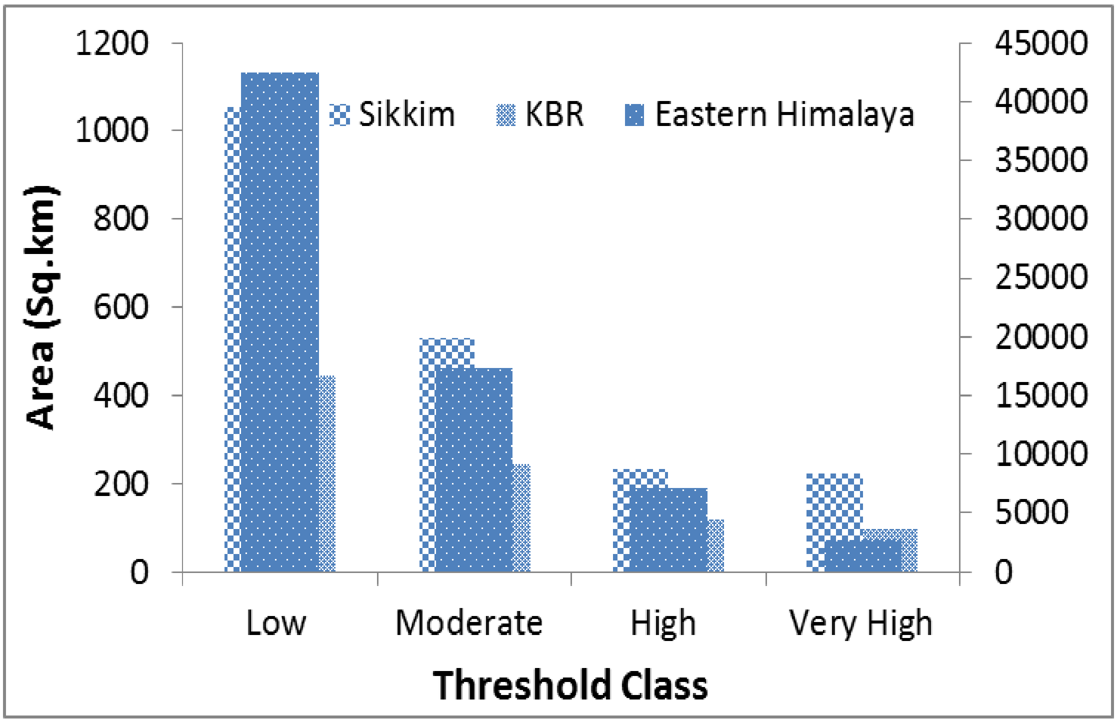

Figure 3.11: Area of potential threshold class of Satyr Tragopan in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR).

In the Khangchendzonga Biosphere Reserve as an independent unit, out of 2931.12 sq. km area; the very high potential threshold class has emerged as the lowest one (96.99 sq.km) followed by the high potential threshold class (120.22 sq.km), the moderate potential threshold class (242.86 sq.km), and the low potential threshold class (444.03 sq.km) (Figure 3.11).

CHAPTER 04

OBJECTIVE 01

DISCUSSION

4.4. DISCUSSION

The MaxEnt model has unique features which allow it to achieve significant results even there is a low number of occurrence records of a species (Hernandez et al., 2006; Pearson et al., 2007). Such the model, offering vital knowledge on the species distribution, is particularly important for the effective conservation planning for a rare, threatened, and endemic species (Thorn et al., 2009). Additionally, MaxEnt modelling does not rely on accounting the historical aspects or geographical barriers that limit the presence of the species in the certain area (Peterson et al., 1999; Soberon & Peterson, 2005). MaxEnt depends on the presence data which lacks many of the complications associated with presence-absence analytical methods compare to others habitat predicting models (Phillips et al., 2006). Therefore, the final distribution map generated by the MaxEnt model the predicting unknown occurrence areas will make it easier to plan a field survey for exploring the presence of the target species with greater confidence (Peterson et al., 2007; Voskamp et al., 2014). However, many species are reported as threatened only by limited sighting along well established routes and transects, without mentioning specifics of any systematic and scientific assessment of population data and exact locations of species' individuals (Vetaas, 2000; Badola & Pradhan, 2010a, b; Pradhan & Badola, 2015), which are largely depending upon local perceptions, which might be misleading for their ecological status. MaxEnt modelling study will be a more effective tool to identify the distribution pattern of a species and easy to evaluate whether that species is really endangered in natural habitats and on its status in the ecological categorization. Moreover, such modelling may offer greater chances to get unexplored populations of the target species in the predicted new area.

The important associated environmental variables of the Satyr Tragopan such as Normalized Difference Vegetation Index (NDVI), Altitudinal gradient, Solar Azimuth Angle, Enhanced Vegetation Index (EVI), Bio 7, and Bio 6 were identified. Similarly, for the Blood Pheasant, Blue reflectance, Bio-3, Solar Azimuth Angle, Bio-9, Bio-11, and Normalised Difference Vegetation Index were important associated environmental variables. For the Himalayan Monal, Solar Azimuth Angle, Bio-3, Blue reflectance, Bio-4, Vegetation Index, and Bio-11 were important associated environmental variables. For Kalij Pheasant, Solar Azimuth Angle, Blue reflectance, Bio-4, Bio-7, Enhanced Vegetation Index, and Red reflectance were the important environmental variables identified. Overall the prediction of the Himalayan Pheasants, the very high potential threshold class of the Kalij Pheasant was highest in the area covered in the Eastern Himalayas followed by the Blood Pheasant, Satyr Tragopan, and Himalayan Monal. Similarly, in Sikkim, the very high potential threshold class of the Kalij Pheasant was highest in the area covered followed by the Satyr Tragopan, Himalayan Monal, and Blood Pheasant. In the Khangchendzonga Biosphere, the very high threshold class of the Kalij Pheasant was highly covered in the area followed by the Satyr Tragopan, Himalayan Monal, and Blood Pheasant.

Photoplate-03

Plate 03: A glimpse of mesmerizing landscape of the study area; view from Dzongri top (A), abandoned yak stall (B), view from Deorali, and Kisong Lake (D).

CHAPTER 05

OBJECTIVE 02

To study of the potential forest communities and habitat composition of Himalayan pheasants along potential altitudinal gradients.

CHAPTER 05

OBJECTIVE 02

BACKGROUND

Chapter 05

Objective- 02

To study of the potential forest communities and habitat composition of Himalayan pheasants along potential altitudinal gradients

5.1. Background

An interaction between animal and its habitat is directly associated within and between the ecosystem and their environmental gradients, which is a vital area of research in the present scenario for biodiversity conservation assessment theme (Chhetri et al., 2017). The Himalayas has a wide altitudinal variation (c.300-8000 m asl) including many biogeographical realms along with high altitudinal amplitude, high slopes and climatic condition (tropical hot to arctic cold), are driving forces for high variation in vegetation type even a small distance. The quest to understand the pattern of vegetation composition structure, its diversification, pattern of change, and the forces behind its diversification along the altitudinal gradients as well as in different climatic condition has always added the fuel to the researchers for the intensive field studies all over the world (Sinha et al., 2018). Even many regions of Himalaya are under-surveyed or un-surveyed due to their tough topography and harsh climatic condition (Chhetri & Badola, 2017); although, the works of Darwin, Wallace, and Von Humboldt are considered to the primary initiatives taken to analyze the change of natural world along elevation (Lomolino, 2001). The study patterns in the Himalayan region in the present scenario are getting deeper into finding the relation of the variation of the vegetation composition structure to various spatial and environmental gradients (Acharya et al., 2011) under the impact of climate change (Gaire et al., 2014). Although, the species composition and richness depend directly on the altitudinal factors like temperature and air pressure, and factors independent to altitudinal variations such as precipitation and cloud cover (Kromer et al., 2013). Globally, biodiversity is under pressure by climate change and anthropogenic pressures, which affect both floral and faunal components, which further, may increase the risk of vulnerability as some of the species show the extremely poor level of adaptation to altered habitats (Lovejoy, 1986; Vermeij, 1986). Therefore, threatened habitat alternation suggests the certain habitats and species are shown the high level of risk of extinction (Terborgh & Winter, 1980; Slobodkin, 1986; Dunn et al., 2016). In Sikkim Himalayas, it has been observed that many threatened birds species found of the landscape of which most of them are confined to restricted elevation range of the region (Acharya et al., 2011) for their specific ecological niche requirements (Chhetri et al., 2017). Due to anthropogenic pressure, habitat fragmentation along with climate change within a restricted range of these birds are becoming more sensitive and vulnerable, hence the immediate task needs to formulate their improved conservation and habitat management strategies, especially in protected areas (Basnet & Badola, 2012; Chhetri et al., 2017). Therefore, the study on pheasants' diversity, distribution, and abundance alone without understanding their habitat synchronization would be inadequate for complete and quality research because either is ecologically inter-related.

CHAPTER 05

OBJECTIVE 02

MATERIALS & METHODS

5.2. Materials and Methods

5.2.1. Area recognized for the study

Sikkim is a part of Eastern Hindu-Kush Himalayas, are contiguous with one of 34 global biodiversity hotspots (Mittermeier et al., 2004). The elevation gradients start from 300 to 8586 m asl, with a beautiful picturesque landscape of the guardian deity of Sikkim, the Mt. Khangchendzonga (8586 m asl), the third highest peak in the world, and comprising many protected areas, including Khangchendzonga Biosphere Reserve (KBR), which recently inscribed as the World Heritage Site on 17 July 2016 by UNESCO (United Nations Educational, Scientific and Cultural Organization), with a geographical location of 27°15’-27°57’ N latitude and 88° 02’-88°40’ E longitude is an important protected area for the conservation of biodiversity, highly enriched flora and fauna, unique in its geographical terrains and with immense natural beauty in the Himalayan Region. The core zone of KBR, as the Khangchendzonga (High altitude) National Park, a major transboundary area, represents unique habitat zone and high endemic flora and fauna. The biosphere reserve falls in the North and West districts of Sikkim state in the north-eastern region of India, neighbouring Nepal in the west and China (Tibet) in the north-west (Badola & Subba, 2012). KBR is represented as one of the richest plant diversity centres in Himalaya for its unique geographical location covering from sub-tropical to arctic region. A wide range of physiography and eco-climate gradients have fully expressed them for providing a rich gene pool of both wild and cultivated plants species. Many plant species from the neighbouring region and far off countries namely Nepal, Bhutan, China, Tibet, Myanmar, Malaysia and to a lesser extent to Peninsular Indian affinities as well as a good number of endemic species are met within this reserve and can be broadly classified in subtropical, temperate and alpine forest types. In KBR, the Yusom-Black Kabru (Dome) transect in West Sikkim and the Tholung-Kisong transect in North Sikkim were identified to access habitat composition of the Himalayan Pheasants. In both the transects, c. 1800-4300 m asl altitudinal gradients were covered to assess the habitat composition of the Himalayan Pheasant of the KBR.

5.2.2. Collection of relevant information

At first, secondary information was collected from the extensive review of the literature and institutional libraries on Khangchendzonga Biosphere Reserve, as well as by taking local perceptions of the people who are related to KBR. The secondary data whatever possible was collected. Based on field visits and interactions with native people who are inhabitants in the buffer and transition zone (western and northern part of Sikkim) of the Khangchendzonga Biosphere Reserve, two major transacts were identified for the biodiversity studies in the wilderness. These are, Yuksom- Mt. Black Kabru (Dome), located in West district of Sikkim and Tholung-Kisong transect in North district of Sikkim. The field studies were conducted in the landscapes for recording information about the study of the vegetation and biodiversity. The help of local folks especially guides and porters were taken for their perception on various changing patterns, besides primary observations.

5.2.3. Field sample collection

Woody vegetation composition structures were studied using stratified random sampling in the target sites. The potential transacts for vegetation was laid down random; stratification and depending upon the requirements, different sites were identified based on homogeneity composition of forest and altitude. For the trees, 10 quadrats of 10 mx10 m size at each site were laid down, within each 10 m x10 m quadrat, 5mx5m size were taken for the shrubs and the sapling, for the seedling 10 quadrats of 1mx1m size were taken. While sampling, due care was taken to sample the most representative area for each site.

5.2.4. Climate data collection

Due to tough topography of the mountainous landscape and lack of weather stations in the study area the climate data for the exact targeted site along the altitudinal gradients were not available. Therefore, the necessary climate data were downloaded for the study area from Global Weather data for SWAT (http://globalweather.tamu.edu/), as CFSR (Climate Forecast System Reanalysis) data of 2013, as followed by Fuka et al., 2014 and Dile et al., 2016). Depending upon the availability and accessibility, crucial climate data like maximum and minimum temperature, precipitation and humidity of the selected nine sites at different altitudes (108 m, 121 m, 144 m, 299 m, 653 m, 1272 m, 1779 m, 3170 m and 3366 m asl.) were procured for the year 2013. Based on these data, estimation was done for the maximum temperature, minimum temperature, precipitation, and relative humidity of all the study sites of the transect by using regression equations: maximum temperature= -0.004(elevation) +28.94 ($p<0.001$), minimum temperature= -0.002(elevation) +17.44 ($p<0.02$), Precipitation= -0.001(elevation) +9.359 ($p<0.04$) and relative humidity= -2E-05(elevation) +0.520 ($p<0.1$) (similar approach also followed by Acharya et al., 2011). From these climate data, the factors affecting the forest composition and structure, such as Potential evapotranspiration, PET (Bhattarai et al., 2004a), Actual evapotranspiration, AET (Truc, 1954) and Moisture Index, MI (Bhattarai et al., 2004a) for all the studied sites were quantified. The quantification was done for these values using the formulae; (PET= Mean annual Bio Temperature, i.e. temperature >0˚C x 58.93; MI= PET/Mean annual Precipitation; AET= P/ [0.9+ (P/L) 2]1/2 with $L=300+25T+0.05T^3$)

5.2.5. Data analysis

The procured data of woody vegetation were quantitatively analysed for density, relative density, relative frequency and relative dominance using formulae given by Misra (1968) and quantified the Important Value Index (IVI: Relative density +Relative frequency +Relative dominance). To evaluate species diversity for each site, Shannon and Wiener index (1963) and Simpson's index (1949) were applied, which are given as,

$$H' = -\sum_{i=1} (n_i/N) \log_2 (n_i/N)$$

Where n_i represents a total number of individuals of particular species and N represents the total number of individuals of all species. The Index of species evenness was determined by Shannon index of species evenness, which can be expressed as, **E=H'/ln(S);** where, H = Shannon's index of diversity, and S = number of species in the sample; species dominance was quantified by Simpson's Index (1949), as,

$$D = \sum_{i=1} (n_i/N)^2$$

Where n_i represents a total number of individuals of particular species and N represents the total number of individuals of all species.

Species richness was quantified by using Margalef's index $\boldsymbol{I} = (\boldsymbol{S}\text{-}\mathbf{1}) / \ln(\boldsymbol{N})$; Where, S = the number of species in the sample; and *N* = the total number of individuals in the sample.

5.2.6. Statistical analysis

The statistical parameters were used such as Pearson correlation, Linear regression, Estimators (Choa 1& Jackknife 1), Cluster analysis, and Species-abundance Distribution Model to better understand the dynamism of the forest communities' composition in the transect.

CHAPTER 05

OBJECTIVE 02

RESULTS

5.3. Results

5.3.1. Habitat composition along altitudinal gradient in Yuksom-Black Kabru (Dome) Transect in western KBR

A total of 17 major sites of different altitudes was identified for habitat assessment of the Himalayan Pheasant in Yuksom-Black Kabru (Dome) transect (Khangchendzonga Biosphere Reserve), covering from baseline 1800 m-4300 m asl (warm temperate-alpine region) almost 30 km apart. Out of 17 sites, 03 sites were identified in the alpine region. The total 107 woody species were recorded within the transect. A total of 99 woody species could be identified under 34 families. For the final reporting was done for only 99 species for the study transect covering 17 major sites (Table 4.1).

Table 4.1: List of woody species found along the transect (Yuksom-Black Kabru Dome transect)

Botanical name of woody taxa	**Family**
1. *Abies densa* Griff.	Pinaceae
2. *Acer campbellii* Hook.f. and Thomson ex Hiern.	Sapindaceae
3. *Acer caudatum* Wall.	Sapindaceae
4. *Acer pectinatum* Wall. Ex G.Nicholson.	Sapindaceae
5. *Acer sikkimensis* Miq..	Sapindaceae
6. *Acer stachyophyllum*Hiern.	Sapindaceae
7. *Aconogonum* sp.	Polygonaceae
8. *Aconogonum molle* (D. Don) H. Hara.	Polygonaceae
9. *Actinodaphne sikkimensis*	Lauraceae
10. *Alnus nepalensis* D.Don	Betulaceae
11. *Ardisia macrocarpa* Wall.	Primulaceae
12. *Artemisia vulgaris* L.	Compositae
13. *Beilschmiedia sikkimensis* King ex Hook.f.	Lauraceae
14. *Berberis aristata* DC.	Berberidaceae
15. *Betula alnoides* Buch.-Ham. Ex D.Don	Betulaceae
16. *Brassaiopsis alpine* C.B.Clarke.	Araliaceae
17. *Brassaiopsis hispida* Seem.	Araliaceae
18. *Castanopsis hystrix* Hook.f.and Thomson ex A. Dc.	Fagaceae

19. Castanopsis tribuloides (Sm) A.Dc.	Fagaceae
20. Castronopsis sp.	Fagaceae
21. Cedrela febrifuga Blume	Meliaceae
22. Cinnamomum cecidodaphne Meisn.	Lauraceae
23. Cinnamomum impressinervium Meisn.	Lauraceae
24. Daphne cannabina Wall.	Thymelaeaceae
25. Deberegeasia velutina Gaud.	Urticaceae
26. *Dichroa febrifuga* Lour	Hydrangeaceae
27. Echinocarpus dasycarpus Benth.	Elaeocarpaceae
28. Edgeworthia gardneri (Wall.) Mesin	Thymelaeaceae
29. Elaeocarpus lanceifolius Roxb.	Elaeocarpaceae
30. *Sorbus cuspidata* (Spach) Hedl	Rosaceae
31. Engelhardia spicata Blume.	Junglandaceae
32. Eriobotrya petiolata Hook.f.	Rosaceae
33. Eurya accuminata DC*	Pentaphylacaceae
34. Eurya japonica Thunb.	Pentaphylacaceae
35. Evodia fraxinifolia (Hook.) Benth.	Rutaceae
36. Exbucklandia populnea (R.Br. ex Griff.) R.W.Br.	Hamamelidaceae
37. Ficus nemoralis Wall. exMiq.	Moraceae
38. Girardinia palmate Gaud.	Urticaceae
39. Glochidion acuminatum Muell.	Euphorbiaceae
40. Ilex Sikkimensis King.	Aquifoliaceae
41. Juglans regia L.	Juglandaceae
42. Juniperus recurva Buch.-Ham. exD.Don.	Cupressaceae
43. Juniperus sp.	Cupressaceae
44. Leucosceptrum canum Sm.	Lamiaceae
45. Lindera assamica (Mesin.) Kurz	Lauraceae
46. Litsaea citrate Blume.	Lauraceae
47. Lyonia ovalifolia (Wall) Drude.	Ericaceae
48. Macaranga denticulata (Blume) Mull.Arg.	Euphorbiaceae
49. Machilus edulis King ex Hook.f.	Lauraceae
50. Maesa rugosa C.B.Clarke	Primulaceae
51. Maesa chisia Buch.-Ham. ex D. Don	Primulaceae
52. Magnolia campbellii Hook.f. and Thomson	Magnoliaceae
53. Mahonia sikkimensis Takeda	Berberidaceae
54. Michelia excels (Wall.) Blume	Magnoliaceae
55. Micromeles thomsonii C.K. Schneid	Rosaceae
56. Myrsine semiserrata Wall.	Primulaceae
57. Mussaenda sp.	Rubiaceae
58. Nyssa javanica (Blume) Wangerin	Cornaceae
59. Pentapanax leschenaultia (DC.) Seem.	Araliaceae
60. Pilea umbrosa Blume	Utricaceae
61. Prunus cerasoides Buch.-ham. Ex D. Don	Rosaceae
62. Prunus nepalensis Hook.f.	Rosaceae

63. *Prunus undulate* Buch.-Ham. exD.Don.	Rosaceae
64. *Quercus fenestrate* Roxb.	Fagaceae
65. *Quercus lamellose* Sm.	Fagaceae
66. *Quercus lineate* Blume	Fagaceae
67. *Quercus pachyphylla* Kurz	Fagaceae
68. *Rhododendron anthopogon* D. Don	Ericaceae
69. *Rhododendron arboreum* Sm.	Ericaceae
70. *Rhododendron barbatum* Wall. ex G. Don.	Ericaceae
71. *Rhododendron campulatum* D.Don.	Ericaceae
72. *Rhododendron campylocarpum* Hook.f.	Ericaceae
73. *Rhododendron dalhousieae* Hook. f.	Ericaceae
74. *Rhododendron falconeri* Hook. f.	Ericaceae
75. *Rhododendron grande* Wight.	Ericaceae
76. *Rhododendron hodgsonii* Hook.f.	Ericaceae
77. *Rhododendron lanatum* Hook. f.	Ericaceae
78. *Rhododendron lepidotum* Wall. ex G. Don	Ericaceae
79. *Rhododendron setosum* D. Don	Ericaceae
80. *Rhododendron thomsonii* Hook.f.	Ericaceae
81. *Rhododendron wightii* Hook.f.	Ericaceae
82. *Rhus insignis* Hook. f.	Anacardiaceae
83. *Rhus succedanea* L.	Anacardiaceae
84. *Rubus ellipticus* Smith.	Rosaceae
85. *Rosa serica* Wall. ex Lindl.	Rosaceae
86. *Rubus paniculatas* Smith.	Rosaceae
87. *Saurauia nepalensis* Dc.	Actinidiaceae
88. *Schefflera impressa* (C.B. Clarke) Harms	Araliaceae
89. *Solanum aculeatissium* Jacq.	Solanaceae
90. *Symplocos glomerata* King ex C.B. Clarke	Symplocaceae
91. *Symplocos ramosissima* Wall. Ex G. Don	Symplocaceae
92. *Symplocos theifolia* D. Don	Symplocaceae
93. *Tsuga dumosa* (D.Don) Eichler	Pinaceae
94. *Urtica parviflora* Roxb.	Urticaceae
95. *Utrica dioca* Linn.	Urticaceae
96. *Viburnum cordifolium* Wall. Ex DC.	Adoxaceae
97. *Viburnum erubescens* Wall.	Adoxaceae
98. *Viburnum* sp.	Adoxaceae
99. *Zanthoxylum armatum* D.C	Rutaceae

Out of 99 woody species, 34% shrub species and 66% tree species were recorded in the Yuksom-Black Kabru (Dome) Transect (Figure 4.1).

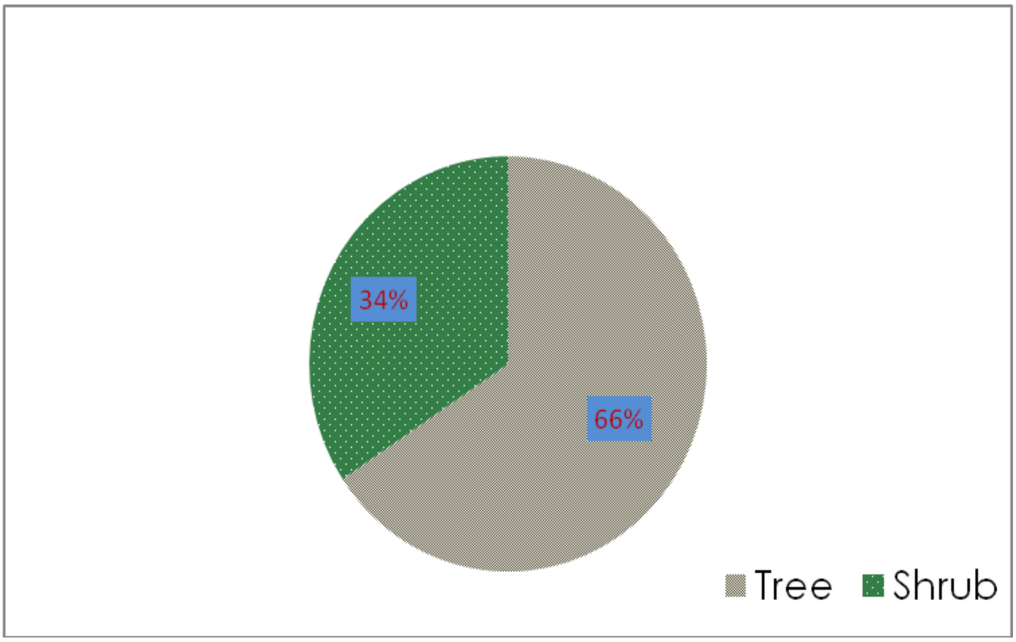

Figure 4.1: Percentage of tree and shrub in Yuksom-Black Kabru transect of the Khangchendzonga Biosphere Reserve.

Out of 34 families of woody taxa (Table 4.1), the family-wise distribution of species was quantified along the transect. The family Ericaceae (15) emerged as the most dominant family for the maximum number of species in the transect followed by Rosaceae (09), Lauraceae (07), and Fagaceae (07) (Figure 4.2) followed the same. It has been observed that the family Ericaceae was the most diverse in high altitude zone, which could be a more suitable habitat for *Rhododendron* spp. The family of Rosaceae and Lauraceae was evenly distributed along the transect but the family Fagaceae was confined up to 2900 m asl.

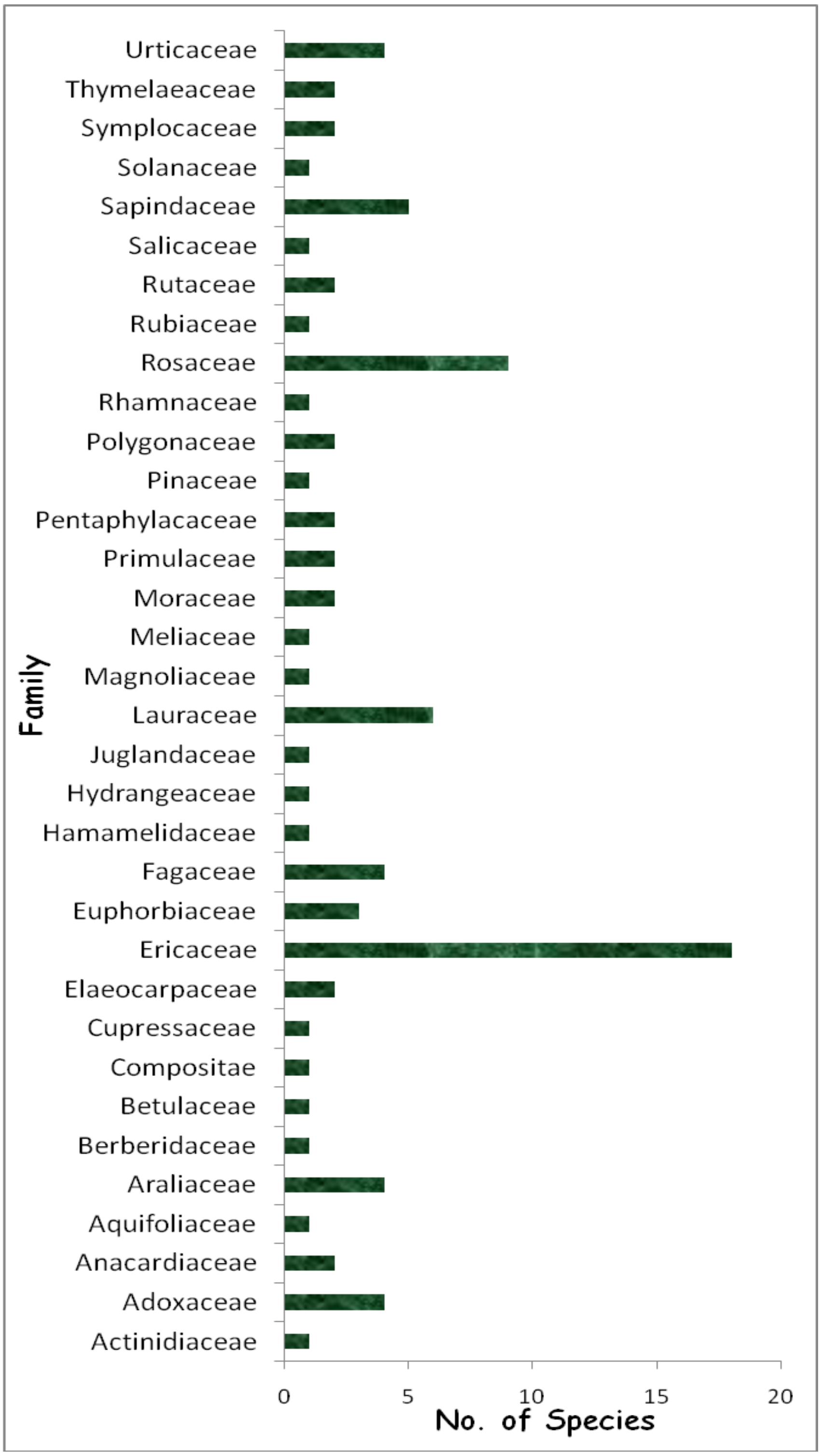

Figure 4.2: Family wise distributions of woody species along Yuksom-Black Kabru Dome transect, Khangchendzonga Biosphere Reserve.

5.3.1.1. Abundance and regeneration pattern of woody species

The maximum number of adult individuals were recorded at 4000 m asl (2070 individuals/hectare) and the minimum number was quantified at 2800 and 2600 m asl (200 individuals/hectare). Good numbers of saplings and seedlings were observed in the lower altitude zone, in comparison to the higher altitudes. In the middle zone of the transect showed the least number of individuals of sapling and seedling. Based on the procured field data on woody taxa for the entire study transect, a good regeneration pattern of sapling and seedling is seen in the low altitude zone, i.e. in warm temperate broad-leaved forests. Whereas, the most sensitive zone of the regeneration trend of sapling and seedling in the forest has been identified between the altitudinal range of 2600 - 2900 m asl (200-500 individuals/hectare) based on the lower number of sapling and seedling. The maximum number of individuals of sapling (11320 individuals/hectare) and seedling (15465 individuals/hectare) was recorded at 1800 m asl. It could be the reason this forest site comes under the fringe area of the private land, which might previously be used by the local villagers for their basic needs. So that, the adult individuals of woody plants were comparatively lower than the other sites of warm temperate forests in the transect (Figure 4.3).

5.3.1.2. Basal area cover along the transect

The maximum basal area of adult woody species was recorded at 2000 m asl (511.6019 sq. meter/hectare) and the minimum basal area of adult woody species 26.596 sq.m/hectare at 4000 m asl (Figure 4.4). The basal area of sapling (45.79 sq. meter/ hectare) and seedling (23.27 sq. meter/ hectare) of woody species was observed good at 1800 m and the lowest one was observed at 2600 and 2800 m asl, whereas, basal area of the adult woody species at 1800 m asl was comparatively lower than other warm temperate broad-leaved forest sites. It could be the reason that the forest site comes under the fringe area and which might have overexploited in the past decades, so no more aged tree encountered at the altitude (Figure 4.4).

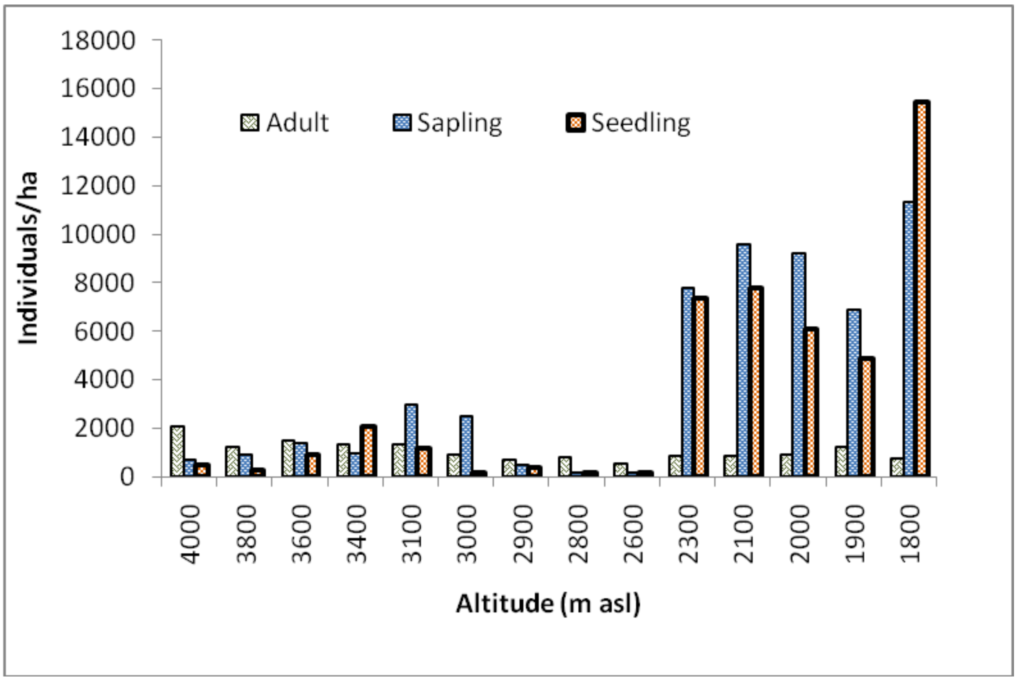

Figure 4.3: Abundance in a hectare of woody species along transect of Yuksom-Black Kabru in the Khangchendzonga Biosphere Reserve.

5.3.1.3. Abundance and basal area of scrub of alpine region

Out of 17 study sites, 03 sites were identified from 4100 - 4300 m asl in scrubs vegetation of the alpine region; the maximum number of individuals were encountered at 4100 m asl (10640 individuals/hectare) and minimum individuals at 4200 m asl (9120 individuals/hectare), whereas, the highest basal area was quantified at 4200 m asl (Figure 4.5).

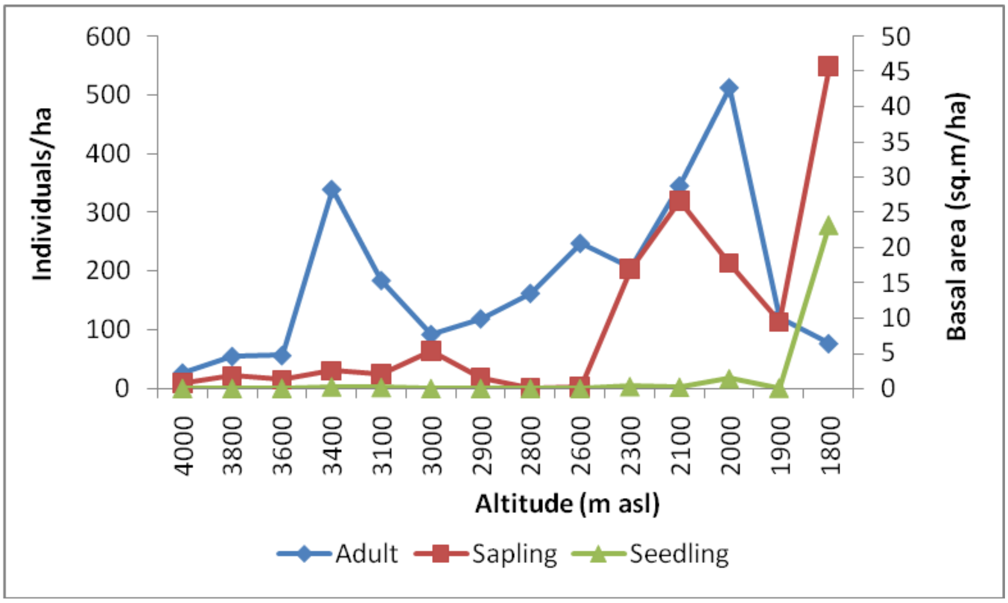

Figure 4.4: Basal area in a hectare of woody species along transect of Yuksom-Black Kabru in the Khangchendzonga Biosphere Reserve.

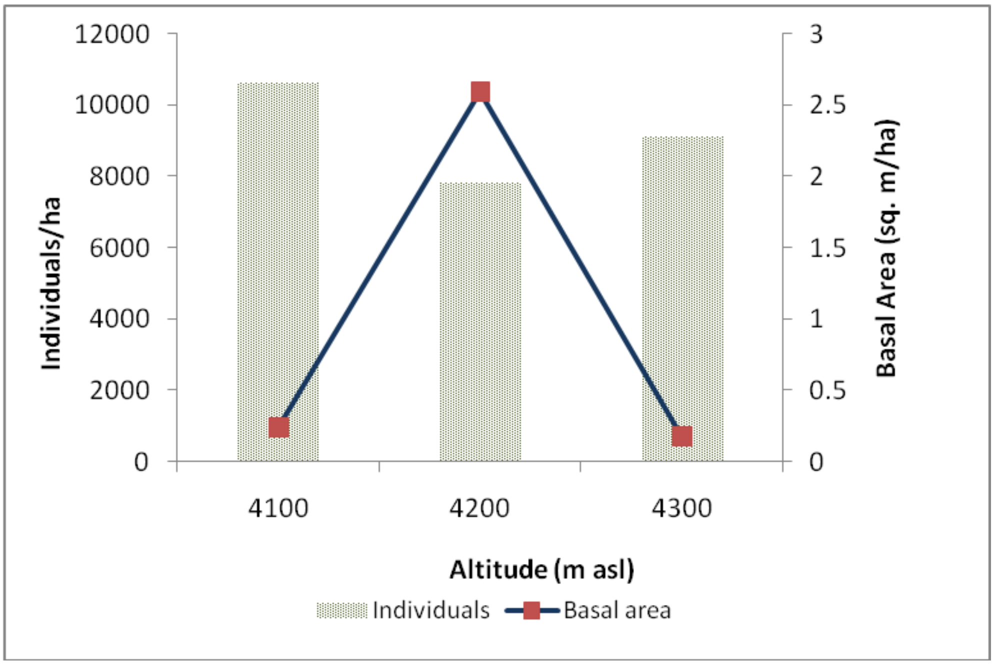

Figure 4.5: Abundance and basal area in hectare of scrubs species in the alpine along transect of Yuksom-Black Kabru in the Khangchendzonga Biosphere Reserve.

5.3.1.4. Ecological indices

Ecological indices such as Margalef's Index of Species Richness, Shannon Index of Species Evenness, Simpson's Index of Dominance and Shannon-Weiner Diversity Index of 17 major sites of the transact were quantified.

Species Richness

The species richness of woody species was negatively correlated with altitude and the regression equation between species richness and altitude, y=-0.016x+66.25 (R^2=0.710) was quantified. The value was ranked from 3.82-58.87 (±18.38) within the transect of the study area (Figure 4.6).

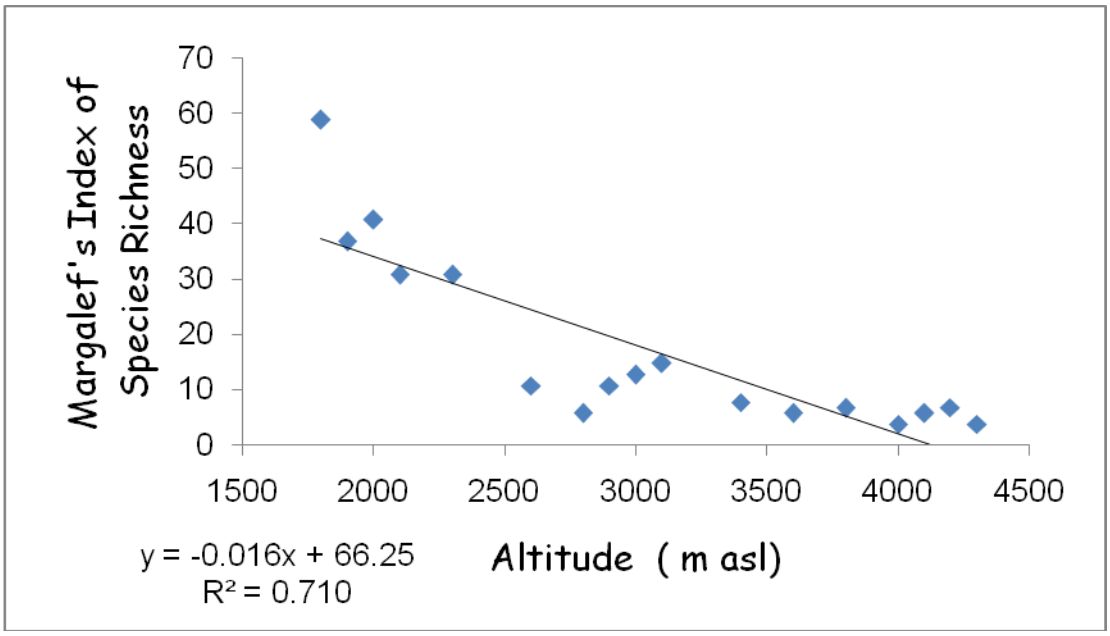

Figure 4.6: Species Richness Index vs. altitude along transect of Yuksom-Black Kabru in the Khangchendzonga Biosphere Reserve.

Shannon-Wiener Diversity Index

The Shannon-Wiener Diversity Index of woody species was negatively correlated with altitude and the regression equation between Shannon-Wiener Diversity and altitude, y=-0.001x+4.968 (R^2=0.863) was quantified. The value was ranked from 0.318-3.176 (±1.008) within the transect of the study area (Figure 4.7).

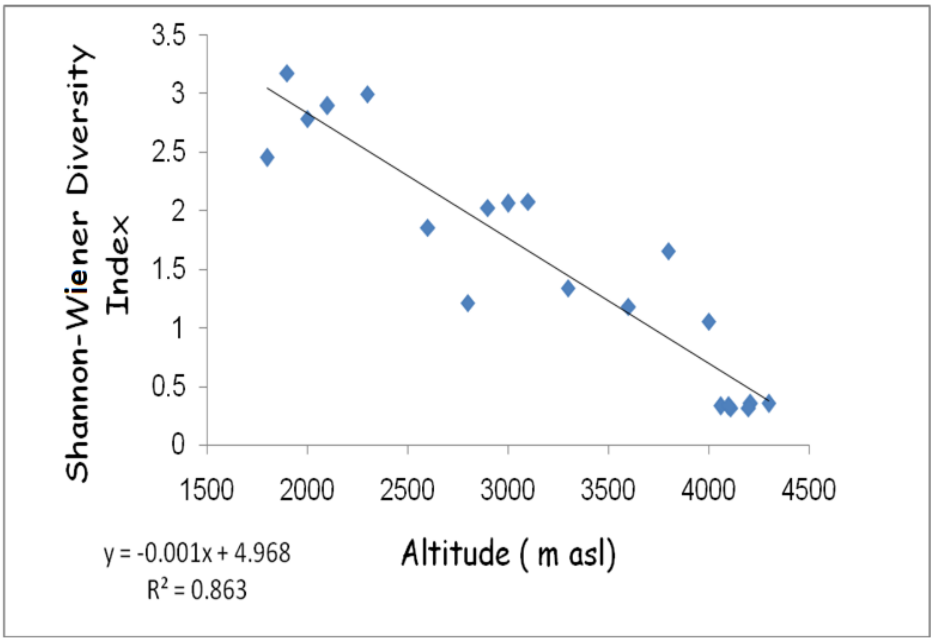

Figure 4.7: Diversity Index vs. altitude along transect of Yuksom-Black Kabru in the Khangchendzonga Biosphere Reserve.

Simpson's Index of Dominance

The Simpson's Index of Dominance of woody species was slightly positively correlated with altitude and the regression equation between Simpson's Index of Dominance and altitude, y=9E-05x-0.021 (R^2=0.38) was quantified. The value was ranked from 0.05288-0.45233 (±0.13887) within the study transect (Figure 4.8).

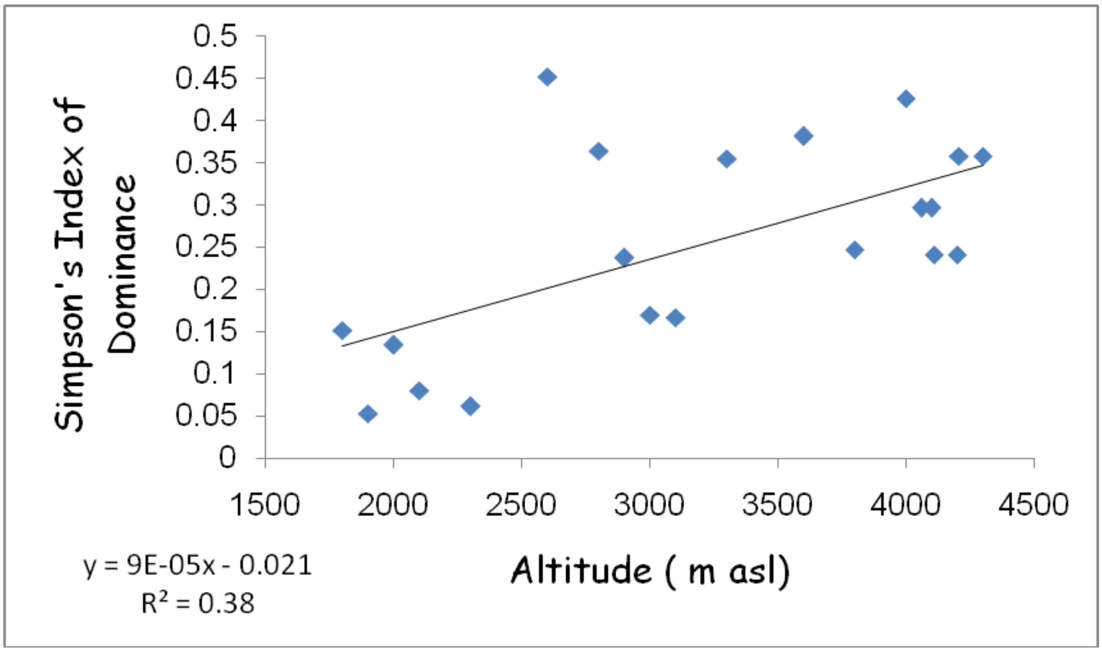

Figure 4.8: Index of Dominance vs. altitude along transect of Yuksom-Black Kabru in the Khangchendzonga Biosphere Reserve.

Shannon Index of Species evenness

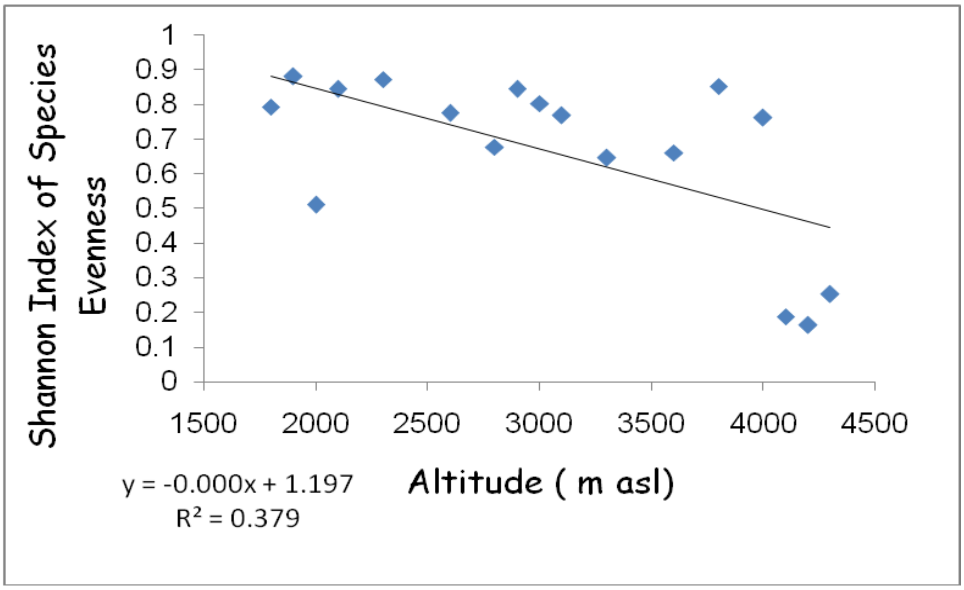

Figure 4.9: Species Evenness Index vs. altitude along transect of Yuksom-Black Kabru in the Khangchendzonga Biosphere Reserve.

The Shannon Index of Species Evenness of woody species was negatively correlated with altitude and the regression equation between species richness and altitude, y=-0.000x+1.197 (R^2=0.379) was quantified. The value was ranked from 0.1632-0.881 (±0.2610) within the transect of the study area (Figure 4.9).

5.3.1.5. Cluster analysis for the forest structure and composition

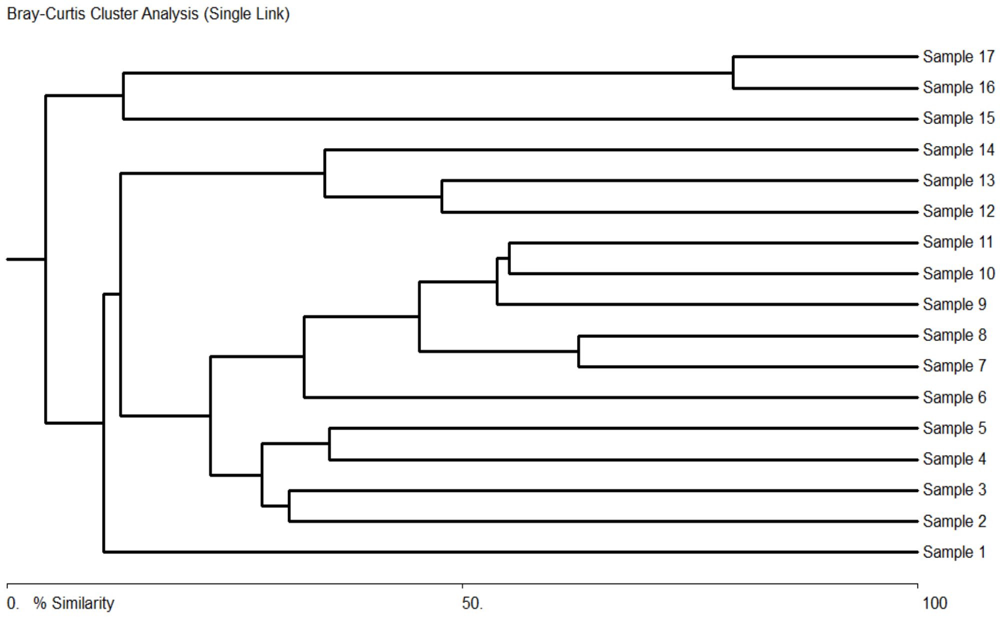

Figure 4.10: Cluster Analysis showing the similarity group among the study sites (Yuksom-Black Kabru transect) in the KBR.

The cluster analysis among the samples of the seventeen sites provided the picture of their forest composition structure as well as homogeneity and heterogeneity level along the altitudinal gradient (Figure 4.10). Accordingly, the site 16 and 17 showed the maximum species composition similarity (>50%) among all sites followed by site 7 & 8, and 11 & 10. Cluster analysis also revealed that the site 1 & 2 showed the maximum species composition dissimilarity followed by site 4 & 5.

5.3.1.6. Estimator Choa and Jackknife

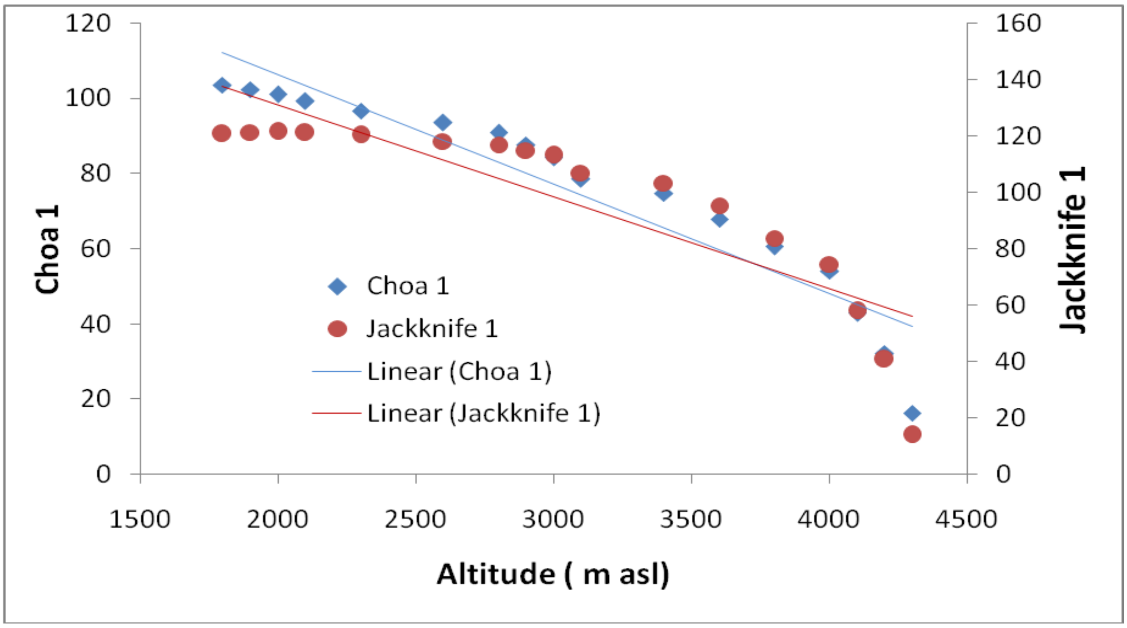

Figure 4.11: Estimated (Choa 1and Jackknife 1) species richness of the woody taxa along in Yuksom-Black Kabru transect of the KBR.

Quantified species estimator, namely Choa 1 and Jackknife 1 were correlated with the altitudinal gradients of the study area. A total of 99 woody species were recorded in the transect, however, the Choa 1 (103 species) and Jackknife 1 (121 species) were estimated. Similarly, a regression line drew between species estimators and the altitudinal gradient and the significant negative quadratic relations quantified as, Choa 1 (y=-0.029x+164.68, R2=0.8883, P<0001) and Jackknife 1 (y=-0.0327x+196.58, R2=0.746, P<0001) (Figure 4.11). Likewise, a declining trend of species estimator was observed in respect to increasing altitudinal gradient in the forest. As per species estimator, there may be more possibilities to find new species in the forests.

5.3.1.7. Species-Abundance distribution model

The four models were used to describe the species-abundance distribution pattern of ecological community such as geometric, log series, truncated log-normal and MacArthur's broken stick.

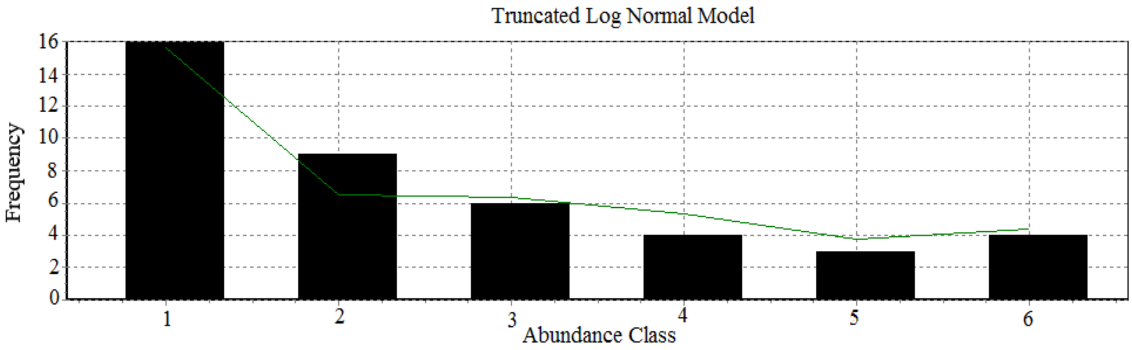

Figure 4.12: Truncated Log-Normal distribution pattern of woody taxa of Yuksom-Black Kabru (Dome) transect in the KBR.

Among the four models for vegetation data of the Yuksom-Black Kabru transect, the truncated log-normal distribution pattern appeared best fitted and that showed no significant difference of the observed and expected number of species in each abundance class (Chi=1.50341; p= 0.912676; df=5). In the truncated log-normal distribution model- observation in the species-abundance distribution pattern showed that a few species were rare in the forest community (Figure 4.12).

5.3.2. Habitat composition along altitudinal gradient in Tholung –Kisong Transect in northern KBR

A total of 17 major sites of different altitudes was identified for habitat assessment of Himalayan Pheasant in Tholung-Kisong transect (Khangchendzonga Biosphere Reserve), along 1800 m-4300 m asl (warm temperate-alpine region) almost 30 km apart. Out of 17 sites, 03 sites were from the alpine region. The total 95 woody species were recorded within the transect whereas 86 species could be identified and 9 species were unidentified. Out of 95, 87 woody species were identified under 33 families. For the final reporting, only 87 species are listed for the studies transect covering 17 major sites (Table 4.2).

Table 4.2: List of woody species found along the transect (Tholung- Kisong transect)

Botanical name of woody taxa	**Family**
1. Abies densa Griff.	Pinaceae
2. Acer campbellii Hook.f. and Thomson ex Hiern.	Sapindaceae
3. Acer caudatum Wall.	Sapindaceae
4. Acer pectinatum Wall. Ex G.Nicholson.	Sapindaceae
5. Acer sikkimensis Miq..	Sapindaceae
6. Acer stachyophyllum Hiern.	Sapindaceae
7. Aconogonum sp.	Polygonaceae
8. Aconogonum molle (D. Don) H. Hara.	Polygonaceae
9. Actinodaphne sikkimensis	Lauraceae
10. Alnus nepalensis D.Don	Betulaceae
11. Artemisia vulgaris L.	Compositae
12. Beilschmiedia sikkimensis King ex Hook.f.	Lauraceae
13. Berberis aristata DC.	Berberidaceae
14.Betula utilis D.Don	Betulaceae
15. Brassaiopsis alpine C.B.Clarke.	Araliaceae
16. Brassaiopsis hispida Seem.	Araliaceae
17.Castanopsis hystrix Hook.f.and Thomson ex A. Dc.	Fagaceae
18. Castanopsis tribuloides (Sm) A.Dc.	Fagaceae
19. Cedrela febrifuga Blume	Meliaceae
20. Cinnamomum cecidodaphne Meisn.	Lauraceae
21. Cinnamomum impressinervium Meisn.	Lauraceae
22. Daphne cannabina Wall.	Thymelaeaceae
23. Daphniphyllum himalayense (Benth.) Müll.Arg	Daphniphyllaceae
24. Deberegeasia velutina Gaud.	Urticaceae
25. Dichroa febrifuga Lour	Hydrangeaceae
26. Echinocarpus dasycarpus Benth.	Elaeocarpaceae
27. Edgeworthia gardneri (Wall.) Mesin	Thymelaeaceae
28. Elaeocarpus lanceifolius Roxb.	Elaeocarpaceae
29. Sorbus cuspidata (Spach) Hedl	Rosaceae
30. Eurya accuminata DC*	Pentaphylacaceae
31. Eurya japonica Thunb.	Pentaphylacaceae

32. *Evodia fraxinifolia (Hook.)* Benth.	Rutaceae
33. *Ficus nemoralis* Wall. exMiq.	Moraceae
34. *Girardinia palmate* Gaud.	Urticaceae
35. *Glochidion acuminatum* Muell.	Euphorbiaceae
36. *Ilex Sikkimensis* King.	Aquifoliaceae
37. *Hovenia dulcis* Thunb.	Rhamnaceae
38. *Juniperus recurva* Buch.-Ham. exD.Don.	Cupressaceae
39. *Juniperus* sp.	Cupressaceae
40. *Leucosceptrum canum* Sm.	Lamiaceae
41. *Litsaea citrate* Blume.	Lauraceae
42. *Lyonia ovalifolia* (Wall) Drude/ Pieris ovalifolia	Ericaceae
43. *Macaranga denticulata (Blume)* Mull.Arg.	Euphorbiaceae
44. *Machilus edulis* King ex Hook.f.	Lauraceae
45. *Maesa rugosa* C.B.Clarke	Primulaceae
46. *Maesa chisia* Buch.-Ham. ex D. Don	Primulaceae
47. *Magnolia campbellii* Hook.f. and Thomson	Magnoliaceae
48. *Mahonia sikkimensis* Takeda	Berberidaceae
49. *Michelia excels* (Wall.) Blume	Magnoliaceae
50. *Mussaenda* sp.	Rubiaceae
51. *Prunus nepalensis Hook.f.*	Rosaceae
52. *Quercus lamellose* Sm.	Fagaceae
53. *Quercus lineate* Blume	Fagaceae
54. *Quercus pachyphylla* Kurz	Fagaceae
55. *Rhododendron anthopogon* D. Don	Ericaceae
56. *Rhododendron arboreum* Sm.	Ericaceae
57. *Rhododendron barbatum* Wall. ex G. Don.	Ericaceae
58. *Rhododendron campulatum* D.Don.	Ericaceae
59. *Rhododendron campanulatum subsp. aeruginosum* (Hook. f.) D.F. Chamb.	Ericaceae
60. *Rhododendron campylocarpum* Hook.f.	Ericaceae
61. *Rhododendron dalhousieae* Hook. f.	Ericaceae
62. *Rhododendron ciliatum* Hook. f.	Ericaceae
63. *Rhododendron falconeri* Hook. f.	Ericaceae
64. *Rhododendron fulgens* Hook. f.	Ericaceae
65. *Rhododendron grande* Wight.	Ericaceae
66. *Rhododendron hodgsonii* Hook.f.	Ericaceae
67. *Rhododendron niveum* Hook. f	Ericaceae
68. *Rhododendron lepidotum* Wall. ex G. Don	Ericaceae
69. *Rhododendron setosum* D. Don	Ericaceae
70. *Rhododendron thomsonii* Hook.f.	Ericaceae
71. *Rhododendron wightii* Hook.f.	Ericaceae
72. *Rhus insignis* Hook. f.	Anacardiaceae
73. *Rhus succedanea* L.	Anacardiaceae

74. Rubus ellipticus Smith.	Rosaceae
75. Rosa serica Wall. ex Lindl.	Rosaceae
76. Saurauia nepalensis Dc.	Actinidiaceae
77. Schefflera impressa (C.B. Clarke) Harms	Araliaceae
78. Solanum aculeatissium Jacq.	Solanaceae
79. Symplocos spicata Roxb	Symplocaceae
80. Symplocos ramosissima Wall. Ex G. Don	Symplocaceae
81. Symplocos theifolia D. Don	Symplocaceae
82. Tsuga dumosa (D.Don) Eichler	Pinaceae
83. Urtica parviflora Roxb.	Urticaceae
84. Viburnum nervosum D. Don	Adoxaceae
85. Viburnum erubescens Wall.	Adoxaceae
86.Viburnum sp.	Adoxaceae
87. *Zanthoxylum armatum* D.C	Rutaceae

Out of 87 woody species, 33% shrub species and 67% tree species were recorded in the Tholung-Kisong Transect (Figure 4.13).

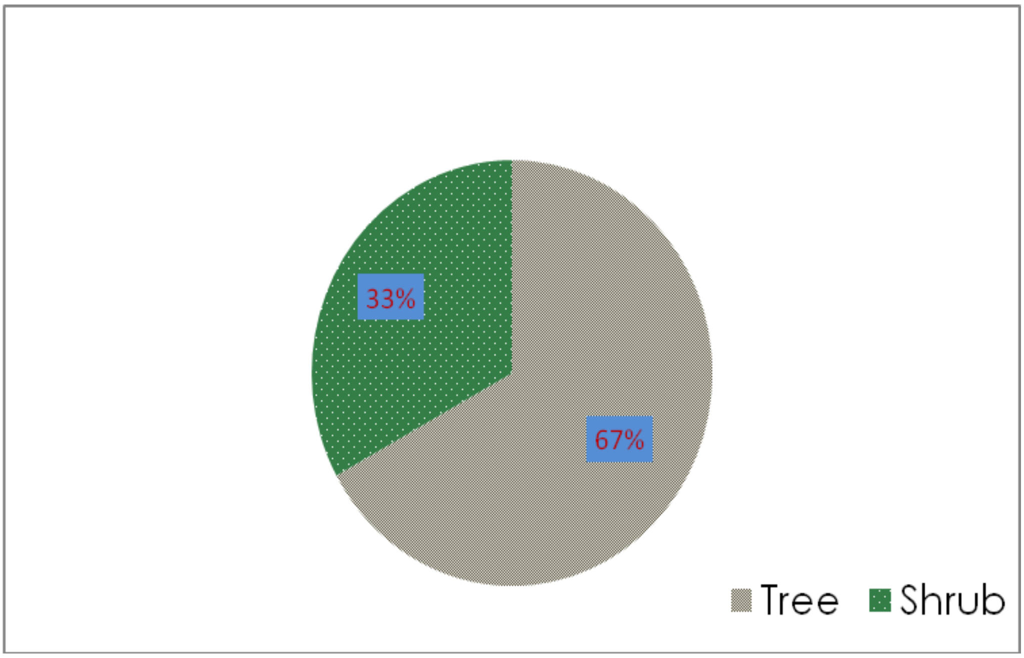

Figure 4.13: Percentage of tree and shrub in Tholung-Kisong transect in the Khangchendzonga Biosphere Reserve.

Out of 33 families of woody taxa (Table 2), the family-wise distribution of species was quantified along the transect, Ericaceae (18) was observed as the most dominant species-rich family in the transect and Lauraceae (06), and Fagaceae (05) followed the same (Figure 4.14). It has been observed that the family Ericaceae was most diverse in the high altitude zone, it could be a more suitable habitat for *Rhododendron* spp.

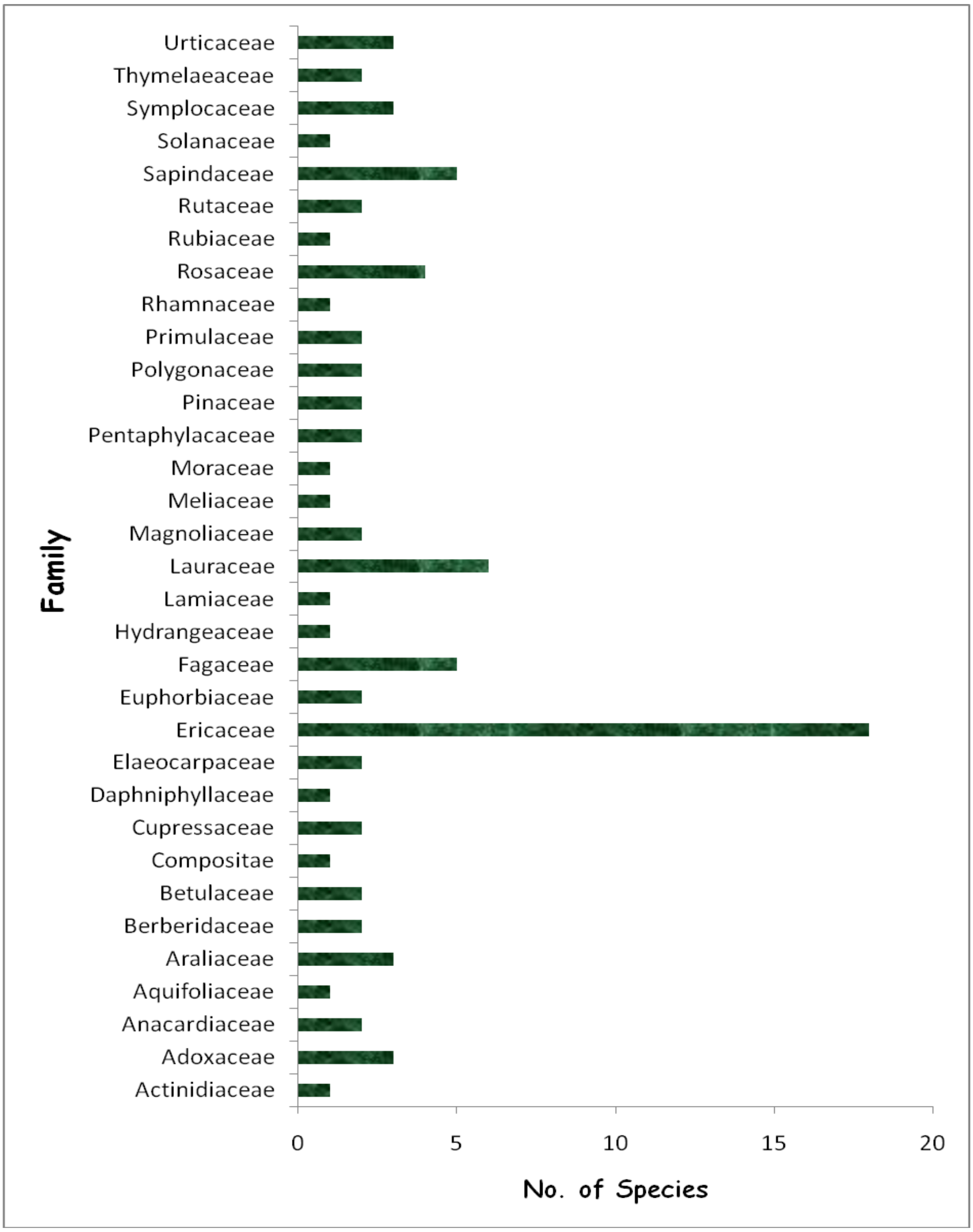

Figure 4.14: Family wise distribution of woody species along Thulong-Kisong transect, Khangchendzonga Biosphere Reserve.

5.3.2.1. Abundance and Regeneration pattern of woody species

The maximum number of adult individuals were recorded at 2900 m asl (9800 individuals/hectare); however, no adult individuals were recorded at 4000 m (Figure 4.15). Good numbers of saplings at 2200 m asl (27640 individuals /hectare) and the least numbers of seedlings at 3000 m asl (1880 individuals/hectare) were recorded. The maximum seedlings (45800 individuals/hectare) and minimum seedlings (1000 individuals/hectare) were recorded at 3100 m asl and 3000 m asl, respectively.

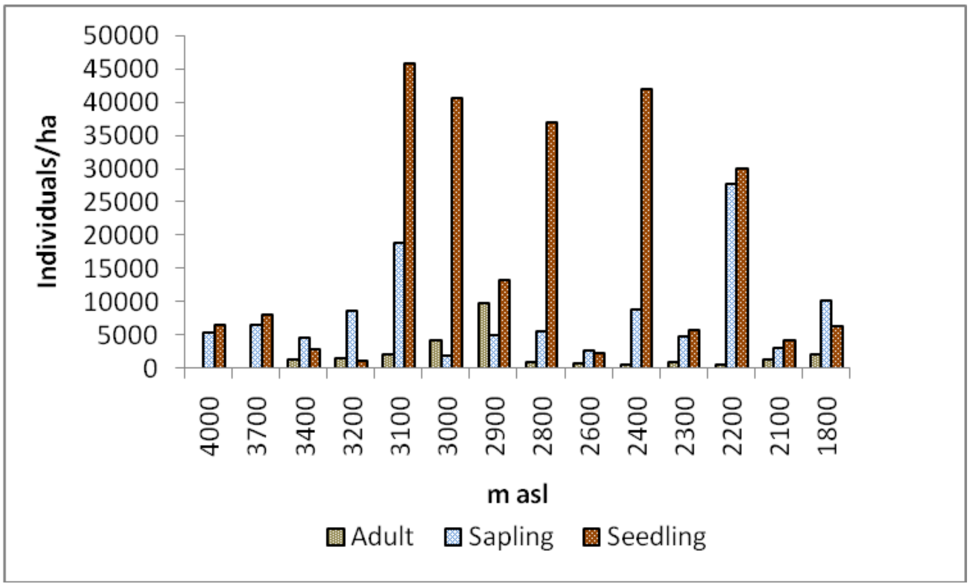

Figure 4.15: Abundance in a hectare of woody species along transect of Tholung – Kisong transect in the Khangchendzonga Biosphere Reserve.

5.3.2.1. Basal area cover along the transect

The maximum basal area of adult woody species was recorded at 2300 m asl (385 sq. meter/hectare) and there were no adult woody (trees) species found at 4000 m asl (Figure 4.16). The maximum basal area of saplings (41.00 sq. meter/ hectare) of woody species was recorded at 2200 m asl and the minimum basal area of saplings (1.63 sq. meter/hectare) was recorded at 2900 m asl. Similarly, the maximum basal area of seedlings (15.6 sq. meter/hectare) was recorded at 3100 m asl and the minimum basal area of seedlings (0.1 sq. meter/hectare) observed at 2600 m asl.

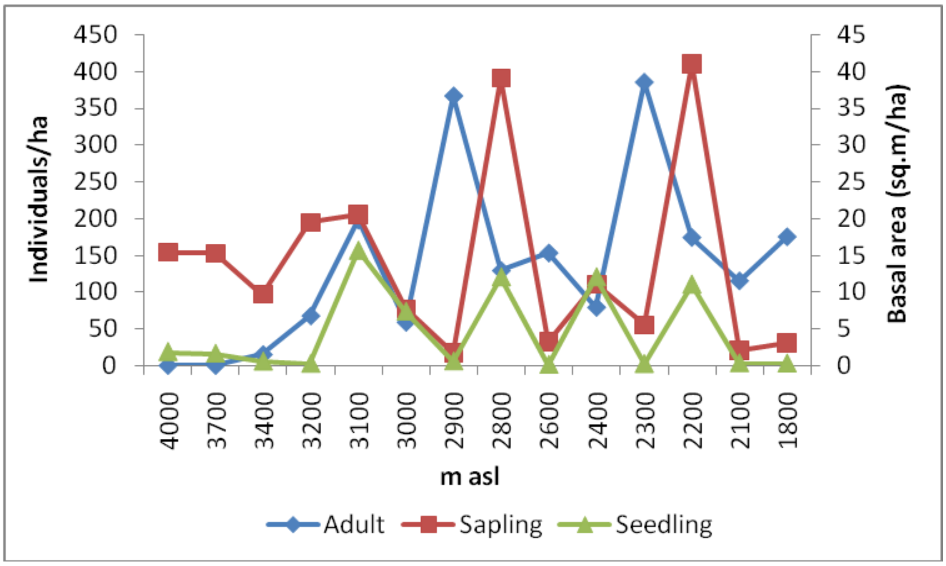

Figure 4.16: Basal area in a hectare of woody species along transect of Kisong-Tholung in the Khangchendzonga Biosphere Reserve.

5.3.2.3. Abundance and basal area of scrub of alpine region

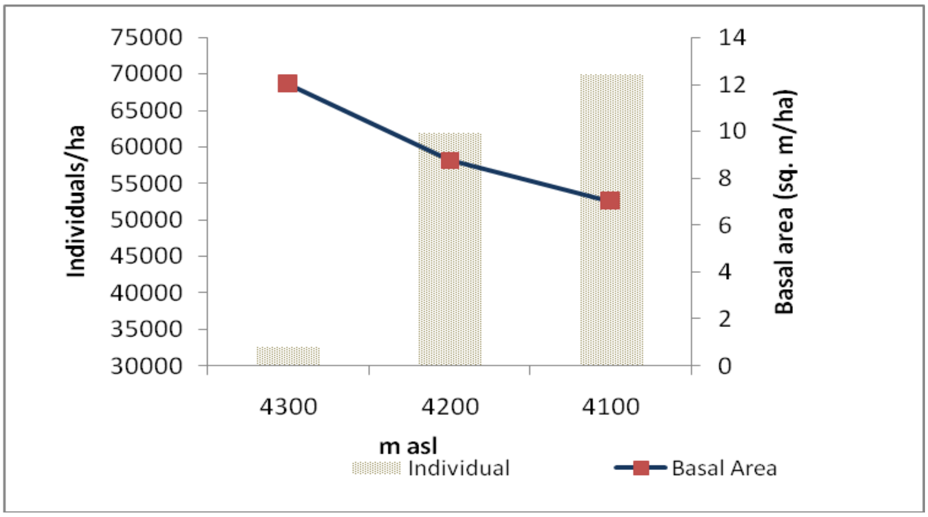

Figure 4.17: Abundance and basal area in hectare of scrubs species in the alpine along transect of Tholung-Kisong transect in the Khangchendzonga Biosphere Reserve.

Out of 17 sites, 03 sites were identified along 4100-4300 m asl in the scrubs vegetation of the alpine region; the maximum number of individuals were encountered at 4100 m asl (69960 individuals/hectare) and minimum individuals at 4300 m asl (32660 individuals/hectare), whereas, the highest basal area was quantified at 4100 m asl (7.00 sq metre/hectare) [Figure 4.17] .

5.3.2.4. Ecological indices

Ecological Indices such as Margalef's Index of Species Richness, Shannon Index of Species Evenness, Simpson's Index of Dominance and Shannon-Wiener Diversity Index of 17 major sites of the transect were quantified.

Species Richness

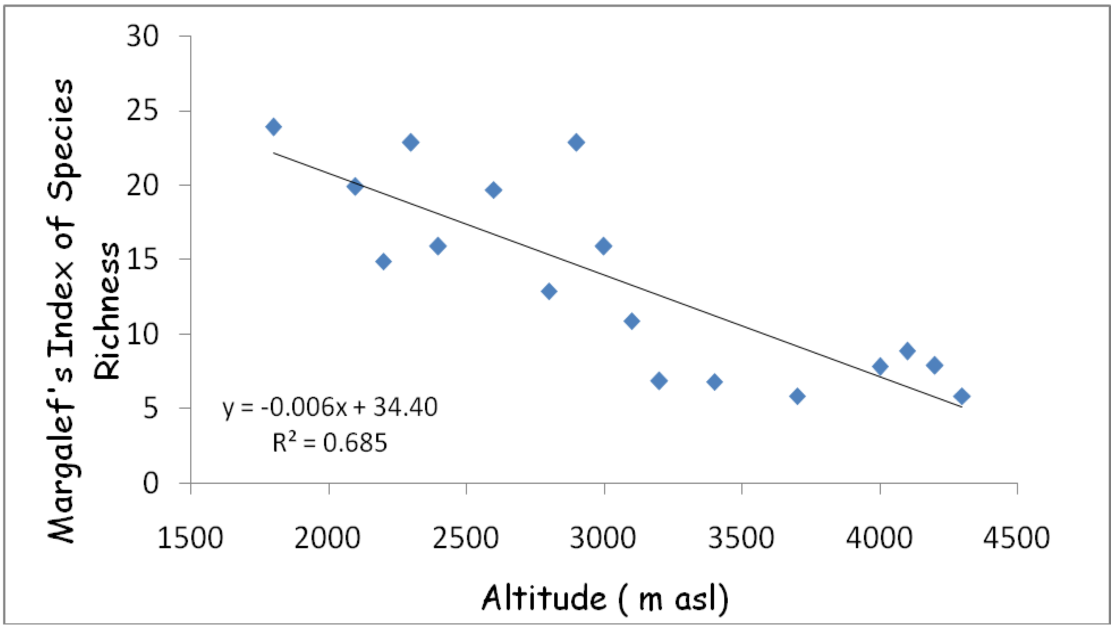

Figure 4.18: Species Richness Index vs. altitude along transect of Tholung-Kisong transect in the Khangchendzonga Biosphere Reserve.

The species richness of woody species was negatively correlated with altitude and the regression equation between species richness and altitude, y= -0.006x + 34.40 (R^2= 0.685) was quantified. The value was ranked from 5.83- 23.88 (±6.487) within the transect of the study area (Figure 4.18).

Shannon-Wiener Diversity Index

The Shannon-Wiener Diversity Index of woody species was slightly positively correlated with altitude and the regression equation between Shannon-Wiener Diversity and altitude, y=0.000x+0.287 (R^2=0.217) was quantified. The value was ranked from 0.318-3.176 (±1.008) within the transect of the study area (Figure 4.19).

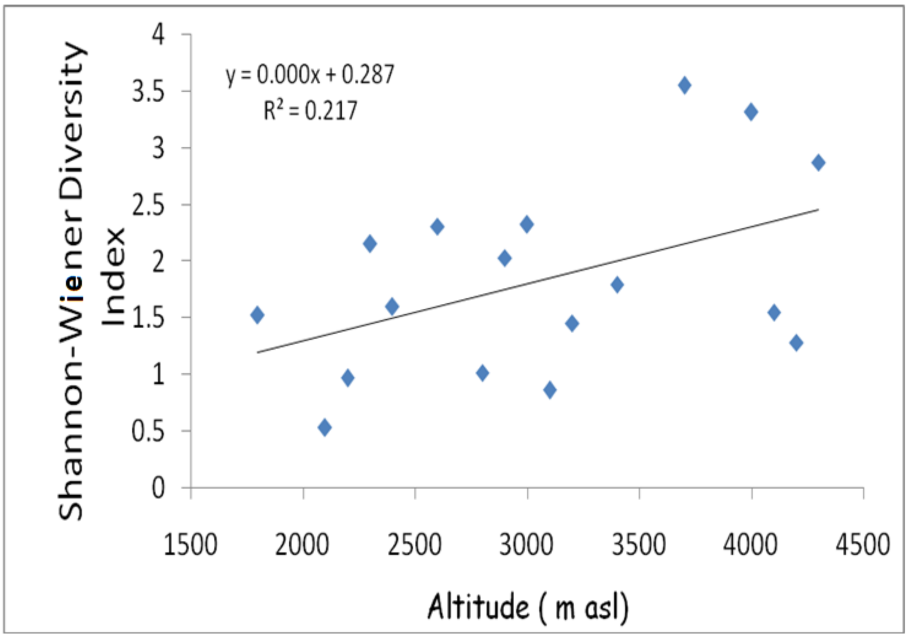

Figure 4.19: Diversity Index vs. altitude along transect of Tholung-Kisong transect in the Khangchendzonga Biosphere Reserve.

Simpson's Index of Dominance

The Simpson's Index of Dominance of woody species was slightly negatively correlated with altitude and the regression equation between Simpson's Index of Dominance and altitude, y=-8E-05x + 0.556 (R^2= 0.118) was quantified. The value was ranked from 0.05288-0.45233 (±0.13887) within the study transect (Figure 4.20).

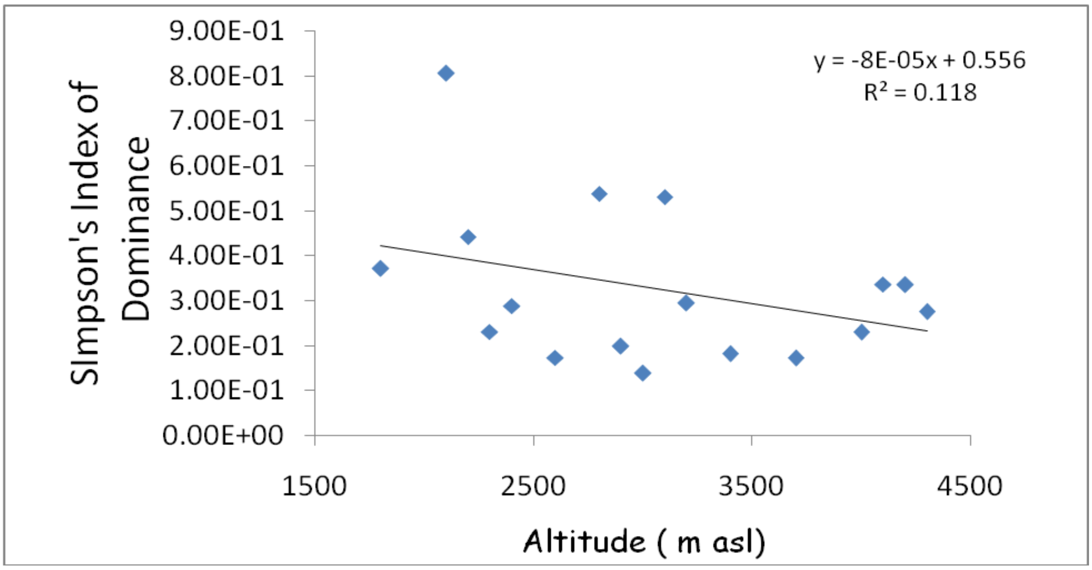

Figure 4.20: Index of Dominance vs. altitude along transect of Tholung-Kisong transect in the Khangchendzonga Biosphere Reserve.

Shannon Index of Species Evenness

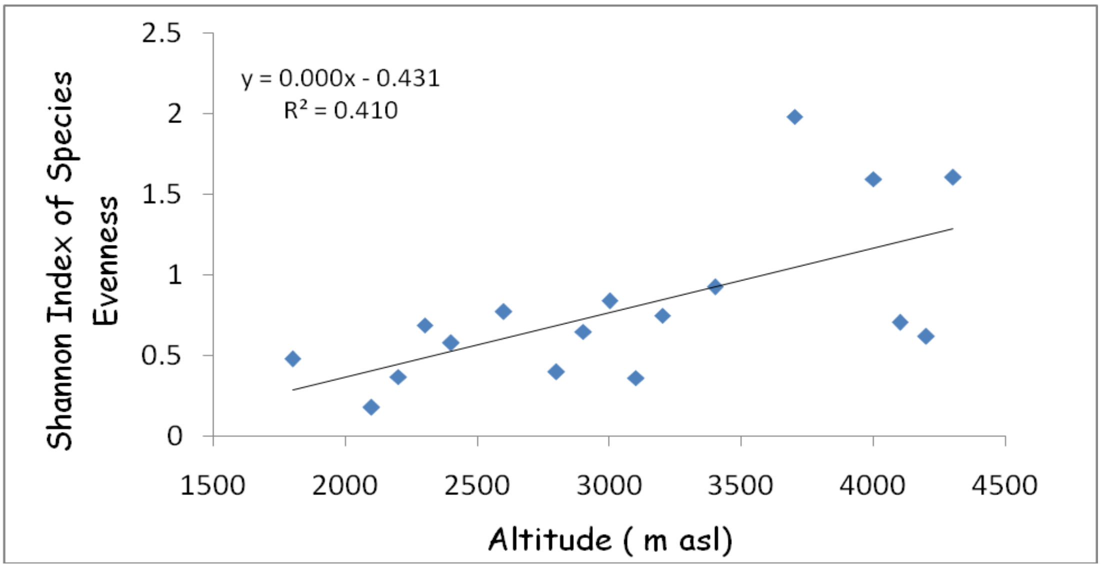

Figure 4.21: Species Evenness Index vs. altitude along transect of Tholung-Kisong transect in the Khangchendzonga Biosphere Reserve.

The Shannon Index of Species Evenness of woody species was positively correlated with altitude and the regression equation between species richness and altitude, y=-0.000x- 0.431 (R^2=0.410) was quantified. Within the study transect, the value was ranked from 0.1632-0.881 (±0.2610) [Figure 4.21].

5.3.2.6. Cluster analysis for the forest structure and composition

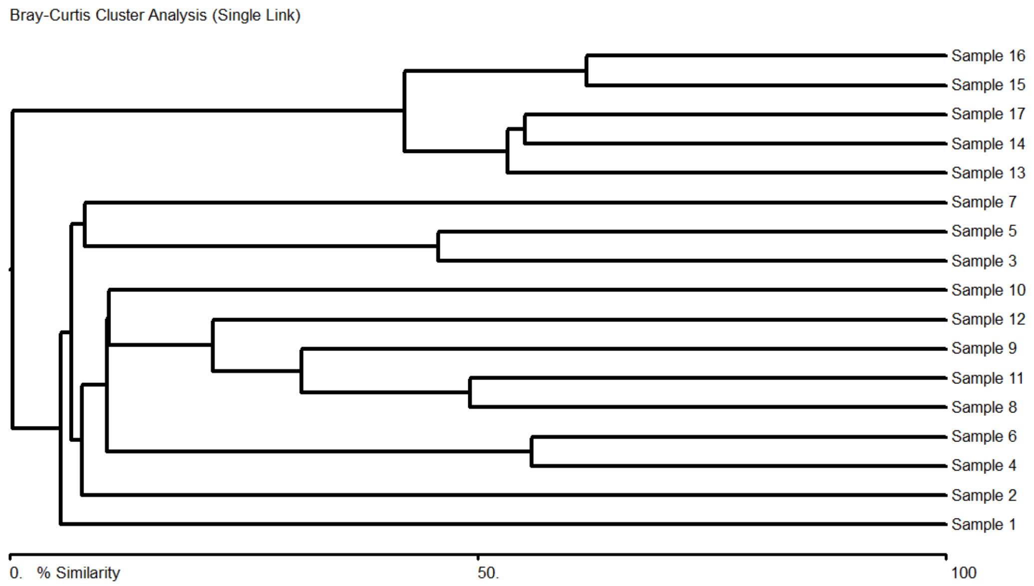

Figure 4.22: Cluster Analysis showing the similarity group among the study sites (Tholung-Kisong transect) in the KBR

The cluster analysis among the sample of the seventeen sites provided the picture of their forest composition structure as well as homogeneity and heterogeneity level along the altitudinal gradients (Figure 4.22). The cluster analysis revealed that the site 15 and 16 showed the maximum species composition similarity (>50%) among all sites followed by site 4 and 6, site, and site 17 and 14. The site 3 and 5 showed a maximum dissimilarity composition of the species in the transect.

5.3.2.7. Estimator Choa and Jackknife

Quantified species estimators, namely Choa 1 and Jackknife 1 were correlated with the altitudinal gradient of the study area. A total of 87 woody species were recorded in the transect, however, the Choa 1 (86 species) and Jackknife 1 (111 species) were estimated. Similarly, a regression line drew between species estimators and the altitudinal gradient and the significant negative quadratic relations quantified; Choa 1 (y=-0.0339x+191, R^2=0.8267, P<0.0001) and Jackknife 1 (y=-0.0269x+144.29, R^2=0.9322, P<0.0001) (Figure 4.23). Likewise, a declining trend of species estimator was observed in respect to increasing altitudinal gradient in the forest. As per species estimator (Jackknife), there may be more possibilities to find new species in the forest.

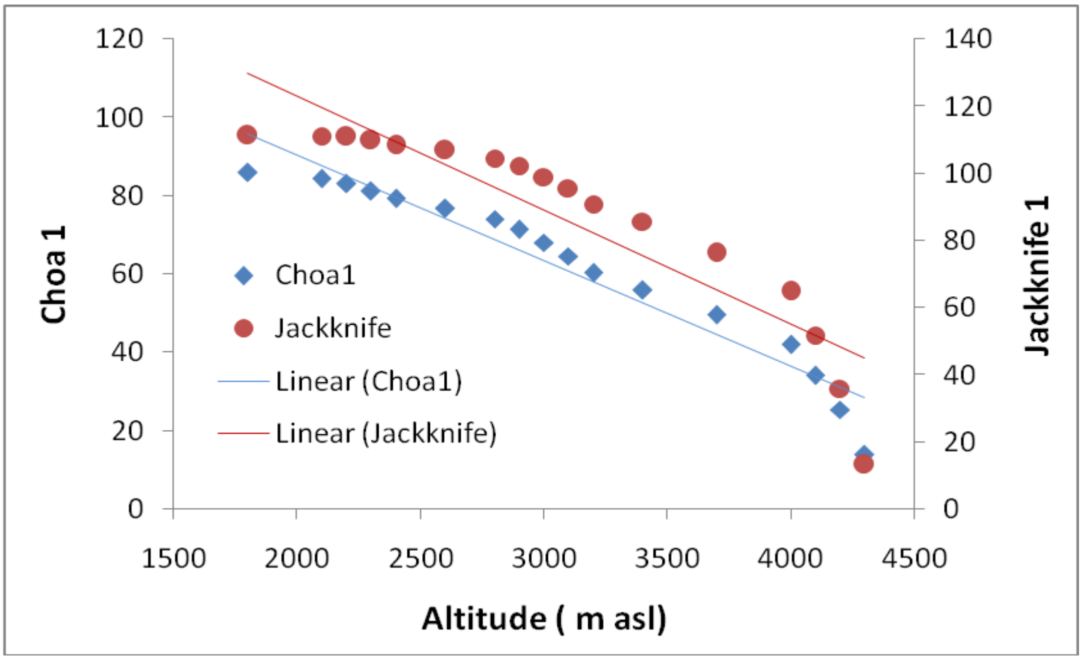

Figure 4.23: Estimated (Choa 1and Jackknife 1) species richness of the woody taxa along in Tholung-Kisong transect in the KBR.

5.3.2.8. Species-Abundance distribution model

The four models were used to describe the species-abundance distribution pattern of ecological community such as geometric, log series, truncated log-normal and MacArthur's broken stick. Among the four models for vegetation data of the Thulong-Kisong transect, the truncated log-normal distribution pattern appeared best fitted and that showed no significant difference of the observed and expected number of species in each abundance class (Chi=3.56891; p=0.467479; df=4). In the truncated log-normal distribution model-observation in the species-abundance distribution pattern showed that a few species were rare in the forest community (Figure 4.24).

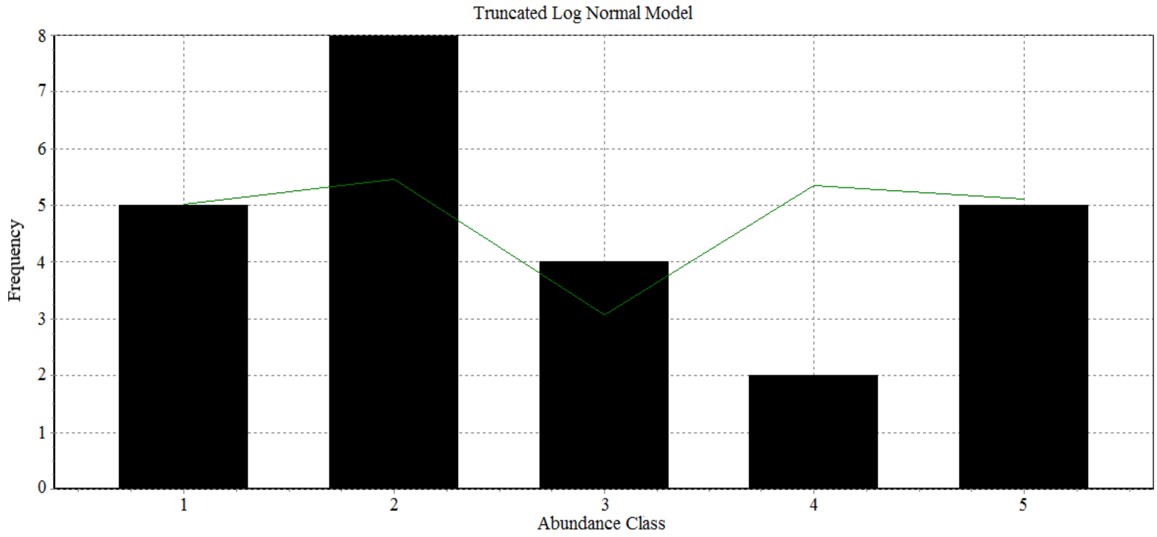

Figure 4.24: Truncated Log-Normal distribution model of woody taxa of Kisong-Tholung transect.

5.3.3. Dominant forest communities

Based on the IVI (Important Value Index), dominant forest communities of the study area were identified by taking three variables i.e. relative frequency, relative dominance and relative density of each study site along the transect. The dominant forest communities of all the study sites (both the transects; Yuksom-Black Kabru and Tholung-Kisong) were classified into four different board forest zones based on forest community composition and altitude. i.e. from ranged 1800-2100 m asl as considered as sub-tropical mixed broad- leaved forest, above 2100-3000 m asl as warm temperate Oak- broad-leaved forest, above 3000-3800 m asl as cold temperate coniferous-broad-leaved forest, and above 3800 m asl as the sub alpine and alpine region (Figure 4.25).

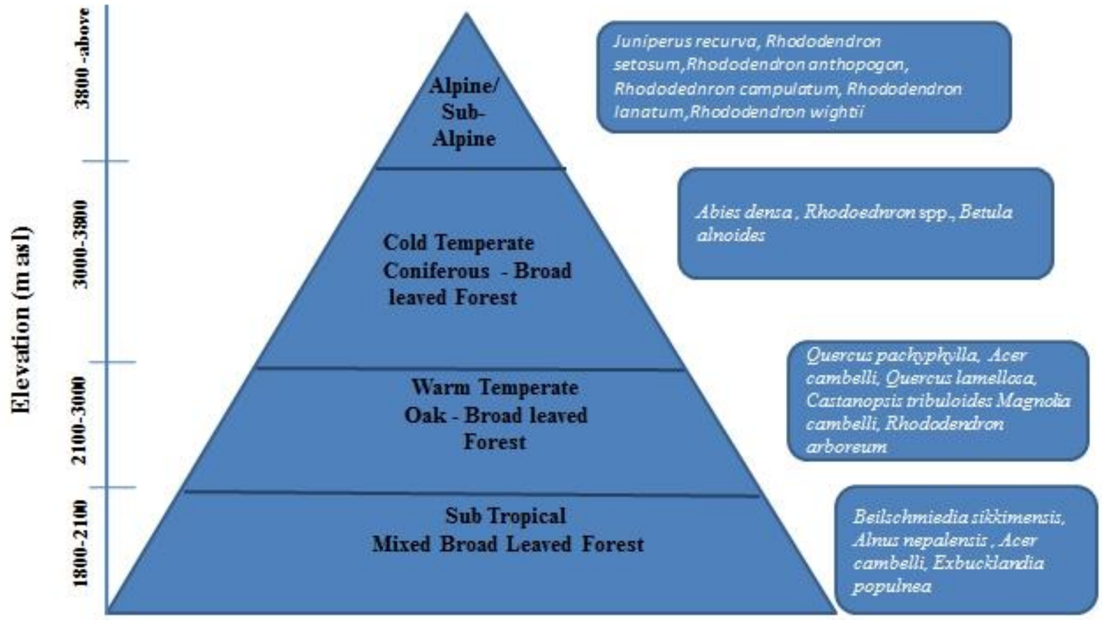

Figure 4.25: Dominant communities of woody species in the transects based on IVI (Important Value Index) in the Khangchendzonga Biosphere Reserve.

5.3.4. Climatic condition of study area

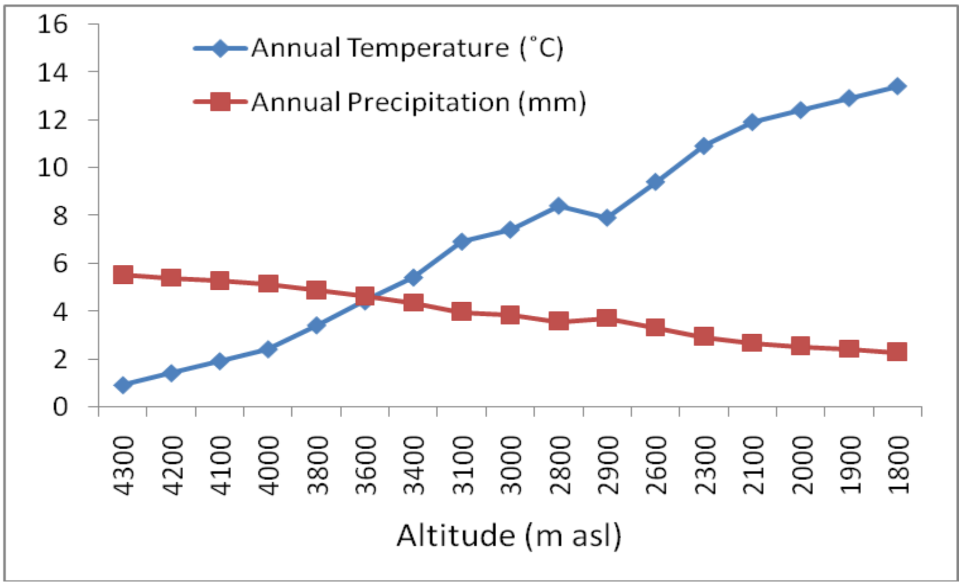

Figure 4.26: Annual mean temperature and annual mean precipitation (2013) of the study area in the Khanchendzonga Biosphere Reserve.

The annual mean temperature of the study area was increased with decreasing of the altitudinal gradient in the study area. Similarly, the annual mean precipitation was directly proportional to the altitudinal gradient of the study area (Figure 4.26).

5.3.3.1. Relationship among climate variables (PET, AET, MI), species richness and altitudinal gradient

From the four climate variables, quantification was done for the PET, AET, and MI of the study area and which were correlated with the species richness of the forest to better understand the factor affecting composition and structure of the forest communities. The results indicated that the AET, PET, and MI are the measures of available environmental energies which drive the final shape of community composition and structure of the forest.

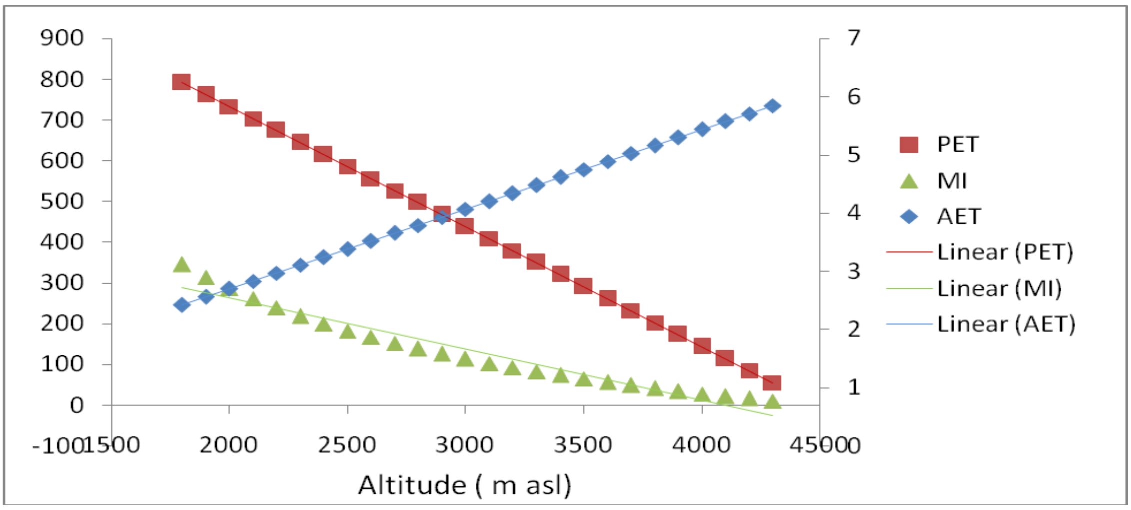

Figure 4.27: Annual Actual Evapotranspiration, Potential EvapoTranspiration, and Annual Moisture Index along with the altitudinal gradient of the study area in the KBR.

The regression line is drawn between the altitudinal gradient of the study area and available environmental energies (AET, PET, and MI); a negative quadratic relation emerged among the altitudinal gradient, and PET (y=-0294x+1321, R^2=1, p>0.000) and MI (y=-0.125x+512.8, R^2=0.945, p>0.000) and a positive quadratic relation was shown between altitudinal gradient and AET (y=0.001x-0.046, R2=1, p>000) (Figure 4.27). The study revealed that the species richness of the two transects showed a significant positive correlation with temperature, PET, and MI and a significant negative correlation with precipitation, AET, and altitudinal gradient of the study area (Table 4.3).

Table 4.3: Pearson correlation of woody species richness vs. climatic variables and altitude for study sites

	Species Richness		Temperature	Precepitation	AET	PET	MI	Altitude
Pearson correlation	Yuksom-Black Kabru transect	r	0.843	-0.843	-0.843	0.843	0.928	-0.843
	Significance	p	0.01	0.01	0.01	0.01	0.01	0.01
	Tholung-Kisong Transect	r	0.828	-0.828	-0.828	0.828	0.825	-0.828
	Significance	p	0.01	0.01	0.01	0.01	0.01	0.01

CHAPTER 05

OBJECTIVE 02

DISCUSSION

5.4. Discussion

Mountain slopes with significant bioclimatic amplitude generally provide more species at the bottom than at the top (Vetaas & Grytnes, 2002). The vegetation assessment in Khangchendzonga Biosphere Reserve, for the woody species richness along altitudinal gradients, showed a directly proportional pattern with bioclimatic variables like temperature, MI, and PET; and inversely proportional with AET and altitude. The studied transects started from temperate to alpine meadow covering amplitude of 2500 m and the region experiences high fluctuation of climate variables leading to changes in species richness, diversity, and major communities' composition of the forest. Even, it was observed that the slope might have played a significant role in the communities' composition of the forests as per the observations were made during field visit, the communities' composition of the forest at the same altitude slightly differed in Yuksom-Black Kabru transect and Tholung-Kisong transect, as the majority parts of Kisong-Tholung landscape were more sloppy than that of Yuksam-Black Kabru landscape.

Based on IVI analysis, the four major different forest types were recorded, warm temperate broad- leaved forest, cold temperate coniferous mixed broad-leaved forest, subalpine, and alpine forest. The dominant vegetation type changes along the altitudinal gradient in both the transects, where the species like *Quercus, Rhododendron, Symplocus,* and *Abies* were dominant when surveyed for the whole area including quadrats' sites. Among the Rhododendrons forest; *Rhododendron niveum, Rhododendron thomsonii, Rhododendron aeruginosum, Rhododendron falconeri, Rhododendron grande, Rhododendron arboreum, Rhododendron ciliatum,* *Rhododendron campylocarpum,* etc. were rare and vulnerable species (Chhetri & Badoal, 2017; Chhetri et al., 2018a). The species richness of woody species in both the transects showed the inversely proportional trend with altitude. The overall increase in the density of one or two common species compensated the reduction in the number of rare species at higher elevations might be appeared as an adaptation to withstand the cold and strong wind (Acharya et al., 2011), thus opting for an alpine refuge (Gentitli et al., 2015). The presence of the higher abundance of young tree species, which generally signifies a healthy growing forest along with backed up of a good regeneration pattern of saplings and seedlings. The relatively lower basal cover of the trees showed at the higher altitudinal gradient may be the result of young woody plant density to be the effect of cold and harsh climatic conditions (Acharya et al., 2011). A total of 99 species in Yuksom-Black Kabru transect was found and according to non-parametric species richness estimators, Choa1 (103 species) and Jackknife1 (121 species). Similarly, in Tholung-Kisong, 87 species were found and according to Choa 1 (86 species) and Jackknife 1 (111 species). Based on non-parametric species richness estimators, the slightly greater number of species richness showed in the forest; as a result, there might be some possibilities of getting newer species in both the transect (Sinha et al., 2018).

Based on the species-abundance distribution pattern, four models were used; geometric, log series, truncated log-normal and MacArthur's broken stick (Magurran & McGill, 2011). Among them, the forest community composition was best fitted under the truncated log-normal distribution model. The truncated log-normal model of species-abundance distribution suggested that the presence of a few rare species in the study transects. Although, the structure and community composition of the forests at high altitudes are controlled by both environmental and biological factors (Chaurasia & Sing, 1996; Kala, 2000), a similar trend was observed in the present study, which showed a strong relationship between the climatic variables and the species richness along with altitudinal gradient of the forest. Even, energy and water play a significant role in the plants' overall physiological process and ultimate survival, which shaping their distribution and community composition along with species richness of forest in particular region (O'Brien, 1993; Hawkins et al., 2003). Furthermore, climate dependent water-energy variables affect the species richness of the forest; have been explained from central Himalayan elevation gradient by Carpenter (Bhattarai et al., 2004b; Acharya et al., 2011) and the similar trend obtained in the present study area as result; the gradual upward decline in the species richness may be a consequence of the decreasing humidity, precipitation, and temperature along the altitudinal gradient. Further, the factors affecting the structure and community composition of forests such as AET, PET (Currie, 1991; Sinha et al., 2018), and MI (Sinha et al., 2018) are the driving forces which control the species richness of the forest along with better shaping the mountainous forests. So, the mountainous landscape provides different types of habitats for different types of faunal components.

Plate 04: A glimpse of Rhododendrons of KBR; *Rhododendron leptocarpum* (A), *Rhodoendron lanatum* (B), *Rhoodendron thomsonii*, and *Rhododendron wightii* (D).

Plate 5: *Rhododendron niveum* in the study area of the Khangchendzonga Biosphere Reserve (a rare species of Rhododendrons as well as the state tree of Sikkim Himalaya).

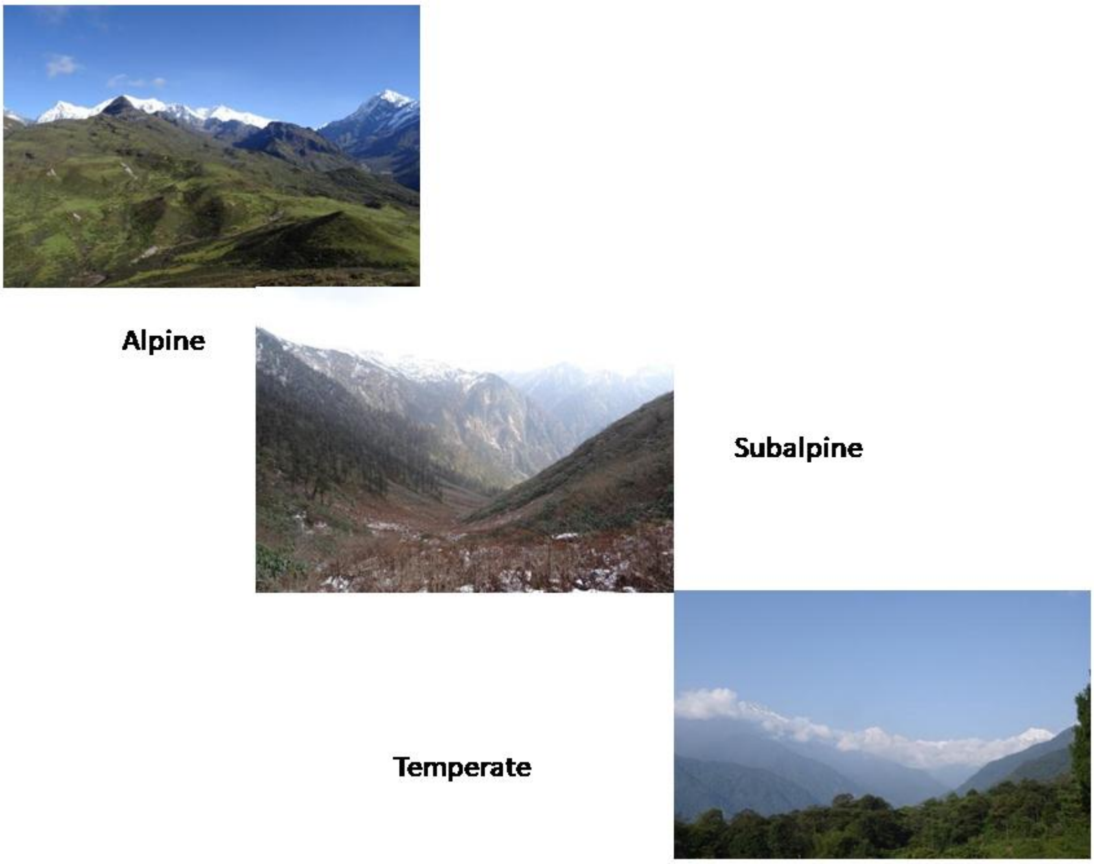

Plate 06: Alpine, subalpine and temperate forest of Khangchendzonga Biosphere Reserve.

CHAPTER 06

OBJECTIVE 03

To study seasonal variation on pheasants' diversity, abundance along habitats.

CHAPTER 06

OBJECTIVE 03

BACKGROUND

Chapter 06

Objective 03

To study seasonal variation on pheasants' diversity, abundance along habitats

6.1. Background

Pheasants represent the most distinctive bird family, with large-bodied, brightly coloured, ground-dwelling birds, exhibiting greater sexual dimorphism in both size and plumage, and belonging to the taxonomic order Galliformes and family Phasianidae. They act as an important role in forest ecosystem services, as considered as bio-indicators for owing to their sensitivity to habitat degradation, indicate habitat quality of forest, vulnerability to anthropogenic pressure and climate change, and central position in the food web (Kaul, 1989; Fuller & Garson, 2000; Chhetri et al., 2018). However, climate change in the Himalayas is more pronounced than the global average (Bhutiyani et al., 2007). Whereas, the diversity and endemism in the Himalayas are under threat due to change in climatic variables and land use pattern (Jetz et al., 2007; Sekercloglu et al., 2008). The ecological implications of the changes remain opaque and un-quantified in much higher faunal taxa, including birds. Quantitatively, climate change effects are more pronounced in the birds and butterflies' populations (Peh, 2007; Parmesan et al., 1999; Root, 1988; Ashmole, 1963; Velasquen- Tibata et al., 2012; Chen et al., 2009), resulting in habitat shifts towards higher altitudinal gradients. The knowledge on these changes is important for the conservationists because that helps them to identify species which are more sensitive towards climate change by directly measuring the changes in the ecological pattern of the species. The pattern of the ecology of species and the forces behind the species range shifts over time in the different topological landscape along the altitudinal gradient have always added further curiosity to intensive field researchers all over the world. Additionally, detecting and understanding the changes in population size and distribution patterns of the species in density, and space and time are also crucial for conservation directives to plan appropriate habitat management and conservation strategies (Bibbly et al., 2000; Martin et al., 2007). Estimation of avian abundance and density is considered as an important tool for investigating dynamism in population size and habitat association in the landscape (Norvell et al., 2003). In this regards, a variety of survey approaches has been developed to model detectability, i.e. to correct the number of animals detected in space and time (reviewed in Buckland et al., 2008). Distance sampling is a biological method used to estimate density and abundance of the species in the target area accounting detection probability. There are publications available for supporting optimizing Distance survey methods, from point to line transect (Rosenstock et al., 2002, Buckland, 2006, Buckland et al., 2008), while others have shown point counts may give more biased estimates than the line transects (Gale et al., 2009; Cassey et al., 2007). Therefore, a line transect has advantages as it increases the detection probability (Wilson et al., 2000) and also the ratio of survey to transit time is increased in line transect design (Buckland, 2006), which shows a line transect to be the most efficient and least biased method for estimating density and abundance of a species in space and time (Chhetri et al., 2017).

CHAPTER 06

OBJECTIVE 03

MATERIALS & METHODS

6.2. Materials and Methods

6.2.1. Population assessment of Himalayan Pheasant in the Khangchendzonga Biosphere Reserve

6.2.1.1. Perception-based information

The secondary information was gathered for the entire region, especially focusing on the area of KBR and surroundings, through a literature survey, and also by interacting with the inhabitants of local area particularly former hunters, Himal-Rakshaks (Protectors), forester, identified the forests and collected the historical data to find out presence or absence of the pheasants in the particular area (Jolli et al., 2011).

6.2.1.2. Field surveys

The field surveys were conducted in the two major altitudinal transects in the Khangchendzonga Biosphere Reserve viz. Yuksom-Black Kabru (Dome), and Tholung-Kisong transects (KBR, extending along 27°15’-27°57' N. lat. 88° 02’-88°40’ E long; Badola and Subba, 2012), in Sikkim Eastern Himalaya, using standardized methodology of line transect during May, 2014 and April, 2017. The Yuksom-Black Kabru transect a part of the southwest KBR in West Sikkim whereas, the Thulong-Kisong transect a part of the southeast KBR in North Sikkim were surveyed for the Himalayan Pheasants especially covering the core zone of KBR, which recently been inscribed as the World Heritage Site on 17.07.2016 by the UNESCO, based on natural and cultural aspects under mixed category. The study areas covered the altitudinal gradient around c. 1760 m-5000 m asl in the KBR.

6.2.1.3. Stratified random sampling

Samples of the Himalayan pheasants and their associated habitat compositions were measured using stratified random sampling: a) Encounter Rate b) Tape recording c) Hide build and d) Photography. GIS (Geographic Information Systems) technologies were used for spatial analysis and also to generate distribution maps and to estimate abundance, density, and encounter rate for these Pheasants.

A. Dawn and Dusk Encounter Rate or Detection rate of pheasants: were calculated by summing up the total number of individuals counted per unit effort in the trail walk. This was obtained using the formula, Encounter rate = n/l, where, n=number of pheasants sighted and l= Distance walked. Each encounter was selected and the GPS readings of elevation, latitude, and longitude were taken for each census point (Jolli et al., 2011).

B. Hide build: Hides were built of available materials in the forest (e.g. Deadwood, moss). In hides, the entry was usually made before dawn and occupied for up to three hours after sunrise to make observations and photography, cautiously.

C. Photography and field notes: Field notes and photography were used as an important tool for identifying pheasants and their habitats.

6.2.4. Sampling design

For the extensive study, the two major transects were selected in the core zone of the KBR, covering the northern and western part of the region. Depending upon the accessibility in the study area, different sub-transects were laid down at major broad habitats based on altitudinal gradient and forest composition. Within sub-transacts, a total of 680 point grids having 200 m x 200 m were laid down to detect the presence of the Himalayan Pheasants at the perpendicular line based on altitude. The minimum 200 m distance between two successive points was maintained in each transect (Jia et al., 2005).

6.2.1.5.. Distance analysis

A line transect method was used which relatively gives an unbiased density of the population study is proven to be more effective only if the assumptions associated with it are addressed effectively and aptly. But in Eastern Himalaya, due to its undulating, steepness, inaccessible mountainous region landscape, the terrain curvilinear transect/trail sampling have been used (Sathyakumar, 1994; Vinod & Sathyakumar, 1999; Ramesh, 2003). Therefore, distance sampling was used on the Himalayan Pheasants' populations obtained from trail sampling method (collected from the year 2014-2017, the three successive years). The distance program was used (Thomas et al., 2005; Anderson et al., 2015) to estimate the Himalayan pheasants' density, encounter rate, detection probability, mean cluster size, and effective strip width (ESW). Distance data were analyzed using the software program Distance 7.0 version, which has basically four key functions such as Uniform, Half-normal, Hazard rate, and Negative exponential all with cosine series adjustment. Akaike's Information Criteria (AIC) and the Chi-square statistical tests were directly used to assess the 'goodness of fit' of each function (followed by the similar approach by Burnham et al., 1981; Buckland et al., 1993; Kidwai et al., 2011). Based on the pooled data across the years were used to increase the number of detections, are recommended to estimate density with a reasonable degree of accuracy using program Distance (followed by the similar approach of Scott et al., 2006).

The Akaike's Information Criterion (AICc) was applied to select the most parsimonious model from all possible combinations for the small size number, i.e. of Uniform, Half normal, and Hazard rate models with Cosine, Simple polynomial and Hermite polynomial adjustment. The Half Normal function with Cosine adjustment was fitted best in the model to achieve consistent convergence (followed by a similar approach of Anderson et al., 2015). Encounter rate was quantified of Himalayan Pheasant of Khangchendzonga Biosphere Reserve using lines transect and trail sampling. The encounter rate is defined as the number of animals seen per unit effort (Rodgers, 1991). Similarly, in this context, Encounter rate was quantified using the formula, Encounter rate = n/L, where n=Number of Sightings and L=the length of transect/trail walked (whereas, a distance was treated as the sampling effort).

CHAPTER 06

OBJECTIVE 03

RESULTS

6.3. Results

6.3.1. Population assessment of Himalayan Pheasant in the Khangchendzonga Biosphere Reserve

6.3.1.1. Presence of Himalayan Pheasant

The total four (04) species of Himalayan Pheasants were confirmed through direct sighting, photo, dropping, and indigenous knowledge of the people who were directly and indirectly associated with the Khangchendzonga Biosphere Reserve.

Table 5.1: Details of sightings of the Himalayan Pheasants in the Khangchendzonga Biosphere Reserve

Species	**Sightings (Individuals)**	**Photograph**	**Dropping**
Blood Pheasant	80 (536)	confirmed	confirmed
Himalayan Monal	35 (74)	confirmed	confirmed
Kalij Pheasant	25 (103)	confirmed	confirmed
Satyr Tragopan	21 (54)	confirmed	confirmed

Table 5.2: Details of encounter male, female, and chick of the Himalayan Pheasants in the Khangchendzonga Biosphere Reserve

Species	Male	Female	Chick	Total
Blood Pheasant	314	186	36	536
Himalayan Monal	43	26	5	74
Kalij Pheasant	54	41	8	103
Satyr Tragopan	12	19	23	54

Presence of Blood Pheasant (*Ithaginis cruentus*), Himalayan Monal (*Lophophorus impejanus*), Kalij Pheasant (*Lophura lecomelanos*), and Satyr Tragopan (*Tragopan satyra*) were confirmed in the Khangchendzonga Biosphere Reserve. The details of their confirmation and abundance of the Himalayan Pheasants in the study area are given (Table 5.1 & 5.2).

6.3.1.1. 1. Detection probability, density and effective strip width of Blood Pheasants in Khangchendzonga Biosphere Reserve, 2014 – 2017

The Blood Pheasant was the most sighted one among the Himalayan Pheasants in the Khangchendzonga Biosphere Reserve.

Table 5.3: Abundance estimation of the Himalayan Pheasant based on Distance sampling in the Khangchendzonga Biosphere Reserve during the study period (2014-2017)

Parameter	Blood Pheasant	Himalayan Monal	Kalij Pheasant	Satyr Tragopan
Detection Probability (CV %)	0.42±0.0036 (CV%7.05)	0.35±0.05 (CV%16.81)	0.75±0.12 (CV%16%)	0.75±0.16 (CV% 21.9)
Encounter Rate (km/walk)	0.78±0.14	0.10±0.20	0.14±0.033	0.079±0.02
Density (≠/km^2) (SE)	11.07±2.23/km^2	1.5±0.33	1.6±0.45	0.79±0.35
ESW (m) (SE)	29.23±3.04	24.94±4.19	46.184±7.8	41.43±9.07
M. Cluster Size (SE)	6.78±1.092	2.09±0.22	4.04±0.48	2.54±0.37
Cluster size Range	1-80	1-5	1-8	1-6

It was sighted with 536 individuals on 80 occasions with aggregations up to range from 1- 80 individuals. Based on Distance 7.0, the detection probability of the Blood

Pheasant in the targeted site was estimated at 0.42±0.0036 (CV% 7.05). Trail sampling resulted in 80 sightings (536 individuals) of Blood Pheasant. The trail sampling data was applied to estimate the abundance of the Blood Pheasant in the intensive study area. Detection probability of Blood Pheasant was modelled using different models and adjustment terms and according to the AIC value, the Half-Normal model without any adjustment term provided the best fit at the point, i.e. detection function of individuals should be 1.0.

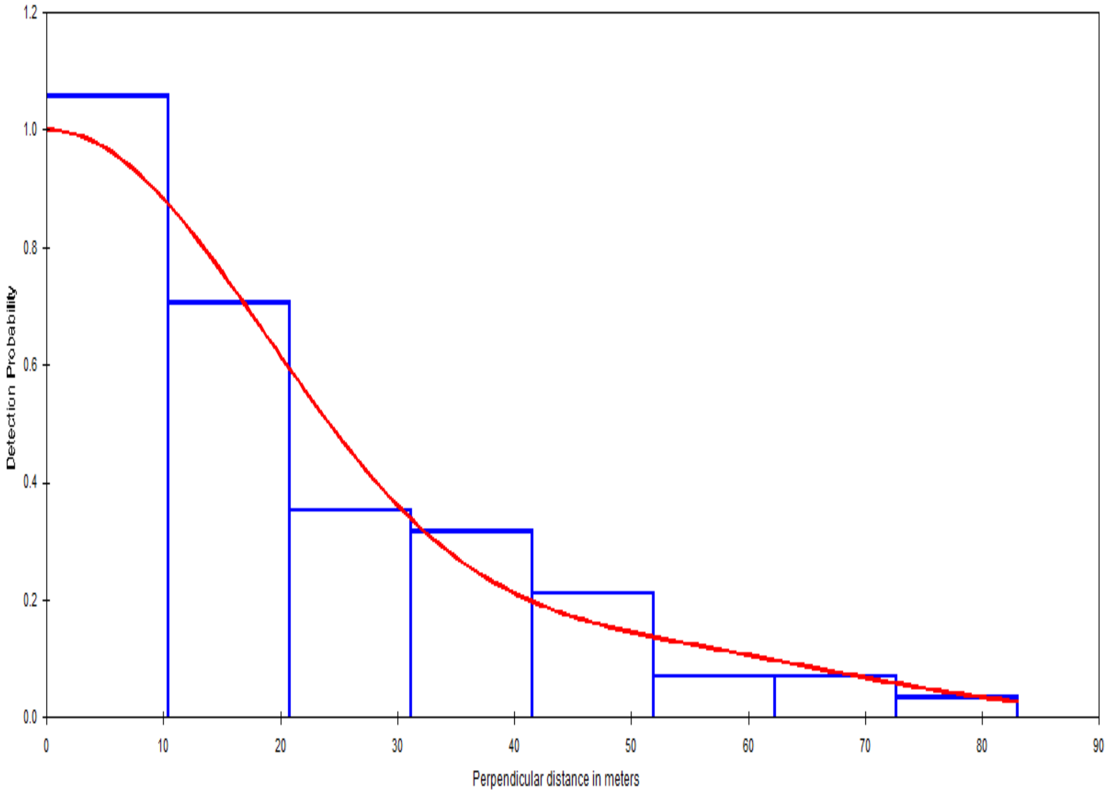

Figure 5.1: The best fit detection function model generated by DISTANCES 0.7 analyses considering all Blood Pheasant in the Khangchendzonga Biosphere Reserve during the study period (2014-2017).

The probability of detecting the Blood Pheasant decreased as the distance from the point increased for observations (Figure 5.1). The overall density (11.07/sq. km) and the encounter rate (0.78±0.14/ km) of the Blood Pheasant were quantified in the Khangchendzonga Biosphere Reserve (Table 5.3).

6.2.3. Detection probability, density and effective strip width of the Blood Pheasant in different major seasons of the Khangchendzonga Biosphere Reserve, 2014 – 2017

The seasonal density (≠/sq. km) of the Blood Pheasant was quantified in the Khangchendzonga Biosphere Reserve (estimated from post stratification option of distance sampling analysis using the same Half-Normal model). The highest seasonal density was quantified during summer (4.7±1.5/ sq. km) followed by winter (2.6±1.4/sq. km) and autumn (2.6±1.6/ sq.km) (Table 4.2.4). In the study site, 49 observations were made during the summer season followed by 18 in winter (18) and 13 in the autumn season (Table 5.4).

Table 5.4: Detection probability, density and cluster size in different seasons of the Blood pheasant in Khangchendzonga BR during the study period (2014-2017)

Season	Observation	Detection probability (SE)	Density (SE) $\#/km^2$	Mean Cluster size (SE)	ESW (SE)
Summer	49	0.33±0.038	4.7±1.5	3.84±0.37	21.58±2.51
Autumn	13	0.70±0.14	2.6±1.6	10.4±2.55	56.63±11.8
Winter	18	0.61±0.11	2.6±1.4	12.77±4.02	43.24±8.07

The density (#/sq. km) of the major forest types were also quantified in the Khangchendzonga Biosphere Reserve (estimated from post stratification option of distance sampling analysis using the same Half-Normal model). The highest density of the Blood Pheasant was quantified in temperate (5.2±2.9/sq.km) followed by subalpine (4.2±2.0/sq. km), and alpine (1.5± 0.73/sq. km). In the study area, 33 observations were made in sub alpine followed by 26 in temperate, and 20 in alpine zone (Table 5.5).

Table 5.5: Detection probability, density and effective strip width of the Blood Pheasant in different major forest types of the Khangchendzonga Biosphere Reserve, 2014 – 2017

Major Forest	Observation	Detection probability (SE)	Density (SE) #/km^2	Mean Cluster size (SE)	ESW (SE)
Alpine	20	0.62±0.11	1.5± 0.73	5.4±1.11	51.39±9.09
Sub-alpine	33	0.35±0.06	4.2±2.0	4.42±0.53	17.76±3.09
Temperate	26	0.58±0.08	5.2±2.9	10.84±2.86	38.38±5.37

6.3.1.1.2. Detection probability, density and effective strip width of the Himalayan Monal in Khangchendzonga Biosphere Reserve, 2014 – 2017

The Himalayan Monal was sighted with 74 individuals on 35 occasions with aggregations up to range from 1- 5 individuals. Based on Distance 7.0, the detection probability of the Himalayan Monal in the targeted site was estimated at 0.35±0.05 (CV% 16.81). Overall density (1.5±0.33/ sq.km) and encounter rate (0.10± 0.20/ km) of the Himalayan Monal in the target area was estimated (Table 5.3).

The trail sampling data was applied to estimate the abundance of the Himalayan Monal in the intensive study area. Detection probability of Himalayan Monal was modelled using different models and adjustment terms and according to the AIC value, the Half-Normal model without any adjustment term provided the best fit at the point, i.e. detection function of individuals should be 1.0. The probability of

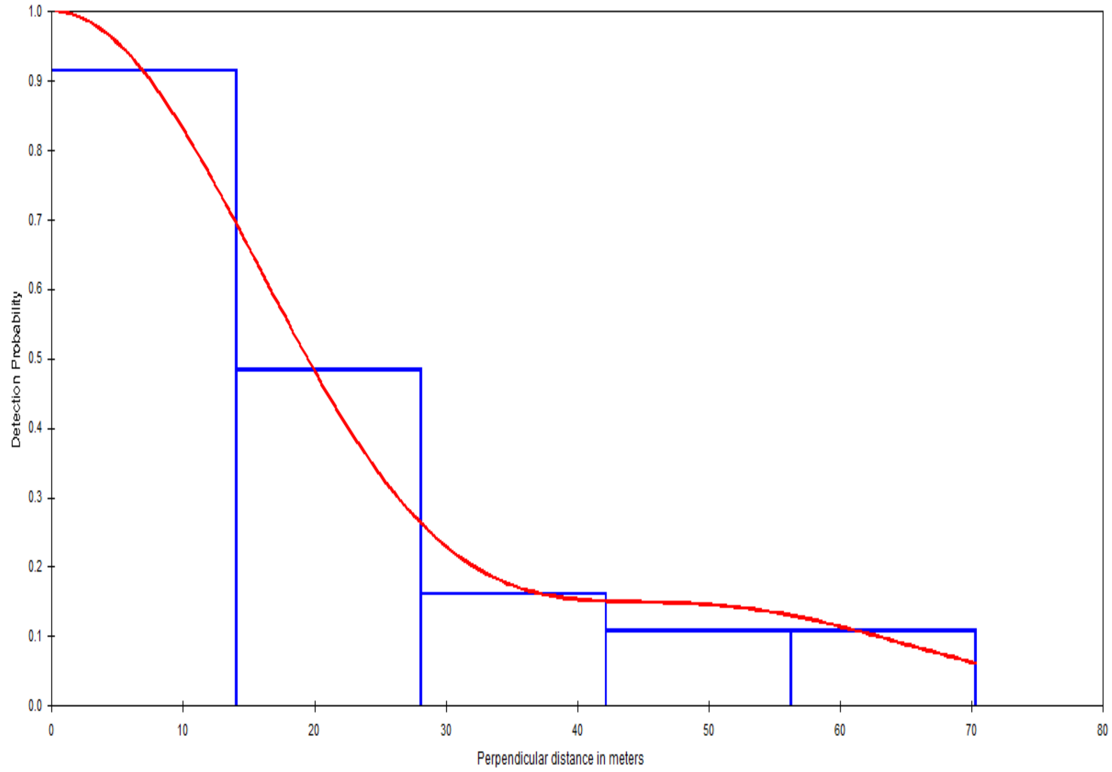

Figure 5.2: The best fit detection function model generated by DISTANCES 0.7 analyses considering all Himalayan Monal in the Khangchendzonga Biosphere Reserve during the study period (2014-2017).

Table 5.6: Detection probalility, density and cluster size in different seasons of the Himalayan Monal in the Khangchendzonga BR during the study period (2014-2017)

Season	Observation	Detection probability (SE)	Density (SE) #/km^2	Mean Cluster size (SE)	ESW (SE)
Summer	19	0.81±0.14	0.55±0.17	2.26±0.34	57.30±10
Autumn	07	0.69±0.19	0.42±0.2	2.28±0.38	28±7.83
Winter	09	0.76±0.22	0.28±0.13	1.66±0.23	38.55±11.37

detecting the Himalayan Monal decreased as the distance from the point increased for observations (Figure 5.2). The seasonal density (≠/sq. km) of the Himalayan Monal was quantified in the Khangchendzonga Biosphere Reserve (estimated from post stratification option of distance sampling analysis using the same Half-Normal model). The highest seasonal density was quantified during summer (0.55±0.17/sq. km) and followed by autumn (0.42±0.2/ sq. km) and winter (0.28±0.13/ sq.km). In the study site, 19 observations were made during the summer seasons followed by 09 in winter and 07 in autumn (Table 5.6).

Table 5.7: Detection probability, density and effective strip width of the Himalayan Monal in different major forest types of the Khangchendzonga Biosphere Reserve, 2014 – 2017

Major forest	Observation	Detection probability (SE)	Density (SE) #/km^2	Mean Cluster size (SE)	ESW (SE)
Alpine	19	0.46±0.06	0.93±0.43	2.21±0.20	33.0±4.3
Sub-alpine	9	0.46±0.19	0.31±0.19	2.11±0.36	28.10±12
Temperate	5	0.99±0.39	0.19±0.15	1.6±0.15	30.49±12

The density (#/sq. km) of the major forest types was quantified in the Khangchendzonga Biosphere Reserve (estimated from post stratification option of distance sampling analysis using the same Half-Normal model). The highest density of the Himalayan Monal was quantified in Alpine (0.93±0.43/sq. km) followed by subalpine (0.31±0.19/sq. km) and alpine (0.19±0.15/sq. km). Observations were made in alpine (19) followed by sub-alpine zone (9) and temperate (5) [Table 5.7].

6.3.1.1.3. Detection probability, density and effective strip width of the Kalij Pheasant in Khangchendzonga Biosphere Reserve, 2014 – 2017

The Kalij Pheasant was sighted with 103 individuals on 25 occasions with aggregations up to range from 1- 8 individuals. Based on Distance 7.0, the detection probability of the Kalij Pheasant in the targeted site was estimated at 0.75±0.12 (CV% 16). Overall density (1.6±0.45/ sq. km) and encounter rate (0.14±0.033/km) of the Kalij Pheasant in the target area was estimated (Table 5.3).

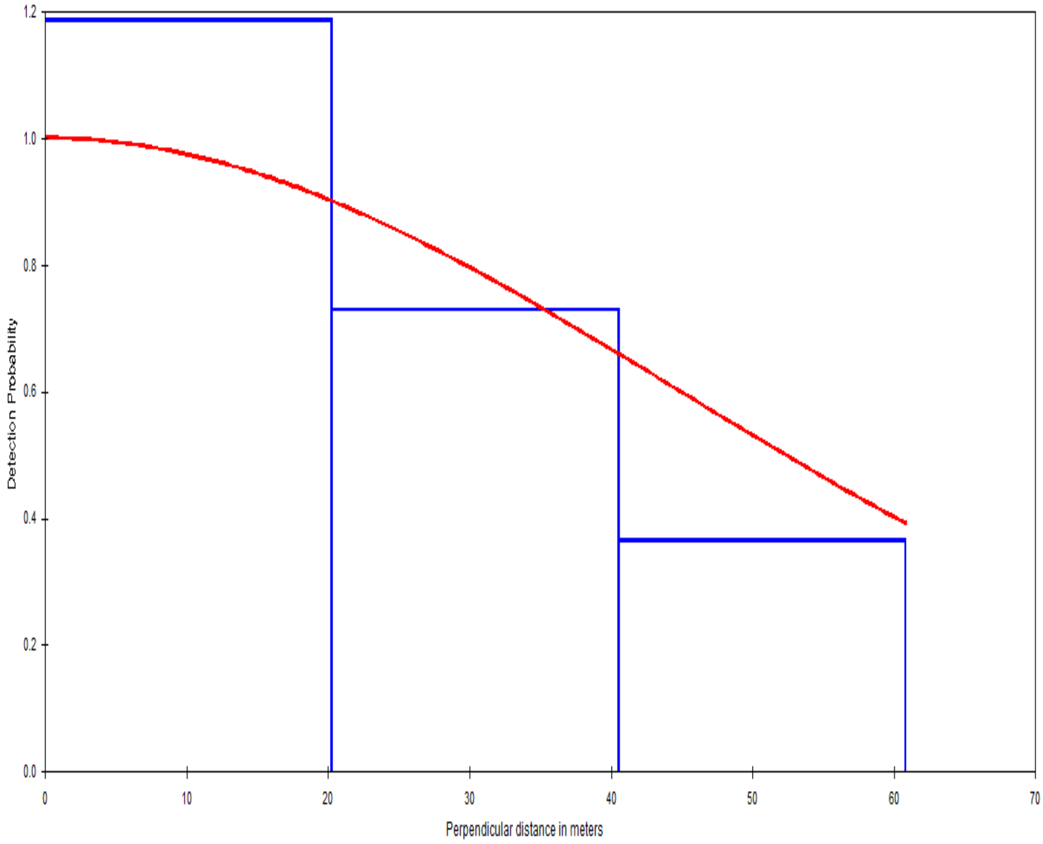

Figure 5.3: The best fit detection function model generated by DISTANCE analysis considering all the Kalij Pheasant in the Khangchendzonga Biosphere Reserve during the study period (20014-2017).

Detection probability of the Kalij Pheasant was modelled using different models and adjustment terms and according to the AIC value, the Half-Normal model without any adjustment term provided the best fit at the point, i.e. detection function of individuals should be 1.0. The probability of detecting the Kalij Pheasant decreased as the distance from the point increased for observations (Figure 5.3).

6.3.1.1.4. Detection probability, density and effective strip width of the Satyr Tragopan in Khangchendzonga Biosphere Reserve, 2014 - 2017

The Satyr Tragopan was sighted for 54 of individuals on 21 occasions with aggregations up to range from 1- 6 individuals. Based on Distance 7.0, the detection probability of the Satyr Tragopan in the targeted site was estimated at 0.75 (CV% 21.9). Overall density (79±0.35/ sq. km) and encounter rate (0.079±0.02/km) of the Satyr Tragopan in the target area was estimated (Table 5.3).

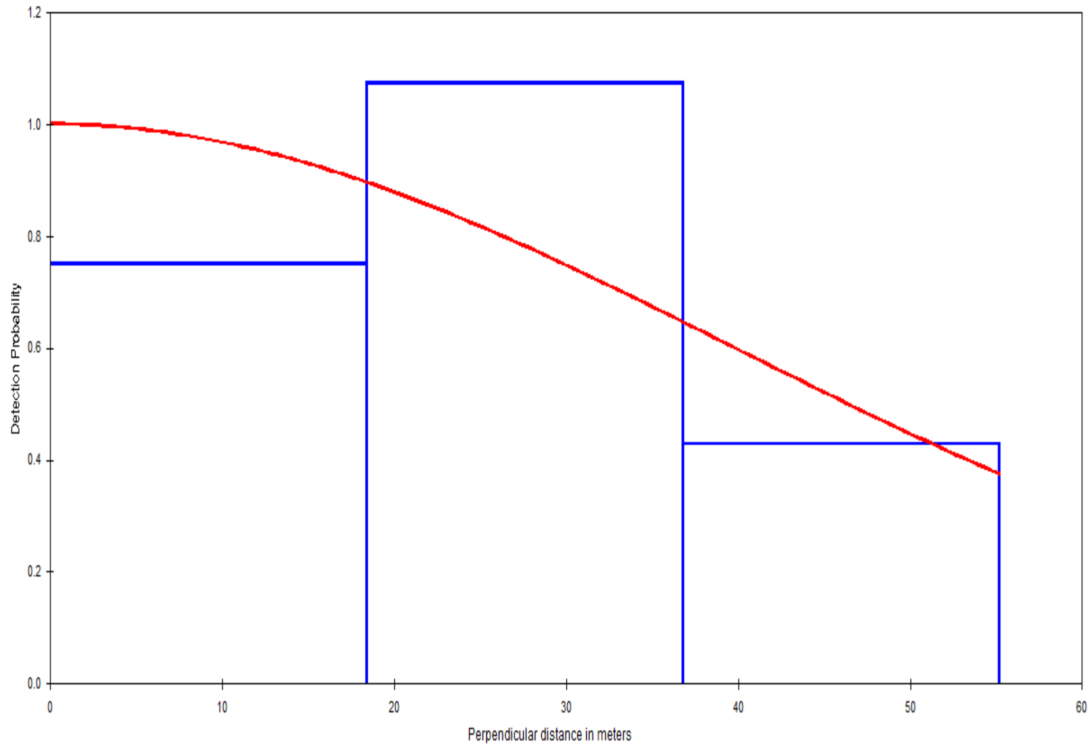

Figure 5.4: The best fit detection function model generated by DISTANCE analysis considering all Satyr Tragopan in the Khangchendzonga Biosphere Reserve during the study period (20014-2017).

Detection probability of Satyr Tragopan was also modelled using different models and adjustment terms and according to the AIC value, the Half-Normal model without any adjustment terms provided the best fit at the point, i.e. detection function of individuals should be 1.0. The probability of detecting the Satyr Tragopan first decreased initially and after a certain distance again the detection probability increased and thereafter decreased with increasing distance from the observer (Figure 5.4).

6.3.1.2. Field observation on Himalayan Pheasants' ecology in KBR

6.3.1.2.1. Blood Pheasant

A total 536 individuals of Blood Pheasant was recorded on 80 occasions which aggregating up to range of 1-80 individuals during May 2014 - March 2017 in the Khanchendzonga Biosphere Reserve across the two major transects, i.e. Yuksom – Black Kabru and Tholung- Kisong. The Blood Pheasant populations were encountered along of 3200 -4900 m asl across the cold temperate forest to the alpine meadows in the Khangchendzonga Biosphere Reserve. Enumerated habitat composition of the Blood Pheasant along the altitudinal gradients was dominated by the following woody taxa: *Rhododendron arboreum* (Ericaceae), *Rhododendron barbatum* (Ericaceae), *Sorbus* sp. (Rosaceae), *Abies densa* (Pinaceae), *Viburnum* spp. (Adoxaceae) and *Betula* spp. (Betulaceae) in the cold temperate forest (cold temperate coniferous-broad-leaved forest, 2800-3600 m asl); *Rhododendron wightii* (Ericaceae), *Rhododendron campanulatum* (Ericaceae), *Rhododendron lanatum* (Ericaceae), *Micromeles thomsonii* (Rosaceae), *Viburnum* spp. (Adoxaceae) and *Prunus cerosoides* (Rosaceae) in the subalpine (3600-4100 m asl); and *Juniperus* spp. (Cupressaceae), *Rhododendron setosum* (Ericaceae) and *Rhododendron anthopogon* (Ericaceae) in the alpine zones (above 4100 m asl) in the Khangchendzonga Biosphere Reserve. Within the three study years, the overall ecology of Blood Pheasants in Khangchendzonga Biosphere Reserve (Sikkim Eastern Himalaya) was investigated by direct encounters, tracing their droppings and foot marks on soil and snow, by especially focusing on the winter, summer, and autumn seasons. Blood Pheasants are swift and strong runners; they usually run uphill and sometimes fly downhill when they have to tackle threats such as sudden encounter of predators and other animals. In comparison to the other Pheasants in the Khangchendzonga Biosphere Reserve, they are very active, hasty, almost restless in a daytime, and are acquainted with people if they are not getting disturbed in the field. The following footless ecology of Blood Pheasant was observed within the three successive years study period:

Social behaviour

Blood Pheasant lives socially organised (dwells in a flock) except during breeding season during an almost entire year, as noted in Sikkim Himalaya. During winter, the Blood Pheasant was found in a big flock sometimes up to 70-80 individuals. The first-time observation was made in Sikkim Himalaya, that the flocks of Blood Pheasants are monitored by the respective older supreme male leader like Guardian, who leads the flock to right direction, and monitor any intruder or danger ahead. In the presence of any notable danger the male guardian of the flock would produce a short sound, then all females and all males along with chicks in the unit follow him and the other associated guardian silently waits for a while to screen and check the area for any predator chasing them or not. During the flock foraging in shrubberies, one or two associated guardians climb on the branches of shrubberies and start screening the foraging ground as well as guard the unit. If there is a presence of more sign of danger a few other males will also join to screen and check the presence of predators in the surroundings. The present observation suggests based on the number of spurs of the male, he may be the guardian male and his maturity may be recognized by counting the number of spurs; it seems that the guardians are much older than others and have lots of expertise to guide the flock to the right direction in the field. In the flock, they show altruism behaviour, each individual tries to save their kin by producing sound if they encounter with any threat and alert their flocks by taking the risk. In the breeding season in summer, the Blood Pheasants start segregating in the couples. During the post-breeding season, having chicks they form nuclear families and again come to join the unit. The Blood Pheasants always try to forage in a flock, if an individual separates from the flock immediately it produces a short sound to the flock, following that the flock also respond back to the sound. This behaviour suggests that the Blood Pheasants feel safer in a flock rather than being isolated and it also increases the probability of their survival rate. The winter flock of Blood Pheasants is larger than those of summer season perhaps the nights are too cold and it is not the perfect time to pair up for breeding couples. During winter, by huddling in the flock they might be maintaining their body temperature which helps them to cope and develop better survival capacity in the harsh climatic conditions.

Foraging behaviour

The foraging time of the flocks of Blood Pheasant starts from dawn to dusk. They relish foraging on lichen laden rocks with small patches of the green grass of alpine region during summer and autumn. As lichens are considered as a bio-indicator of pollution free zone (Conti and Cecchetti, 2001), they forage lichen laden area, it also indicates that Blood Pheasants prefer pollution -free areas. They feed on lichens, small white pebbles, insects, and young shoots of plants and during winter the Blood Pheasants also exhibit an arboreal mode of feeding. As observed, in the winter, the Blood Pheasants mainly forage on branches of shrubberies and a small tree for mosses, lichens, berries, insects and dry leaf litters and sometimes they also take a small hop to catch a flying insect. During summer, the Blood Pheasants also act as an indicator for the *Ophiocordycep sinsensis* (an expensive medicine as Himalayan gold of the Himalayas used for eternal youth and energy booster for the immune system) because the Pheasants forage on the species laden habitat ground in the alpine meadow and relish feeding the same.

Breeding Season

The breeding season of Blood Pheasant starts from the month of April to June. During nidification, the couples of Blood Pheasant descend slightly towards lower altitudinal level in the subalpine region. This may be that they maintain hatching temperature and make nests within the base of shrubberies of Rhododendrons such as *Rhododendron lanatum, Rhododendron campanuatum* and *Rhododendron wightii,* so on. Throughout the incubation period, the male partner guards the female along with the nest while sitting on the branches of trees. After hatching, the female mostly rears the chicks and the male guides the territory. The Blood Pheasants keep their chicks in the same area within shrubberies of Rhododendron forest of *Rhododendron campanulatum, Rhododendron aeruginosum, Rhododendron wightii, Rhododendron lanatum, Rhododendron hogdsonii*, and *Sorbus* sp., for two months to provide them protection from the predators such as eagle, snow leopard, and fox. Then the nuclear family of the Blood Pheasant moves towards higher altitude to join the main flock. May be the breeding time slightly varies for different couples of Blood Pheasants because some hatch earlier than others may be depending upon the maturity of the couples. It was observed that at the same time the size of chicks differs in different nuclear families. It was observed that during autumn season lots of nuclear families of the Blood Pheasant having 5-8 chicks.

Seasonal Migration

Blood Pheasant exhibits a short distance migration during summer and winter, in the summer they are found in the altitude regions of sub-alpine and alpine meadow (c. 3800-4900 m asl) and in winter they descend in the cold temperate broad- leaved forests (in and around 3200 m asl). In summer, Blood Pheasants inhabit in the shrubberies and the scrubs (*Rhododendron lanatum, Rhododendron wightii, Rhododendron campanulatum, Rhododendron anthopogon, Rhododendron setosum, Juniperus recurva* and others), in small caves and in the crevices of rock as shelters. In winter, the Blood Pheasants prefer shrubberies of the cold broad leaved forests (*Rhododendron grande, Rhododendron barbatum, Eurya japonica* and so on) and their branches for shelter. During winter the high altitude alpine and the subalpine zones are covered with snow making the temperature unbearable, and all foods are snow covered then this situation makes Blood Pheasant to slowly shift towards the lower altitudinal range in the cold temperature broad- leaved forests to cope up with the harsh conditions of winter. Although, the winter is harsh for the Blood Pheasants due to the severe climatic conditions and scarcity of foods along with the threats of getting snared at a lower altitude range. With the onset of summer season, the temperature slowly rises in the high altitude region and the snow- covered area starts melting on the slope, and varieties of vegetation start sprouting, which call forth the upward movement of the Blood Pheasant in the region. The study did not record a sign of any presence of the Blood Pheasant below 3200 m asl.

6.3.1.2.2. Himalayan Monal

The Himalayan Monal was sighted for 74 individuals on 35 occasions with aggregating 1-5 individuals during May, 2014- April, 2017 in the Khangchendzonga Biosphere Reserve across the two major transects i.e. Yuksom –Black Kabru and Tholung-Kisong transects. The Himalayan Monal populations were encountered between ranges of 3000 m asl -5000 m asl across the cold temperate forest to alpine meadow in the Khangchendzonga Biosphere Reserve. Similarly, the habitat of the Himalayan Monal along the altitudinal gradients was dominated by various woody taxa, viz. *Rhododendron arboreum* (Ericaceae), *Rhododendron barbatum* (Ericaceae), *Sorbus* sp. (Rosaceae), *Abies densa* (Pinaceae), *Viburnum* spp. (Adoxaceae), and *Betula* spp. (Betulaceae) in the cold temperate forest (cold temperate coniferous-broad-leaved forest, 2800-3600 m asl); *Rhododendron wightii* (Ericaceae), *Rhododendron campanulatum* (Ericaceae), *Rhododendron lanatum* (Ericaceae), *Micromeles thomsonii* (Rosaceae), *Viburnum* spp. (Adoxaceae), and *Prunus cerosoides* (Rosaceae) in the subalpine (3600-4100 m asl); and *Juniperus* spp. (Cupressaceae), *Rhododendron setosum* (Ericaceae) and *Rhododendron anthopogon* (Ericaceae) in the alpine zones (above 4100 m asl) of the study area. The overall ecology of Himalayan Monal in the Khangchendzonga Biosphere Reserve (Sikkim Eastern Himalaya), observed within the three successive years, by direct encounters, tracing their droppings and foot marks on soil and snow, by especially focusing on the winter, summer, and autumn seasons. Himalayan Monal is a strong runner; they usually run uphill and sometimes fly downhill when they have to tackle with threats as a sudden encounter of predators and other animals. When the male Himalayan Monal flies then it's all nine colours of beautiful patterns of plumage can be seen.

Social behaviour

The whole year, usually the male Himalayan Monal lives in the male group and the female Himalayan Monal in the female group; some time they live in solitary and a small group of individuals (2-4), except breeding season.

Foraging behaviour

The foraging time of the Himalayan Monal starts from dawn to dusk. They relish foraging on lichen laden rocks with small patches of the green grass of wet area of the alpine region during summer and autumn. During a sunny day, they love to sun basking on the top of the hills especially male Himalayan Monal. They feed on lichens, small pebbles, insects and young shoots and roots of the plants. During foraging, they love to dig wet soil in search of worms and insects under the soil. During summer, the Himalayan Monal also acts as an indicator for the *Ophiocordycep sinsensis* (an expensive medicine in the Himalayas used for eternal youth and energy booster for the immune system) because they love to forage on the species laden habitat ground in the alpine meadow.

Breeding Behaviour

The breeding season of Himalayan Monal starts from the month of April to June and during nidification, the couples of Himalayan Monal descend slightly towards the lower altitudes in the alpine region, similar to Blood Pheasant, may be to maintain hatching temperature and to make nests in the crevice of rocks. Similarly, like Blood Pheasant, the chicks of the Himalayan Monal can be seen in the lower altitude of alpine (3900-4100 m asl) for two months after that they shift to the higher altitudes in the alpine zone when they can able to tackle with threats.

Seasonal Migration

Himalayan Monal exhibits a temporal migration during summer and winter, in the summer they are found in the altitudinal ranges between 3900 -5000 m asl (or even more than our transects) and in winter the male can be seen up to 3000 m asl down in cold temperate broad-leaved forest but the female remains in the lower altitude in alpine region. The Himalayan Monal shares almost similar habitat and ecological niche of the Blood Pheasant during their seasonal migration. They slowly move towards the higher altitudes with the offset of winter.

6.3.1.2.3. Kalij Pheasant

The Kalij Pheasant was sighted with 103 individuals on 25 occasions, and aggregating up to range from 1-8 individuals during May, 2014-April, 2017 in the Khangchendzonga Biosphere Reserve across the two major transects i.e Yuksom-Black Kabru and Tholung- Kisong. The Kalij Pheasant populations were encountered in a habitat range, which starts in the study transects from 1700 m asl – 2800 m asl the temperate broad leaved forest in the Khangchendzonga Biosphere Reserve. The enumerated habitat composition of the Kalij Pheasant was *Rhododendron arboreum,* *Magnolia cambellii, Quercus pachyphylla* as dominated forest at 2600 m asl, *Quercus lamellosa, Quercus lineata, Castronopsis* spp., *Acer cambellii* as dominated forest at 2000 m asl and *Alnus nepalensis, Macaranga denticulatum,* so on at 1800 m asl.

Foraging behaviour

The Kalij Pheasants forage mainly in dense undergrowth bamboos and big bushes of the deep cold temperate broad-leaved forest in the KBR. They feed on insects, wild seeds, and young shoot of plants. They forage in a group (2-8 individuals) and take shelter on the branches of trees for the nights.

Breeding Behaviour

The breeding season of Kalij Pheasant starts from the month of March-May and during nidification, the couple uses bore of a sloppy area for nesting. During the incubation period, the male partner guards the nest by sitting on the branch of the tree. After breeding season the chicks are mainly reared by the female partners and the male guards the territory.

6.3.1.2.4. Satyr Tragopan

The Satyr Tragopan was sighted with 54 individuals on 21 occasions with aggregating up to range from 1-6 individuals during May, 2014-April, 2017 in the Khangdchendzonga Biosphere Reserve across the two major transects i.e Yuksom-Black Kabru and Tholung- Kisong transects. The Satyr Tragopan populations were encountered in a narrow stretch of habitat range (2800 m- 3400 m asl) of the ecotone of cold temperate broad leaved forest and subalpine regions of the Khangchendzonga Biosphere Reserve. The enumerated habitat composition of the Satyr Tragopan was *Abies densa, Rhododendron falconeri, Betula alnoides,* and *Rhododendron barbatum* at 3400 m asl, *Rhododendron falconeri, Rhododendron arboreum,* and *Abies densa* at 3100 m asl, and *Abies densa, Rhododendron falconeri,* and *Rhododendron arboreum* at 3000 m asl, *Rhododendron arboreum* and *Magnolia campbellii* at 2900 m asl, *Rhododendron arboreum, Magnolia campbellii,* and *Quercus pachyphylla* at 2800 m asl in study areas.

Foraging behaviour

The Satyr Tragopan mainly forage in dense undergrowth bamboos patches areas of the cold temperate broad- leaved forest and subalpine region in the KBR. They mostly like to forage in a deep forest and feed on insects, ferns, wild seeds. They forage in a small group (up to 6 individual) or solitary. They mostly shelter on the branches of trees during the nights.

Breeding Behaviour

The breeding season of Satyr Tragopan starts from the month of March-May and during nidification, the couple uses dead logs and/or branches of a tree for nesting. After breeding season the chicks are mainly reared by the female partner.

CHAPTER 06

OBJECTIVE 03

DISCUSSION

6.4. Discussion

Out of the four Himalayan Pheasants, the populations of Blood Pheasant were comparatively large in size than the other Pheasants in the Khangchendzonga Biosphere Reserve, followed by Himalayan Monal, Kalij Pheasant, and Satyr Tragopan. Overall, during the study period, the encounter rate (0.78±0.14) and the density (11.07± 2.23 / sq. km) of the Blood Pheasant were recorded. Whereas, some adjacent parts of Annapurna Conservation (ACA) in Nepal revealed more or less similar results, which observed the encounter as 0.81±1.39 (Poudayl, 2008). The seasonal trend of the Blood Pheasant for major seasons showed that the highest density was in summer (4.7±1.5) and followed by winter (2.6±1.4) and autumn (2.6± 1.6). Habitat-wise, Blood Pheasant showed its highest density in the temperate region (5.42±0.73/sq.km) of the Khangchendzonga Biosphere Reserve followed by sub-alpine (4.2±2.0/sq.km) and alpine region (1.5±0.73/sq.km). This pattern shows their preference for the particular habitat types. In Khangchendzonga Biosphere Reserve, the study estimated the overall encounter rate (0.10±0.20) and the density (1.5±0.33/sq.km) of the Himalayan Monal. Whereas, the previous study recorded in Western Himalaya by Ramesh et al. (1999) from Kedarnath Wildlife Sanctuary estimated the relative abundance of 1.5±0.35 to 3.5 ± 0.38 birds/ km walk and encounter rate as 1.5±0.35 and 3.9±0.32 birds/ km walk. Similarly, in Annapurna Conservation Area, Nepal, Poudyal (2008) quantified the encounter rate of the Himalayan Monal as 6.74 birds /km which was much high as compared to our present study. The overall density (79±0.35/ sq. km) and encounter rate (0.079±0.02) of the

Satyr Tragopan in the target area was estimated in the Khangchendzonga Biosphere Reserve, whereas, from Nepal, encounter rate of Satyr Tragopan with a pooled mean 0.42±0.91 birds/km was quantified excluding the trails where the birds were not observed at all (Poudyal, 2008). The density estimation of Satyr Tragopan was done by Khaling et al. (1998), in Singhalila National Park, Darjeeling, which showed 6.19 birds /sq.km, 4.52 birds/sq.km, and 5.46 birds/ sq.km during three successive years.

The overall density (1.6±0.45/ sq. km) and encounter rate (0.14±0.033) of the Kalij Pheasant in the Khangchendzonga Biosphere Reserve was recorded, however, similar studies in Annapurna Conservation (ACA), showed a pooled mean encounter rate 0.36±0.76 birds/km walk (Poudyal, 2008). The official IUCN Red List of Threatened Species Assessment designated the status of the Himalayan Pheasants and provided their altitudinal range, which quite differed with the primary observation of present altitudinal range in the Khangchendzonga Biosphere Reserve. The result also indicated that these Himalayan Pheasants are shifting their habitat range towards the high-altitude mountain landscape. According to IUCN Red List of Threatened Species Assessment, the altitudinal habitat range of Blood Pheasant is given as 2500-4500 m asl (Birdlife International, 2016), whereas in the Khangchendzonga Biosphere Reserve the present study reported 3200-4900 m asl range for the Blood Pheasant. This is may be a sign that the Blood Pheasant is shifting their habitat range towards high altitude mountainous landscape and making their amplitude of habitat range narrower compared to the last century. Similarly, reported from northeast India, Blood Pheasant in summer goes up to 4600 m asl and in winter descend to lower altitude at 2600 m asl (Ali & Reply, 1987). Cheng et al (1978) have reported that the altitudinal range of Blood Pheasant was 2000 m -3500 m asl in China and similarly, studies from Nepal, reported 3200 m-4400 m asl range for the same (Poudyal 2008). Based on IUCN Red List of Threatened Species Assessment, the altitudinal range of Himalayan Monal given as 2100-4500 m asl and whereas our reported range for the Himalayan Monal in Sikkim Himalaya is 3000 -5000 m asl and the similar habitat range reported by Choudhury (2005) from Arunachal Pradesh and Sikkim with their elevation ranges of 2500 m-5000 m asl. Himalayan Monal occupies habitat range from temperate forest to alpine meadow along 2400-4500 m asl but they largely concentrate in a narrow belt of 2700 -3700 m asl (Grimmet et al., 1998), whereas, Ramesh (2003) has reported that they largely concentrated in the middle elevation mostly in 2600-3000 m asl and they exhibit clear attitudinal migration up to the lower belt 2000 m, also in winter. Himalayan Monal was found in the altitudinal range from 3000 m-3500 m asl in the subalpine forest and tree line in Nanda Devi Biosphere forest (Bhattacharya et al., 2007). Based on the studies from Jiva Valley of Great Himalayan National Park, HP, the Himalayan Monal were found in the altitudinal range from 2800-3400 m asl (Yahya, 1992). It seemed that the Habitat range of the Himalayan Monal is also shifting in the Sikkim Himalaya towards the high altitude mountain landscape. Treeline is found at slightly higher altitude range (up to 4100 m asl) in the Eastern Himalayas than the Western Himalayas, it may be the reason, the upper range limit of the Himalayan Monal is slightly higher altitudinal in the Eastern Himalayas compared to the Western Himalayas. The Western Himalayas as being the closest to Tran Himalaya zone and the most of the higher altitude zones are covered with snow which is the main reason for restricted altitudinal distribution of the Himalayan Monal (Ramesh, 2003). For Satyr Tragopan the altitudinal range given by IUCN Red List of

Threatened Species Assessment, is 2200-4250 m asl compare to its present range of 2800 m -3400 m asl in Khangchendzonga Biosphere Reserve. Similarly, Satyr Tragopan reported from eastern and western Bhutan along 2743–3353 m asl altitudinal range (Ludlow & Kinnear, 1937). Satyr Tragopan range has been reported from the Nepal Himalayas by several authors, along 1600-3200 m asl (Lelliott & Yonzon, 1980; Forster, 1982; Roberts, 1983; Picozzi, 1985; Roberts, 1987; Amatya, 1997; Maskay, 1997; Poudyal, 2008). Although, the maximum species density of Satyr Tragopan was associated within the altitudinal range of 2625 – 2900 m asl in Singhalila National Park (Khaling et al., 1999). However, in Kumaun Himalaya, Satyr Tragopan is distributed along the 2400-4250 m asl (Young & Kaul, 1987). It seemed that the Satyr Tragopan’s habitat range is under threat because it is confined in a narrow stretch of habitat range from 2800 m -3400 m asl of cold temperate and subalpine regions in Khangchendzonga Biosphere Reserve, within an ecotone of the cold temperate and subalpine region, where community’s succession always occur (Chhetri et al., 2017). Similarly, in Khangchendzonga Biosphere Reserve, the Kalij Pheasant is recorded along 1700 m -2800 m asl, however, Kalij was also found in the lower elevation but the present study is focused only on the core zone of Khangchendzonga National Park, which started from c. 1700 m asl. The similar altitudinal range of Kalij Pheasant was reported (550m -2700 m asl) in Dodoha district of Western Himalaya (Pandey & Tandon, 2007). Whereas in Kinnaur district, the range of the species is reported from 1800-2650 m asl in the oak forest (Pandey & Tandon, 2007). This species is reported to have a wide range of altitudinal distribution from 200- 2800 m asl, covering low tropical forests to temperate forests (Sinha & Chandola, 2007). Overall, these Himalayan Pheasants are slowly altering their habitat range towards high altitude mountainous landscape and making their amplitude of habitat range narrower compared to the last century. However, due to climate change, Eastern Himalaya is reported for its widespread warming of generally 0.01 to 0.04˚C per year (Sharma et al., 2009) and uncertain rainfall (Goswami et al., 2006). Consequently, the climate change in the Himalayas is drastically intensified which affects its biodiversity and ecological pattern of the species including range shifts in several species. Several authors have reported that the tree lines are shifting from lower elevation to higher elevation (Löffler et al., 2004, Bakkenes et al., 2002), and diversity of flora is increasing in high altitude zones due to climate change. Studies found *Abies spectabilis* has been shifting towards higher altitude at the rate of 2.61m/per year since 1850 (Gaire et al., 2014), and tree phenology is shifting in the Himalayas (Badola, 2010; Gaira et al, 2014). It is documented that the climate change in the Himalayas may be the main reason for Himalayan Pheasants shifting their range; adopting suitable strategies in an attempt to cope with the possible effects of future environmental changes (Gentili et al., 2015).

Plate 07: Challenges for studying in mountain ecosystem like KBR; Poisonous plants like *Aconitum ferox* Wall. Ex Ser. (A), walking on delicate bridge due to landside wiped the trekking trail (B), field study in harsh weather in alpine (C), and halt in freezing night in winter (D).

Photo plate-08

Plate 08: Rough trail due to mudslide (A), hanging bridge (B), snare for Blood Pheasant (C), and snare for Himalayan Monal (D)

CHAPTER 07(I)

OBJECTIVE 04

To study the climate change impact on the distribution of pheasants and their associated elements, including using perception tools.

Climate change impact on Himalayan Pheasants based on climate change model (I).

CHAPTER 07(I)

OBJECTIVE 04

BACKGROUND

Chapter 07

Objective 04

To study the climate change impact on the distribution of pheasants and their associated elements, including using perception tools

7.1: Climate change impact on Himalayan Pheasants based on climate change model

7.1.1. Background

Current rates of climate change will dramatically affect community assemblages on Earth's biodiversity hotspots (Wiens et al. 2009; Wang et al. 2014; Hu et al. 2015) and these changes have been more noticeable in the Himalayas. The temperatures of the Himalayas have risen by 0.74º C over the past 100 years (Du et al. 2004; Solomon et al. 2007), and are projected to climb by 0.3-4.5º by the end of the 21st century (Stocker et al., 2013). As a result, many historical ecosystems of the earth have become fragmented, which has had subsequent ramifications on biodiversity like Himalayas (Chazdon et al., 2009; Hu et al., 2015). Additionally, a little fluctuation in temperature in the Himalayas can convert ice and snow into water or vice versa, and extreme slopes may lead to rapid changes in climatic zones over small distances, will exhibit noticeable changes in terms of biodiversity (Sharma et al., 2009). Himalaya is the home for the primitive tribes and native communities, who are highly dependent on the biological resources (Kollmair et al., 2005) and home for some of the world's most threatened and endemic species as well as; and high altitude ecosystems are more threatened and sensitive due to climate change (Shrestha et al., 1999, Liu & Chen, 2000). Therefore, realizing the vital importance of the Himalayas and mountainous landscape, in the year 2004, the Convention on Biological Diversity had developed a programme to minimize the loss of mountain biodiversity at global, regional, and national levels by 2010. However, the complexities of mountainous landscapes exhibit an extreme dearth of records on populations of most threatened species and climate data. Therefore, conservation directives have a traditional focus on protecting single species using habitat suitability assessments to formulate an appropriate conservation stratagem (Wiens et al., 2009; Hu et al.. 2015), but determining the geographical range of a species is critical part of these endeavours (Mace et al., 2008; Boakes et al., 2010) in changing climate scenario. So, advances in modeling technique approaches have illuminated the potential impact of various climatic scenarios on biodiversity hotspots and even some climate models have proven particularly useful for understanding distribution range and climate change impact on the threatened species. In recent decade for modeling technique, MaxEnt has shown potential ability for the prediction of changes in biodiversity and biodiversity loss under different future climate scenarios (Bertrand et al., 2012); and it also contributed significantly in the prediction of threats to species based on Python-based GIS toolkit, SDM projection (Brown et al. 2014) for upcoming climate change (Wang et al., 2014; Hu et al., 2015; Chhetri et al., 2018). The Modelling techniques have helped contextualize these global changes in terms of ecosystems to formulate landscape conservation. MaxEnt has become a popular model in the conversation scene for its utility in climate-driven habitat shifting of a particular species or in a group of species. Nowadays, Representative Concentration Pathways (RCPs) models help to illuminate future climate scenarios on distribution range and suitable habitat of the species based on possible future greenhouse gas emission trajectories. Four RCPs (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) were coded and developed according to possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5W.m^{-2}, respectively; Weyant et al., 2009). Climate change has significantly affected the ecology of avian species throughout the Himalayas, however, existing literature mostly lacks the quantitative analysis needed to formulate conservation policies in the Himalayas. The global climate change will affect posing several threats to the endemic avian species in the Himalayas, these changes have been described in general terms, including range shifts and habitat alteration (Acharya & Vijayan, 2007; Chettri et al., 2010; Chhetri et al., 2017, Chhetri et al., 2018). These changes are crucial for conservation directives to formulate landscape conservation because extant range may soon shift beyond protected areas. To get a better understanding of the possible threats of current global climate change on the Himalayan Pheasants, taking Eastern Himalayas as a case study, these models are adopted in the present study. These models can (i) identify the key climatic factors associated with the habitat shifting of the Himalayan Pheasants under future climate scenarios and (ii) project and quantify the spatial pattern of alteration of the suitable potential habitat of the species in terms of loss and gain within the landscape under different future climate scenarios and also providing a hypothetical clue for global change biology.

CHAPTER 07(I)

OBJECTIVE 04

MATERIALS & METHODS

7.2.2. Materials and Methods

MaxEnt software version 3.3.3 was used for projecting the future potential distribution habitat of the Himalayan Pheasants (Satyr Tragopan, Blood Pheasant, Himalayan Monal, and Kalij Pheasant) based on future climate scenario and the present climatic condition (present climate data was downloaded from www.world clim.org). For future climate scenario, a new set of Representative Concentration Pathways (RCPs) scenarios (AR5-2050, downloaded from www.ccafs-climate.org/data) of future climatic models was used, under the RCP-2050 scenarios three general circulation models (GCMs) were used for the projection of the future distribution of the species (adopted by Hu et al., 2015), namely Miroc-esm (Japan Agency for Marine-EarthScience Technology Atmosphere and Ocean ResearchInstitute, and National Institute for Environmental Studies), Hadgem2-AO (National Institute of Meteorological Research/Korea Meteorological Administration) and Gfdlcm3(Geophysical Fluid Dynamics Laboratory, USA). Minimization of biasness of these models was maintained by taking an ensemble of at least three different models (Miroc-esm, Hadgem2-AO, and Gfdl-cm3) based on their mean values (following a similar approach taken by Molloy et al., 2017). These were further used to get a better understanding of the climate change impacts on the distribution of Himalayan Pheasants and their associated elements. The jackknife validation methodology, developed by Pearson et al. 2007, was followed directly for predicting the future potential habitat of the Himalayan Pheasants. The regularization multiplier value was set at 0.1 to avoid over fitting (Phillips et al., 2004). For the projection of future distribution modelling of the Pheasants, the maximum number of background points was set at 1,000 along with the use of threshold feature. The 10-percentile threshold rule was applied, provided 80% of the data for training and the remaining 20% for testing, and total 3 replicates run (as boot strip) was set to avoid overfitting predictors for predicting accurate model (followed by Flory et al., 2012). The final output was divided into the five potential distribution areas that were reclassified with a range between 0-1: a very low potential class (<0.20); a low potential class (0.20-0.40); a moderate potential class (0.40-0.60); a high potential class (0.60-0.80), and a very high potential class (>0.80), followed by Sarman et al. 2015. In the final projected map, as a very low potential class had covered the maximum area under consideration, it was excluded from the results as a suitable future habitat area. Based on a probability threshold of binary habitat and non-habitat charts, potential changes in the future habitat of species compared to the present distribution model for the Pheasants was determined. For that purpose, the 'maximum training sensitivity plus specificity" threshold was observed to produce highly accurate predictions (Jimenez-Valverde & Lobo, 2007). Based on the climate variables selected by Principal Component Analysis (PCA) (Satyr Tragopan -06 climatic variables, Blood Pheasant-10 climatic variables, Himalayan Monal-09 climatic variables, and Kalij Pheasant-09 climatic variables) the future suitable habitat area of the Himalayan Pheasants was projected in the Eastern Himalayas, the Sikkim Himalayas, and the Khangchendzonga Biosphere Reserve, separately. The future projection was performed for different future climate scenarios based on RCP-2050 (RCP 2.6; RCP 4.5; RCP 6.0; RCP 8.5). The four RCPs (RCP 2.6, RCP 4.5, RCP 6.0, and RCP 8.5) scenarios were coded according to the possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5W.m-2, respectively) [Weyant et al., 2009].

7.2.2.1. Impact of future climate change on gain and loss of suitable habitat of Himalayan Pheasants

Python-based GIS toolkit, SDM projection was used to identify and quantify the regions that had become (i) unsuitable, (ii) suitable, and (iii) remained unchanged areas in the future condition with cross-checking against the present distribution of the Himalayan Pheasants in respect to current climate variables (adopted by Hu et al., 2015).

7.2.2.2. The core distributional shifts

Python-based GIS toolkit, SDM tool-box was used to observe the trend of suitable area changes and the changes were quantified by comparing the centroids of the future and the present suitable area of the Himalayan Pheasants (Brown, 2014). The SDM toolbox quantified the distributional changes between two binary SDMs, and this analysis was based on summarizing the core distributional shift of the range of the Himalayan Pheasants. This analysis focused on the convergence of species' distribution to the centroid and created a vector file having magnitude and direction of predicted change through time for better understanding on the future climatic impact on the Himalayan Pheasants. The core distributional shifts of the Himalayan Pheasants were observed by tracking the changes in centroid among different SDMs based on creating vector files.

CHAPTER 07(I)

OBJECTIVE 04

RESULTS

7.1.3. Results

7.1.3.1. Future spatial distribution model

7.1.3.1.1. Impact of future climate change on distribution of the Blood Pheasant in the Eastern Himalayas

The future suitable habitat area of Blood Pheasant was quantified in the Eastern Himalaya according to different future climate scenario of RCP-2050 (Figure 6.1).

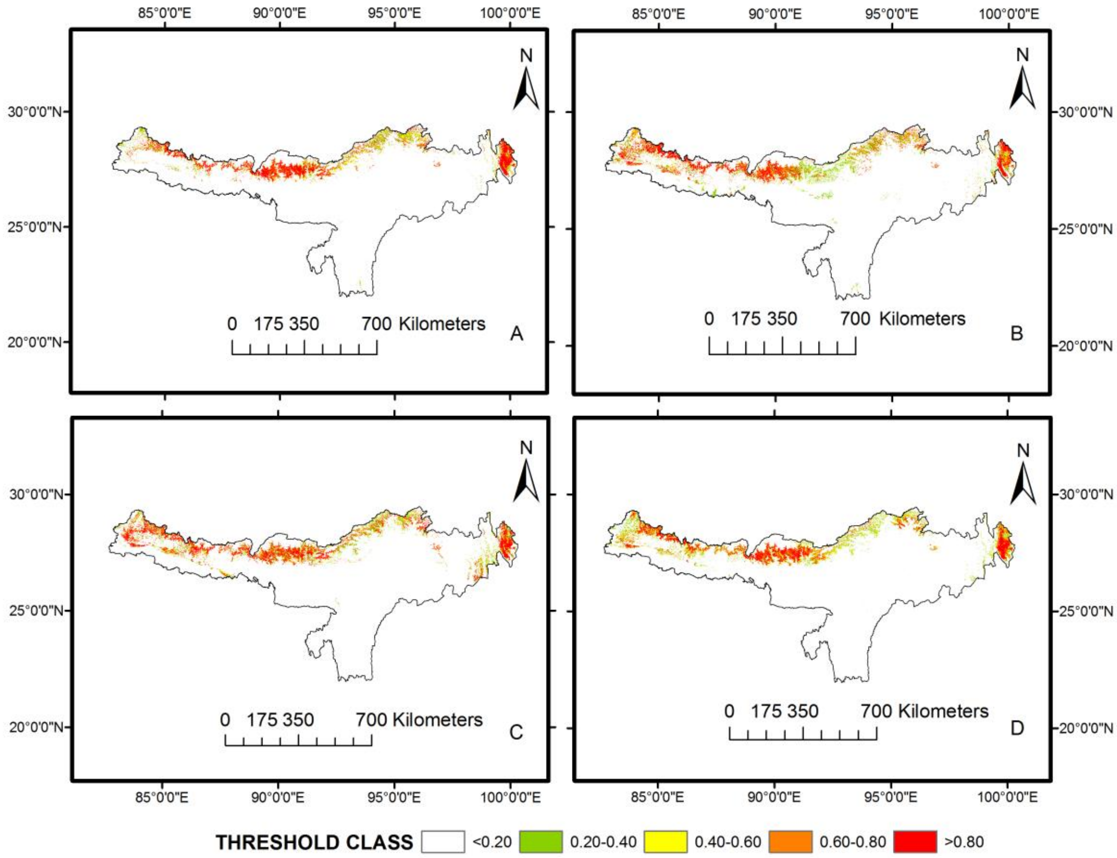

Figure 6.1: Future climate change impact on distribution of the Blood Pheasant in the Eastern Himalayas; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively

In RCP 2.6, based on threshold categories, the very high potential threshold class of the Blood Pheasant was emerged as the maximum area (33118.27 sq. km) covered in the Eastern Himalaya followed by the low potential threshold class (20438.19 sq. km), the moderate potential threshold class (13851.01 sq. km), and the high potential threshold class (8092.78 sq. km). Similarly, in RCP 4.5, the very high potential threshold class emerged as maximum area (33118.27 sq. km) followed by the low potential threshold class (21421.13 sq. km), the moderate potential threshold class (13421.53 sq. km), and the high potential threshold class (8092.78 sq. km). Again, in RCP 6.0, the similar result obtained; the very high potential class emerged the highest area (33118.27 sq. km) followed by the low potential threshold class (22382.99 sq. km), the moderate potential threshold class (14049.54 sq. km), and high potential threshold class (7894.25 sq. km). In RCP- 0.8, the very high potential threshold class represents the maximum area cover (33118.27 sq. km) followed by the low potential threshold class (22382.99 sq. km), the moderate potential threshold class (14049.54 sq. km), and the high potential class (7894.25 sq. km) [Figure 6.1].

7.3.3.1.2. Impact of future climate change on distribution of the Blood Pheasant in the Sikkim Himalayas

The future suitable habitat area of Blood Pheasant was quantified in the Sikkim Himalaya according to the different future scenario of RCP-2050 (Figure 6.2). In RCP 2.6, the very high potential threshold class of Blood Pheasant emerged as the maximum area (1430.90 sq. km) covered in Sikkim Himalayas followed by the moderate potential threshold class (370.73 sq. km), the low potential class (327.06 sq. km), and the high potential threshold class (198.84 sq. km). Similarly, RCP 4.5, the very high potential threshold class (1730 sq. km) was the highest one followed by the low potential threshold class (691.29 sq. km), the moderate potential threshold class (436.70 sq. km), and high potential threshold class (264.81 sq. km). Again, in RCP 6.0, the similar result emerged; the very high potential threshold class was the maximum area (1526.61 sq. km) followed by the low potential threshold class (559.35 sq. km), the moderate potential threshold class (379.09 sq. km), and the high potential class (299.18 sq. km).

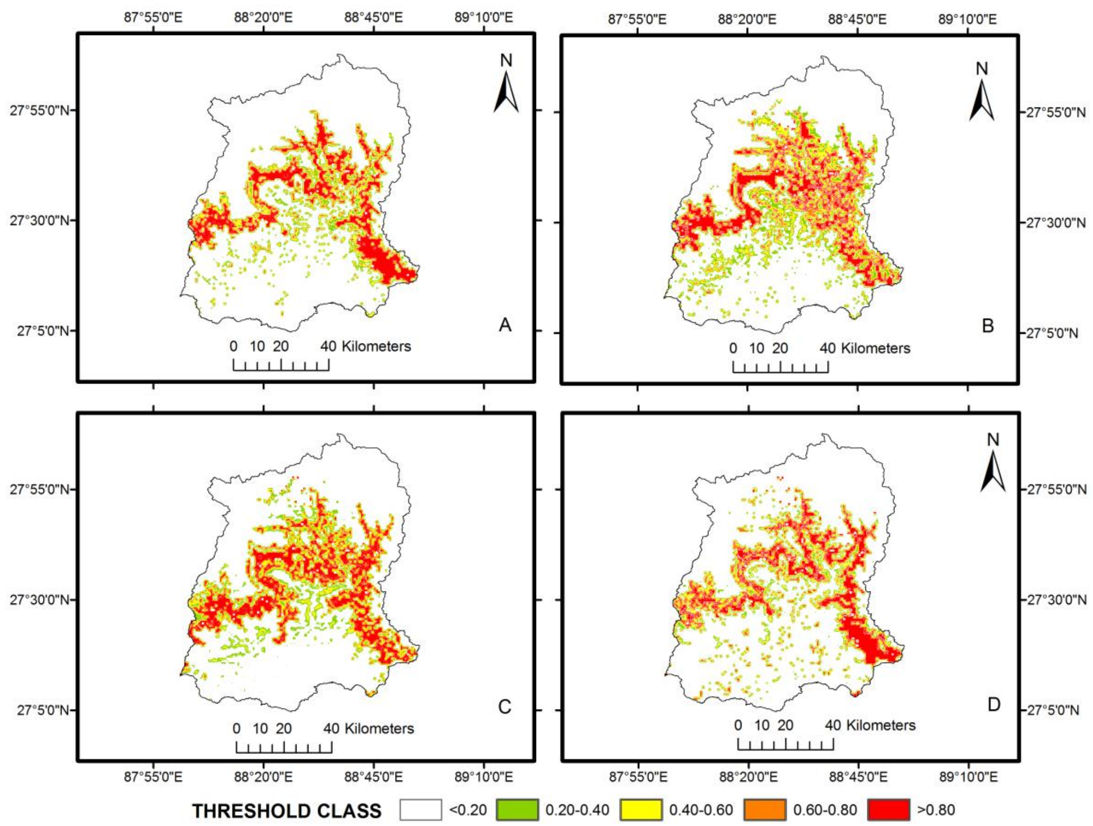

Figure 6.2: Future climate change impact on Blood Pheasant in the Sikkim Himalayas; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively

In RCP 8.5, similarly the very high threshold class emerged as the highest area (1573.99 sq. km) followed by the low potential threshold class (288.03 sq. km), the moderate potential class (280.60 sq. km), and the high potential threshold class (222.99 sq. km) (Figure 6.2).

7.3.3.1.3. Impact of future climate change on distribution of the Blood Pheasant in the Khangchendzonga Biosphere Reserve

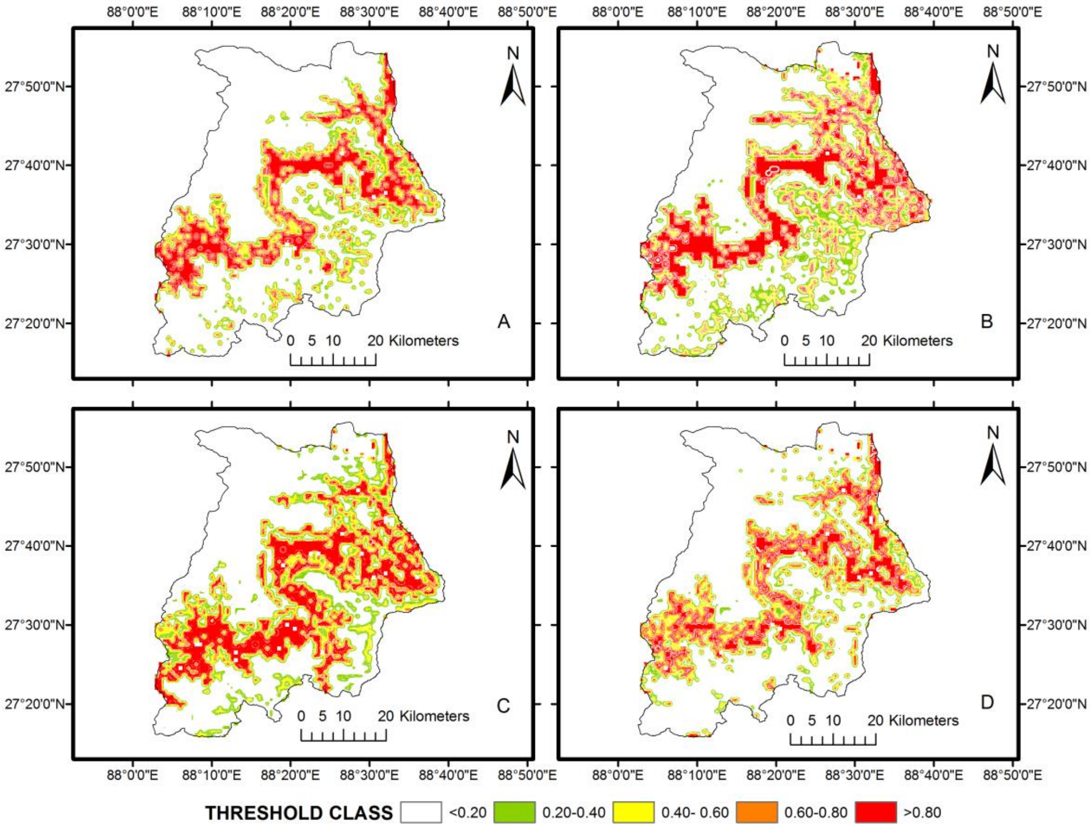

Figure 6.3: Future climate change impact on Blood Pheasant in the Khangchendzonga Biosphere Reserve; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively

According to the different future scenario of RCP-2050 the future suitable habitat area of Blood Pheasant was quantified in the Khangchendzonga Biosphere Reserve (Figure

6.3). In RCP 2.6, the very high potential threshold class of the Blood Pheasant emerged as the maximum area cover in the Khangchendzonga Biosphere Reserve (678.58 sq. km) followed by the moderate potential threshold class (170.85 sq. km), the low potential threshold class (143.45 sq. km), and the high potential threshold class (91.06 sq. km). In RCP 4.5 the very high threshold class emerged as the highest area (862.33 sq. km) followed by the low potential threshold class (289.32 sq. km), the moderate potential threshold class (181.33 sq. km), and the high potential threshold class (131.36 sq. km). Similarly, in RCP 6.0, the very high potential threshold class emerged as the maximum area (772.06 sq. km) followed by the low potential threshold class (254.66 sq. km), the moderate potential threshold class (217.59 sq. km), and the high potential threshold class (125.72 sq. km). Again, RCP 8.5, the very high potential threshold class shown the highest area coverage (649.56 sq. km) followed by the low potential threshold class (182.94 sq. km), the high potential threshold class (165.2 sq. km), and the moderate potential threshold class (136.2 sq. km) (Figure 6.3).

7.3.3.1.4. Impact of future climate change on distribution of the Himalayan Monal in the Eastern Himalayas

Based on different future climate scenario of RCP-2050, the future suitable habitat area of Himalayan Monal was quantified in the Eastern Himalayas (Figure 6.4). In RCP 2.6, based on potential threshold categories, the low potential threshold class of the Himalayan Monal was emerged as the highest area (16907.48 sq. km) covered in the Eastern Himalayas followed by the moderate potential threshold class (8267 sq. km), the high potential threshold class (3807 sq. km), and the very potential threshold class (852.43 sq. km). Similarly, in RCP 4.5, the low potential threshold class covered the highest area (10132.87 sq. km), followed by the high potential threshold class (7271.18 sq. km), the moderate potential threshold class (6309 sq. km), and the very high threshold class (4345.54 sq. km).

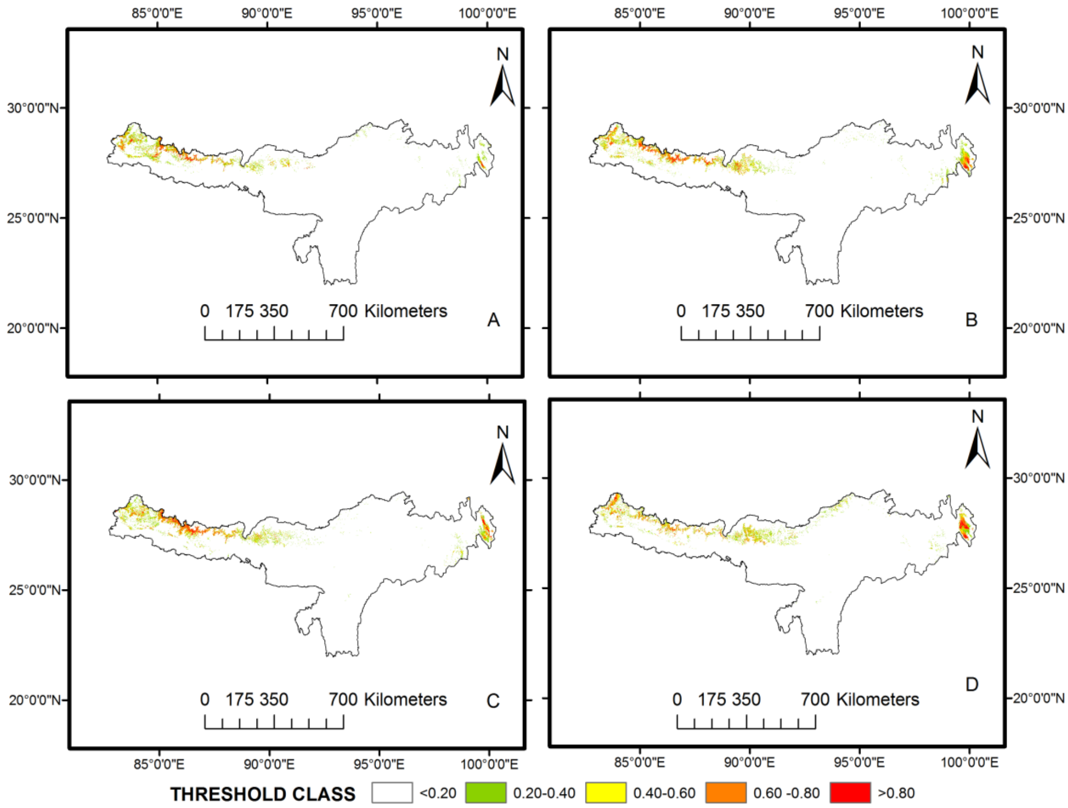

Figure 6.4: Future climate change impact on Himalayan Monal in the Eastern Himalayas; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively.

Again, in RCP 6.0, a similar result was obtained; the low potential threshold class emerged as the highest area cover (10601.15 sq. km) followed by the high potential threshold class (7221.80 sq. km) the moderate potential threshold class (5951.65 sq. km), and the very high potential threshold class (4430.55 sq. km). In RCP 8.5, the low potential area emerged as the maximum area (10776.44 sq. km) cover, followed by the high potential threshold class (6869.66 sq. km), the moderate potential threshold class (5712.034 sq. km), and the very high threshold class (4131.024 sq. km) [Figure 6.4].

7.3.3.1.5. Impact of future climate change on distribution of the Himalayan Monal in the Sikkim Himalayas

The future suitable habitat area of Himalayan Monal was quantified in the Sikkim Himalayas following different future climate scenario of RCP-2050 (Figure 6.5). In RCP 2.6, based on potential threshold categories, the low potential threshold class of the Himalayan Monal emerged for highest area cover (835.2052 sq. km) in the Sikkim Himalayas followed by the moderate potential threshold class (509.83 sq. km), the high potential threshold class (245.64 sq. km), and the very threshold class (210.42 sq. km). Similarly, in RCP 4.5, the low potential threshold class was the highest area cover (756.41 sq. km) followed by the moderate potential threshold class (696.15 sq. km), and the very high threshold class (507.98 sq. km) and the very potential threshold class (213.20 sq. km). Whereas, in RCP 6.0, the high potential threshold class emerged as the maximum area cover (429.18 sq. km) followed by the low potential threshold class (389.32 sq. km), the moderate potential threshold class (364.30 sq. km), and the very high potential threshold class (320.73 sq. km). Again, in RCP 8.5, the low potential threshold class emerged for the highest area cover (835.20 sq. km), followed by the moderate potential threshold class (509.83 sq. km), the high potential threshold class (245.64 sq. km), and the very high potential threshold class (210.42 sq. km) [Figure 6.5].

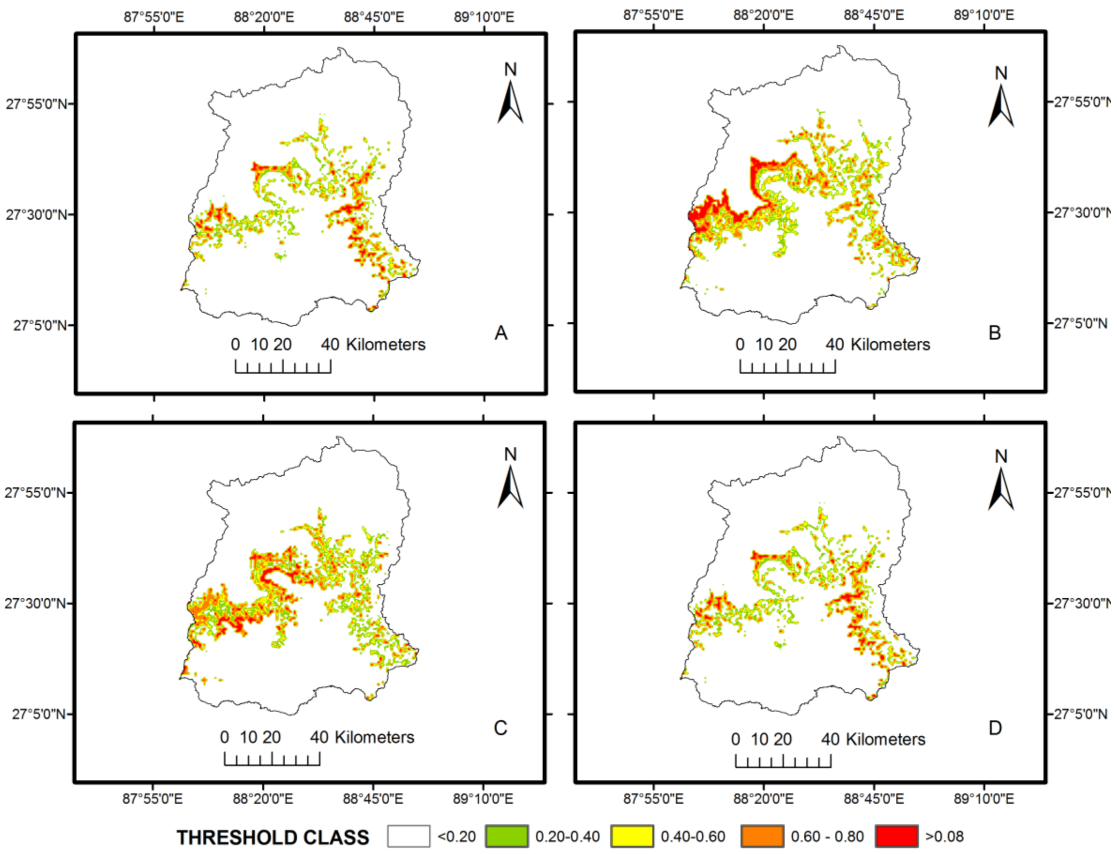

Figure 6.5: Future climate change impact on Himalayan Monal in the Sikkim Himalayas; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively.

7.3.3.1.6. Impact of future climate change on distribution of the Himalayan Monal in the Khangchendzonga Biosphere Reserve

Based on different future climate Scenario of RCP-2050 the future suitable habitat area of the Himalayan Monal was quantified in the Khangchendzonga Biosphere Reserve (Figure 6.6). In RCP 2.6, according to different threshold classes, the low potential threshold class of Himalayan Monal emerged for the highest area cover (195.34 sq. km) in the Khangchendzonga Biosphere Reserve followed by the

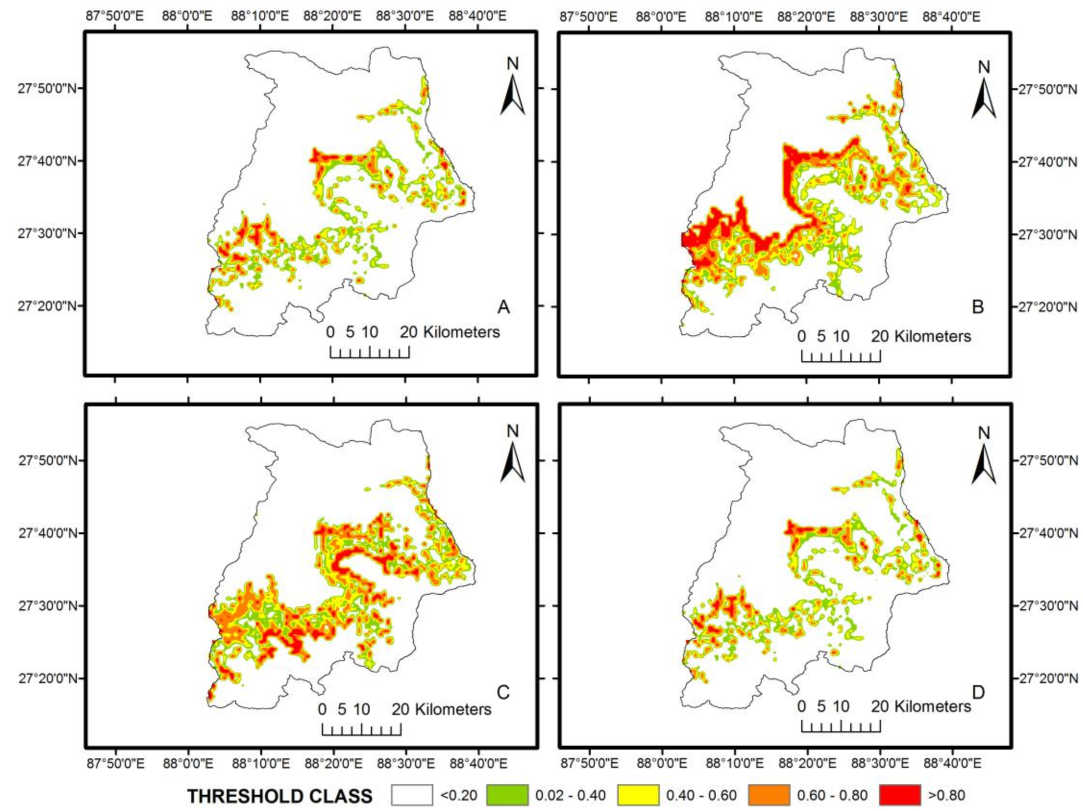

Figure 6.6: Future climate change impact on Himalayan Monal in the Khangchendzonga Biosphere; A depicts RCP 2.6, B depicts RCP 4.5, C depicts RCP 6.0 and D depicts RCP 8.5 respectively.

high potential threshold class (124.50 sq. km), the moderate potential threshold class (122.09 sq. km), and the very high potential threshold class (93.17 sq. km). In RCP 4.5, the very high potential class emerged for the maximum area cover (261.86 sq. km) followed by the very high potential threshold class (230.53 sq. km), the low potential threshold class (194.39 sq. km), and the moderate potential threshold class (179 sq. km).

Again, the similar result obtained in RCP 6.0, the high potential threshold class (247.93 sq. km) emerged for the highest area cover followed by the very high potential threshold class (214.23 sq. km), the low potential threshold class (189.36 sq. km), and the moderate potential threshold class (170.90 sq. km). In RCP 8.5, the very low potential threshold class emerged for the highest area cover (190.17 sq. km) followed by the very high potential threshold class (131.53 sq. km), the moderate potential threshold class (123.61 sq. km), and the high potential threshold class (122.82 sq. km) [Figure 6.6].

7.3.3.1.7. Impact of future climate change on distribution of the Kalij Pheasant in the Eastern Himalayas

Based on different future climate scenario of RCP-2050 the future suitable habitat area of the Kalij Pheasant was quantified in the Eastern Himalayas (Figure 6.7).

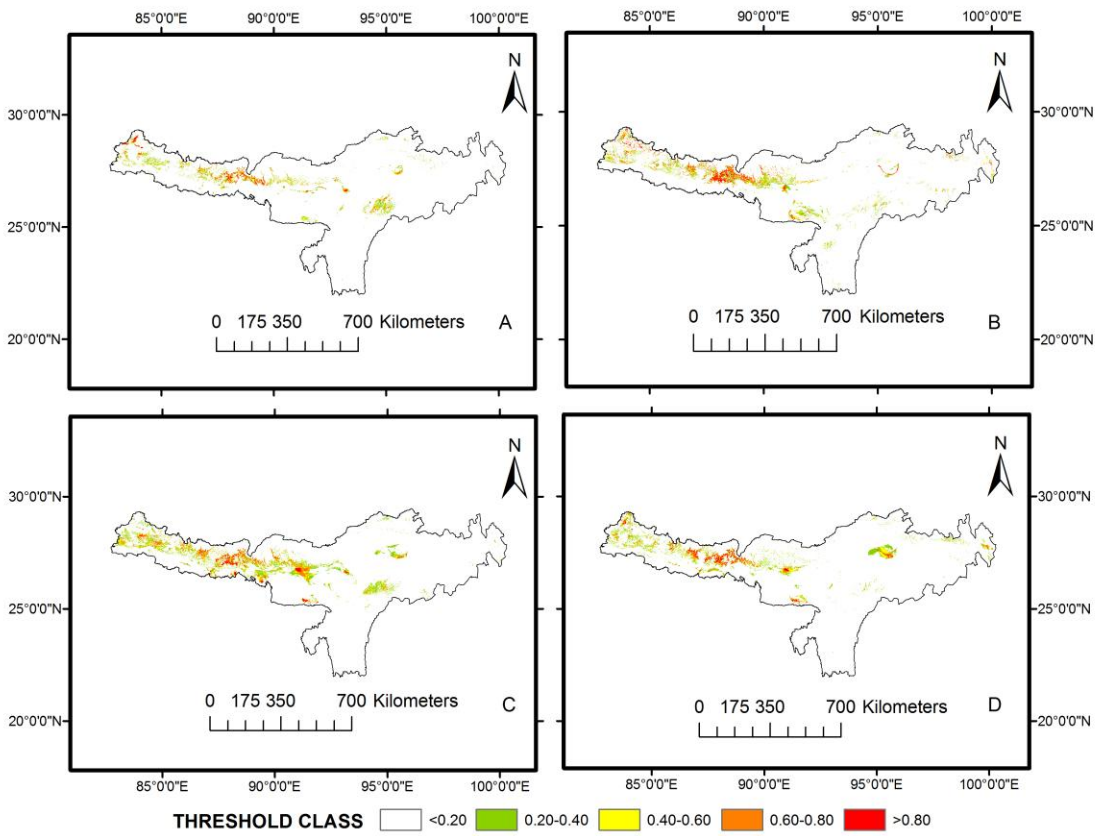

Figure 6.7: Future climate change impact on Kalij Pheasant in the Eastern Himalayas; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively

In RCP 2.6, the low potential threshold class of the Kalij Pheasant emerged highest in area coverage (10065.14 sq. km) in the Eastern Himalaya followed by the high potential threshold class (5496.91 sq. km), the moderate potential threshold class (5440.33 sq. km), and the very high potential threshold class (4461.54 sq. km). Whereas, in RCP 4.5, the low potential threshold class was the highest cover area (22284.27 sq. km) followed by the moderate potential threshold class (12222.36 sq. km), the high potential threshold class (10898.45 sq. km), and the very high potential threshold class (6487.018 sq. km).

Similarly, in RCP 6.0, the low potential threshold class was the highest cover area (7063.85 sq. km) followed by the moderate potential threshold class (30470.23 sq. km), the high potential threshold class (14983.35 sq. km), and the very high potential threshold class (6685.03 sq. km). In RCP 8.5, a similar result emerged; the low potential threshold class was the highest cover area (62645.87 sq. km) followed by the moderate potential threshold class (22385.3 sq. km), the high potential threshold class (9910.76 sq. km), and the very high potential threshold class (5488.02 sq. km) [Figure 6.7].

7.1.3.18. Impact of future climate change on distribution of the Kalij Pheasant in the Sikkim Himalayas

Based on different future climate scenario of RCP-2050, the future suitable habitat area of the kalij Pheasant was quantified in the Sikkim Himalayas (Figure 6.8). In RCP 2.6, the low potential threshold class was of the Kalij Pheasant emerged highest for maximum area cover (522.7852 sq. km) in the Sikkim Himalayas followed by the moderate potential threshold class (458.01 sq. km), the high potential threshold class (455.24 sq. km), and the very high potential threshold class (147.12 sq. km).

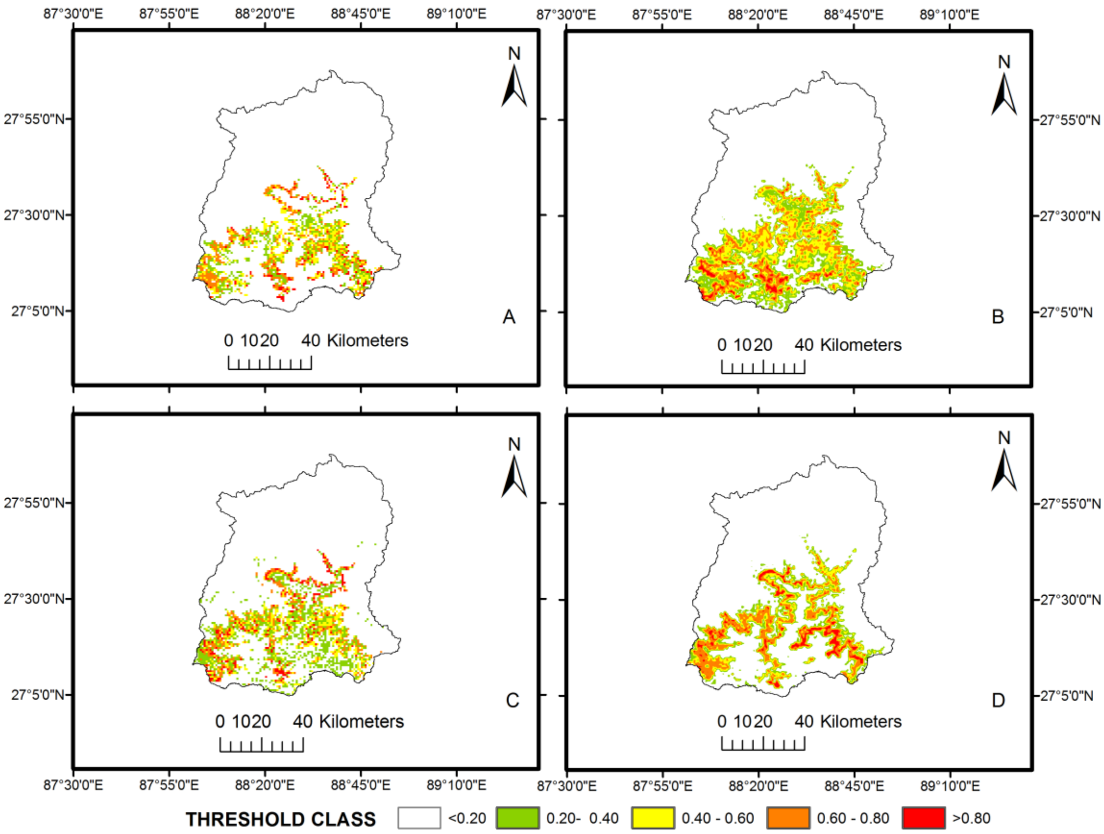

Figure 6.8: Future climate change impact on Kalij Pheasant in the Sikkim Himalayas; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively

Whereas, in RCP 4.5, the very high potential threshold class was the highest area cover (1910.35 sq. km) followed by the low potential threshold class (773.06 sq. km), the moderate potential threshold class (535.19 sq. km), and the high potential threshold class (295. 47 sq. km). Again, in RCP 6.0, the low potential threshold class emerged as the maximum area cover (915.10 sq. km) followed by the moderate potential class (458.94 sq. km), the high potential class (405.27 sq. km), and the very high potential class (218.36 sq. km). Whereas, in RCP 8.5, the high potential threshold class emerged as the highest area cover (608.83 sq. km) followed by the low potential threshold class (497.80 sq. km), the very high potential class (453.38 sq. km), and the moderate potential class (360.83 sq. km) (Figure 6.8).

7.1.3.1.9. Impact of future climate change on distribution of the Kalij Pheasant in the Khangchendzonga Biosphere Reserve

The future suitable habitat area of the Kalij Pheasant was quantified in the Khangchendzonga Biosphere Reserve, based on different future climate scenario of RCP-2050 (Figure 6.9).

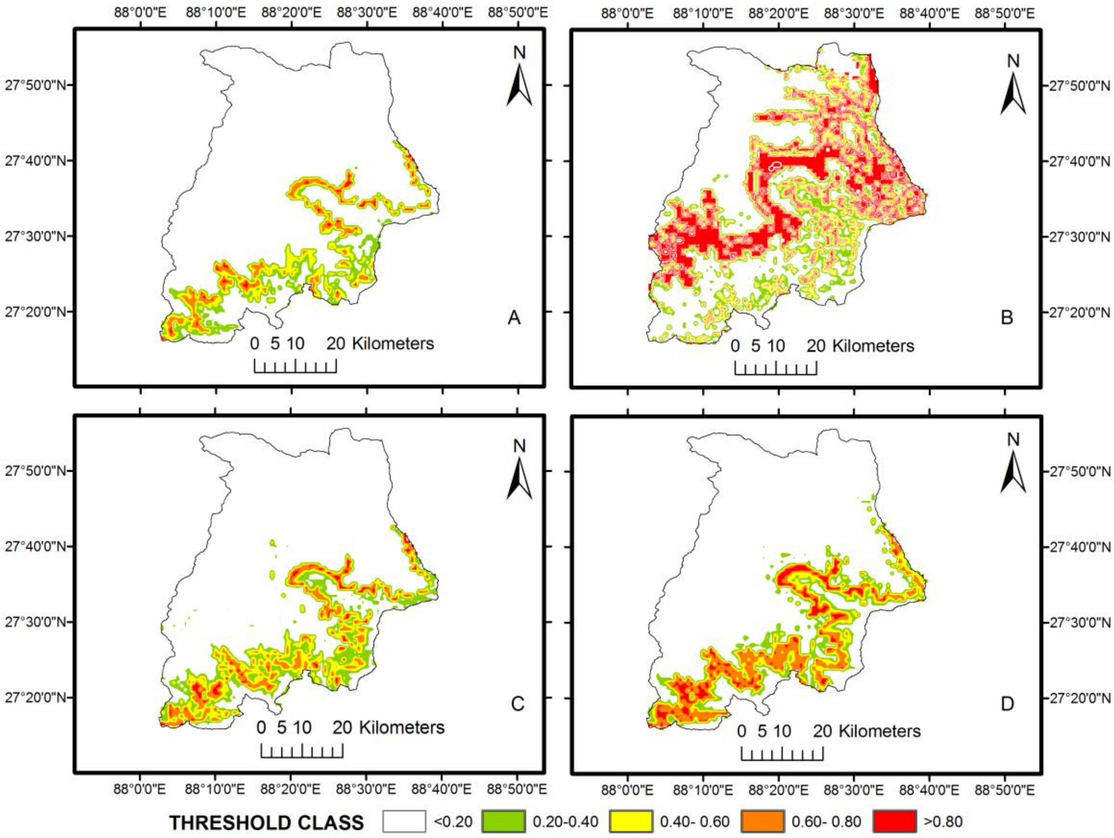

Figure 6.9: Future climate change impact on Kalij Pheasant in the Khangchendzonga Biosphere Reserve; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively.

In RCP 2.6, the low potential threshold class of the Kalij Pheasant emerged as maximum for its area cover (151.48 sq. km) in the Khangchendzonga Biosphere Reserve followed by the high potential threshold class (130.64 sq. km), the moderate potential threshold class (120.22 sq. km), and the very high potential threshold class (72.13 sq. km). Whereas, in RCP 4.5, the very high potential threshold class was the highest for its area cover (871.19 sq. km) followed by low potential threshold class (283.68 sq. km), the high potential threshold class (187.77 sq. km), and the moderate potential threshold class (182.94 sq. km).

Again, in RCP 6.0, the low potential threshold class emerged highest for its maximum area cover (280.52 sq. km) followed by the high potential threshold class (165.11 sq. km), the moderate potential threshold class (135.45 sq. km), and the very high potential threshold class (103.39 sq. km). In RCP 8.5, the high potential threshold class emerged at the top for its the highest area cover (219.61 sq. km) followed by the low high potential threshold class (196.36 sq. km), the very high potential threshold class (179.53 sq. km), and the moderate potential threshold class (120.23 sq. km) [Figure 6.9].

7.3.3.1.10. Impact of future climate change on distribution of the Satyr Tragoapn in the Eastern Himalayas

Based on the different future scenario of RCP-2050, the future suitable habitat area of Satyr Tragopan was quantified in the Eastern Himalaya (Figure 6.10). In RCP 2.6, based on threshold categories, the low potential threshold class area (28023.44 sq. km) of Satyr Tragopan was emerged as the highest area covered in the Eastern Himalaya followed by the high potential threshold class (10167.7 sq. km), the moderate potential threshold class (4967.47 sq. km), and the very high potential threshold class (2279.25 sq. km). Similarly as the result shown in RCP 4.5, the low potential threshold class was quantified the highest area (24809.06 sq. km), followed by the moderate potential threshold class (13532.43 sq. km), high potential threshold class (5020.81 sq. km), and very high potential threshold class (2381.087 sq. km).

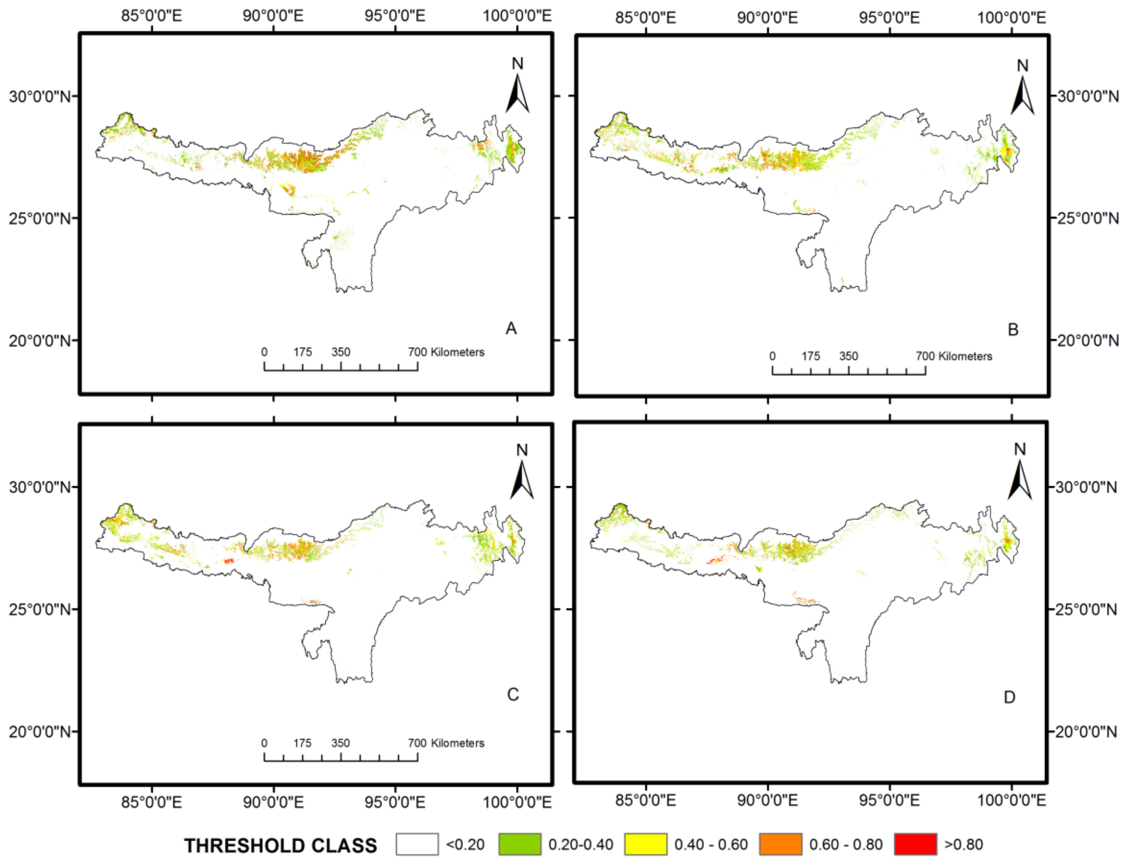

Figure 6.10: Future climate change impact on distribution of the Satyr Tragopan in the Eastern Himalayas; ‘A’ depicts RCP 2.6, ‘B’ depicts RCP 4.5, ‘C’ depicts RCP 6.0 and ‘D’ depicts RCP 8.5 respectively

Again, in RCP 6.0, the low potential threshold class (19570.82 sq. km) was the highest area covered in the Eastern Himalaya followed by the moderate potential threshold class (10805.42 sq. km), high potential threshold class (5149.324 sq. km), and very high potential threshold class (2307.53 sq. km). In RCP 8.5, the low potential threshold class (17439.5 sq. km) was quantified as maximum followed by the moderate potential threshold class (8305.52 sq. km), high potential threshold class (3503.74 sq. km), and very high potential threshold class (1631.04 sq. km) (Figure 6.10).

7.3.3.1.11. Impact of future climate change on distribution of the Satyr Tragoapn in the Sikkim Himalayas

Based on different future climate scenario of RCP-2050, the future suitable habitat area of the Satyr Tragopan was quantified in the Sikkim Himalayas (Figure 6.11).

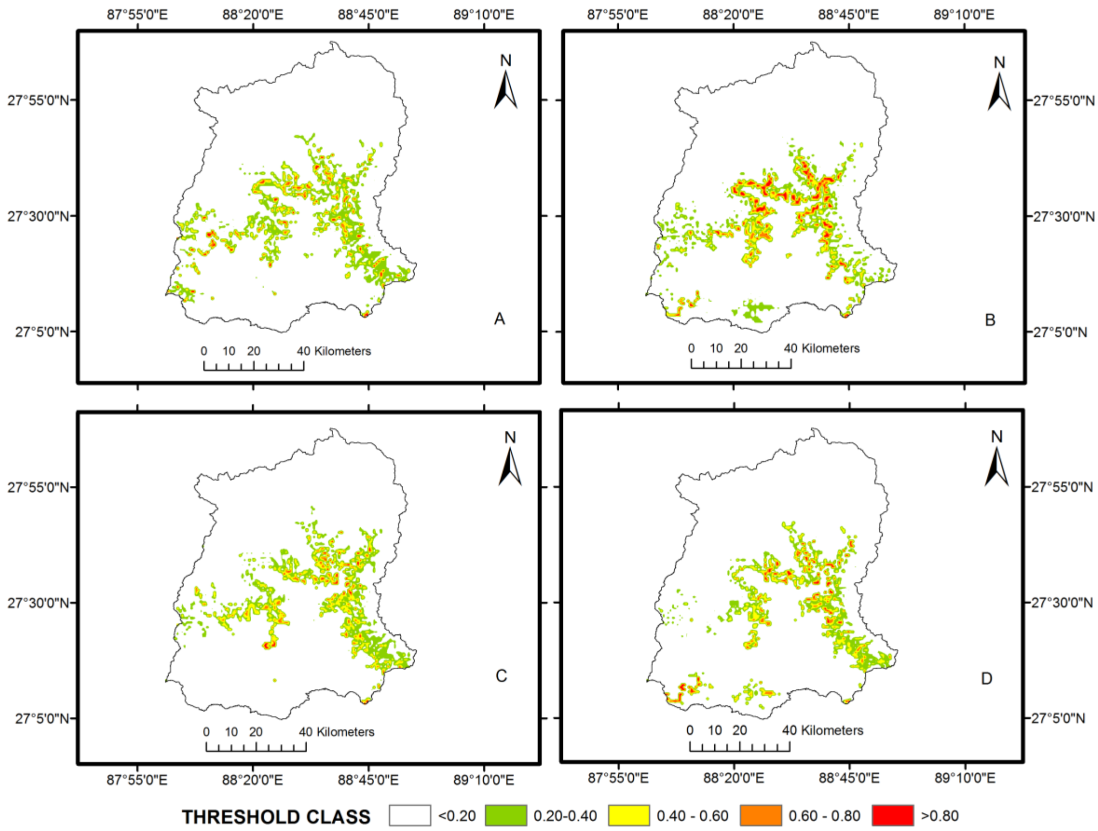

Figure 6.11: Future climate change impact on distribution of the Satyr Tragopan in Sikkim Himalayas; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively.

In RCP 2.6, the low potential threshold class area of the Satyr Tragopan (627.26 sq. km) was emerged as highest area covered in the Sikkim Himalaya followed by the moderate potential class (158.203 sq. km), high potential class (147.10 sq. km) and the very high (123.97 sq. km). Whereas, in RCP 4.5, a similar result was obtained as the low potential threshold area (519.94 sq. km) was the maximum, followed by the moderate potential class (259.97 sq. km) but the very high threshold area emerged greater than that in the high potential threshold class (139.7 sq. km). In RCP 6.0, the low potential threshold class emerged as the highest area ((513.53 sq. km) followed by the moderate potential threshold class (280.36 sq. km), the high potential threshold class (168.40 sq. km) and very high potential threshold class (80.50 sq. km). In RCP 8.5, a similar result was obtained; the low potential threshold class emerged with the maximum area (385.79 sq. km) followed by the moderate potential threshold class (234.99 sq. km), the high potential threshold class (164.68 sq. km) and the very high potential threshold class (129.52 sq. km) (Figure 6.11).

7.3.3.1.12. Impact of future climate change on the distribution of the Satyr Tragoapn in the Khangchendzonga Biosphere Reserve

Based on different future climate scenario of RCP-2050 the future suitable habitat area of Satyr Tragopan was quantified in the Khangchendzonga Biosphere Reserve (Figure 6.12). In RCP 2.6, the low potential threshold class emerged with maximum area (230.77 sq. km) covered in the Khangchendzonga Biosphere Reserve, followed the moderate potential threshold class (80.93 sq. km), and high potential threshold class (80.93 sq. km), as equal coverage, and very high potential threshold class (60.09 sq. km) was the lowest. Similarly, in RCP 4.5, the low potential threshold class (194.71 sq. km) calculated as the highest cover area followed by the moderate potential threshold class (137.82 sq. km), very high potential threshold class (88.94 sq. km), and high potential class (65.70 sq. km). Whereas, in RCP 6.0, the low potential threshold class (196.31 sq. km) emerged as the highest area followed by the moderate potential threshold class (108.17 sq. km), high potential threshold class (89.74 sq. km), and very high potential threshold class (26.44 sq. km).

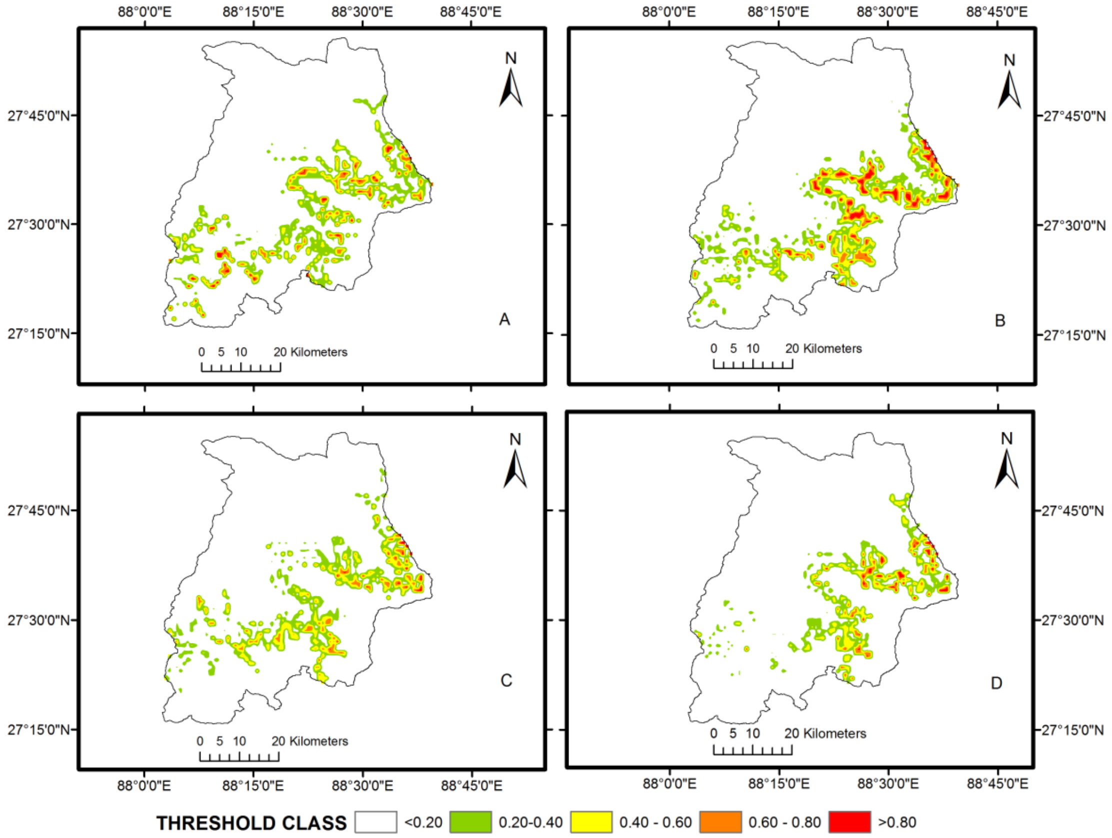

Figure 6.12: Future climate change impact on distribution of the Satyr Tragopan in the Khangchendzonga Biosphere Reserve; 'A' depicts RCP 2.6, 'B' depicts RCP 4.5, 'C' depicts RCP 6.0 and 'D' depicts RCP 8.5 respectively.

A similar result was shown in RCP 8.5; the low potential threshold class (145.83 sq. km) emerged with the maximum coverage area followed by moderate potential threshold class (95.35 sq. km), high potential threshold class (48.07 sq. km), and very high potential threshold class (43.26 sq. km) [Figure 6.12].

7.1.3.2. Future gain and loss of suitable habitat of the Himalayan Pheasants

7.1.3.2.1. Impact of future climate change on gain and loss of suitable habitat of the Blood Pheasant in the Eastern Himalayas

The gain and loss of suitable habitat area of Blood Pheasant were predicted using Python-based GIS toolkit, SDMtool-box, for the future climatic scenario/year combination RCP-2050.

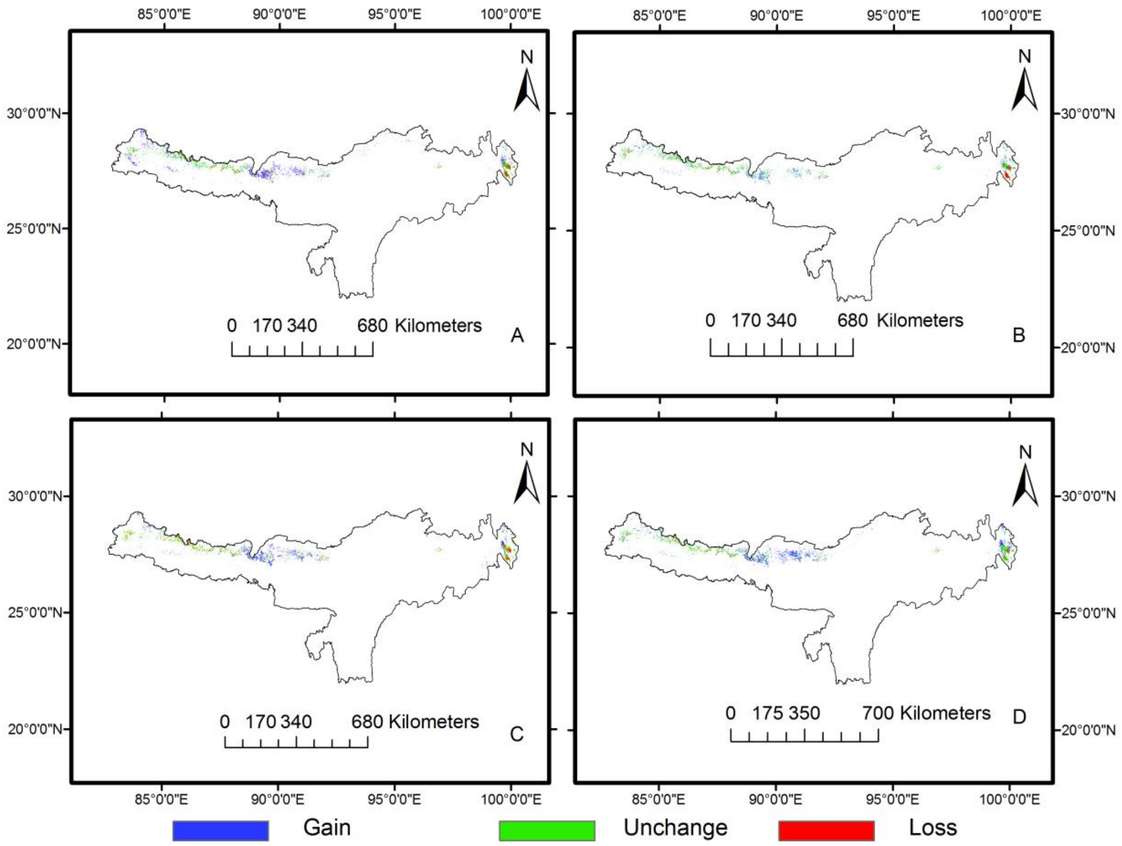

Figure 6.13: Gain and loss in sq. km of suitable habitat of Blood Pheasant in the Eastern Himalayas

Based on RCP-2050 models, the highest predicted gain area is found to be increased by 5814.71 sq. km or 1.11% of the present suitable area under RCP 8.5 followed by RCP 2.6 (5622.59 sq. km or 1.08%), RCP 6.0 (4574.49 sq. km or 0.87%), and RCP 4.5 (3090.93 sq. km or 0.59%), whereas the highest predicted loss area is found to be decreased by 3680.08 or 0.70% under RCP 2.6 followed by RCP 4.5 (3607.51 sq. km or 0.69 %), RCP 6.0 (3578.70 sq. km or 0.68%), and RCP 8.5 (3013.02 sq. km or 0.58%). However, the maximum suitable habitat area of the species, 2138.90 sq. km or 0.41% will remain unchanged in both the present and future climate scenario based on RCP 8.5 followed by RCP 6.0 (1573.21 sq. km or 0.30%), RCP 4.5 (1544.40 sq. km or 0.29), and RCP 2.6 (1471.82 sq. km or 0.28%). Overall, the maximum total suitable habitat area would have increased by 2801.69 sq. km or 0.53% under RCP 8.5 followed by RCP 2.6 (1942.51 sq. km or 0.38%) and RCP 6.0 (995.79 sq. km or 0.19%), whereas, the model RCP 4.5 would have decreased area by 516.58 sq. km or 0.1% of the present suitable area of Blood Pheasant in the Eastern Himalayas (Table 6.1, Figure 6.13).

Table 6.1: Predicting dynamic changes in suitable habitat area for Blood Pheasant in the Eastern Himalayas under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**Unchanged**	**Total**
RCP 2.6	10774.50	3680.08	5622.59	1471.82	1942.51	0.70	1.08	0.28	0.38
RCP 4.5	8242.84	3607.51	3090.93	1544.40	-516.58	0.69	0.59	0.29	-0.1
RCP 6.0	9726.40	3578.70	4574.49	1573.21	995.79	0.68	0.87	0.30	0.19
RCP 8.5	10966.62	3013.02	5814.71	2138.90	2801.69	0.58	1.11	0.41	0.53

7.1.3.2.2. Impact of future climate change on gain and loss of suitable habitat of Himalayan Monal in the Eastern Himalayas

The gain and loss of suitable habitat area of Himalayan Monal were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050.

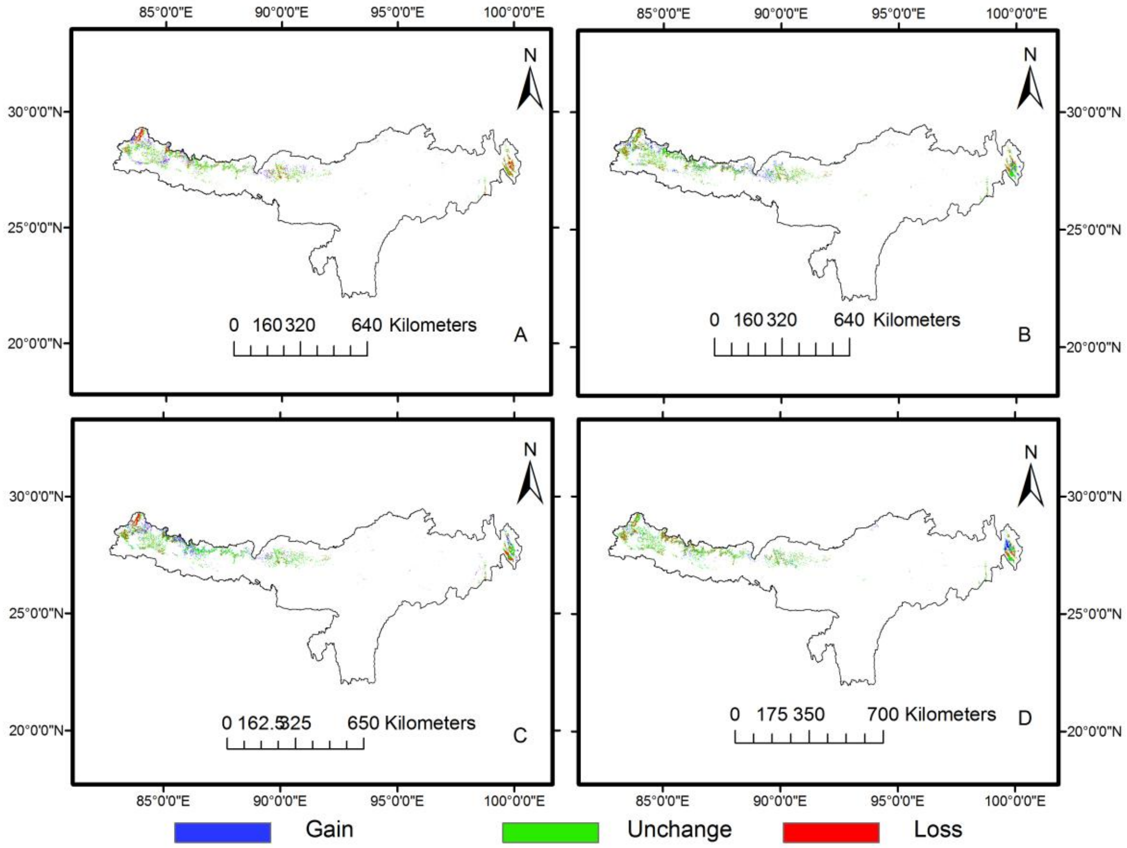

Figure 6.14: Gain and loss in sq. km of suitable habitat of Himalayan Monal in the Eastern Himalayas

Based on RCP-2050 models, the highest predicted gain area is found to be increased by 5825.38 sq. km or 1.11 % of the present suitable area under RCP 6.0 followed by RCP 4.5 (4999.28 sq. km or 0.95%), RCP 2.6 (4683.36 sq. km or 0.89%), and RCP

8.5 (2352.35 sq. km or 0.49%), whereas the highest predicted loss area is found to be decreased by 10752.09 sq. km or 2.05 % under RCP 8.5 followed by RCP 2.6 (8972.88 sq. km or 1.71 %), RCP 4.5 (8460.58 sq. km or 1.61%) and RCP 6.0 (8235.37 sq. km or 1.57%). However, the maximum suitable habitat area of the species, 5503.05 sq. km or 1.01% will remain unchanged in both the present and future climate scenario based on RCP 4.5, followed by RCP 4.5 (5277.85 sq. km or 1.01%), RCP 2.6 (4765.54 sq. km or 0.91%), and RCP 8.5 (2986.33 sq. km or 0.57%). Overall, the maximum total suitable habitat area would be decreased by 8399.74 sq. km or 1.56 % under RCP 8.5 followed by RCP 2.6 (4289.52 sq. km or 0.82 %), RCP 4.5 (3461.30 sq. km or 0.66%), and RCP 6.0 (2409.99 sq. km or 0.46%) [Table 6.2, Figure 6.14].

Table 6.2: Predicting dynamic changes in suitable habitat area for Himalayan Monal in the Eastern Himalayas under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**Unchanged**	**Total**
RCP 2.6	18421.78	8972.88	4683.36	4765.54	-4289.52	1.71	0.89	0.91	-0.82
RCP 4.5	18737.71	8460.58	4999.28	5277.85	-3461.30	1.61	0.95	1.01	-0.66
RCP 6.0	19563.81	8235.37	5825.38	5503.05	-2409.99	1.57	1.11	1.05	-0.46
RCP 8.5	16090.78	10752.09	2352.35	2986.33	-8399.74	2.05	0.49	0.57	-1.56

7.1.3.2.3. Impact of future climate change on gain and loss of suitable habitat of the Kalij Pheasant in Eastern the Himalaya

The gain and loss of suitable habitat area of Kalij Pheasant were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050. Based on RCP-2050 models, the highest predicted gain area is found to be increased by 3963.99 sq. km or 0.76 % of the present suitable area under RCP 4.5 followed by RCP 6.0 (3921.30 sq. km or 0.75%), RCP 8.5 (3867.93 sq. km or 0.74%),

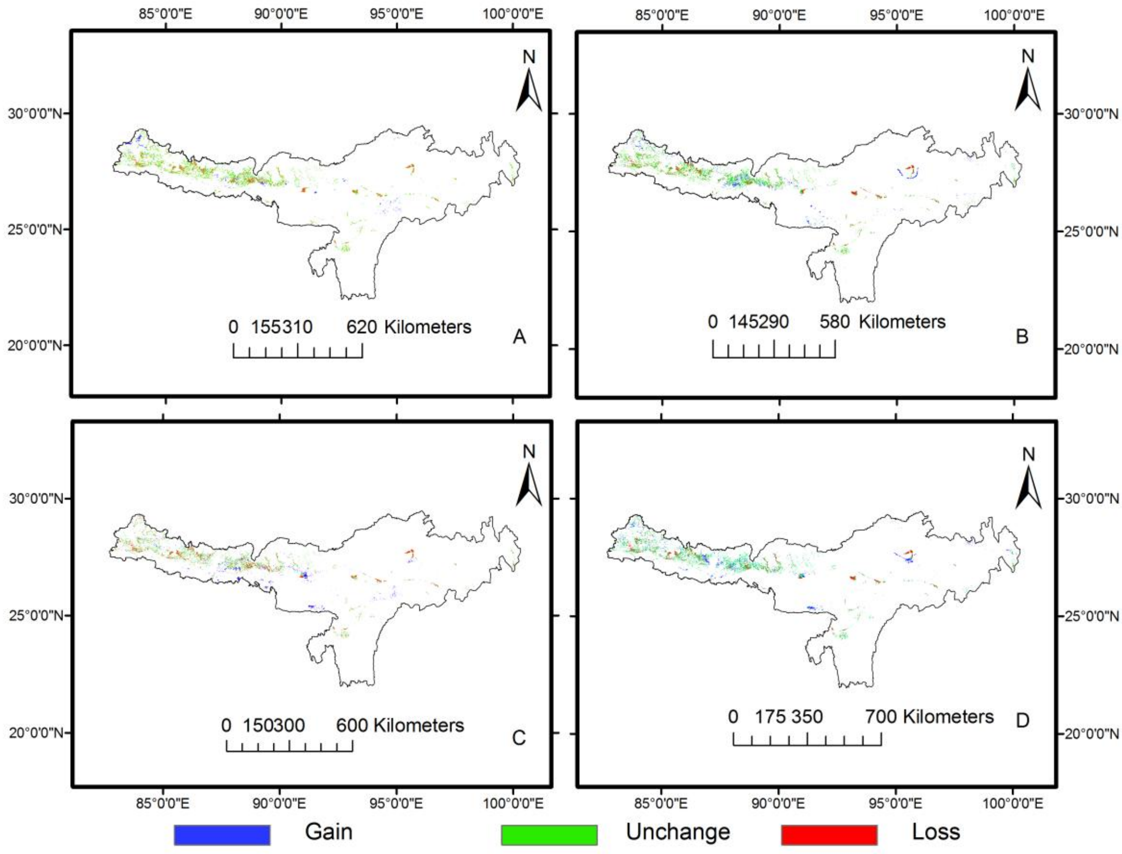

Figure 6.15: Gain and loss in sq. km of suitable habitat of Kalij Pheasant in Eastern Himalaya

and RCP 2.6 (2381.17 sq. km or 0.45%), whereas the highest predicted loss area is found to be decreased by 11988.03 sq. km or 2.29 % under RCP 2.6 followed by RCP 6.0 (10583.45 sq. km or 2.02 %), RCP 8.5 (10500.20 sq. km or 2.00%), and RCP 4.5 (9543.90 sq. km or 1.82 %). However, the maximum suitable habitat area of the species, 4342.89 sq. km or 0.83% will remain unchanged in both the present and future climate scenario based on RCP 4.5 followed by RCP 8.5 (3386.58 sq. km or 0.65%), RCP 6.0 (3303.33 sq. km or 0.63), and RCP 2.6 (1898.75 sq. km or 0.36%). Overall, the maximum total suitable habitat area would be decreased by 9606.86 sq. km or 1.84% under RCP 2.6 followed by RCP 6.0 (6662.15 sq. km or 1.27%) and RCP 8.5 (6632.27 sq. km or 1.26 %), and RCP 4.5 (5579.91 sq. km or 1.06%) [Table 6.3, Figure 6.15].

Table 6.3: Predicting dynamic changes in suitable habitat area for Kalij Pheasant in the Eastern Himalayas under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**unchanged**	**Total**
RCP 2.6	16267.95	11988.03	2381.17	1898.75	-9606.86	2.29	0.45	0.36	-1.84
RCP 4.5	17850.77	9543.90	3963.99	4342.89	-5579.91	1.82	0.76	0.83	-1.06
RCP 6.0	17808.08	10583.45	3921.30	3303.33	-6662.15	2.02	0.75	0.63	-1.27
RCP 8.5	17754.72	10500.20	3867.93	3386.58	-6632.27	2.00	0.74	0.65	-1.26

7.1.3.2.4. Impact of future climate change on gain and loss of suitable habitat of the Satyr Tragopan in the Eastern Himalayas

The gain and loss of suitable habitat area of Satyr Tragopan were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/ year combination RCP-2050.

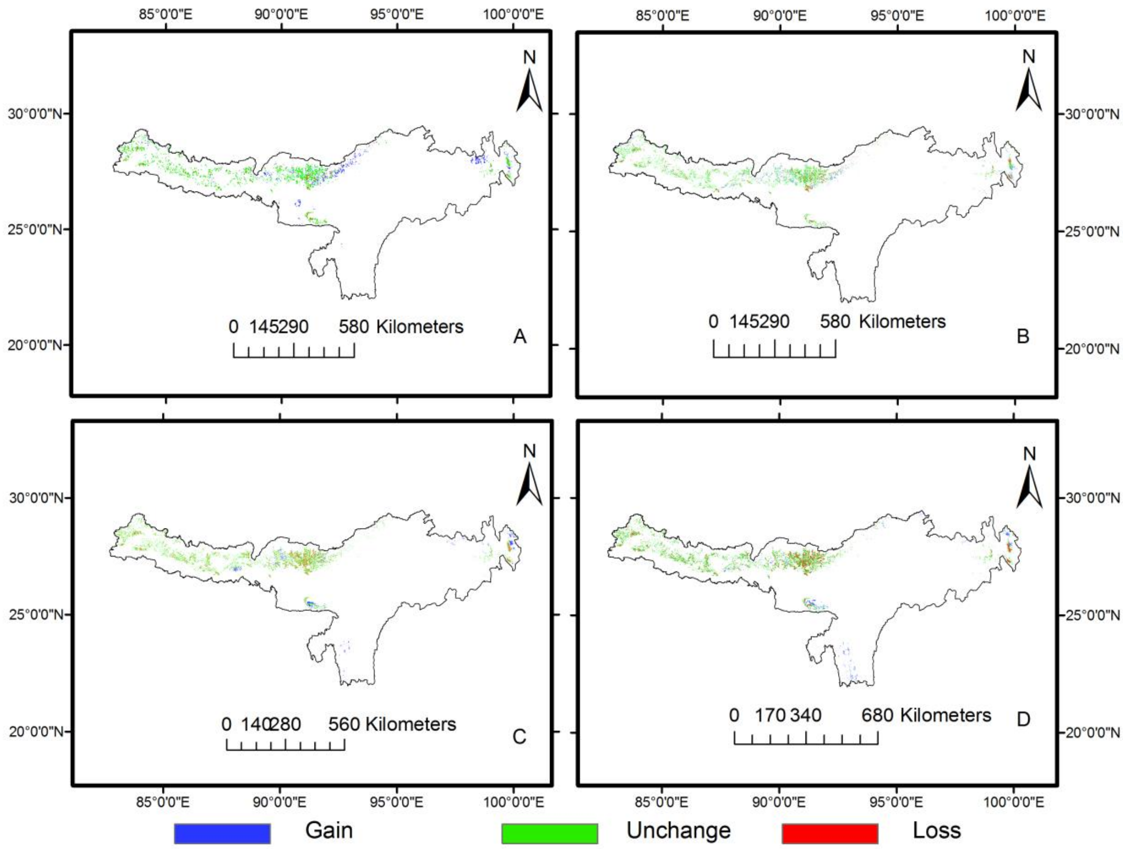

Figure 6.16: Gain and loss in sq. km of suitable habitat of Satyr Tragopan in the Eastern Himalayas.

Based on RCP-2050 models, the highest predicted gain in the area is found to be increased by 5808.11 sq. km, which is 1.11% of the present suitable area under RCP2.5 model followed by RCP 4.5 (3836.98 sq. km or 0.73% of the present suitable habitat area), RCP 6.0 (2975.66 sq. km or 0.57%), and RCP 8.5 (2518.85 sq. km or

0.48%). Whereas, the highest predicted loss in the area cover is found to be decreased by 14120.52 sq. km, i.e. 2.69% of the present suitable area under RCP8.5 model followed by RCP 6.0 (13674.39 sq. km, i.e. 2.61%), RCP 2.6 (9253.75 sq. km or 1.77%), and RCP 4.5 (8073.14 sq. km or 1.54%). However, the maximum cover of suitable habitat area of 6305 sq. km or 1.20% will remain unchanged in both present and future climate scenario based on RCP 4.5 followed by RCP 2.6 (5002.14 sq. km or 0.96%), RCP 6.0 (701.22 sq. km or 13%) and RCP 8.5(258.29 sq.km or 0.05%). Overall, the maximum total suitable habitat area of Satyr Tragopan would have decreased by 11601.67 sq.km or 2.21% under RCP 8.5 followed by RCP 6.0 (10698.73 sq. km or 2.04%), RCP 4.5 (4236.16 sq. km or 0.81%) and RCP 2.6 (3445.64 sq. km or 0.66%)[Table 6.4, Figure 6.16].

Table 6.4: Predicting dynamic changes in suitable habitat area for Satyr Tragopan in the Eastern Himalayas under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**Unchand**	**Total**	**Loss**	**Gain**	**Unchand**	**Total**
RCP 2.6	20064.01	9253.75	5808.11	5002.14	-3445.64	1.77	1.11	0.96	-0.66
RCP 4.5	18215.79	8073.14	3836.98	6305.67	-4236.16	1.54	0.73	1.20	-0.81
RCP 6.0	17351.27	13674.39	2975.66	701.22	-10698.73	2.61	0.57	0.13	-2.04
RCP 8.5	16897.67	14120.52	2518.85	258.29	-11601.67	2.69	0.48	0.05	-2.21

7.1.3.2.5. Impact of future climate change on gain and loss of suitable habitat of the Blood Pheasant in Sikkim Himalayas

The gain and loss of suitable habitat area of the Blood Pheasant were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050 in Sikkim Himalaya.

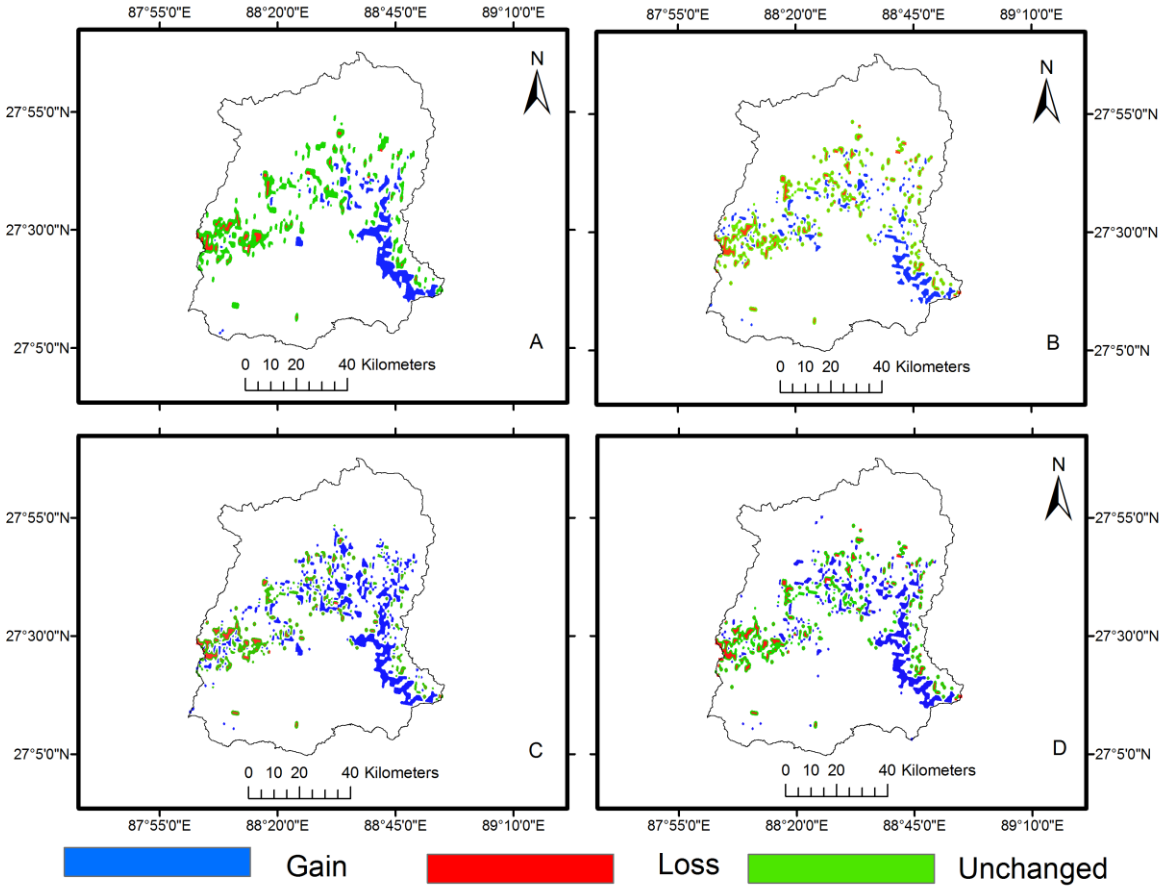

Figure 6.17: Gain and loss in sq. km of suitable Habitat of Blood Pheasant in the Sikkim Himalayas.

Based on RCP-2050 models, the highest predicted gain in the geographic area is found to be increased by 747.2942 sq. km or 10.5312 % of the present suitable area under RCP 6.0 followed by RCP 8.5 (556.1872 sq. km or 7.838038%), RCP 2.6

(379.3522 sq. km or 5.219169 %), and RCP 4.5 (336.0847 sq. km or 4.736256 %). Whereas, the highest predicted loss area is found to be decreased by 336.0847 sq. km or 4.736256 %, under RCP 4.5 followed by RCP 8.5 (329.4948 sq. km or 4.643388 %), RCP 6.0 (204.2868 sq. km or 2.878901 %), and RCP 2.6 (102.8024 sq. km or 1.448737 %).

Table 6.5: Predicting dynamic changes in suitable habitat area for Blood Pheasant in the Sikkim Himalayas under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**unchanged**	**Total**
RCP 2.6	1062.291	102.8024	370.3522	589.1367	267.55	1.44	5.22	6.49	3.77
RCP 4.5	798.6954	336.0847	336.0847	126.526	0	4.73	4.74	1.39	0
RCP 6.0	1209.905	204.2868	747.2942	258.3239	543.007	2.88	10.53	2.84	7.65
RCP 8.5	1018.798	329.4948	556.1872	133.1159	226.692	4.64	7.83	1.46	3.19

The maximum suitable habitat area of the species, 589.1367 sq. km or 6.491149 % will remain unchanged in both the present and future climate scenario based on RCP 2.6 followed by RCP 6.0 (258.3239 sq. km or 2.846231%), RCP 8.5 (133.1159 sq. km or 1.46668 %), and RCP 4.5 (336.084 sq. km or 1.394072 %). Overall, the maximum total suitable habitat area would be increased by 543.007 sq. km or 7.652297 % under RCP 6.0 followed by RCP 2.6 (267.55 sq. km or 3.770434 %), and RCP 8.5 (226.692

sq. km or 3.194645 %), and under RCP 4.5 overall suitable habitat area would not be either increased and decreased (Table 6.5, Figure 6.17).

7.1.3.2.6. Impact of future climate change on gain and loss of suitable habitat of the Himalayan Monal in Sikkim Himalayas

The gain and loss of suitable habitat area of Himalayan Monal were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050 in Sikkim Himalaya.

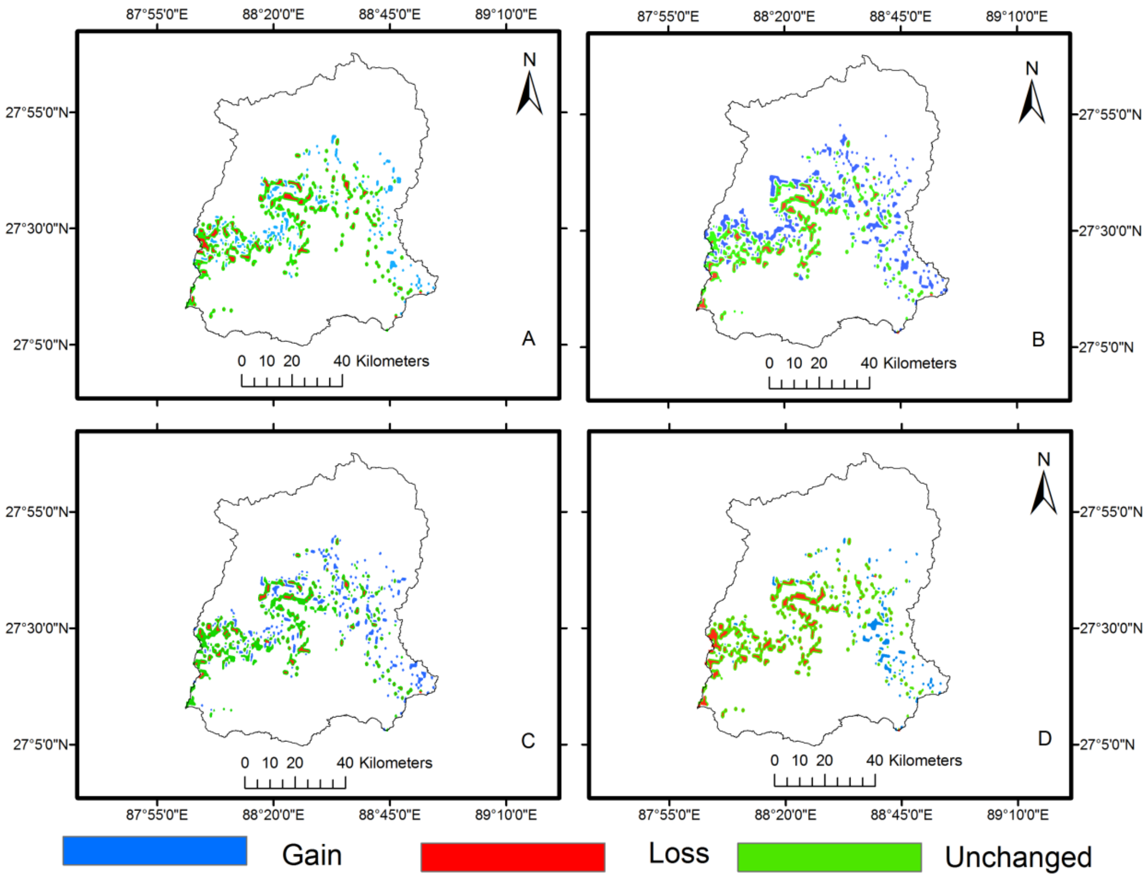

Figure 6.18: Gain and loss in sq. km of suitable habitat of Himalayan Monal in the Sikkim Himalayas

Based on RCP-2050 models, the predicted gain area is found to be increased by 554.9503 sq. km or 7.820607 % of the present suitable area under RCP 4.5 followed by RCP 6.0 (369.5285 sq. km or 5.207561%), RCP 2.6 (284.0504 sq. km or 4.002965), and RCP 8.5 (189.3669 sq. km or 2.668643 %). Whereas, the highest predicted loss area is found to be decreased by 399.7746 sq. km or 5.633802 %, under RCP 8.5 followed by RCP 2.6 (337.9674 sq. km or 4.762787 %), RCP 4.5 (324.8169 sq. km or 4.577465%), and RCP 6.0 (220.9281 sq. km or 3.113417 %). However, the maximum suitable habitat area of the species, 326.1319 sq. km or 4.595996 % will remain unchanged in both the present and future climate scenario based on RCP 6.0 followed by RCP 4.5 (222.2431 sq. km or 3.131949 %), RCP 2.6 (209.0927sq. km or 2.946628%), and RCP 8.5 (147.2854 sq. km or 2.075612%). Overall, the total suitable habitat area would have increased by 230.133 sq. km or 3.24314% under RCP 4.5 and RCP 6.0 by 148.6 sq. km or 2.09414%, and the total suitable habitat area

Table 6.6: Predicting dynamic changes in suitable habitat area for Himalayan Monal in the Sikkim Himalayas under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**unchanged**	**Total**
RCP 2.6	831.1105	337.9674	284.0504	209.0927	-53.917	4.76	4.00	2.94	-0.76
RCP 4.5	1102.01	324.8169	554.9503	222.2431	230.133	4.58	7.82	3.13	3.24
RCP 6.0	916.5885	220.9281	369.5285	326.1319	148.6	3.11	5.20	4.59	2.09
RCP 8.5	736.4269	399.7746	189.3669	147.2854	-210.41	5.63	2.67	2.07	-2.97

would have decreased by 210.4077 sq. km or 2.965159 %, and RCP 2.6 by 53.917 sq. km or 0.759822 % (Table 6.6, Figure 6.18).

7.1.3.2.7. Impact of future climate change on gain and loss of suitable habitat of the Kalij Pheasant in Sikkim Himalaya

The gain and loss of suitable habitat area of Kalij Pheasant were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050 in Sikkim Himalaya. Based on RCP-2050 models, the predicted gain area is found to be increased by 626.2335 sq. km or 8.825162 % of the present suitable area under RCP 4.5 followed by RCP 8.5 (413.5504 sq. km or 5.827937 %), RCP 6.0 (307.2089 sq. km or 4.329325 %), and RCP 2.6 (236.3145 sq. km or 3.330249%).

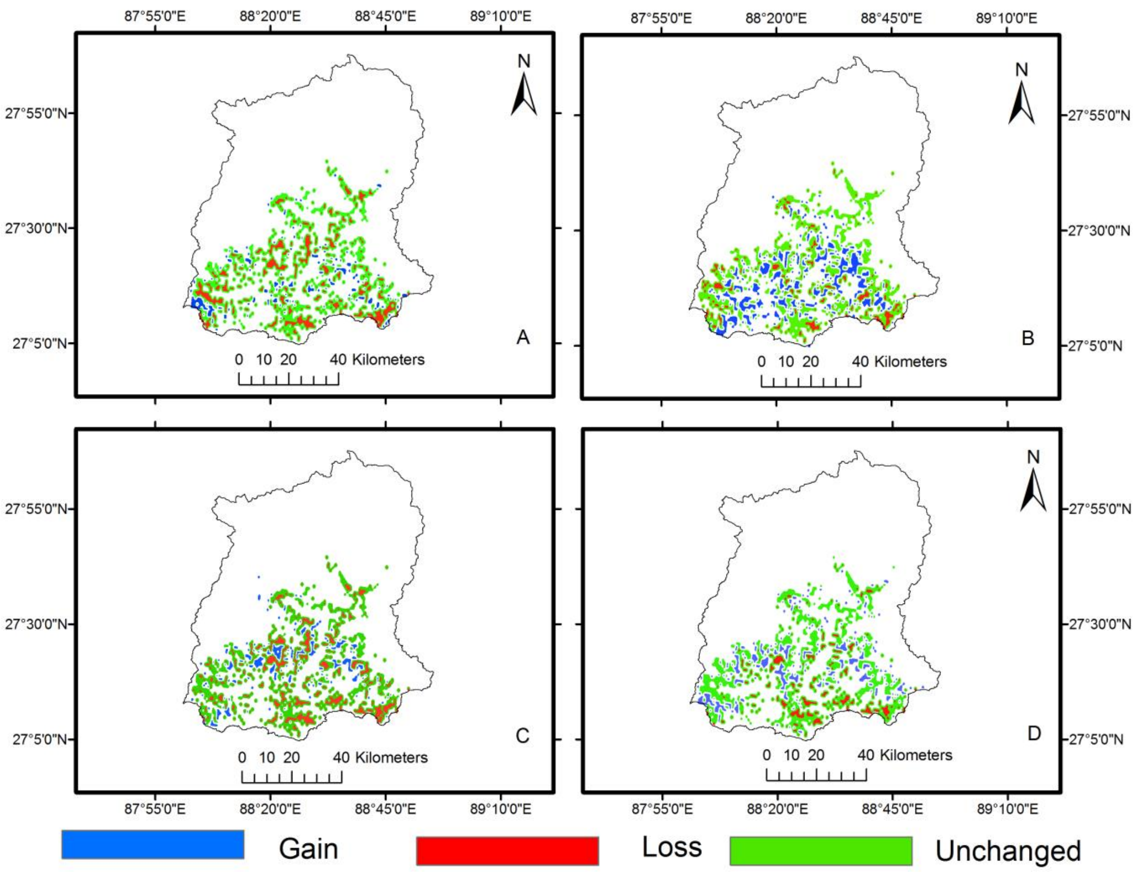

Figure 6.19: Gain and loss in sq. km of suitable habitat of Kalij Pheasant in the Sikkim Himalayas

Whereas, the highest predicted loss area is found to be decreased by 783.7765 sq. km or 11.04533%, under RCP 2.6 followed by RCP 6.0 (712.8821 sq. km or 10.04625 %), RCP 8.5 (405.6733 sq. km or 5.716929%), and RCP 4.5 (355.7846 sq. km or 5.013875 %). The maximum suitable habitat area of the species, 891.4309 sq. km or 12.56244 % will remain unchanged in both the present and future climate scenario based on RCP 4.5 followed by RCP 8.5 (841.5423 sq. km or 11.85939 %), RCP 6.0 (534.3334 sq. km or 7.530065 %), and RCP 2.6 (463.439 sq. km or 6.530989). Overall, the total suitable habitat area would have increased by 270.449 sq. km or 3.81129 % under RCP 4.5 and RCP 8.5 by 7.8771 sq. km or 0.11101%, and the total suitable habitat area would be decreased by 547.462 sq. km or 7.715079 % under RCP 2.6 and RCP 6.0 by 405.6732 sq. km or 5.716928% (Table 6.7, Figure 6.19).

Table 6.7: Predicting dynamic changes in suitable habitat area for Kalij Pheasant in the Sikkim Himalayas under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**unchanged**	**Total**
RCP 2.6	1483.53	783.7765	236.3145	463.439	-547.462	11.04	3.33	6.53	-7.71
RCP 4.5	1873.449	355.7846	626.2335	891.4309	270.449	5.01	8.82	12.56	3.81
RCP 6.0	1554.424	712.8821	307.2089	534.3334	-405.673	10.04	4.32	7.53	-5.72
RCP 8.5	1660.766	405.6733	413.5504	841.5423	7.8771	5.71	5.83	11.86	0.11

7.1.3.2.8. Impact of future climate change on gain and loss of suitable habitat of the Satyr Tragopan in Sikkim Himalayas

The gain and loss of suitable habitat area of Satyr Tragopan were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050 in Sikkim Himalaya.

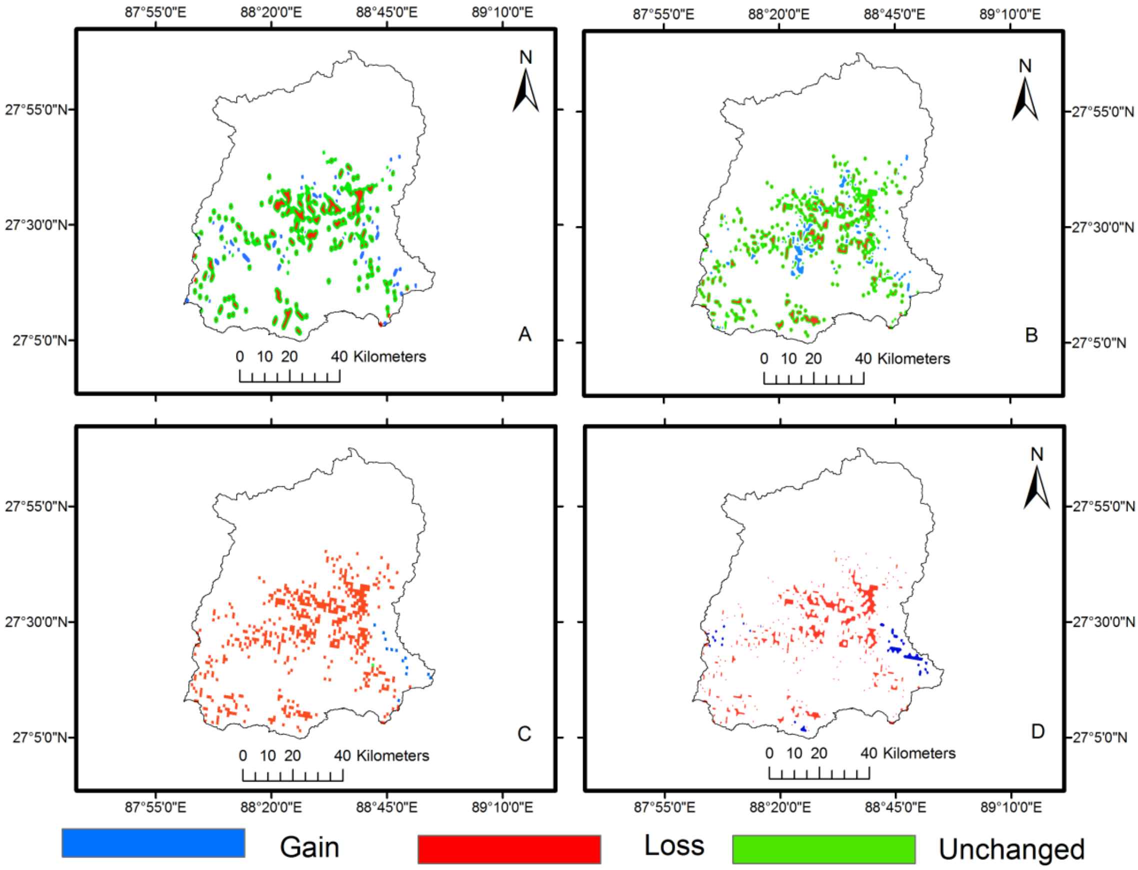

Figure 6.20: Gain and loss in sq. km of suitable habitat of Satyr Tragopan in the Sikkim Himalayas.

Based on RCP-2050 models, the highest predicted gain area is found to be increased by 165.389567 sq. km or 2.33 % of the present suitable area under RCP 4.5 followed by RCP 2.6 (151.6462786 sq. km or 2.13 %), RCP 8.5 (64.31817 sq. km or 0.90%), and RCP 6.0 (17.06716004 sq. km or 0.240518 %), whereas the highest predicted loss area is found to be decreased by 724.56 sq. km or 10.21 % under RCP 8.5 followed by RCP 6.0 (723.385sq. km or 10.19 %), RCP 2.6 (507.2306559 or 7.14%) and RCP 4.5 (413.47391 sq. km or 5.83 %).

Table 6.8: Predicting dynamic changes in suitable habitat area for Satyr Tragopan in the Sikkim Himalayas under different future climate scenario/year combination

Area (sq. km)						Proportion of area (%)			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**unchanged**	**Total**
RCP 2.6	836.6691	507.2306559	151.6462786	177.792	-355.584	7.14	2.13	2.50	-5.01
RCP 4.5	889.9534	413.4739179	165.3895671	311.089	-248.084	5.83	2.33	4.38	-3.50
RCP 6.0	741.765	723.385	17.06716004	1.3128	-706.137	10.19	0.24	0.01	-9.95
RCP 8.5	788.882	724.5638	64.31817	0	-660.246	10.21	0.90	0	-9.31

However, the maximum suitable habitat area of the species, 311.0899001 sq. km or 4.384018 % will remain unchanged in both the present and future climate scenario based on RCP 4.5 followed by RCP 2.6 (177.7922 sq. km or 2.505527 %), and RCP 6.0 (1.312858 sq. km or 0.018501) and in RCP 8.5, these will not remain unchanged for the suitable habitat area of the Satyr Tragopan. Overall, the maximum total suitable habitat area would be decreased by 706.1378 sq. km or 9.953746% under RCP 6.0 followed by RCP 8.5 (660.246 sq.km or 9.31%), RCP2.6 (355.5844 sq.km or 5.01%) and RCP 4.5 (244.084 sq.km or 3.50%) [Table 6.8, Figure 6.20].

7.1.3.2.9. Impact of future climate change on gain and loss of suitable habitat of the Blood Pheasant in Khangchendzonga Biosphere Reserve

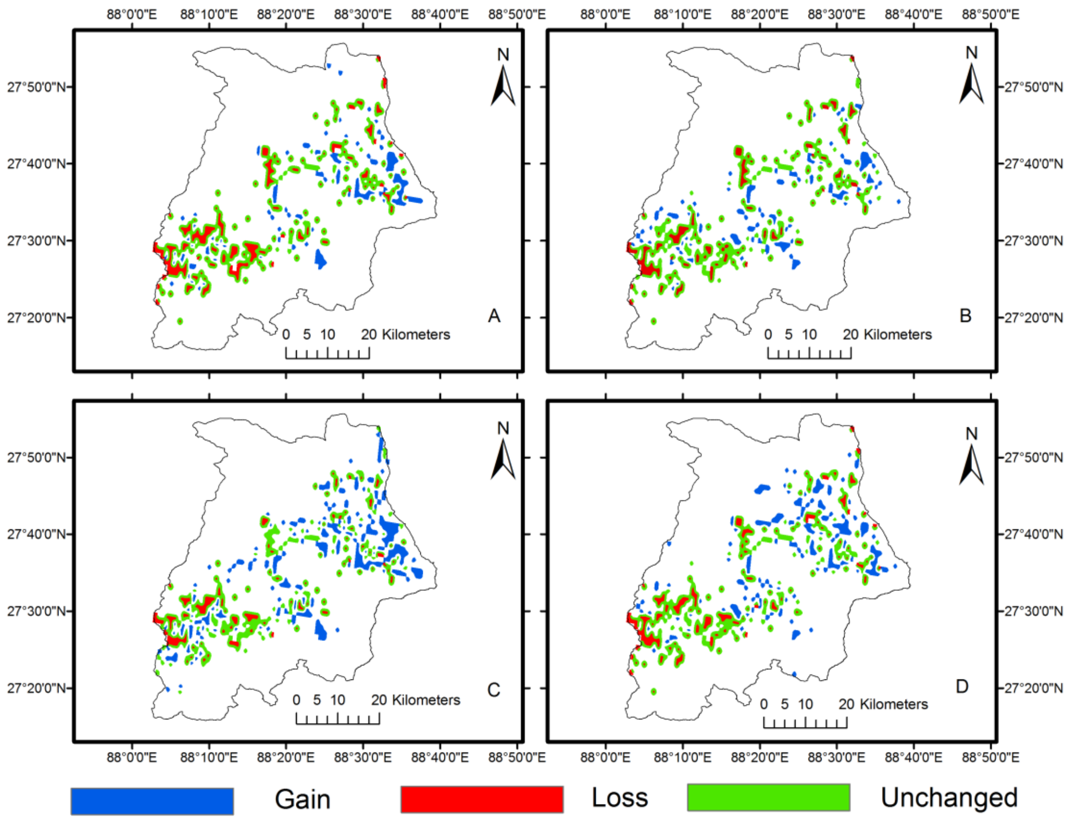

Figure 6.21: Gain and loss in sq. km of suitable habitat of Blood Pheasant in the Khangchendzonga Biosphere Reserve

In the Khangchendzonga Biosphere Reserve, the gain and loss of suitable habitat area of Blood Pheasant were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050. Based on RCP-2050 models, the predicted gain area is found to be increased by 272.3708 sq. km or 9.29238 % of the present suitable area under RCP 6.0 followed by RCP 8.5 (190.3177sq. km or 6.493003 %), RCP 2.6 (135.6156 sq. km or 4.62675 %), and RCP 4.5 (131.8379 sq. km or 4.497868 %); whereas the highest predicted loss area is found to be decreased by 243.8801 sq. km or 8.320372 % under RCP 2.6 followed by RCP

4.5 (188.6646 sq. km or 6.436604 %), RCP 8.5 (184.6195 sq. km or 6.298599%), and RCP 6.0 (137.8948 sq. km or 4.704509 %).

Table 6.9: Predicting dynamic changes in suitable habitat area for Blood Pheasant in the Khangchendzonga Biosphere Reserve under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**Unchanged**	**Total**
RCP 2.6	422.8015	243.8801	135.6156	43.30582	-108.265	8.32	4.62	1.47	-3.69
RCP 4.5	418.2444	188.6646	131.8379	97.74188	-56.827	6.43	4.49	3.33	-1.93
RCP 6.0	559.5567	137.8948	272.3708	149.2911	134.476	4.70	9.29	5.09	4.59
RCP 8.5	477.5036	184.6195	190.3177	102.5664	5.698	6.29	6.49	3.49	0.19

However, the maximum suitable habitat area of the species, 149.2911 sq. km or 5.093312 % will be remaining unchanged in both the present and future climate scenario based on RCP 6.0 followed by RCP 8.5 (102.5664 sq. km or 3.499222 %), RCP 4.5 (97.74188 sq. km or 3.334626 %), and RCP 2.6 (43.30582 sq. km or 1.47745 %). Overall, the total suitable habitat area would have increased by 134.476 sq. km or 4.587871% under RCP 6.0 and in RCP 8.5 by 5.6982 sq. km or 0.194404%, whereas, the total suitable habitat area would have decreased by 108.2645 sq. km or 3.693622 % under RCP 2.6 and in RCP 4.5 by 56.8267 sq. km or 1.938737% (Table 6.9, Figure 6.21).

7.1.3.4. Impact of future climate change on gain and loss of suitable habitat of the Himalaya Monal in Khangchendzonga Biosphere Reserve

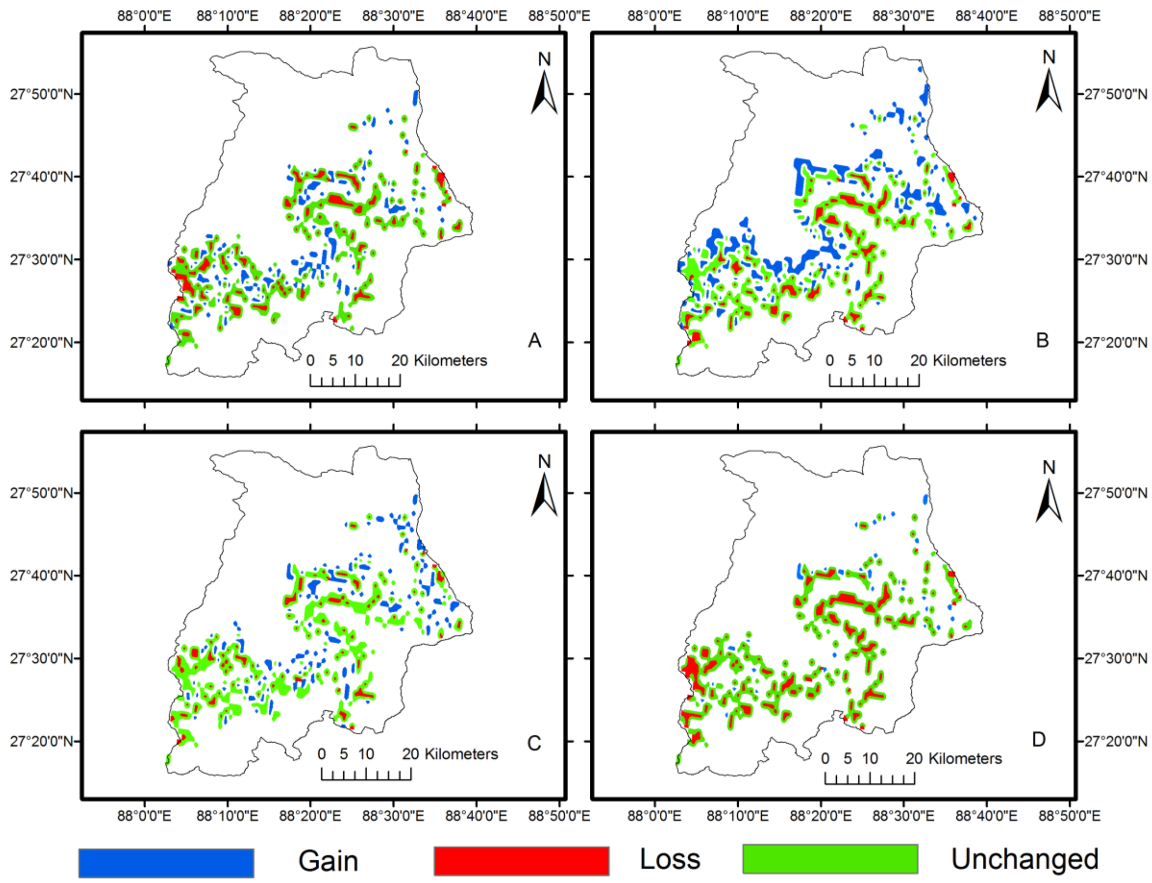

Figure 6.22: Gain and loss in sq. km of suitable habitat of Himalayan Monal in the Khangchendzonga Biosphere Reserve

Using python-based GIS toolkit, SDM tool-box, the gain and loss of suitable habitat area of Himalayan Monal were predicted for the future climatic scenario/year combination RCP-2050 in the Khangchendzonga Biosphere Reserve.

Table 6.10: Predicting dynamic changes in suitable habitat area for Himalayan Monal in the Khangchendzonga Biosphere Reserve under different future climate scenario/year combination

Area (sq. km)						Proportion of area (%)			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**Unchanged**	**Total**
RCP 2.6	541.9164	218.1299	162.4613	161.3252	-55.6686	7.44	5.54	5.50	-1.89
RCP 4.5	672.5671	213.5855	293.112	165.8696	79.5265	7.28	10.00	5.65	2.71
RCP 6.0	566.9104	145.4199	187.4553	234.0352	42.0354	4.96	6.39	7.98	1.43
RCP 8.5	423.7627	282.8872	44.30763	96.56791	238.5796	9.65	1.51	3.29	-8.13

Based on RCP-2050 models, the predicted gain area is found to be increased by 293.112 sq. km or 10.00% of the present suitable area under RCP 4.5 followed by RCP 6.0 (187.4553 sq. km or 6.395347 %), RCP 2.6 (162.4613 sq. km or 5.542636%), and RCP 8.5 (44.30763 sq. km or 1.511628 %); whereas the highest predicted loss area is found to be decreased by 282.8872 sq. km or 9.651164 % under RCP 8.5 followed by RCP 2.6 (218.1299 sq. km or 7.441862 %), RCP 4.5 (213.5855 sq. km or 7.286822 %), and RCP 6.0 (145.4199 sq. km or 4.96124 %). The maximum suitable habitat area of the species, 234.0352 sq. km or 7.984497 % will be remaining unchanged in both the present and future climate scenario based on RCP 6.0 followed by RCP 4.5 (165.8696 sq. km or 5.658915 %), RCP 2.6 (161.3252 sq. km or 5.503876%), and RCP 8.5 (96.56791 sq. km or 3.294574 %).

Overall, the total suitable habitat area would have increased by 79.5265 sq. km or 2.71318 % under RCP 4.5 and in RCP 6.0 by 42.0354 sq. km or 1.43411 %, whereas, the total suitable habitat area would be decreased by 238.5796 sq. km or 8.139536 % under RCP 8.5 and in RCP 2.6 by 55.6686 sq. km or 1.899226% (Table 6.10, Figure 6.22).

7.1.3.11. Impact of future climate change on gain and loss of suitable habitat of the Kalij Pheasant in Khangchendzonga Biosphere Reserve

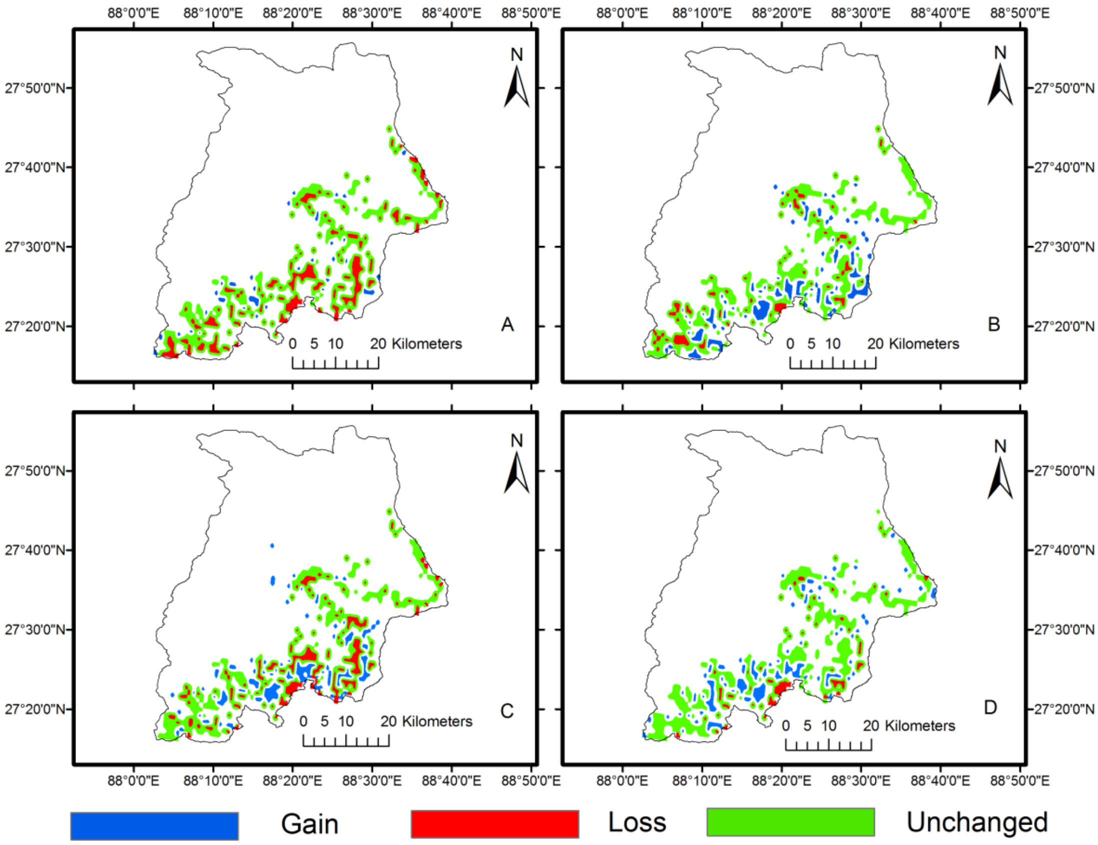

Figure 6.23: Gain and loss in sq. km of suitable habitat of Kalij Pheasant in the Khangchendzonga Biosphere Reserve

In the Khangchendzonga Biosphere Reserve, the gain and loss of suitable habitat area of Kalij Pheasant were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050. Based on RCP-2050 models, the predicted gain area is found to be increased by 141.6274 sq. km or 4.831853 % of the present suitable area under RCP 4.5 followed by RCP 8.5 (133.9033 sq. km or 4.568332 %), RCP 6.0 (130.2972 sq. km or 4.445304 %), and RCP 2.6 (45.32076 sq. km or 1.546193 %); whereas the highest predicted loss area is found to be decreased by 230.0028 sq. km or 7.846925% under RCP 2.6 followed by RCP 6.0 (198.2783 sq. km or 6.764592 %), RCP 4.5 (100.8387 sq. km or 3.440279%), and RCP 8.5 (79.43415 sq. km or 2.710027 %).

Table 6.11: Predicting dynamic changes in suitable habitat area for Kalij Pheasant in the Khangchendzonga Biosphere Reserve under different future climate scenario/year combination

Area (sq. km)						**Proportion of area (%)**			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**unchanged**	**Total**
RCP 2.6	440.7444	230.0028	45.32076	165.4208	-184.68	7.85	1.54	5.64	-6.30
RCP 4.5	537.051	100.8387	141.6274	294.5849	40.7887	3.44	4.83	10.05	1.39
RCP 6.0	525.7208	198.2783	130.2972	197.1453	-67.981	6.76	4.4	6.72	-2.31
RCP 8.5	525.4002	79.43415	133.9033	312.0627	54.469	2.71	4.57	10.64	1.85

The maximum suitable habitat area of the species, 312.0627 sq. km or 10.64653% will remain unchanged in both the present and future climate scenario based on RCP 8.5 followed by RCP 4.5 (294.5849 sq. km or 10.05025%), RCP 6.0 (197.1453 sq. km or 6.725938%), and RCP 2.6 (165.4208 sq. km or 5.643604 %). Overall, the total suitable habitat area would have increased by 54.4692 sq. km or 1.85831 % under RCP 8.5 and in RCP 4.5 by 40.7887 sq. km or 1.39157 %, whereas, the total suitable habitat area be decreased by 184.682 sq. km or 6.300733 % under RCP 2.6 and in RCP 6.0 by 67.9811 sq. km or 2.319288% (Table 6.11, Figure 6.23).

7.1.3.12. Impact of future climate change on gain and loss of suitable habitat of Satyr Tragopan in the Khangchendzonga Biosphere Reserve

The gain and loss of suitable habitat area of Satyr Tragopan were predicted using Python-based GIS toolkit, SDM tool-box, for the future climatic scenario/year combination RCP-2050 in the Khangchendzonga Biosphere Reserve. Based on RCP-2050 models, the predicted gain area is found to be increased by 86.07617 sq. km or 2.936631 % of the present suitable area under RCP 4.5 followed by RCP 2.6 (68.3776 sq. km or 2.332815%), RCP 8.5 (12.45839sq. km or 0.425039%), but in RCP 6.0 there was no predicted gain; whereas the highest predicted loss area is found to be decreased by 319.3879 sq. km or 10.89645% under both RCP 6.0 and RCP 8.5 followed by RCP 2.6 (239.3216 sq. km or 8.164852%), and RCP 4.5 (172.1523 sq. km or 5.87326 %). The maximum suitable habitat area of the species, 147.2355 sq. km or 5.023182 % will remain unchanged in both the present and future climate scenario based on RCP 4.5 and in RCP 2.6 by 100.2872 sq. km or 3.421463 %), whereas, both RCP 6.0 and RCP 8.5 will be totally remain changed.

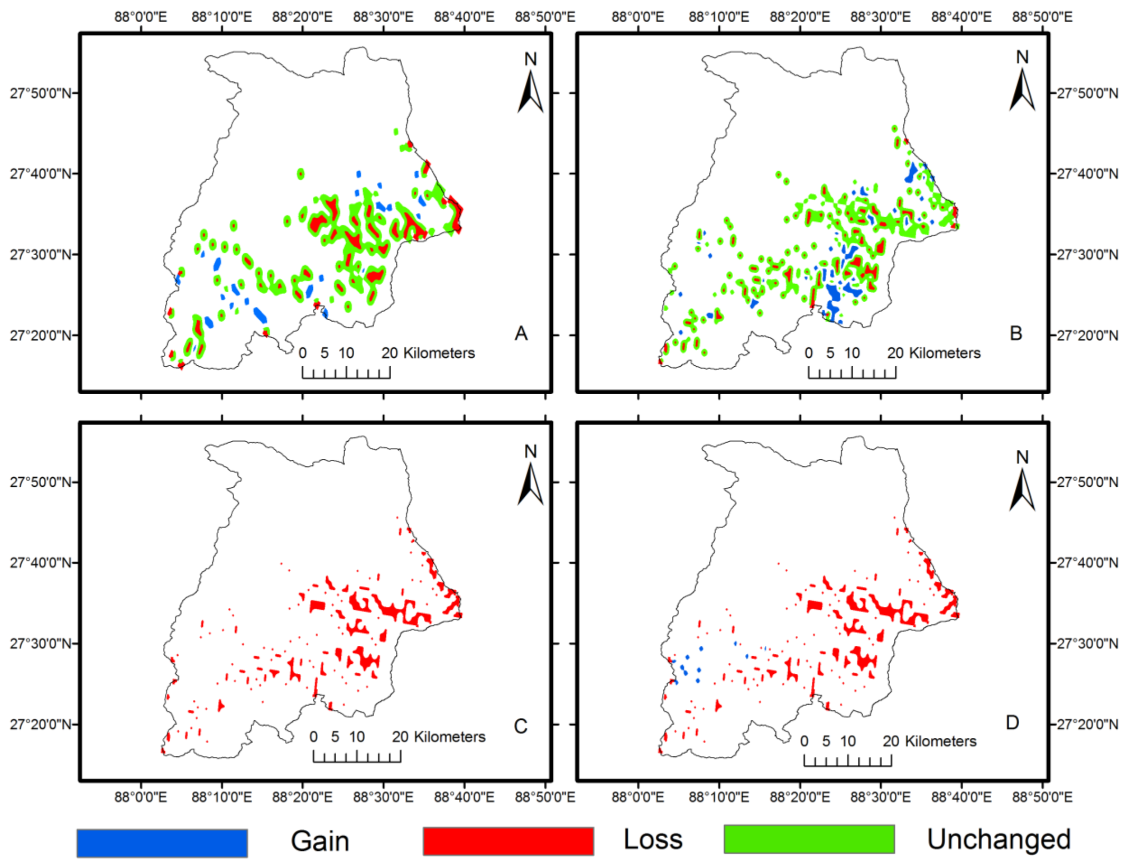

Figure 6.24: Gain and loss in sq. km of suitable habitat of Satyr Tragopan in the Khangchendzonga Biosphere Reserve

Overall, the total suitable habitat area would have decreased by 319.387 sq.km or 10.89 % under RCP 6.0 followed by RCP 8.5 (306.9295 sq. km or 10.47141%), RCP 2.6 (170.944 sq. km or 5.832037 %), and RCP 4.5 (86.07613 sq. km or 2.936629%), whereas in RCP 6.0, the future suitable habitat area of the Satyr Tragopan will be lost (Table 6.12, Figure 6.24).

Table 6.12: Predicting dynamic changes in suitable habitat area for Satyr Tragopan in the Khangchendzonga Biosphere Reserve under different future climate scenario/year combination

Area (sq. km)						Proportion of area (%)			
Model	**Future**	**Loss**	**Gain**	**unchanged**	**Total**	**Loss**	**Gain**	**unchanged**	**Total**
RCP 2.6	407.9864	239.3216	68.3776	100.2872	-170.94	8.16	2.33	3.42	-5.83
RCP 4.5	405.464	172.1523	86.07617	147.2355	-86.076	5.87	2.93	5.023	-2.94
RCP 6.0	319.3879	319.3879	nil	nil	-319.38	10.89	0	nil	-10.89
RCP 8.5	331.8463	319.3879	12.45839	nil	-306.93	10.89	0.42	nil	-10.47

7.1.3.3. Distributional shifts in the core zone

7.1.3.3.1. Centroid Change of the Blood Pheasant in Eastern Himalaya

The core distribution shift of the suitable habitat area for the Blood Pheasant was quantified in the Eastern Himalayas. The centroid of the present distribution of the suitable habitat of the Blood Pheasant was located at the geo-referenced position of 91.228E in the longitude and 27.771 N in the latitude of the part of Bhutan in the Eastern Himalayas. Under future climatic scenario RCP 2.6, the centroid of suitable habitat of the Blood Pheasant would be shifted towards the west of Bhutan at the geo-referenced position of 89.812 E in the longitude and 27.779 N in the latitude.

Similarly, in RCP 4.5, the present centroid of the suitable habitat of the Blood Pheasant would be shifted towards the western part of Bhutan at the geo-referenced position of 90.646 E in longitude, and 27.754 N in longitude. In RCP 6.0, the present centroid of the suitable habitat of the Blood Pheasant would be shifted towards the south-west of Bhutan at the geo-referenced point of 91.125 E in longitude, and 27.651 N in latitude. Whereas, under RCP 8.5, the present centroid of the suitable habitat of the Blood Pheasant would be shifted towards the eastern part of Bhutan at the geo-referenced point 91.728 E in longitude, and 27.701 in latitude (Figure 6.25).

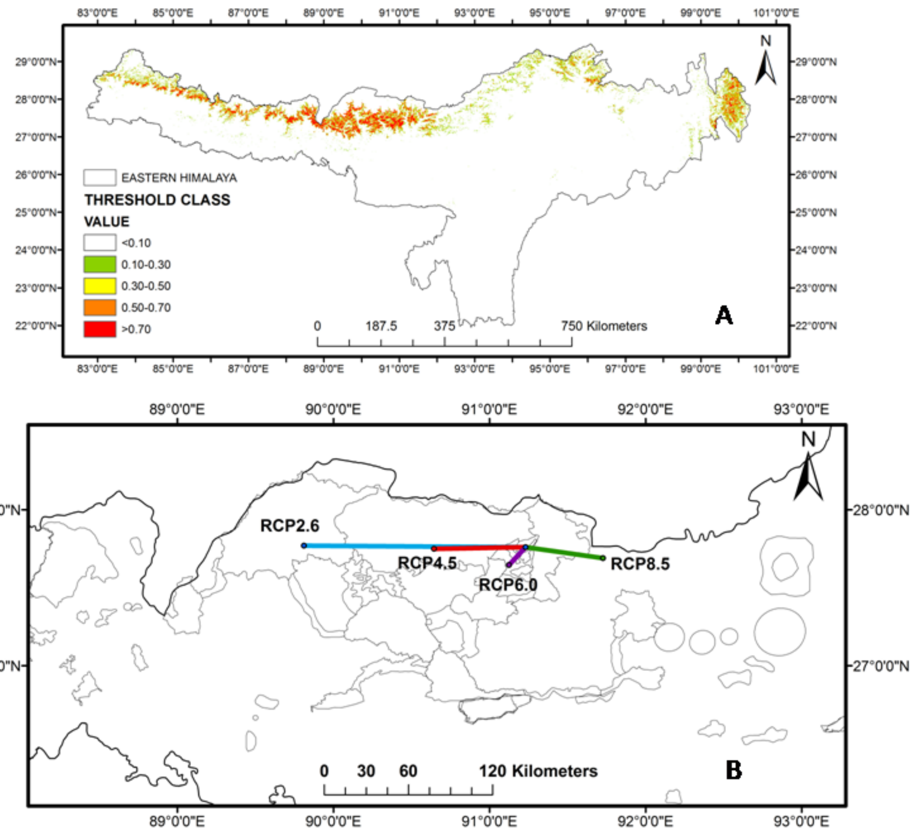

Figure 6.25: Centroid change of Blood Pheasant in the Eastern Himalayas (grey lines depict protected areas).

7.1.3.3.2. Centroid Change of the Himalayan Monal in Eastern Himalaya

The core distribution shift of the suitable habitat area for the Himalayan Monal was quantified in the Eastern Himalayas. The centroid of the present distribution for the suitable habitat of the Himalayan Monal was located at the geo-referenced position of 88.531 E in longitude and 27.887 N in latitude of part of Sikkim Himalaya. The present centroid of the suitable habitat of the Himalayan Monal under RCP 2.6 would be shifted towards the western part of the Sikkim Himalayas at the geo-referenced of 86.614 E in the longitude and 27.974 N in latitude.

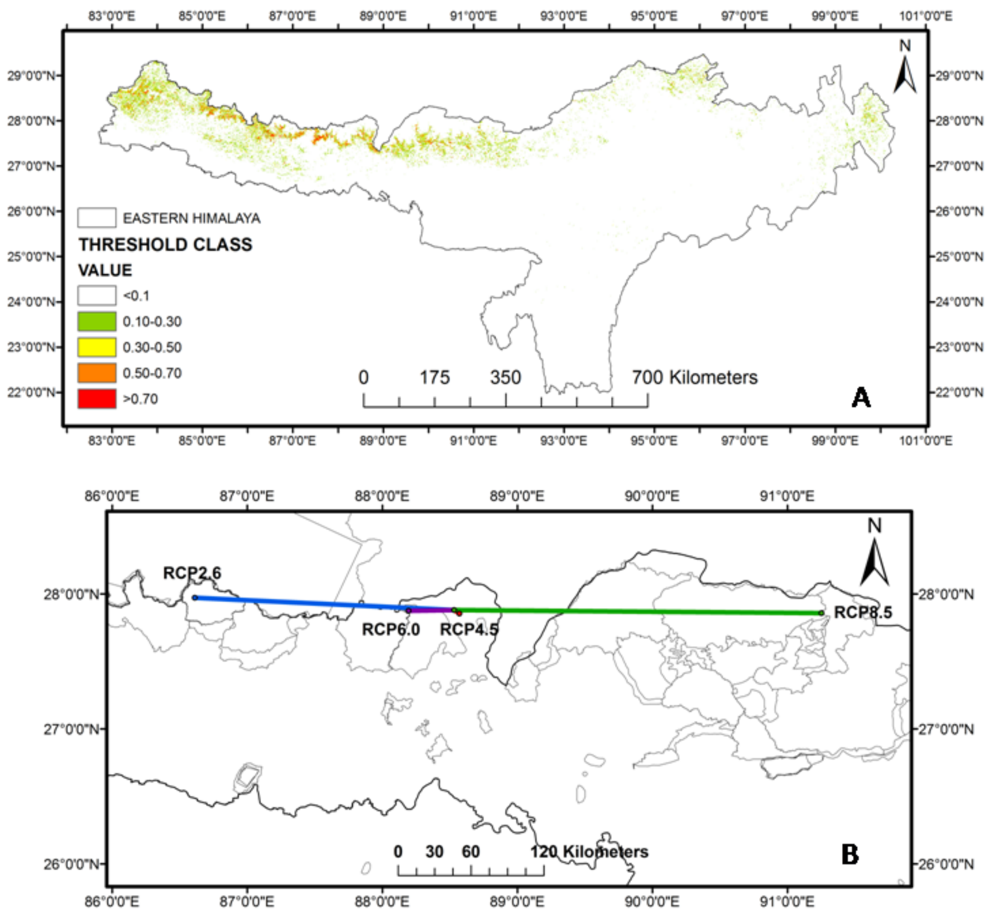

Figure 6.26: Centroid change of Himalayan Monal in the Eastern Himalayas (grey lines depict protected areas).

Under RCP 4.5 the present centroid of the suitable habitat of the Himalayan Monal would not much be affected and shifted around the present centroid at the geo-referenced position of 88.573 E in longitude and 27.974 N in latitude in the Sikkim Himalayas. Whereas, in RCP 6.0 the present centroid of the suitable habitat of the Himalayan Monal would be shifted towards the western part of Nepal at the geo-referenced of 88.188 E in the longitude and 27.878 N in latitude. In RCP 8.5 the centroid of the suitable habitat of the Himalayan Monal would be shifted towards the extreme north-east part of India at the geo-referenced position of the 91.252 E in longitude and 27.861 in latitude (Figure 6.26).

7.1.3.3.3. Centroid Change of the Kalij Pheasant in Eastern Himalaya

The core distribution shift of the suitable habitat area for the Kalij Pheasant was quantified in the Eastern Himalayas. The centroid of the present distribution for the suitable habitat of the Kalij Pheasant was located at the geo-referenced position of 88.065 E in Longitude, and 27.478 N in latitude of part of Sikkim. The present centroid of the suitable habitat of the Khalij Pheasant under RCP 2.6 would be shifted towards north-west part of Sikkim at the geo-referenced position of 88.065 E in the longitude and 27.478 N in latitude. Under RCP 4.5 the present centroid of the suitable habitat of the Kalij Pheasant would be shifted towards the eastern part of Sikkim at the geo-referenced position of 88.563E in longitude and 27.335 N in latitude in the Sikkim Himalayas. Whereas, in RCP 6.0 the present centroid of the suitable habitat of the Kalij Pheasant would be shifted towards eastern part of Sikkim at the geo-referenced position of 88.717 E in the longitude and 27.063 N in latitude. In RCP 8.5 the centroid of the suitable habitat of the Kalij Pheasant would be shifted towards the south -east part of Darjeeling (West Bengal) of India at the geo-referenced position of the 88.563 E in the longitude and 27.347 N in latitude (Figure 6.27).

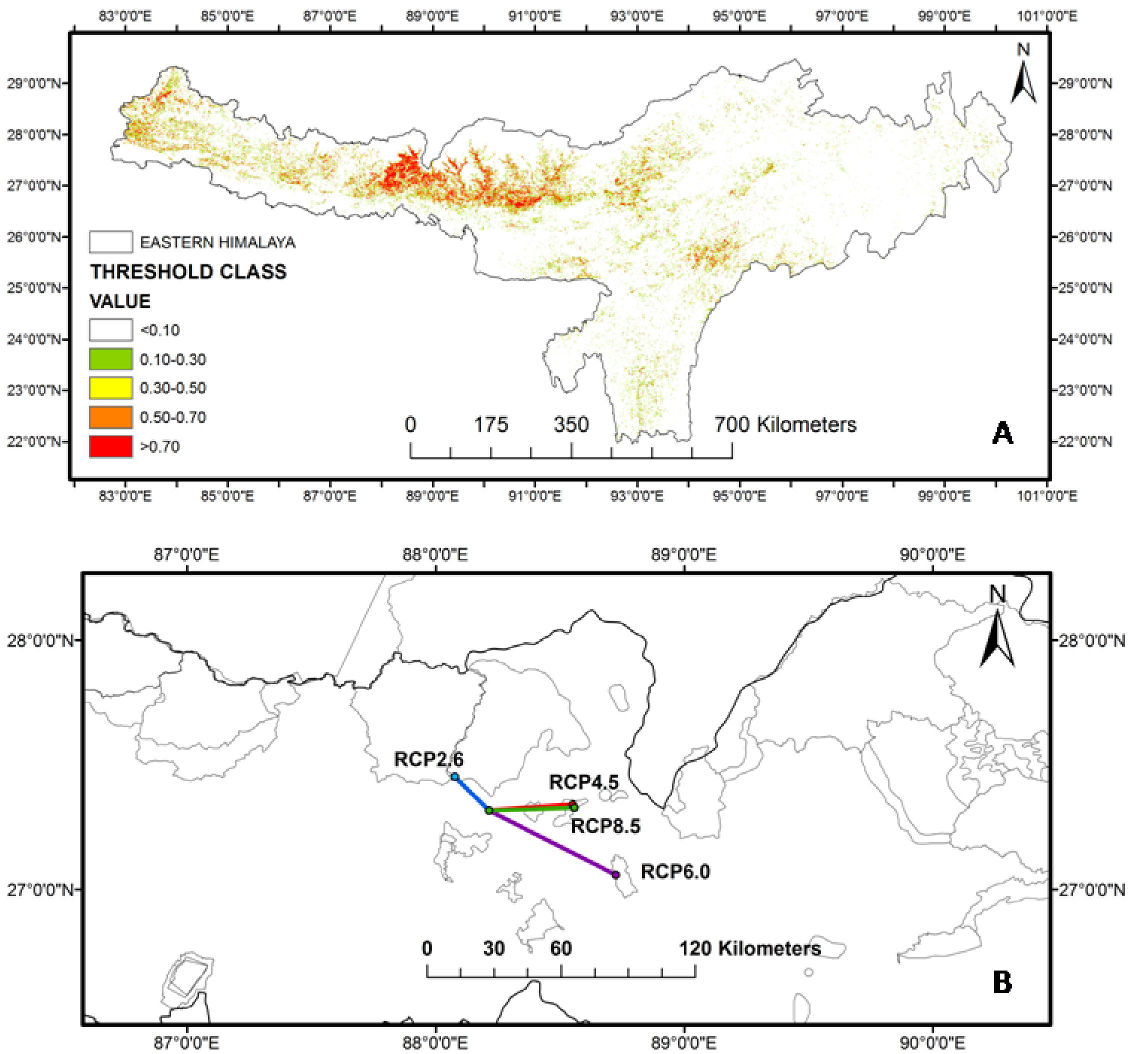

Figure 6.27: Centroid change of Kalij Pheasant in the Eastern Himalayas (grey lines depict protected areas).

7.1.3.3.4. Centroid Change of the Satyr Tragopan in Eastern Himalaya

The core distribution shift of the suitable habitat area for the Satyr Tragopan was quantified in the Eastern Himalayas. The centroid of the present distribution for the suitable habitat of the Satyr Tragopan was located at the geo-referenced position of 89.511E in longitude and 27.454 N in latitude of part of Bhutan. The present centroid of the suitable habitat of the Satyr Tragopan under RCP 2.6 would be shifted towards the eastern part of Bhutan at geo-referenced position of 91.561 E in longitude and 27.561 N in latitude.

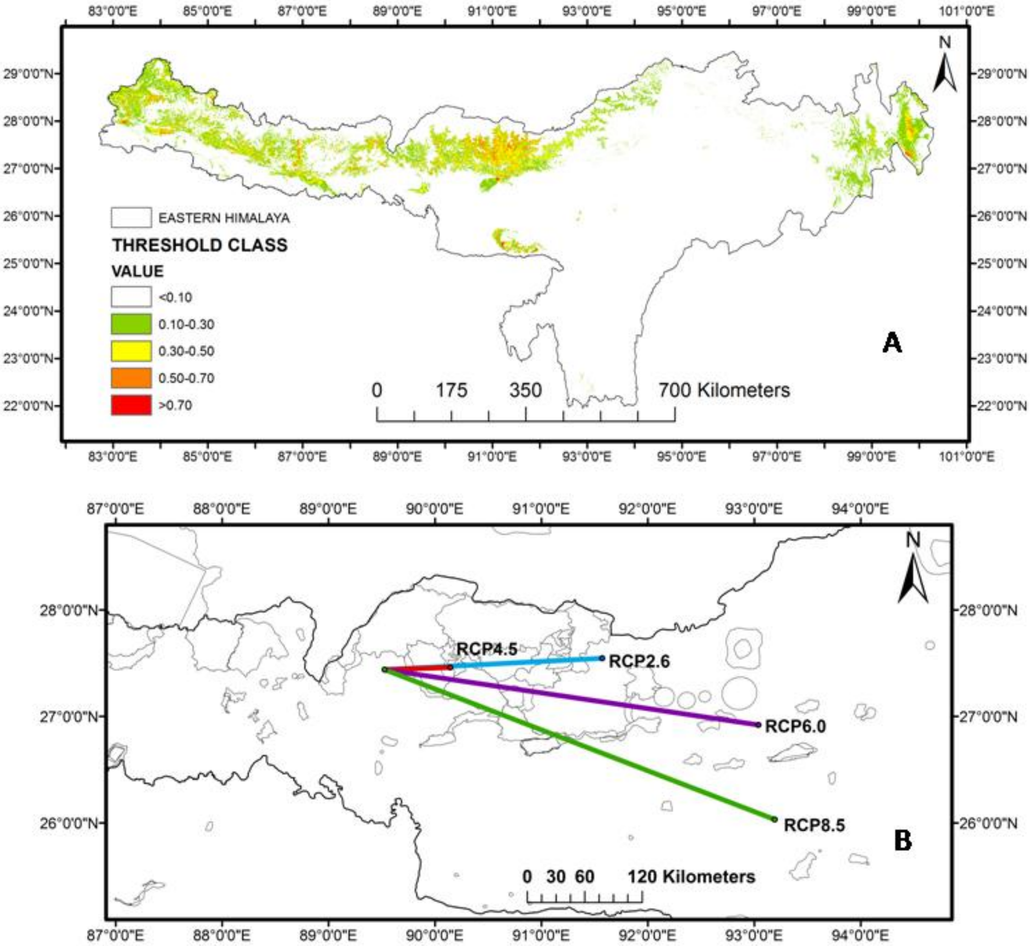

Figure 6.28: Centroid change of Satyr Tragopan in the Eastern Himalayas (grey lines depict protected areas).

Under RCP 4.5 the present centroid of the suitable habitat of the Satyr Tragopan would not much be affected and shifted towards the eastern part of Bhutan at the geo-referenced position of 93.03 E in the longitude and 26.956 N in latitude in the Sikkim Himalayas. Whereas, in RCP 6.0 the present centroid of the suitable habitat of the Satyr Tragopan would be shifted towards the north-east part of India at the geo-referenced position of 90.127 E in longitude and 27.489 N in latitude. Again, in RCP 8.5 the centroid of the suitable habitat of the Satyr Tragopan would be shifted towards the extreme north-east part of India at the geo-referenced position of 93.196E in the longitude and 26.044 N in latitude (Figure 6.28).

CHAPTER 07(I)

OBJECTIVE 04

DISCUSSION

7.1.4. Discussion

The results of climate change distribution model also demonstrated that the future global climate change will have a significant impact on the availability and distribution of Himalayan pheasants in the Eastern Himalayas, Sikkim Himalayas, and Khangchendzonga Biosphere Reserve; that will be an indication of future climate change impact on avian distribution in the Himalayas. Some of the species are restricted to a particular habitat, which is very difficult for them to cope up with altered habitat. Additionally, the population loss and along with altering distribution and abundance of many species are driven by climate change threatening both species diversity and the delivery of critical ecosystem services (Wang et al., 2014; Hu et al., 2015). Most of the climate change researches and forecasts have focused the shifts in climatic means around the world. According to IPCC, 2013 AR5 report the Greenhouse gases contributed a global mean surface warming in the range of 0.5°C to 1.3°C over the period 1951 to 2010 (Stocker et al., 2013). The Himalayas are experiencing a rapid process of climate change, wherein the temperature is increasing (Sharma et al., 2009) and the rainfall is uncertain (Goswami et al., 2006). Furthermore, Himalaya is considered as a data deficient region, the main reasons for this data deficit are the limited number of long-term research stations and systematic data collection; in addition there are uncertainties about the consequences of various drivers of change due to a lack of long-term data (Chettri et al., 2015; Chhetri et al., 2017). Based on IPCC, 2013 AR5 report the Greenhouse gases have contributed to a global mean surface warming in the range of 0.5°C to 1.3°C over the period 1951 to

2010 (Stocker et al., 2013). In the study, the three models (GCMs) were an ensemble, based on their means to reduce the bias among the models for predicting the impacts of future climate change on the distribution of the Himalayan Pheasants in the Himalayas. The results indicate that various forms of temperature and precipitation have an important role in shaping the distribution range of the Himalayan Pheasants in the future climate scenario RCP-2050. The present study predicts that under different concentrations of greenhouse gas emission scenario RCP 2.6-2050, RCP 4.5-2050, RCP 6.0-2050 and RCP 8.5-2050, most of the suitable habitat range will be shrinking in the Khangchendzonga Biosphere Reserve, Sikkim Himalayas, and Eastern Himalayas, until a genuine policy change to reduce greenhouse gas emission is in place and implemented effectively. Based on the result of loss and gain of suitable habitats of the Himalayan Pheasants under different future scenario RCP-2050 in the Eastern Himalayas, Sikkim Himalayas, and Khangchendzonga Biosphere Reserve, on assessing separately, the models reveal that the majority of suitable habitats of the Himalayan Pheasants will be shifting towards higher altitude and latitude in the Himalayan landscape. Although, the estimates of anthropogenic based climate change impacts on biodiversity rely on the projection of different climate models but the uncertainties in those have been a limiting factor, in particular at local scales, a new generation of more complex scenarios' climate change models, perhaps naively, expected to provide more certain projections (Knutti & Sedláček, 2013). Sometime robustness of new generation models can be weaker in consistency than simpler models for accuracy. Even theoretical process understanding and some experimental observations provide strong support for the argument that climate change will probably exceed in the twenty-first century compared to the past century

(Solomon et al., 2007) but the RCP 2.6 scenario, in which global greenhouse-gas emission is reduced by about 90% in 2100, is compared with the present status (Knutti & Sedláček, 2013). However, most of the suitable habitat of the Himalayan Pheasants would be lost in low altitude and latitude landscapes under the different future climate scenario. In general, the present study reveals that the trend of habitat shift to the higher altitude and higher latitude would gradually become more prominent and significant with climate warming. However, the protected areas are considered be have a vital role to play in achieving the global biodiversity targets (Rodriguez et al., 2007; Dunn et al., 2016); additionally, this type of climate change model will help to identify very sensitive areas or habitats of species besides protected areas (PAs). Such type of areas ideally is placed under biodiversity conservation management where the level of biodiversity is under risk or climatic impacts with very high threatening factors (Ricketts et al., 2005). Based on Dunn et al. (2016), the study has strongly challenged the conservation policy for management of protected areas of the Himalayas because the existing protected area network was significantly worse than their optimal zonation result and not up to both Aichi Target 11 and CBD targets for Himalayan Pheasants conservation viewpoint. Within protected areas effective reinforcement is needed to prevent pheasant species extinctions, whereas, from South –East Asia, it is reported that the protected areas have not prevented habitat loss of species (Clark et al., 2013). Furthermore, biodiversity threats have reported that the hunting of Himalayan Pheasants is prevalent across the Himalayas for food and features (Kaul et al., 2004; Hilaluddin & Ghose 2005; Baral, 2005), especially Himalayan Pheasants (Inskipp et al., 2016), wherein even their population is declining (IUCN, 2016). The study suggests the presently protected area networks in the Eastern Himalayas do not cover adequately the distribution of suitable habitat area of the Himalayan Pheasants, thus questioning conservation potential of the same. Although, the species distributions may depend on climate change (Root et al., 2003; Hu et al., 2015; Wang et al., 2014), there may be possibilities in future, that many PAs in the Eastern Himalayas may offer better habitat opportunities for the species (Hannah et al., 2007). However, the Himalayan region comes under the influence of anthropogenic threats due to overexploitation of biodiversity by the people for their survival and largely for commercial purposes (Badola & Aitken, 2010). Moreover, the sustainable use of native biodiversity and improved area management is equally important. Or else, overexploitation of natural resources may result in an alternation of the habitat of certain faunal diversity including Himalayan Pheasants and birds, which is highly threatened for its great sensitivity towards habitat degradation. Hitherto, Himalayan Pheasants are largely ignored for their conservation management and researches, as most of them are found in high elevation habitats, it is often very difficult to monitor them in sloppy and undulating terrains. More sophisticated modelling under climate scenario is needed to attain a goal and vision for the conservation management programmes. The present study further suggests the following management strategies for the Himalayas in response to future climate change, especially in the context of Himalayan Pheasants:

A) Conserve the threatened or climate sensitive species by making suitable conservation policy or programme to introduce/translocate the same in the new projected area(s) at present and in future; B) Implement long-term monitoring of the Himalayan Pheasants in highly sensitive zones, where there are potential threats, which may cause habitat loss of the Himalayan Pheasants under the future climate change scenario; C) Promote and support establishing and extending more PAs within newly projected highly suitable habitat areas in the trans-boundary landscapes, at present and in future climatic conditions, to protect sensitive or endemic species, before they plunge to extinction by poor human management and ignorance.

CHAPTER07(II)

OBJECTIVE 04

To study the climate change impact on the distribution of pheasants and their associated elements, including using perception tools.

Climate change impact on Himalayan Pheasants based on local perception (II).

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OBJECTIVE 04

BACKGROUND

7.2: Climate change impact on Himalayan Pheasants based on local perception

7.2.1. Background

Conceptual frameworks of the impact of climate change on biodiversity have given more emphasis to the understanding linkage between indigenous people and their environment. Indigenous and traditional ecological knowledge plays a crucial role to develop as baseline long-term data sets assembled over centuries of trial and error (Turner, 2009), which can be utilized by scientists, and policy-makers to develop an action plan of the landscape for future perceptive. Indigenous people are closely related to the natural rhythms and processes of their ecosystem (Vogt et al., 2002). Therefore, their perception of changing in their ecosystem with the time is crucial for understanding the ongoing biodiversity process and pattern, and climate change trends of the landscape. With diminishing of such cultures, their indigenous and traditional ecological knowledge system is also vanished, for example taking with it the repository of long- term phenological data (see Barnard & Thuiller, 2008) and range shift data of species that we desperately need. Similarly, in many developed countries, loss of traditional culture and Indigenous knowledge has led to a gap between people and nature. Nowadays, this loss also accelerated by modernization, new technology, and anthropogenic pressure for the betterment of our lifestyle. In Polar regions, hunting and fishing strategies depend on stable ice for Arctic people; yet, the temperature in the Arctic is predicted to rise by as much as 8˚C in the 21st century under present century (Pachauri et al., 2014). In the alpine region, climate warming is critically viewed in response to the loss of alpine biodiversity. Upward movement of plant species, predicted to be displaced off the top of mountains, off their "sky islands" (Gottfriedetal, 1999). Increases in mean annual temperature are not uniform across the globe. Instead, some of the highest average temperature increases are experienced in the high-mountain ecosystem of the Himalayas (Pachauri et al., 2014). Rural people already have in-depth knowledge of local climate variability and these changes as part of their traditional ecological knowledge which evolving by adaptive processes and handed down through generation by cultural transmission (Berkes et al., 1995, 2000). Therefore, 'local perceptions' refer to the way how local people identify and interpret their long- term observation and concepts (Byg & Salick, 2009; Vignola et al., 2010). Most studies on the perceptions of climate deal with temperature and rainfall (Deressa et al., 2009; Fisher et al., 2010), even meteorological data are often used to confirm villagers' assessments (Orlove et al., 2000; Vedwan & Rhoades, 2001; Deressa et al., 2009; Fisher et al., 2010), and perception of risks and threats related to climate variability (Adger et al., 2009; McCarthy, 2011; Saroar & Routray, 2012). Furthermore, the collaboration between indigenous and scientific knowledge to address more precise time frames of climate change and its impact on biodiversity could be explored. Using this strategy the first time attempt was made to assess the impact of climate change on Himalayan Pheasants and their resilience in the Sikkim Himalayas based on perception tool.

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OBJECTIVE 04

MATERIALS & METHODS

7.2.2. Materials and Methods

The perception-based survey was carried out in and around villages of the Khangchendzonga Biosphere Reserve in Sikkim especially focusing it's in the northern region and western region. The perception-based information was gathered by interviewing those who are directly or indirectly associated with the KBR such as forester, *Himal Rakshak,* guides, porters and pack owners. The semi-structured questionnaire was used followed by a snowball technique to collect the data from the 46 respondents. The interviews consisted of a series of questionnaires based on, 1) present availability of the Himalayan Pheasants, 2) status of the temperature in the locality, 3) Changes of availability of the Himalayan Pheasants compared to the last 10-20 years back, 4) present status of Poaching & Hunting of the Himalayan Pheasants, 5) experience of climate change in your locality, 6) Maximum poaching and hunting of the Himalayan Pheasants by forefathers, 7) range shift of the Himalayan Pheasants, 8) factor of range shift of the Himalayan Pheasants, 9) food habit of the Himalayan Pheasants, 9) predator of the Himalayan Pheasants, and 10) uses of Himalayan Pheasants.

7.2.2.1. Analytical analysis

From the procured data, the percentages of the responses and Priority Index was quantified by using formula,

Percentage of the response= no. of respondents respond the question /Total no. respondent*100

Priority Index= no. of a score of respondent given for a particular question/total score *100

The maximum possible score for each question was 10.

7.2.2.2. Statistical analysis

After gathering the data (Range shift, factor of range shift, and phenology shift of the Himalayan pheasants) various descriptive statistics were used. For establishing reliability constructs of the questionnaire Cronbach's alpha value was used (followed by a similar approach of Gliem & Gliem, 2003). Factor analysis was used to establish the scale dimensionality. Subsequently, to ensure the use of Principal Component Analysis, the Barlett Test of Sphericity (BTS) and Kaiser-Meyer-Olkin (KMO) test of appropriateness were used (followed by a similar approach of Olawale & Garwe, 2010). KMO (Kaiser-Meyer-Olkin) test was used to measure sample size adequacy (Norusis, 1985). A value the KMO test falls between one and zero if the value above 0.60 suggests that a factor analysis of the variables is appropriate (followed by a similar approach of Crane et al., 1991; Olawale & Garwe, 2010). In addition to this, a multiple regression analysis was used to find the degree of relationship between two explanatory variables (Factors of range shift of Himalayan pheasant and shift of phenology of Himalayan pheasant) and one dependent variable (Range shift of Himalayan pheasant). Collected the data of range shift, factor of range shift (climate change), and phenology shift of Himalayan Pheasants from the respondents was frame into 3 point scale for statistical analysis.

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RESULTS

7.2.3. Results

7.2.3.1. Analytical analysis

A total of 46 local persons, directly associated with the Khangchendzonga Biosphere Reserve, were interviewed. The respondents totally agreed to the fact that within the KBR, the four Himalayan Pheasants are found. They are Blood Pheasant, Himalayan Monal, Satyr Tragopan and Kalij Pheasant. Information gathered through interaction and semi-structured questionnaires revealed that the majority of the Himalayan Pheasants are found in the high-altitude region of the KBR except for the Kalij Pheasant, confined to the subtropical forest to the temperate forest of the region. This information was also validated by the current field surveys.

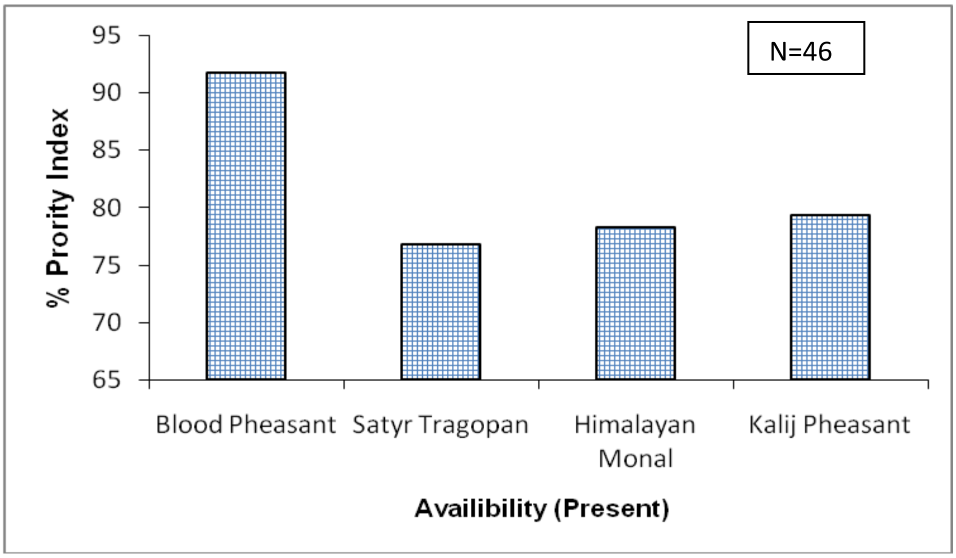

Figure 6.29: The present status of availability of the Himalayan Pheasants in the KBR based on perception of the local people

Using respondents' knowledge, the present status of availability of the Himalayan Pheasants was quantified and it seemed that the availability of Blood Pheasant population in the KBR was highest followed by Kalij Pheasant, Himalayan Monal, and Satyr Tragopan (Figure 6.29). The changes in the availability of the Himalayan Pheasants compared to the last 10-20 years back was also quantified from the respondents' perception and knowledge (Figure 6.30). Respondents revealed that the availability of the Himalayan Pheasants is moderate compared to the last decade; they did not see drastically changes. A few respondents also agreed that the populations of most of the Himalayan Pheasants of KBR are decreasing, except that of Blood Pheasant, which is increasing in the biosphere reserve.

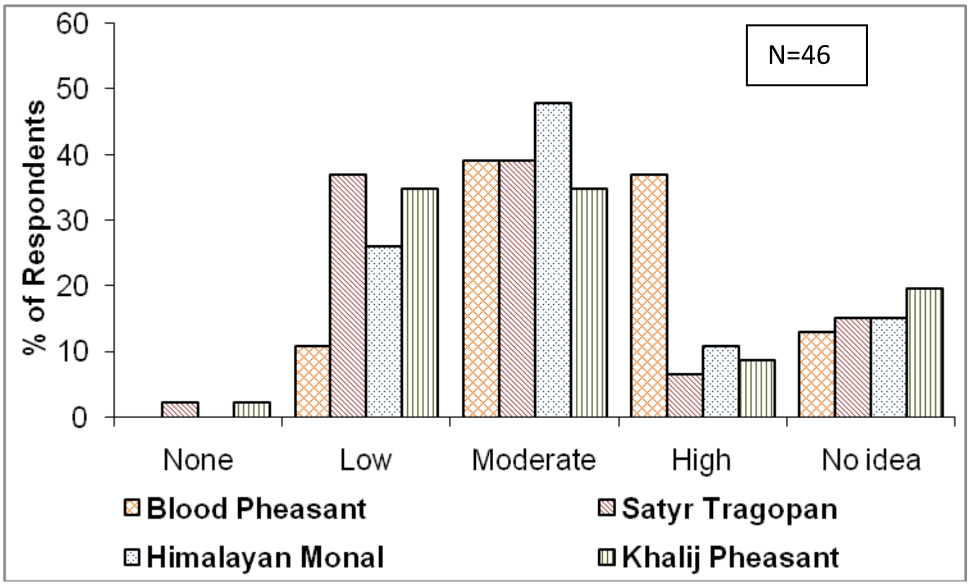

Figure 6.30: Availability of the Himalayan Pheasants compared to the 10-20 years back based on perception of the local people.

The respondents were also asked about the poaching or hunting of the Himalayan Pheasants in the Khangchendzonga Biosphere Reserve. Most of the respondents did not accept that they saw or encountered any poaching /hunting of the Himalayan Pheasants in the KBR except for a few numbers of respondents (Figure 6.31). The respondents were also asked for the maximum poaching/ hunting pressure of the Himalayan Pheasants in the Khangchendzonga Biosphere Reserve compared to the last decades, it was revealed that the maximum hunting pressure was on Kalij Pheasant followed by Satyr Tragopan, Blood Pheasant, and Himalayan Monal (Figure 6.32).

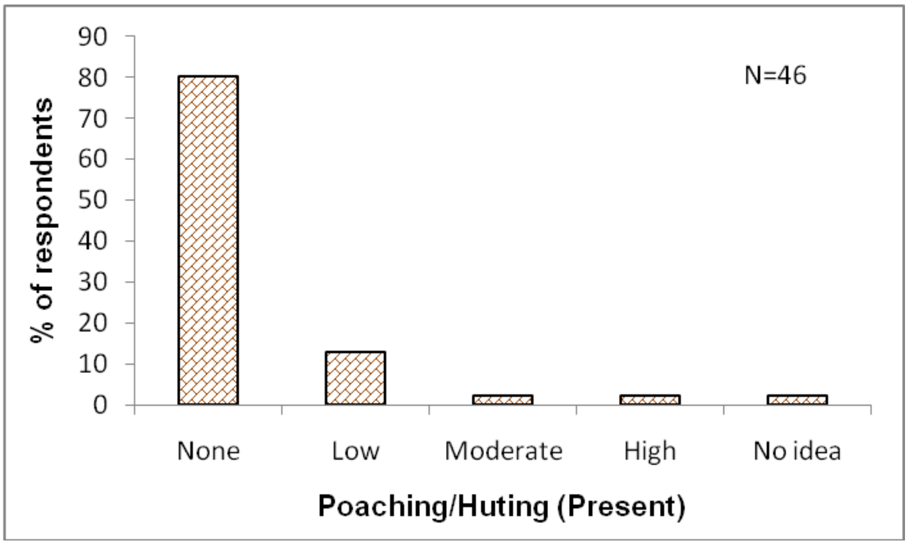

Figure 6.31: Poaching/hunting of the Himalayan Pheasant in present scenario based on perception of the local people.

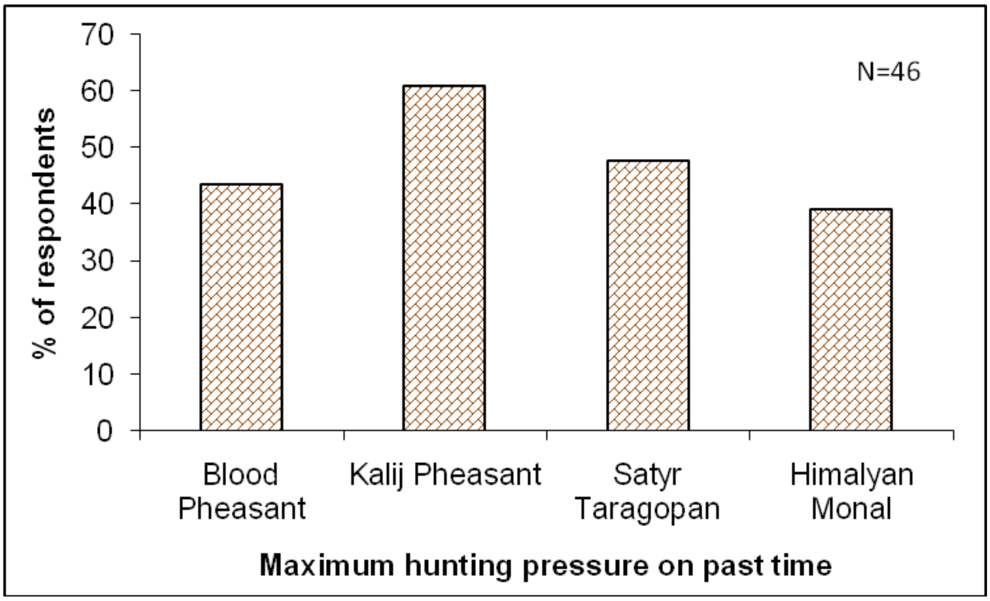

Figure 6.32: Maximum pressure on the Himalayan Pheasant during the last decades based on perception of the local people.

Through respondents, it was understood that the lower altitudinal Pheasants had more poaching/hunting pressure compared to the high altitudinal pheasants because the maximum human settlement is restricted to the lower altitudinal ranges, so it could be the main reason that the lower attitudinal range Pheasants are more threatened; however, such poaching was limited to fewer instances often, as per interaction with stakeholders. The most of the respondents also experienced that the temperature in and around the villages has been increasing compared to the last 10-20 years back (Figure 6.33).

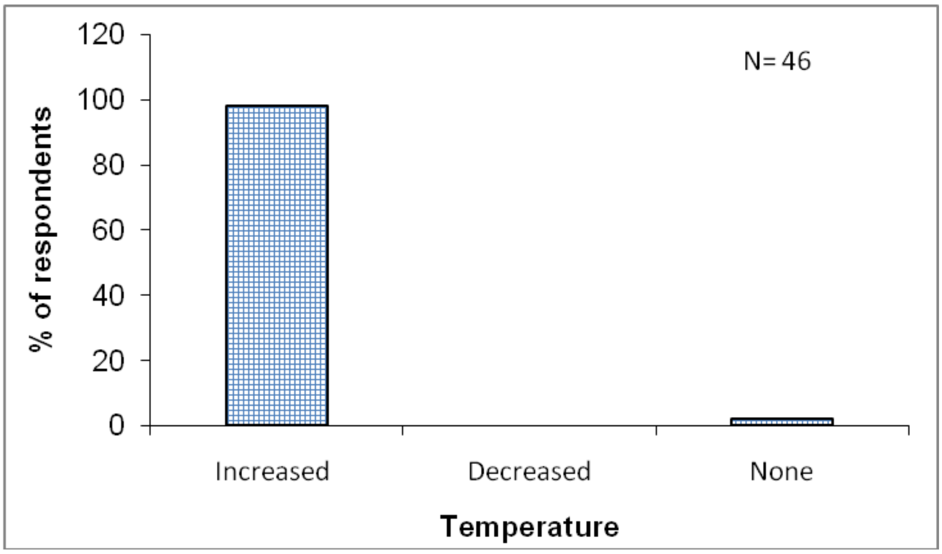

Figure 6.33: Experience of the temperature in the local premise based on perception of the local people.

The respondents were also asked about the experience of climate change in the village; most of the respondents agreed that the climate change in their area is prominent (Figure 6.34). Such as increasing temperature, drying wetland and springs, reducing snow cover, etc.

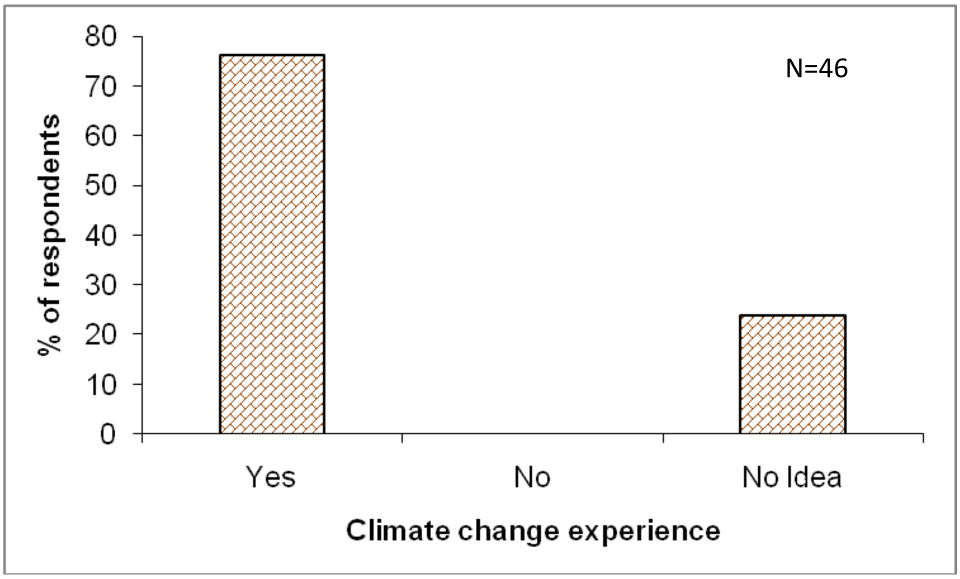

Figure 6.34: Experience of the climate change in the local premise based on perception of the local people.

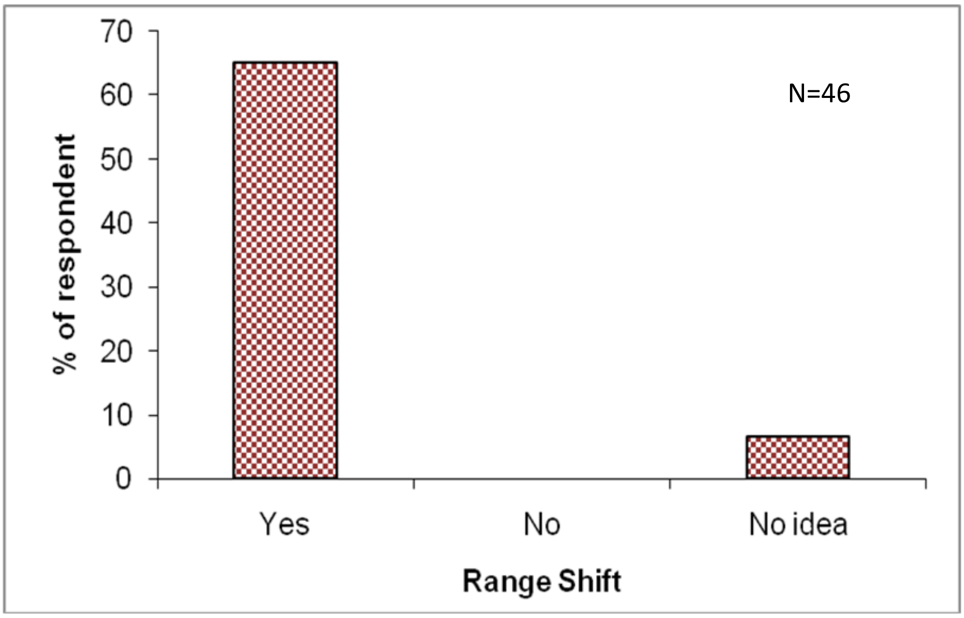

Figure 6.35: Range shift of Himalayan Pheasants based on perception of the local people.

According to respondents, the Himalayan Pheasants are shifting their range compared to the last 10-20 years back (Figure 6.35). Most of the respondents agreed that the Himalayan Pheasants are shifting their habitat range compared to the last decades and gave their views on different factors which could be the reasons for their range shifting.

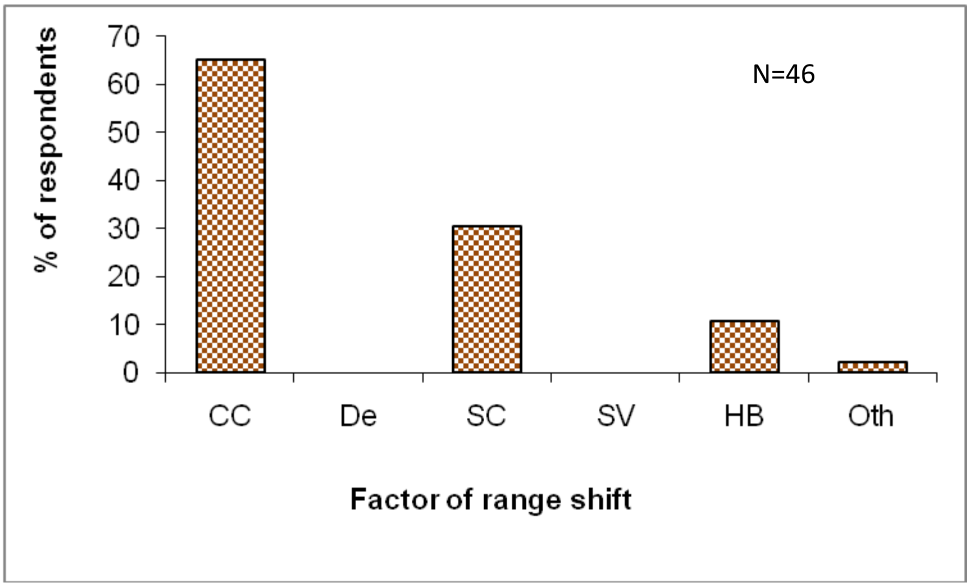

Figure 6.36: Factor of range shift of Himalayan Pheasants in KBR based on the local perception (climate hange,CC; deforestation, De; scarcity of food, SC; shifting vegetation, SV; habitat disturbance, HB; and others,Oth)

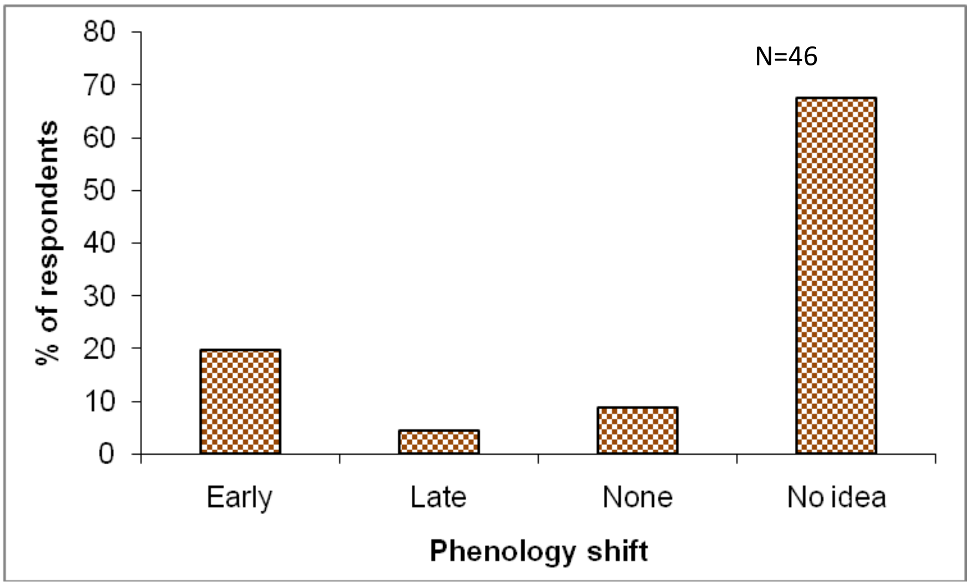

Figure 6.37: Phenology shift of Himalayan Pheasants in KBR based on perception of the local people.

The highlighted factors were climate change (CC), deforestation (De) scarcity of food (SC), shifting vegetation (SV) habitat disturbance (HB) and others (Oth); among them climate change, scarcity of food, and habitat disturbance appeared as the main causes for the Himalayan Pheasants' range shift (Figure 6.36). The people were also asked about any phenology shift of the Himalayan Pheasants, it was understood that the most of the respondents were unknown about it and only a few persons have noticed that the phenology of the Himalayan Pheasants is shifting earlier such as their breeding time compared to the last few decades (Figure 6.37).

The respondents were also asked about the food habits of the Himalayan Pheasants. The perception-based Priority Index (Figure 6.38) suggested that the moss is the most preferred food for the Blood Pheasant, followed by a fungus (*Ophicordceps sinensis*), grass and medicinal plant (*Arisema* spp.). Whereas, the medicinal Plants (*Arisema* spp. and *Aconitum* spp.) and *Ophiocordycep sinesis* are the preferred foods for Himalayan Monal. Similarly, people knew the preferred foods for the Satyr Tragopan are the fern followed by moss, insect, and medicinal plant (*Arisema* spp.). The Kalij Pheasant, however, highly prefers the wild seeds followed by the insect, and medicinal plant, *Arisima* spp. The above people's knowledge many times could be validated during field surveys on pheasants under current study. The study also developed the perception based Priority Index of the predators on the Himalayan Pheasants. Eagle (*Buteo hemilasius*) emerged as the top predator of the Blood Pheasant followed by the fox (*Vulpes ferrilata*), marten (*Martes Flavigula*), mongoose (*Herpestes urva*), and wildcat (*Neofelis nebulosa*). Similarly, the top predator of the Himalayan Monal emerged eagle, followed by mongoose, marten and fox.

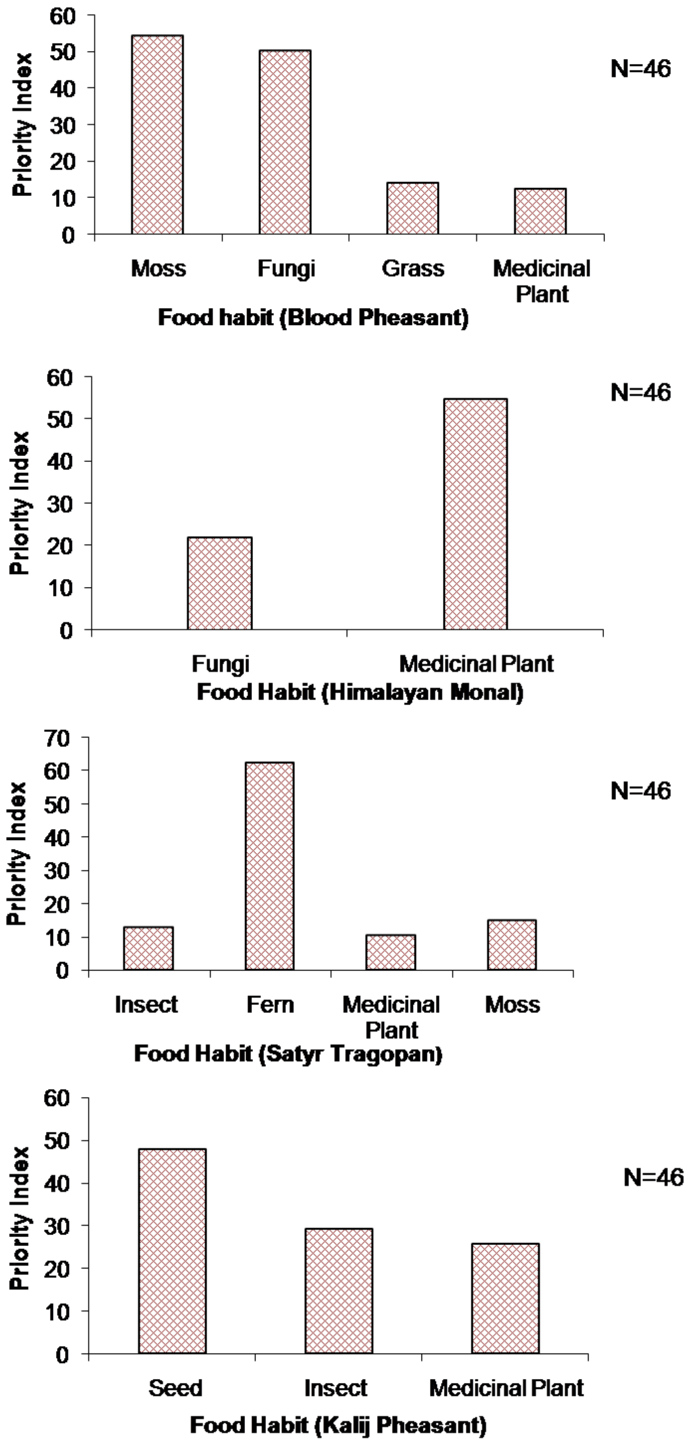

Figure 6.38 : Food habit of the Himalayan Pheasants in KBR, as per respondents' perception.

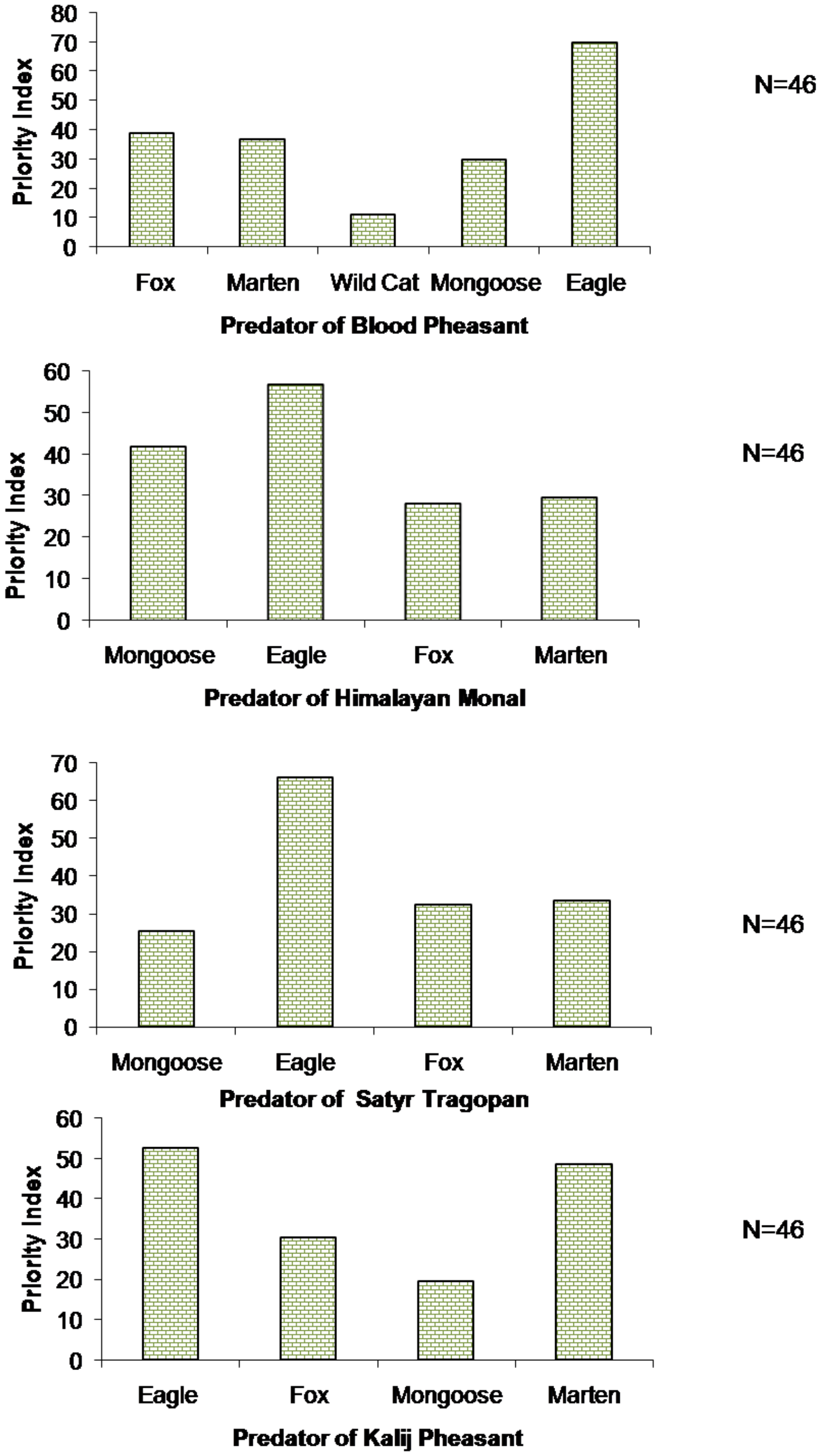

Figure 6.39: Predator of the Himalayan pheasants in KBR, as per respondents' perception.

For both the Satyr Tragopan and Kalij, the eagle emerged as the top perceived predator, followed by marten, fox, and mongoose (Figure 6.39).

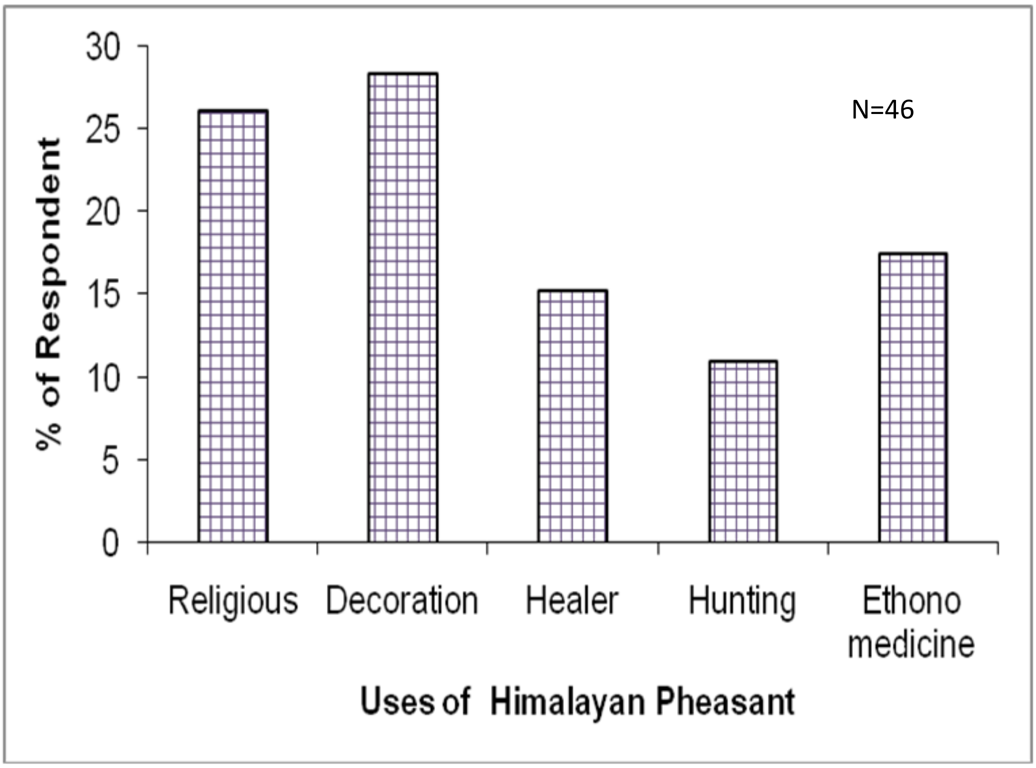

Figure 6.40: Uses of Himalayan Pheasants in past decades, as per respondents' perception.

The respondents were also asked about the uses of the Himalayan Pheasants in the past decades; most of the respondents agreed that the feathers of the Himalayan Pheasants were used in decoration and religious proposes, parts of the Himalayan Pheasant used in ethnomedicine, feathers are used by healers as well as in hunting for making arrows, etc (Figure 6.40).

7.2.3.2. Statistical Results

The descriptive statistics of variables considered in the study was self explanatory and the mean, mode, and median were very close which suggested that the variables not much of departure from the normal distribution. The standard deviation was not very high representing similarity in responses (Table 6.13). The findings of confirmatory factor analysis simply demonstrate that the sample size was adequate enough for the data as denoted by KMO test, the model is well fitted as revealed by the chi-square statistic which was significant beyond p<.000 (Table 6.14).

Table 6.13: Descriptive statistic for the explanatory variables of the questionnaire

Descriptive statistic	Range shift	Range shift factor	Phenology Shift
Mean	0.234	0.462	0.182
Median	0.250	0.512	0.144
Mode	0.300	0.600	0.100
Std. Deviation	.092	.180	.128

Bartlett's Test of Sphericity (BTS) result indicated that the data were appropriate for the purpose of Principal Component Analysis (the BTS at 42.814 and the level of significance at P = 0.000).

Table 6.14: KMO and Bartlett's Test for the explanatory variables of the questionnaire

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.631
Bartlett's Test of Sphericity	Approx. Chi-Square	42.814
	Df	3
	Sig.	.000

Reliability of the questionnaire was denoted by Cronbach's Alpha of which the value was quite high in spite of smaller numbers of items. This signifies that the scale employed in this study demonstrates a high degree of reliability (Table 6.15). Having established the scale reliability and validity, a linear regression analysis is found to be appropriate to judge the pheasant range shift.

Table 6.15: Reliability statistics for the explanatory variables of the questionnaire

Cronbach's Alpha	N of Items
.701	3

Table 6.16 shows only one component with Eigen values greater than one account for 68.813% of the total variance. According to the rules of Principal Component Analysis only factors that have Eigen values greater than one should be retained. The component has an Eigen value of 2.064 and percentage of variance of 68.813 %. The

component consists of three items. These items are range shift, factor of range shift, and phenology shift of Himalayan Pheasant.

Table 6.16: Total variance explained the explanatory variables of the questionnaire

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.064	68.813	68.813	2.064	68.813	68.813
2	0.666	22.191	91.004			
3	0.270	8.996	100.00			

Extraction Method: Principal Component Analysis.

The regressions results are presented in Table-6.17a and Table-6.17b to establish the relationship between the explanatory variables and the dependent variable which indicates the overall Pheasant range shifting. The results of the regression amply demonstrate that the goodness of fit was quite acceptable considering the F value which was significant beyond $p<0.000$. The factors of range shift significantly influence the overall Pheasant range shift as revealed by the data obtained from the respondents. Whereas, the shift of pheasant phenology and range shift of pheasant did not show significant relations. Table 6.17a shows the value of R Square which signifies that 55% of the variance in the dependent variable is explained by the taken independent or explanatory variable

Table 6.17a: Linear regression for the explanatory variables of the questionnaire

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.742[a]	.550	.530	.06339

Table 6.17b: Linear regression for the explanatory variables of the questionnaire

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
RS (Dependent Variable)	.109	.020		5.436	.000
FS	.286	.048	.669	5.945	.000
Psh	.105	.081	.146	1.294	.203

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DISCUSSION

7.2.3.4. Discussion

The local people residing within Khangchendzonga Biosphere Reserve are often great observers of changes in weather phenomena and biotic distribution, presumably related to global climate change. The local perception largely relies on their long-term personal experiences and is much extensive and acute than the science and media dialogue on global climate change (Marin & Berkes, 2013). People's general observations of climate change were consistent with scientific observation (Perez et al., 2010; Marengo et al., 2011). Therefore, nowadays, the traditional knowledge and the perception-based information considered as the baseline data for the modern scientific world because they have had gathered long-term experience about the natural elements in the people's surrounding environments. Unfortunately, most of the traditional knowledge and people's long time experience and observations are rapidly vanishing because of the lack of proper documentation. The mean annual temperature is increasing but not evenly distributed across the globe but some of the largest average temperatures are indicated for high-mountain ecosystems (Pachauri et al., 2014). Similarly, increasing abundance of thermophilic (heat-loving) plants is observed at high elevations (Gottfried et al., 2012; Gaire et al., 2014). The local communities are the witness of changes in natural elements of thier surroundings in targeted areas. This present information can be considered as the baseline data, which should offer vital clues for further research work. Based on the perception of the local people around Khangchendzonga Biosphere Reserve, it appeared that the impact of climate change is more prominent in the Himalayan region which has not only affected the abiotic components (such as increasing temperature, drying springs, and wetlands are drastically reduced, decreasing snow coverage in winter, etc), but also it equally impacted the biotic components (such as range shift of Himalayan Pheasant towards high altitude, upward movement of plant species, phenology change, etc). Further, Dash et al., (2007) observed that the maximum temperature increased over North East India by 1°C during winter and 1.1°C during the post-monsoon months compared to the last century. Most of the respondents highlighted the climate change impacts on the resilience of the Himalayan pheasants such as range shift and phenology change. Climate–driven range shift of the Himalayan Pheasants is correlated with the reduction of snow cover in the region, suggested by most of the respondents. The result also indicates the factors of range shift significantly influence ($P<0.000$) the overall Himalayan Pheasant range shift as revealed by the data obtained from the respondents. Similarly, it was reported that in Himalaya's annual temperature increased by 0.01˚C in the foothills, 0.02˚C in the middle mountains, and 0.04 ˚C in the higher Himalayas which drives biophysical responses like duration of snow cover reduced, snow disappears earlier and less snowfall, therefore, changes in snow-cover dynamics will directly affect biodiversity at high elevations (Tse-ring et al., 2010). From the semi-open structured questionnaire, the respondents also agreed that the Himalayan pheasants are shifting their habitat range to towards high altitudes in the mountain landscape and abandoned their lower altitude ranges. Various studies also suggest that the species are shifting their habitat range due to climate change in the Himalayas (Acharya & Vijayan 2010; Gaire et al., 2014). Therefore, it is important that the long -term monitoring researches should be prioritized on the Himalayan Pheasants especially on their range shift and phenology change before they plunge to extinction.

Plate 09: A glimpse of religious spots of KBR; Coronation Throne of Norbugang Yuksom (A), Tholung Ghumpa/ Monastery (B), Devta Dhunga near Tholung ghumpa/ Monastery (C), and Dubdi ghumpa (D).

CHAPTER 08

SUMMARY & CONCLUSION

Chapter 08

SUMMARY AND CONCLUSION

Summary

- The recent advances in modelling techniques and field studies along with existing records help in improving conservation and management approaches for vulnerable and threatened species. This is significant and reliable because the prediction distribution model helps in finding the possibilities of new populations of threatened species in the new projected areas, where no scientific exploration reached so far. There are also possibilities of a relocation of the threatened species in newly predicted areas which may further help for promoting and strengthening its long-term conservation and habitat management.
- However considering the tough topography and inaccessible mountain terrains of the Eastern Himalaya, Sikkim and Khangchendzonga Biosphere Reserve, the recommendation will be given to the distribution patches predicted under 'very high potential' threshold category of MaxEnt model map in the current study may offer vital clues for more scientific explorations. This will help to assess whether the Himalayan Pheasants are merely vulnerable or rare to be at risk of becoming extinct in the near future in the wilderness of the Khangchendzonga Biosphere Reserve, Sikkim, Eastern Himalaya, or elsewhere. For evaluation of ecological status and conservation management of Himalayan Pheasants, the further recommendation will be given for field level systematic population explorations for Himalayan Pheasants as the global priority.

- ❖ The study helps to weigh up the geometric constraints and the effect of environmental forces and in giving shape to the present structure and community composition of woody taxa of the forest of the Khangchendzonga Biosphere Reserve. The spatial and temporal distribution of the species of any forest is not only affecting the topography and anthropogenic activities but is equally contributed by the influence of climatic forces. Additionally, the relationship between the species richness pattern and climatic variables showed a declined trend of species richness to the decreasing temperature, humidity, and precipitation along the altitudinal gradient of the study area.
- ❖ Understanding the adaptability of species in different climatic conditions and in different community composition is needed for their conservation and habitat management stratagem. Furthermore, it was observed that the different pheasants used different types of the forests and habitat range which offer the diversity of Himalayan Pheasant in the study area. Therefore, the mountain forests offer different types of habitats in respect to climatic variables in the particular site of the forest which is very essential for the species that are found in very restricted habitat(s) and also harbours a rich gene pool of both the floral and faunal elements in the forests. Due to different habitats of the study area, the Himalayan Pheasants use a specific habitat range for sustaining their existence in the forests which is crucial in understanding their habitat composition in the forests for conservation perspectives.

- ❖ The climate change is a more rapid process in the Himalayas which has had significantly affected the ecology pattern of the species. However, in the present study, the similar trends are highlighted; the habitat range of the Himalayan Pheasants is altering compared to the last 2 or 3 decades. The present study reports a new record of habitat range of Blood Pheasant up to 4900 m asl. The shifting of its habitat range towards higher altitude may be the signal of changes in their behavioural ecology in response to climate. The results indicated that the habitat of the Satyr Tragopan is under threat because they are found in a narrow stretch of habitat range from 2800 m -3400 m asl of ecotone of the cold temperate and subalpine regions in the Khangchendzonga Biosphere Reserve where community's composition is often changed.
- ❖ Therefore, conservation directives should focus on a long-term monitoring mechanism in the Himalayan landscape to allow interpretation of the changes in behavioural ecology pattern of the Himalayan pheasants. This should be related with the upward range shifts to extreme elevations and their associated habitat's composition in respect to climate change in order to strengthen the conservation management of Himalayan pheasants by involving policymakers, community people, government and non-governmental organizations.
- ❖ Based on three ensemble models (GCMs) of future climate projection of different scenarios under RCP-2050, the present study revealed that the most suitable habitats of the Himalayan Pheasants will be shifting towards higher altitude and latitude landscapes and would be lost in low altitude and latitude landscapes under the future climate scenarios RCP -2050. The trend of habitat

shifting to higher altitude and latitude are gradually becoming more prominent and significant and the potential habitat of the Himalayan Pheasants will shrink with greenhouse gas intensification.

- ❖ Overall, the predicting climate-driven habitat shifting of the Himalayan Pheasants as a suitable model species will offer suitable guidelines for improving conservation and management approaches for the same and others associated climate sensitive vulnerable species of the Himalayas.
- ❖ The traditional knowledge and perception based information of particular species are the baseline data for conservation directives and biodiversity management. The traditional knowledge and perception based information along with the field data, literature, and the projection model will help to solve many queries related to biodiversity management and conservation strategies for any targeted species. Unfortunately, most of the traditional knowledge and perception based information on long time observations is vanishing due to the lack of proper documentation which is the vital clue for any finding related to biodiversity management and conservation strategies.

Conclusion

The recent advances in modeling techniques, field studies and local perception along with existing records help in improving conservation and habitat management approaches for vulnerable and endemic species before they are forced to go through the door of extinction.

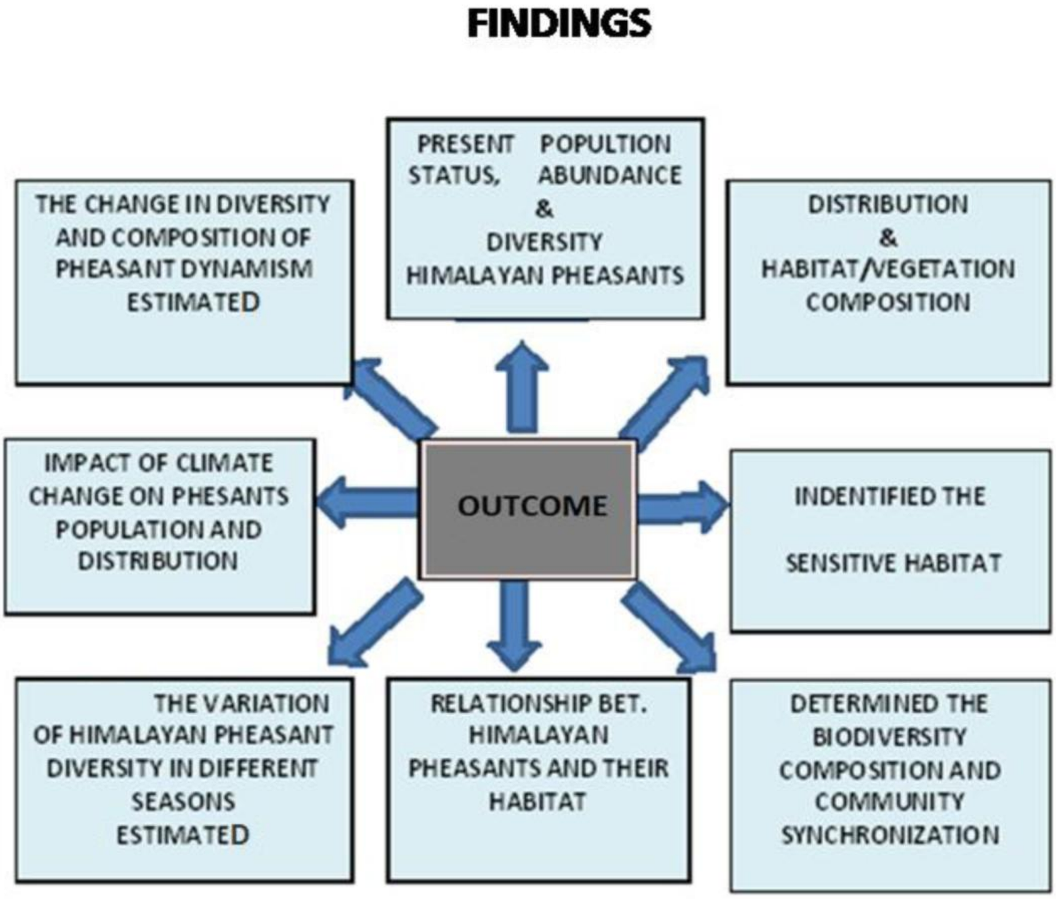

Plate 10: Pictorial representation of a flowchart of the outcome from research work.

CHAPTER 09

BIBLIOGRAPHY

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BIBLIOGRAPHY

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CHAPTER 10

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APPENDIX

Chapter 11

LIST OF APPENDICES

List of Publications (Appendix-A)

Title of published paper	Name of the journal, year, issue, page no	DOI	Remarks
Predicting climate-driven habitat shifting of the Near Threatened Pheasant Satyr Tragopan (*Tragopan satyra*; Galliformes) in the Himalayas	*Avian Research Biology*,2018, 11 (4), 221–230	https://doi.org/10.3184/175815618X15316676114070	ISSN 1758-1559
Effect of altitude and climate in shaping the forest compositions of Singalila National Park in Khangchendzonga Landscape, Eastern Himalaya, India	*Journal of Asia-Pacific Biodiversity*, 2018, 11 (2018) 267-275	doi10.1016/j.japb.2018.01.012	ISSN 1823-6243
Rhododendron diversity along Kusong-Panch Pokhari transect in Khangchendzonga Biosphere Reserve, Eastern Himalaya: a conservation perspective	*Journal of Threatened Taxa*, 2018, 10(1): 11192–11200	http://doi.org/10.11609/jott.3728.10.1.11192-11200	ISSN 0974-7907
Root holoparasite *Balanophora polyandra* Griff.(Balanophoraceae) in eastern Himalaya (Sikkim, India): Distribution, range, status and threats	*Journal of Threatened Taxa*, 2018, 10(8): 12123–12129	doi.org/10.11609/jott.3644.10.8.12123-12129	ISSN 0974-7907
Ecological study of Satyr Tragopan (*Tragopan satyra*) in sikkim-india: a threatened bird species of Eastern Himalaya	*International Journal of Recent Scientific Research*, 2017, 8(9):20362-20368	doi:http://dx.doi.org/10.24327/ijrsr.2017.0809.0880	ISSN 0976-3031
Predicting suitable habitats for the vulnerable species, *Rhododendron niveum* Hook.f. (Ericaceae) in Eastern Himalaya	*NeBIO*, 2017, 8(3):139-146		ISSN 2278-2281
First record of *Cuscuta chinensis* lam. (convolvulaceae) in Sikkim Eastern Himalaya	*International Journal of Botany and Research* ,2016, 6(1): 1-4		ISSN 2319-4456

LIST OF CONFERENCES/SEMINARS PARTICIPATED

(Appendix-B)

Title of the Oral Presentation	**Name of Conference/Seminar participated**	**Venue**
Himalayan Pheasant with especial reference to Sikkim Himalayas: status and conservation implication	National Conference on ZooCon 2017: Animal Science in 21st Century	University of North Bengal
How the advance modelling helps in the status and conservation implication of *Rhododendron niveum* (Hook. f.); a case study in Sikkim Himalaya	International Zoology Seminar (2017) on "Concepts on conservation and propagation of indigenous life forms in Eastern Himalayan region	Darjeeling, Govt. College

Point location of georeference of Himalayan Pheasants in Eastern Himalaya (Appendix-C)

	Blood Pheasant		**Himalayn Monal**		**Kalij Pheasant**		**Satyr Tragopan**	
Serial no.	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1.	27.59557	88.50639	27.44979	90.35156	26.6438	93.3982	27.2928	91.1475
2.	27.59836	88.50592	27.4181	89.41223	27.263	95.4601	27.7641	84.924
3.	27.59286	88.49958	27.551	90.7561	27.4181	89.41223	27.5056	90.0183
4.	27.63603	88.51361	27.4662	90.3825	27.0874	88.6592	27.4788	90.8756
5.	27.62422	88.51236	27.5058	90.0783	26.093	91.7429	27.5371	90.2021
6.	27.63494	88.51825	27.5504	90.7572	25.853	94.8196	27.3468	91.0311
7.	27.6195	88.51092	27.3697	89.3467	27.7078	91.7326	27.0799	88.694
8.	27.67631	88.50918	27.8252	86.7181	27.0525	88.2741	28.1223	85.3439
9.	27.63566	88.52438	27.8085	86.7142	27.44979	90.35156	27.0799	88.0678
10.	27.63021	88.52691	27.7897	86.7185	26.7172	90.9338	27.4862	90.3385
11.	27.69827	88.43802	27.7767	86.7219	26.95	90.73	27.5064	90.8693
12.	27.70172	88.45595	27.801	86.7109	27.3471	95.5603	27.3614	91.032
13.	27.69157	88.44231	27.9956	85.9776	27.7079	91.7305	27.4551	90.9566
14.	27.72779	88.45309	28.2115	85.4894	27.5857	89.8534	27.312	91.133
15.	27.73053	88.45574	27.4994	92.1073	26.6667	91.0019	27.3279	91.0899
16.	27.47267	88.16206	27.4958	92.1056	27.0848	88.6689	27.402	90.9963
17.	27.47292	88.16208	27.5371	90.2021	27.8104	85.3567	27.5504	90.7555
18.	27.473	88.16125	28.5721	83.734	27.0999	88.6832	27.1433	91.4866
19.	27.46003	88.17017	27.402	90.9963	27.551	90.7561	27.4686	90.9101
20.	27.45892	88.17528	28.2176	85.5849	27.6446	89.7834	27.3801	88.8208
21.	27.47367	88.16256	27.48102	88.15695	27.2368	88.7691	27.4413	90.4298
22.	27.47353	88.16261	28.2102	85.5397	25.8265	94.9082	27.3608	91.0258
23.	27.49878	88.15931	28.2053	85.4696	25.8109	94.9478	27.2937	91.1591

24.	27.46553	88.16614	27.4697	90.1712	25.826	94.8044	27.4972	90.9051
25.	27.457	88.17739	27.3699	89.3463	25.574	94.3434	27.3133	91.0672
26.	27.45589	88.17725	27.97805	86.64949	27.8038	85.3948	27.338	91.0408
27.	27.45625	88.17658	27.5235	89.8084	27.1054	87.9456	27.3226	91.0533
28.	27.46697	88.16394	27.4972	90.9051	26.6154	93.2663	27.4783	89.4287
29.	27.467	88.164	27.4413	90.4298	27.141	88.5804	28.0308	85.6964
30.	27.46858	88.16408	27.29	91.273	26.73	91.0102	27.5042	89.9557
31.	27.46844	88.18061	27.4551	90.9566	27.3697	89.3467	28.2176	85.5849
32.	27.47689	88.15725	27.4783	89.4287	24.4801	92.2994	27.3827	91.0145
33.	27.47008	88.1635	28.0471	85.4651	27.1668	88.225	27.5116	90.5486
34.	27.50394	88.15556	27.6446	88.7283	27.4509	90.4134	27.3404	91.0392
35.	27.47608	88.16136	27.6604	89.8064	27.2821	88.3218	27.3263	91.0842
36.	27.47714	88.17214	27.5168	90.2417	26.9669	88.3108	27.3139	91.0679
37.	27.58565	88.50878	27.4145	90.224	27.4272	89.4172	27.4257	89.649
38.	27.58538	88.50533	28.1151	85.537	26.85	88.161	27.4279	90.9682
39.	27.58807	88.51286	27.9667	86.6129	27.326	88.123	27.7079	91.7305
40.	27.68583	88.44203	27.3027	92.4109	26.745	87.704	26.8625	91.4756
41.	27.68546	88.44369	27.8148	86.7174	27.354	87.685	27.359	91.032
42.	27.68485	88.44291	27.5719	85.4066	26.698	87.181	27.0999	88.6832
43.	27.68431	88.44303	27.5172	90.5768	27.364	87.238	27.3681	88.6608
44.	27.43678	88.17769	27.8361	86.7638	27.773	87.285	27.4662	90.3825
45.	27.44197	88.17383	27.5056	90.0183	26.707	86.695	27.4388	90.9603
46.	27.43944	88.1775	27.8668	86.7308	27.821	86.676	27.1054	87.9456
47.	27.44207	88.17392	27.2928	91.1475	27.278	86.225	27.801	86.7109
48.	27.43688	88.17769	27.7641	84.924	27.288	85.239	27.33008	88.39167
49.	27.74533	88.71435	28.0145	85.1796	27.764	85.22	27.32953	88.39158

50.	27.74657	88.72281	27.8231	86.7072	28.297	85.248	27.33213	88.3825
51.	27.74851	88.72074	27.8653	86.8033	27.764	84.706	27.33065	88.38232
52.	27.37697	88.772	27.8479	86.7486	27.754	84.239	27.26406	88.79518
53.	27.37142	88.77084	27.836	86.7639	28.22	84.278	27.26439	88.79459
54	27.37063	88.76734	27.8224	86.7395	27.735	83.716	27.26276	88.78258
55.	27.37951	88.77061	27.8167	86.7167	28.773	83.764	27.37708	88.72469
56.	27.39105	88.77743	27.8187	86.7364	28.773	83.745	27.37064	88.72149
57.	27.7276	88.75546	27.8354	86.7464	27.773	83.259	27.37263	88.72743
58.	27.80109	88.76957	27.852	86.7908	27.40058	88.20803	27.37223	88.70513
59.	27.36971	89.34666	27.816	86.7336	27.38781	88.21819	27.35476	88.53955
60.	27.38617	91.00027	28.6424	83.7598	27.09331	88.70183	27.35441	88.54085
61.	27.40201	90.99627	27.72972	87.2025	27.12554	88.71809	27.43319	88.182
62.	27.50561	90.73763	27.57108	88.4917	27.5947	88.44277	27.43331	88.18211
63.	27.41018	89.41004	27.754	87.733	27.59334	88.44236	27.43325	88.18206
64.	27.38627	89.37809	27.307	87.257	27.59136	88.44073	27.43542	88.18089
65.	27.45505	90.95657	27.764	87.285	27.58474	88.43982	27.44436	88.17953
66.	27.50565	92.10609	27.811	86.752	27.26177	88.10261	27.43478	88.18144
67.	27.5371	90.20208	27.84	86.219	26.99651	88.24333	27.4325	88.17881
68.	27.40423	90.98763	27.84	85.734	26.95263	88.2692	27.43294	88.18219
69.	27.49579	92.1056	28.287	85.715	26.98499	88.18321	27.44489	88.17933
70.	27.494	90.84417	28.24	85.229	26.98061	88.1797	27.43617	88.18064
71.	27.46197	88.17113	28.259	84.772	27.055	88.23289	27.59011	88.49431
72.	27.47509	88.16004	28.245	84.297	27.36709	88.56517	27.58064	88.49883
73.	27.7562	88.72243	28.782	84.239	27.36665	88.56246	27.59322	88.50436
74.	27.45413	88.17895	27.47458	88.16256	27.36533	88.56449	27.59314	88.50428
75.	27.4181	89.41223	27.47367	88.16256	27.49631	88.54984	27.59322	88.50458
76.	27.44979	90.35156	27.50017	88.15458			27.59353	88.49978

77.	27.35225	91.11511	27.50125	88.154			27.59347	88.49967
78.	27.35904	91.03203	27.47719	88.15831			27.13492	88.72769
79.	27.48246	90.92427	27.70236	88.44178			27.13526	88.73483
80.	27.43882	90.96027	27.70732	88.45231			27.1372	88.74253
81.	27.34683	91.03111	27.71012	88.4529			27.1385	88.74357
82.	27.32293	91.13053	27.70172	88.45595			28.3577	84.57717
83.	27.50664	89.75301	27.69745	88.43782			28.25876	85.41105
84.	27.50335	92.10397	27.50003	88.154			27.83475	86.21667
85.	27.80104	86.71085	27.43303	88.17919			27.80649	86.58414
86.	27.82625	86.735	27.434	88.17836			27.79235	87.44629
87.	28.20602	85.47363	27.44411	88.17997			27.87715	86.64655
88.	28.24545	85.50161	27.47522	88.15906			27.80649	86.58414
89.	27.38274	91.01452	27.46425	88.16989			28.6424	83.7598
90.	27.42572	89.64904	27.46908	88.16319			28.4168	83.7286
91.	27.49944	92.10732	27.43122	88.18464			28.4849	83.40409
92.	27.42785	90.96817	27.43914	88.17747				
93.	27.37924	88.73692	27.43314	88.18211				
94.	27.3139	91.06791	27.43858	88.17744				
95.	28.09244	85.3805	27.43544	88.18094				
96.	28.10106	85.36918	27.23621	88.03146				
97.	27.48368	90.83681	27.25019	88.03642				
98.	27.3699	89.34625	27.37583	88.73694				
99.	27.39529	90.99555	27.37577	88.76077				
100.	27.8042	99.6314	27.37538	88.7682				
101.	28.02668	100.0695	27.37216	88.7678				
102.	27.68512	99.73775	28.5721	83.734				
103.	27.44665	90.96041	28.4315	83.8321				

104.	27.47878	90.87565	28.249	83.754				
105.	27.63357	90.90914	28.782	83.745				
106.	27.49716	90.90508	28.24	83.24				
107.	27.36079	91.02585						
108.	27.32309	91.05726						
109.	27.39048	90.98139						
110.	27.29003	91.27304						
111.	27.6738	89.74182						
112.	27.47826	89.42871						
113	27.32949	91.04902						
114.	28.04714	85.46514						
115.	27.98864	86.66393						
116.	28.50113	83.89873						
117.	27.46858	90.91015						
118.	27.33396	91.04713						
119.	27.06	88.00						
120.	28.57126	99.82912						
121.	27.88005	99.63827						
122.	27.61936	86.8404						
123.	27.08704	88.6624						
124.	28.0349	85.48111						
125.	27.51716	90.57683						
126.	27.836	86.7639						
127.	27.8117	86.7165						
128.	27.81868	86.73637						
129.	27.85201	86.79079						
130.	28.04503	85.4717						

131.	27.816	86.73363						
132.	28.64239	83.75977						
133.	27.925	88.425						

CHAPTER 12

REPRINTS OF PUBLICATIONS

AVIAN BIOLOGY RESEARCH **11** (4), 2018 221–230

Predicting climate-driven habitat shifting of the Near Threatened Satyr Tragopan (*Tragopan satyra*; Galliformes) in the Himalayas

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ABSTRACT

Current rates of climatic change will affect the structure and function of community assemblages on Earth. In recent decades, advances in modelling techniques have illuminated the potential effects of various climatic scenarios on biodiversity hotspots, including community assemblages in the Himalayas. These techniques have been used to test the effects of representative concentration pathways (RCPs) AR5-2050, based on future greenhouse gas emission trajectories of climate change scenario/year combinations, on pheasants. Current bioclimatic variables, Miroc-esm, Hadgem2-AO and Gfdl-cm3, in future climate change scenario models, were used to predict the future distribution and the gain/loss of future habitat area, within the Himalayas, of the pheasant, Satyr Tragopon (*Tragopan satyra*). The results indicate that future climatic conditions may significantly affect the future distribution of Satyr Tragopon and the effectiveness of protective areas (PAs). Using the python based GIS toolkit, SDM projection, regions of high risk under climate change scenarios were identified. To predict the present distribution of the species, environment parameters of bioclimatic variables, red reflectance, blue reflectance, solar azimuth angle, altitude, slope, aspect, NDVI, EVI, VI, and LCLU were used. The forest cover (NDVI) and the canopy cover (EVI), and variables affecting forest structure, namely altitude, slope, solar azimuth angle and Bio7, were the primary factors dictating the present distribution of *T. satyra*. The predicted trend of habitat shifting of *T. satyra* in the Himalayas to higher altitudes and latitudes will gradually become more prominent with climate warming.

Keywords: climate change modelling, conservation, species distribution, Himalayas, threatened species

1. INTRODUCTION

Current rates of climate change will dramatically affect community assemblages on Earth's biodiversity hotspots (Wiens *et al*., 2009; Wang *et al*., 2014; Hu *et al*., 2015). These changes have become prominent in the Himalayas where temperatures have risen by 0.74 °C over the past 100 years (Du *et al*., 2004; Solomon *et al*., 2007b), and are projected to climb by 0.3–4.5 °C by the end of the 21st century (Stocker *et al*., 2013). As a result, many historical ecosystems have become fragmented, which has had subsequent ramifications on the Himalayan biodiversity hotspot (Chazdon *et al*., 2009; Hu *et al*., 2015). Additionally, a small fluctuation in temperature can convert ice and snow into water or *vice versa*, and extreme fluctuations may lead to rapid changes in climatic zones over small distances, and will result in noticeable impacts in terms of biodiversity (Sharma *et al*., 2009). The Himalayas are the home of a number of the world's endemic and most threatened species, as well as primitive tribes, who are highly dependent on biological resources (Kollmair *et al*., 2005). High altitude ecosystems are particularly vulnerable to the effects of climate change (Shrestha *et al*., 1999; Liu and Chen, 2000) and as a result, in 2004, the Convention on Biological Diversity developed a programme to reduce the loss of mountain biological diversity at global, regional, and national levels by 2010. However, owing to the complexities of mountainous landscape records on populations and climate, data on the most threatened species are sparse. Therefore, conservation directives have a traditional focus on protecting single species using habitat suitability assessments (Wiens *et al*., 2009; Hu *et al*., 2015); however determining the geographical range of a species is a critical part of these endeavours (Mace *et al*., 2008; Boakes *et al*., 2010), especially in a changing climate scenario. Advances in modelling techniques have illuminated the potential effects of various climatic scenarios on biodiversity hotspots. Some climate models have proven particularly useful in the understanding of

 Paper 1700829 https://doi.org/10.3184/175815618X15316676114070

distribution range and the impact of climate change on threatened species. In recent years, MaxEnt has shown the potential to predict biodiversity loss under future climate scenarios (Bertrand *et al.*, 2012) and has also significantly contributed to the prediction of threats to species by upcoming climate change (Wang *et al.*, 2014; Hu *et al.*, 2015), based on python-based GIS toolkit and SDM projection (Brown *et al.*, 2014). Modelling techniques have helped contextualise these global changes in terms of ecosystems. MaxEnt has become a popular model in the conservation scene for its utility in climate-driven habitat shifting. In particular, representative concentration pathway (RCP) models help to illuminate future climate scenarios and their impact on distribution range and the suitable habitat of species based on possible future greenhouse gas emission trajectories. Four RCPs (RCP2.6, RCP4.5, RCP6.0, and RCP8.5) were coded according to the possible range of radiative forcing values in the year 2100 relative to pre-industrial values (+2.6, +4.5, +6.0, and +8.5 W m^{-2}, respectively) (Weyant *et al.*, 2009). Climate change has significantly affected the behavioural ecology of avian species throughout the Himalayas, however, existing reports generally lack the quantitative analysis needed to have an impact on conservation policies. Global climate change will pose several threats to the biodiversity of endemic avian species in the Himalayas, and these changes have been described in general terms, including range shifts (Acharya and Vijayan, 2007; Chettri *et al.*, 2010). It is crucial that these changes are taken into account when conservation planning, in part because the existing range may soon shift beyond protected areas (PAs). For a better understanding of the threats towards avian fauna of the Himalayas by global climate change, these models were adopted on a species of pheasant, Satyr Tragopan (*Tragopan satyra*, Galliformes). In this article, our objectives were to: (*i*) predict the present potential habitat distribution of this Near Threatened species, Satyr Tragopan, in the Himalayas, covering four countries: India, Bhutan, Nepal and P.R. China to promote and strengthen their conservation status; (*ii*) assess whether the management of PAs of the Himalayas represents adequately the conservation concerns for Satyr Tragopan, (*iii*) identify the key climatic factors associated with this Near Threatened species for habitat shifting under present and future climate scenarios; and (*iv*) project and quantify the spatial pattern of change of suitable potential habitat distribution of the species under various future climate scenarios.

2. METHODS

2.1 Model species

Satyr Tragopan is an IUCN Red List Near Threatened (NT) species (IUCN, 2016) of pheasant, found in the Greater Himalayas. In the Eastern Himalayas, it is considered a bioindicator of forest quality and anthropogenic disturbance (Fuller and Garson, 2000). Pheasants have a central position in the food web (Ramesh *et al.*, 1999) and also act as an indicator of climate change due to their high sensitivity to temperature. Researchers and bird hunters noted that this species is uncommon throughout Nepal and India but is fairly common in Bhutan, and in P.R. China the species is found within limited pockets of the south and south-east Tibet region (Kaul *et al.*, 2004, Hilaluddin and Ghose, 2005; BirdLife International, 2012); however, other assessments are pending.

2.2 Occurrence records and population assessments

The geo-reference records of Satyr Tragopan were collected from fields covering the Indian Himalayas and were especially focussed on Sikkim and the Darjeeling Himalayas (*ca* 1,700–4,600 m above sea level), using a standard methodology of open width point count along transects (Bibby *et al.*, 2000) and from available literature (Lelliott, 1981; Khaling, 1998; Poudyal, 2008; Chhetri *et al.*, 2017). The historical species records were also reviewed using the Global Biodiversity Information Facility (GBIF) database (www.gbif.org) following a similar approach to Mota-Vargas and Octavio (2016) and Wang *et al.* (2014), in which species records available in the GBIF databases were checked against a set of occurrence point locations of Satyr Tragopan within the GALLIFORM: Eurasian Database v. 10 (Boakes *et al.*, 2010a, 2010b), the IUCN distribution map of the species (BirdLife International, 2012) and a geographical grid point location map of the species from 'The Status of Nepal Birds' (Inskipp *et al.*, 2016). The point locations with a reported location inaccuracy greater than 500 m for the species (Friggens and Finch, 2015) were excluded. According to our knowledge of the distribution of the species, our dataset (containing a total of 97 point locations of primary observations and existing records; Table S1) reflects the current distribution point locations of the species.

2.3 Current environmental predictors

The environmental parameters used in our study included climatic parameters (19 variables of climatic envelopes downloaded from www.worldclim.org), physical parameters (blue reflectance, red reflectance and sun zenith angle; downloaded from https://modis.gsfc.nasa.gov/), topography parameter (altitude, aspect and slope; downloaded from www.worldclim.org; aspect and slope were generated by ArcGis v. 9.3), bio-physical parameter (NDVI, EVI, VI; download from https://modis.gsfc.nasa.gov/), and human modified mosaic landscape (land cover and land use; downloaded from http://diva-gis.org/) for the prediction of the present distribution of *Tragopan satyra* in the Himalayas. These high resolution environmental data were pre-processed at a spatial resolution of 30″ latitude and longitude using ArcGis 10.2.2 (around 1 km at ground level).

2.4 Future climate scenario data

A new set of RCP scenarios (AR5-2050; downloaded from www.ccafs-climate.org/data) of future climatic models was used. Under the RCP scenarios three general circulation models (GCMs) were used for the projection of the future distribution of the species (adopted by Hu *et al.*, 2015), namely Miroc-esm (Japan Agency for Marine-Earth Science Technology Atmosphere and Ocean Research Institute, and National Institute for Environmental Studies), Hadgem2-AO (National Institute of Meteorological Research/Korea Meteorological Administration) and Gfdl-cm3 (Geophysical Fluid Dynamics Laboratory, USA). Bias of these models was minimised by taking an ensemble of at least three different models (Miroc-esm, Hadgem2-AO and Gfdl-cm3) based on their mean values (following a similar approach taken by Molloy *et al.*, 2017).

2.5 Model validation for the prediction of potential habitats

The potential associated environmental variables were selected through principal component analysis (PCA) to predict the present distribution habitat of Satyr Tragopan. PCA was applied to test the independence between each pair of environmental variables, and to reduce autocorrelation among the variables using SPSS v. 21 (following a similar approach taken by Afifi *et al.,* 2012; Cruz-Cardenas *et al.,* 2014). Variables were excluded from the analysis if their highest loading values were > 0.7 and only variables whose loading values were < 0.7 in principal components were used for the prediction of the distribution of the species (following a similar approach to Sarman *et al.*, 2015; Molloy *et al.*, 2017). MaxEnt software v. 3.3.3 was used to predict the present and future potential distribution habitat of Satyr Tragopan using the jackknife validation methodology (adopted by Pearson *et al.*, 2007). The regularisation multiplier value was set at 0.1 to avoid over fitting (Phillips *et al.*, 2004). For the modelling, the maximum number of background points was set at 1,000 along with the use of the threshold feature. The 10-percentile threshold rule was applied, 80% of the data was provided for training and the remaining 20% for testing, and in total three replicate runs were set to avoid over fitting predictors (as adopted by Flory *et al.*, 2012). The area under the receiving operator curve (AUC) was used to test the model's goodness-of-fit. The perfect model has an AUC of 1; the performance is considered good when the AUC is > 0.9 (Swets, 1988). The final output was divided into five potential distribution areas that were regrouped with a threshold range between 0–1: very low potential threshold = 0.10; low potential threshold = 0.11–0.30; moderate potential threshold = 0.31–0.50; high potential threshold = 0.51–0.70; and very high potential threshold > 0.70. In the final projected map, as a very low potential threshold class had covered the maximum area under consideration, it was excluded from the results as a suitable habitat area (as adopted by Sarman *et al.*, 2015). Determination of potential changes in the future habitat of the species was based on a probability threshold of binary habitat and non-habitat charts (following a similar approach taken by Hu *et al.*, 2015). For that purpose, the 'maximum training sensitivity plus specificity' threshold, which has been observed to produce highly accurate predictions, was selected (Jimenez-Valverde and Lobo, 2007). The future suitable habitat area of the species based on six potent climate variables selected by principal PCA was projected (loading value under 0.7 in principal components). The future suitable habitat area was projected based on the different future climate scenarios RCP-2050 (RCP 2.6, RCP2.4, RCP2.6 and RCP2.8). The model validation for the prediction of potential habitat in future scenarios of the species followed a similar approach to the present distribution of the species. The final output was also divided into five potential distribution areas that were regrouped with a threshold range between 0–1. The python-based GIS toolkit, SDM projection, was used to identify and quantify the regions that had become (*i*) unsuitable, (*ii*) suitable, and (*iii*) remained unchanged (areas were cross-checked against the present distribution of the species in respect to current climate variables) following a similar approach to that taken by Hu *et al.* (2015). Based on the python-based GIS toolkit, the loss and gain of suitable habitat areas of the species in future scenarios were also quantified.

2.6 The core distributional shifts

The python-based GIS toolkit (SDM toolbox) was used to observe the trend of suitable habitat area changes and quantified the changes by comparing the centroids of future and present suitable areas (Brown, 2014). The SDM toolbox quantified the distributional changes between two binary SDMs; this analysis is based on summarising the core distributional shift of the range of Satyr Tragopan. The focus of the analysis was on convergence species' distribution to the centroid and it created a vector file having magnitude and direction of predicted change through time (Hu *et al.*, 2015). The core distributional shift of the species was observed by tracking the alternation in centroid changes among different SDMs, based on creating vector files.

3. RESULTS

3.1 Current habitat distribution model

The model demonstrates the current suitable habitat of Satyr Tragopan in the Eastern Himalayas. This habitat spans along the moist, temperate broadleaved-coniferous and rhododendron forest with dense undergrowth which includes bamboo (Figure 1). The result of the model calibration test for *Tragopan satyra* (Auc_{train} = 0.997 ± 0 and Auc_{test} = 0.958 ± 0.20) was found to be satisfactory. Among the inputs, namely, physical parameter, topography parameter, biophysical parameter, climate and human modified mosaic landscape, the biophysical parameter (34.1%) had the highest contribution to the model followed by topography (24.7%), climate (20.4%), physical (18.1%) and human modified mosaic landscape (2.6%). Within input variables, the normalised difference vegetation index (NDVI, 18.1%) was the highest performer for the prediction map followed by altitude (14.1%), solar azimuth angle (13.6%), enhanced vegetation index (EVI, 13.1%) and Bio7 (temperature annual range [Bio5-Bio6], 8.6%) (Table 1).

The areas under four potential threshold categories were quantified in the Himalayas, namely the low potential (33,607.82 km^2), the moderate potential (11,285.3 km^2), the high potential (7,964.1 km^2) and the very high potential (28,406.15 km^2). Within the Himalayas, we also quantified country-wise suitable potential habitat of Satyr Tragopan (Figure 2).

The most suitable habitat of the species under the very high potential threshold category was Bhutan, followed by Nepal, India and P.R. China. The observation was made by projecting the present and future mapping of the distribution of suitable habitats of Satyr Tragopan. The majority of suitable habitats fell on locations that were not identified as PAs (downloaded from https://www.protectedplanet.net) in the Himalayas (Figure 1).

3.2 Future projection habitat distribution model

The potential future habitat area of Satyr Tragopan was projected based on different future climate scenarios/year combinations of RCP-2050 (RCP2.6-2050, RCP4.5-2050, RCP6.0-2050 and RCP8.5-2050). In RCP2.6-2050, the very high potential area appeared to be as low as 4,430.073 km^2 over the high area projections, *i.e.* the low potential area (47,601.66 km^2), the moderate potential area (15,400.2 km^2) and the high potential area (7,586.21 km^2). Quantitatively, in RCP4.5-2050, the low potential was largest (46,282.7 km^2), followed by the moderate potential area (15,989.05 km^2), and the high potential (6,250.482 km^2) and the very high potential (2,810.951 km^2). In RCP6.0-2050, again the very high potential area emerged lower (2,879.81 km^2) than those of the low potential area (40,615.77 km^2), the moderate potential (14,661.27 km^2), and the high potential (7,271.93 km^2) categories. The RCP8.5-2050 based quantification yet again found the lowest area for coverage for Satyr Tragopan under the very high potential (2,746.50 km^2) category for the species over others, *viz* the low potential area

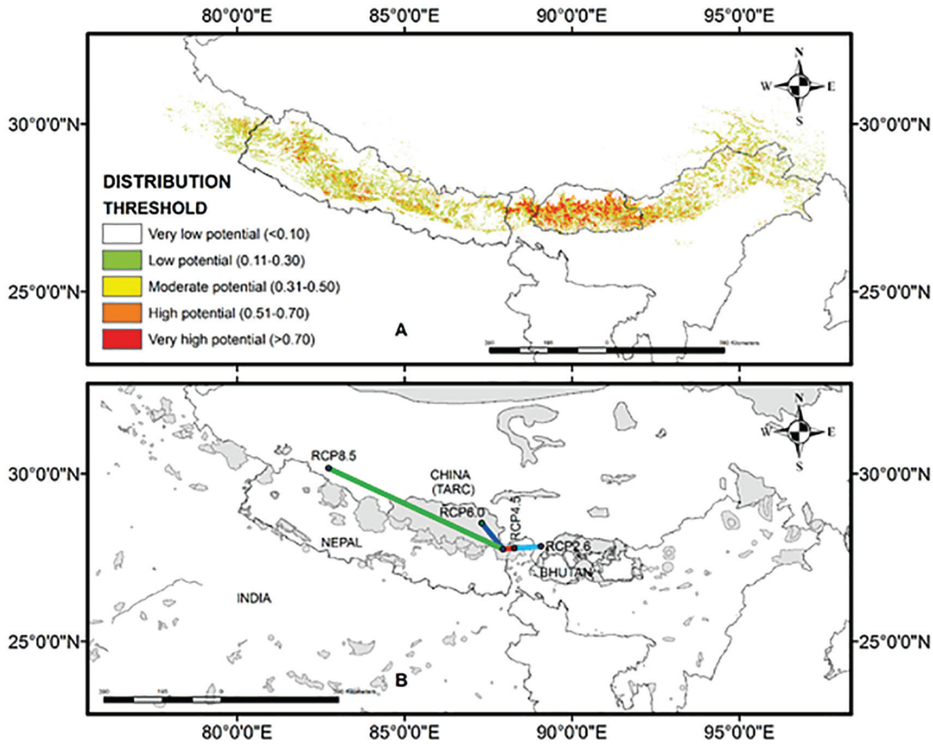

Figure 1 (A) Prediction map of present species distribution model (SDM) of Satyr Tragopan in the Himalayas. (B) Core distribution shifts under future climate scenarios RCP-2050/year combination (central axis indicates the geometric centre under current climatic condition; sky blue, red and green lines depict the centroid direction and magnitude under RCP2.6, RCP 4.5, RCP6.0 and RCP8.5 respectively); grey patches represent the protected areas (PAs).

Table 1 Environmental parameters and associated variables used in the study and their percentage contribution to the prediction present species distribution model (SDM) developed for potential habitat of Satyr Tragopan in the Himalayas. Variables used in the modelling were selected through the multicollinearity test (PCA)

Parameter	Variable	Percent contribution	Permutation importance
Physical	1. Red reflectance	2.5	1.9
	2. Blue reflectance	2	2.8
	3. Solar azimuth angle	13.6	2.9
	Subtotal	18.1	7.6
Topography	1. Altitude	14.1	42.4
	2. Slope	4.9	0.2
	3. Aspect	5.7	4.1
	Subtotal	24.7	46.7
Biophysical	1. NDVI (normalised difference vegetation index)	18.1	14.9
	2. EVI (enhanced vegetation index)	13.1	3
	3. VI (vegetation index)	2.9	0.5
	Subtotal	34.1	18.4
Climate	1. Bio2 (mean diurnal range [mean of monthly (max temp – min temp)]	2.5	6.7
	2. Bio3 [isothermality (P2/P7) (×100)]	4.5	5.6
	3. Bio4 [temperature seasonality (standard deviation ×100)]	3.7	11.1
	4. Bio7 [temperature annual range (P5–P6)]	8.6	0.5
	5. Bio14 (precipitation of driest month)	0.9	1
	6. Bio15 (precipitation seasonality (coefficient of variation)	0.2	1.4
	Subtotal	20.4	26.3
Mosaic landscape	1. LCLU (land cover and land use)	2.6	0.8

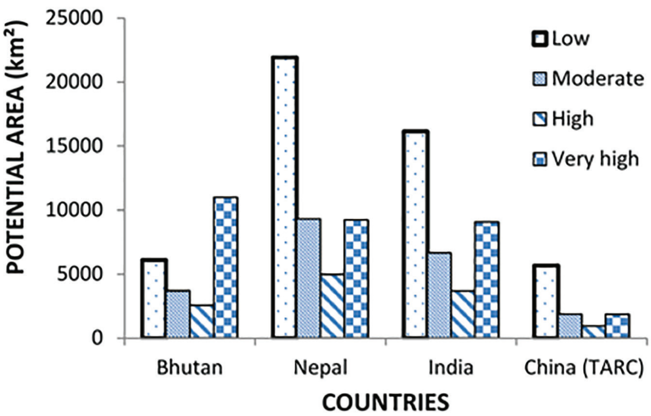

Figure 2 Spatial areas under each threshold category of the predicted species distribution model (SDM) of Satyr Tragopan in different countries within the Himalayas.

(34,431.51 km^2), the moderate potential (10,846.53 km^2), and the high potential (3,782.95 km^2) (Figures 3 and 4).

3.3 Loss and gain of suitable habitat area in the future scenario

The gain and loss of suitable habitat areas of Satyr Tragopan was predicted using the python-based GIS toolkit, SDM toolbox, for the future climatic scenario/year combination RCP-2050. Based on RCP-2050 models, the highest predicted gain in area is found to increase by 6,510.92 km^2, which is 0.888799% of the present suitable habitat area under the RCP2.5 model followed by RCP8.5 (4,367.831 km^2 or 0.596248% of the present suitable habitat area), RCP4.5 (4,361.12 km^2 or 0.595332 of the present suitable habitat area) and RCP6.0 (3,033.433 km^2 or 0.414091% of the present suitable habitat area). Whereas, the highest predicted loss in area is found to decrease by 14,711.93 km^2, *i.e.* 2.00831% of the present suitable area under the RCP8.5 model followed by RCP6.0 (14,480.39 km^2 or 1.97670% of the present suitable habitat area), RCP2.5 (6,510.92 km^2 or 1.33862% of the present suitable habitat area) and RCP4.5 (9,806.087 km^2 or 1.33862% of the present suitable habitat area). The majority expansion area shows a shift under different future climate models towards India's northeast states (RCP2.5), Bhutan (RCP4.5), P.R. China (RCP6.0) and India (RCP8.5), while the majority constriction area inclined towards Nepal (RCP2.5 and RCP4.5) and Bhutan (RCP6.0 and RCP8.5). However, the maximum area of suitable habitats of 6,640.6686 km^2 or 0.9065104% remains unchanged in both the present and future climate scenarios based on the RCP4.5 model followed by RCP2.6 (5,223.5004 km^2 or 0.7130544% of the present suitable habitat area), RCP6.0 (527.9466 km^2 or 0.0720689% of the present suitable habitat area) and RCP8.5 (317.66041 km^2 or 0.0433635% of the present suitable habitat area). The maximum total suitable habitat area would decrease by 11,446.96 km^2 or 1.562612% of the present suitable habitat area under the RCP6.0 model followed by the RCP8.5 model (10,344.1 km^2 or 1.412061% of the present suitable habitat area), RCP4.5 (4,027.8 km^2 or 0.549831% of the present suitable habitat area) and RCP2.6 (3,295.168 km^2 or 0.44982% of the present suitable habitat area) (Figure 5).

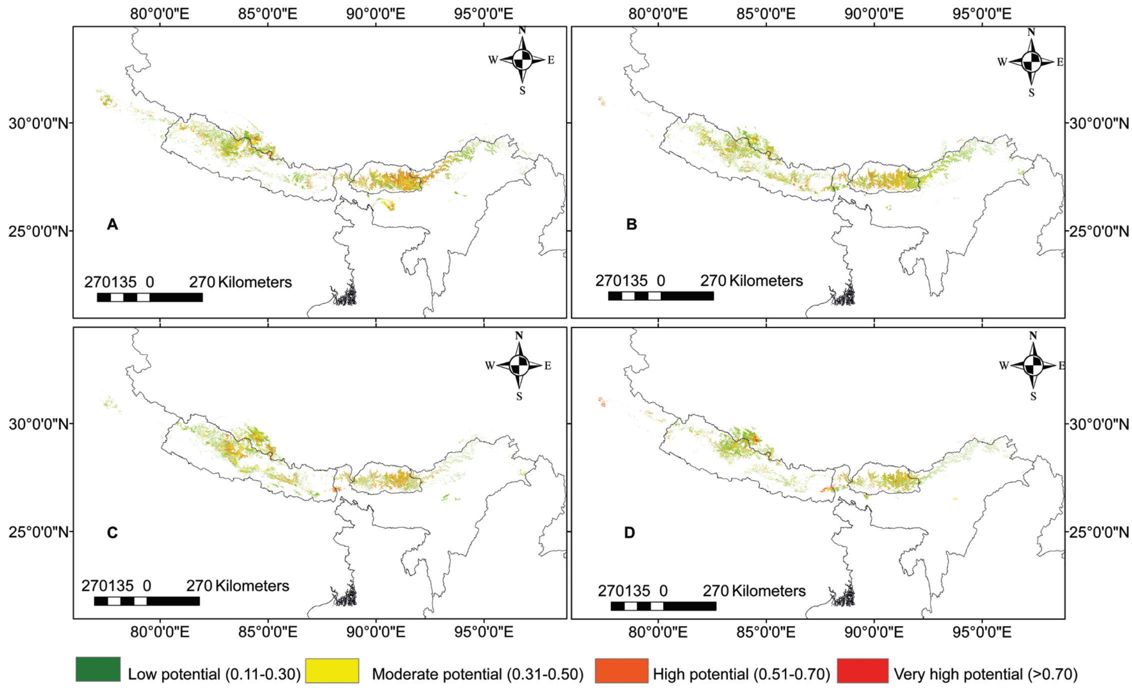

Figure 3 Predicting species distribution models (SDMs) of Satyr Tragopan under (A) RCP2.6-2050, (B) RCP4.5-2050, (C) RCP6.0-2050 and (D) RCP8.0-2050.

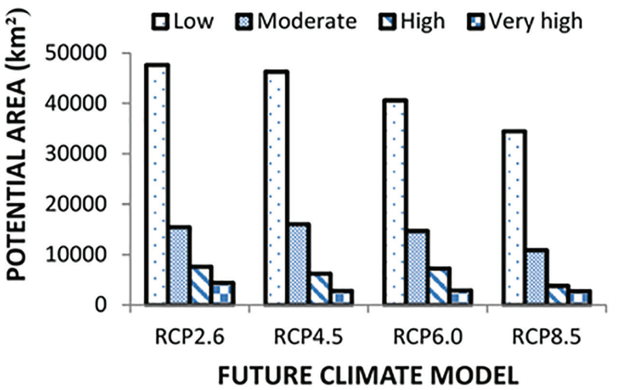

Figure 4 Predicting species distribution models (SDMs) of Satyr Tragopan under potential species distribution model (SDM) threshold categories of different future climate scenarios RCP2.6-2050, RCP4.5-2050, RCP6.0-2050 and RCP8.0-2050 respectively.

Overall, a restricted range contraction of suitable habitat area under different future climate scenario models of the RCP-2050/year combination for Satyr Tragopan was assessed (Table 2).

3.4 Distributional shifts in the core zone

The core distributional shift of suitable habitat area for Satyr Tragopan was quantified. The centroid of the present distribution of suitable habitat area of Satyr Tragopan was located at the geo-referenced position of 27°47′4.153″N in latitude and 87°56′50.082″E longitude in Nepal (Figure 1). The centroid of the future distribution of suitable habitat area most likely shifts towards east P.R. China at the geo-referenced position of 27°55′8.897″N in latitude and 89°4′41.934″E in longitude under the climate scenario RCP.2.6-2050 compared to the present centroid. Under the RCP4.5-2050 scenario the centroid of the future distribution of suitable habitat area would shift towards east India (Sikkim) at the geo-referenced position of 27°47′4.153″N in latitude and 88°14′36.517″E in longitude. The centroid of the future distribution of most likely suitable habitat area shifts towards northwest P.R. China at geo-referenced position of 28°33′55.670″N in latitude and 87°16′26.357″E in longitude under the RCP6.0-2050 scenario. Under the RCP8.5 scenario the centroid of the future distribution of suitable habitat area would move towards northwest

Table 2 Predicting dynamic changes in suitable habitat area for Satyr Tragopan in the Himalayas under different future climate scenario/year combination. Negative values indicate suitable area contraction

	Area (km^2)					Proportion of area (%)			
Model	Future	Loss	Gain	Unchanged	Total	Loss	Gain	Unchanged	Total
RCP2.6	11,734.42	9,806.09	6,510.92	5,223.50	–3,295.17	1.339	0.889	0.713	–0.450
RCP4.5	11,001.79	8,388.91	4,361.12	6,640.67	–4,027.80	1.145	0.596	0.907	–0.549
RCP6.0	3,561.38	14,480.39	3,033.43	527.94	–114,46.96	1.977	0.414	0.0721	–1.562
RCP8.5	4,685.49	14,711.93	4,367.83	317.66	–103,44.10	2.01	0.597	0.043	–1.412

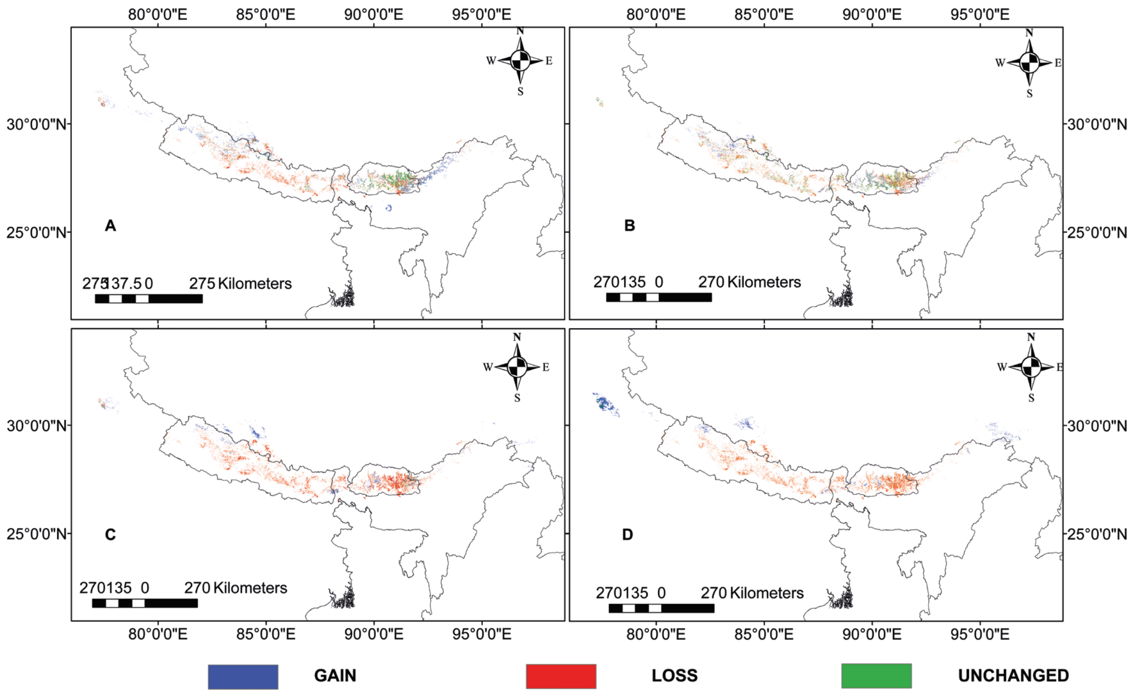

Figure 5 The gain and loss area of suitable habitat under different future climate scenarios models of RCP-2050 compared to present suitable habitat of Satyr Tragopan (A. RCP2.5, B. RCP4.5, C. RCP6.0, and D. RCP8.0).

P.R. China at geo-referenced position 30º9′15.656″N in latitude and 82º40′8.094″E in longitude. By and large, the core distributional shift of suitable habitat of Satyr Tragopan has expressed a southeast tendency in the Himalayas under both future emission trajectories (RCP2.6-2050 and RCP4.5-2050). However, the core distributional shift indicated a southwest tendency in the Himalayas under both future emission trajectories (RCP6.0-2050 and RCP8.5-2050) compared to the present centroid (Figure 1).

4. DISCUSSION

The models demonstrate that associated environmental variables are equally important to determine the geographical distribution range of the species for their conservation prospects. The results also indicate that the forest cover (NDVI) and the canopy cover (EVI) and variables affecting forest structure, namely altitude, slope, solar azimuth angle and climate variables, will have an impact on the prevalence of Satyr Tragopan in the Himalayas. Geographical mapping for the present distribution of suitable habitat of Satyr Tragopan revealed that the largest area of suitable habitat is in Bhutan followed by Nepal, India and P.R. China. Very similar results were reported by Bird Life International, Satyr Tragopan being common in Bhutan and uncommon in Nepal, India and P.R. China (local, with a limited range in south and southeast of Tibet; BirdLife International, 2012). The results of the climate change distribution model demonstrated that future global climate change will have a significant impact on pheasant prevalence and distribution; it will be an indication of future climate change impact on avian distribution in the Himalayas. In particular, the population loss, altering distribution and abundance of many species is caused by climate change threatening both species diversity and the delivery of critical ecosystem services (McLaughlin *et al.*, 2002; Wang *et al.*, 2014; Hu *et al.*, 2015). Most climate change research and forecasts have focussed the shifts in climatic means, based on the IPCC 2013 AR5 report that greenhouse gases contributed a global mean surface warming in the range of 0.5 °C to 1.3 °C over the period 1951 to 2010 (Stocker *et al.*, 2013). In the study, the three models (GCMs) were an ensemble, based on their means, to reduce the bias among the models for predicting the impact of future climate change on the distribution of Satyr Tragopan in the Himalayas. The results indicate that the various forms of temperature and precipitation have important roles in shaping the distribution range of Satyr Tragopan in the future climate scenario RCP-2050. The study predicts that under different concentrations of greenhouse gas emission scenarios RCP2.6-2050, RCP4.5-2050, RCP6.0-2050 and RCP8.5-2050, the suitable habitat range of Satyr Tragopan will shrink, until a genuine policy change to reduce greenhouse gas emission is in place and implemented effectively. Based on the results of the loss and gain of suitable habitat of Satyr Tragopan under different future scenario RCP-2050 in the Himalayas, the model reveals that the majority of suitable habitats will shift towards higher altitudes and latitudes in the Himalayan landscape, except the model RCP4.5-2050 which showed that some extend towards lower altitudes and latitudes. Although, the estimate of anthropogenic based climate change impact on biodiversity relies on projections from different climate models, the uncertainties in these have been a limiting factor, in particular at local scales. A new generation of more complex scenario climate change models, perhaps naively, were expected to provide more certain projections (Knutti and Sedláček, 2013). Sometimes robustness of new generation models can be weaker in consistency than simpler models. Even theoretical process understanding and observed changes provide strong support for the argument that climate change will probably exceed those in the 21st century compared to the past century (Solomon *et al.*, 2007a) except for the RCP2.6 scenario in which global greenhouse gas emissions are reduced by about 90% in 2100 compared with the present status (Knutti and Sedláček, 2013). However, most suitable habitat would be lost in low altitude and latitude landscapes under the future climate conditions. In general, the trend of habitat shift to higher altitudes and latitudes would gradually become more prominent and significant with climate warming. Additionally, the indigenous knowledge based on perception tools indicates that the Himalayan pheasants are shifting towards the mountainous peaks of high altitude landscapes, abandoning their low elevation ranges. The model has also identified that high risk landscapes or climate change driven sensitive habitats of Satyr Tragopan are in different countries of the Himalayas. In Bhutan, these are the Monggar, Trashigangtse, Zhemyang; in Nepal, Kaski, Banlung, Manang, Khotang, Bhojpur, Sandhikharka, Jumla; in India, Sikkim, Darjeeling; and in P.R. China, the Tibet autonomous region. These landscapes suggest that the majority of present suitable areas may become unsuitable habitats in future climate change conditions for Satyr Tragopan under different greenhouse gas emission RCP-2050 scenarios. However, the PAs play a vital role in achieving global biodiversity targets (Rodrigues *et al.*, 2004; Dunn *et al.*, 2016); additionally, the model will help to identify the very sensitive areas or habitats of species besides the PAs. These types of areas should ideally be placed under biodiversity conservation management where the level of biodiversity under risk or impacts of threatening factors are very high (Ricketts *et al.*, 2005). In the present distribution model of suitable habitat, it was found that most of the suitable habitats of Satyr Tragopan fall on different regions other than the PAs alone in the Himalayas. Based on Dunn *et al.* (2016), authors strongly challenged the conservation policy for the management of PAs of the Himalayas because the existing PA network was significantly worse than their optimal zonation result and did not achieve Aichi Target 11 and the CBD targets from the Himalayan Galliformes conservation viewpoint. Within PAs effective reinforcement is needed to prevent extinction, but it is reported that the designated PAs of Southeast Asia have not prevented habitat loss of the species (Clark *et al.*, 2013). Furthermore, the hunting of Himalayan pheasants is prevalent across the Himalayas for food and feathers (Kaul *et al.*, 2004; Baral, 2005; Hilaluddin and Ghose, 2005), especially Satyr Tragopan (Ripley, 1950; Inskipp *et al.*, 2016) and that their population is declining (IUCN, 2016). The study suggests the present PA networks in the Himalayas do not cover adequately the distribution of suitable habitat areas of Satyr Tragopan, thus questioning their conservation potential. Although, the distribution of Satyr Tragopan may depend on climate change (Root *et al.*, 2003; Hu *et al.*, 2014; Wang *et al.*, 2015), there may be possibilities in future for PAs in the Himalayas to offer better habitat opportunities for the species (Hannah *et al.*, 2007). On the other hand, our results do not show any sign of adequate management or effectiveness of the PAs of the Himalayas for the distribution of suitable habitats of Satyr Tragopan based on the very high threshold category under the present and future projection mappings. However, the Himalayan region also comes under the influence of anthropogenic threats due to the over exploitation of biodiversity by people for their survival as well as for commercial purposes (Badola and Aitken, 2010). Therefore, the sustainable use of native biodiversity and improved area management is equally important. Over exploitation of natural resources may result in the degradation of habitat of certain species including Himalayan pheasants and birds which are highly threatened owing to their specific habitat requirements. Today, conserving biodiversity is one of the top priorities for protected and sensitive areas, especially for climate sensitive landscapes like the Himalayas; to ensure that this happens appropriate initiatives are urgently required. As most Himalayan pheasants are found in high elevation habitats which make them very difficult to monitor, they are largely ignored in conservation management and research. More sophisticated climate scenario modelling is needed to attain a goal and vision for conservation management and programmes. We suggest the following management strategies for the Himalayas in response to future climate change, especially in the context of Satyr Tragopan: (*i*) conserve threatened or climate sensitive species by making suitable conservation policies or programmes to introduce/translocate species to new PA(s) at present and in the future; (*ii*) implement long-term monitoring of species in highly sensitive zones, where there are potential threats, which may cause habitat loss of species under future climate change scenarios; and (*iii*) promote and support establishing and extending more PAs within newly projected highly suitable habitat areas in the trans-boundary landscapes, at present and in future climatic conditions, to protect sensitive or endemic species before they become extinct.

5. CONCLUSIONS

This article uses recent advances in ecological modelling to quantitatively justify management strategies of Himalayan pheasants. The results indicate that 28,406.15 km^2 is the present suitable habitat for Satyr Tragopan under the very high threshold category. The forest cover (NDVI) and the canopy cover (EVI), and variables affecting forest structure, such as altitude, slope, solar azimuth angle and Bio7, were the primary factors dictating the final shaping of the present distribution of *T. satyra*. Based on three ensemble models

(GCMs) of future climate projection of different scenarios under RCP-2050, our study revealed that the suitable habitats of the species will shift towards higher altitude and latitude landscapes and would be lost in low altitude and latitude landscapes in future climate scenarios except for the model RCP4.5-2050, which showed that some suitable habitats extend towards lower altitudes and latitudes. The trend of habitat shifting to higher altitudes and latitudes are gradually becoming more prominent and significant, and the potential habitat of Satyr Tragopan will shrink with greenhouse gas intensification. Overall, the article suggests that Satyr Tragopan are a suitable model species to predict climate-driven habitat shifting, and therefore could be used to inform guidelines for improving the conservation and management of the species and other associated climate sensitive vulnerable species of the Himalayas.

6. ELECTRONIC SUPPLEMENTARY INFORMATION

The ESI, Table S1, is available through:
http://ingentaconnect.com/content/stl/abr/2018/00000011/00000003.

7. ACKNOWLEDGEMENTS

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Research Article

ECOLOGICAL STUDY OF SATYR TRAGOPAN (*TRAGOPAN SATYRA*) IN SIKKIM-INDIA: A THREATENED BIRD SPECIES OF EASTERN HIMALAYA

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ABSTRACT

Climate change is a rapid process in Himalaya, it has significantly affected the ecological pattern of the species, however, Himalaya is considered as data deficient region which generally lacks quantitative analysis needed to impact conservation and management policies for avian species. A few phenological changes are well documented, whereas, the changes in behaviour and ecological interactions remain opaque for many higher taxa. The present paper, the first time, we detailed out ecological interaction and community-level ramifications of the Satyr Tragopan (*Tragopan Satyra*, Phasianidae) in Sikkim Eastern Himalaya especially focusing upon the Khangchendzonga Biosphere Reserve (the core zone, Khangchendzonga National Park is recently inscribed by the UNESCO as world heritage site). Overall, the results during study period quantified the overall density of the Satyr Tragopan at 0.79±0.35/sq.km and the encounter rate at 0.079±0.02 in the region, by using Distance software 0.7. The result also indicated that the species is confined in a narrow stretch of habitat range (2800 m- 3400 m asl) of the ecotone of cold temperate and subalpine regions of the Khangchendzonga Biosphere Reserve. It seemed that their habitat is under threat due to ecotone zone, where always community's succession occurs. Our analysis addresses the necessary aspects of conservation planning for long-term monitoring of the species and may guide future IUCN Red List of Threatened Species Assessments in Eastern Himalaya before plunging to extinction.

INTRODUCTION

An interaction between plants and animals is directly associated within and between the ecosystem and their external environment variables, which is a priority area of research in the current scenario for on-going biodiversity conservation assessment theme. Globally, biodiversity is under tremendous environmental and anthropogenic pressures, which applies equally to all its elements including the plant and animal species. It may increase the risk of vulnerability as some species show the extremely poor level of adaptation to altered habitats (Lovejoy, 1986; Vermeij, 1986). Therefore, habitat alternation suggests that certain habitats and species are under the risk of extinction (Terborgh and Winter, 1980; Slobodkin, 1986; Dunn *et al,* 2016). Sikkim (India) records many threatened bird species (Acharya & Vijayan, 2010) and most of them are confined to restricted elevation range (Acharya *et al,* 2011), for their possible specific ecological niche requirements. Due to anthropogenic pressures and habitat fragmentation these birds are becoming more sensitive within restricted range and hence, the immediate task is needed for their improving conservation and management practices, especially in protected areas (Basnet and Badola, 2012; Dunn *et al,* 2016). Additionally, understanding the changes in population size and distribution patterns of species including density, space and time, are equally important to plan appropriate habitat management and conservation strategies (Bibbly *et al,* 2000; Martin *et al,* 2007; Clark *et al,* 2013). Estimation of avian abundance and density provides baseline information for investigating their population size and habitat associations (Norvell *et al,* 2003; Piana, 2016) within a particular landscape. Distance sampling method applied to provide estimates of density and abundance of the species in the particular region; the method can be applied to point and line transects for any

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systems and species (Sutherland, 1996). However, a line transect has merit as it increases the detection probability (Wilson *et al,* 2000) and also the ratio of survey to transit time is increased in line transect designs (Buckland, 2006), which makes a line transect be the most efficient and least biased method for estimating density and abundance of the species. In distance method survey, if point locations are combined with distance sampling then it is possible to estimate detection probabilities and thereby the species densities (Rosenstock *et al,* 2002; Piana, 2016), because distance sampling reduces bias in estimation of the species populations (Buckland *et al,* 2001; Thomas *et al,* 2010), these data are more reliable and helpful for conservation and habitat management planning of the species which further help for IUCN assessment of threatened species. In this paper, to begin understanding the ecological interaction of a species, the first time a study was attempted on Satyr Tragopan, as a case study in the Khangchendzonga Biosphere Reserve, using line transect. The Satyr Tragopan is Himalayan Peasant; a Near Threatened species, occurs in the Himalayas of Nepal (uncommon), India (uncommon), Bhutan (fairly common) and China (local, with a limited range in the south and south-east Tibet) (BirdLife International, 2001).

MATERIALS AND METHODS

Himalaya Pheasant

Satyr Tragopan is one of the Himalayan Pheasants. The Himalayan Pheasants represent the most distinctive bird family in the Himalayas owing to their charismatic features, they act as an indicator of habitat quality and adverse human impacts in the high-altitude ecosystems and play a vital role in the food web (Ramesh *et al,* 1999; Fuller and Garson, 2000). For Satyr Tragopan, the male has red underparts with black-bordered white spots and olive-brown coloration to upper parts including rump and upper tail -coverts and facial skin is blue. Female varies from rufous-brown to ochraceous -brown in coloration; wings, tail, and under parts are generally brighter and more rufescent than on other female tragopans (Grimmett *et al,* 2011). These diagnostic characters help to identify the species in the field.

Perception-based information

The secondary information of Satyr Tragopan was gathered from all over the region, especially focusing in and around the area of Khangchendzonga Biosphere Reserve (KBR) in Sikkim through literature survey, and also through interactive meets with the local people particularly former hunter, Himal-Rakshaks (officially designated protector volunteers in KBR by the Sikkim Government) and Foresters in order to identify the potential forest areas. The historical data of the species was also collected to find out the presence or absence of pheasants in the particular area (followed by Jolli *et al,* 2011).

Field Surveys

The field surveys were conducted in two major altitudinal transects, Yuksom-Black-Kabru transect and Tholung-Kisong transect of the Khangchendzonga Biosphere Reserve (KBR, extending along 27°15’-27°57' N. lat. 88° 02’-88°40’ E long, Badola and Subba, 2012), in Sikkim Eastern Himalaya, using a standardized methodology of line transect during May 2014-March 2017. The Yuksom-Black Kabru transect, a part of the southwest KBR in West Sikkim and the Thulong-Kisong transect, a part of the southeast KBR in North Sikkim were surveyed for the species especially covered the core zone, the Khangchendzonga National Park of KBR, which recently been inscribed as the World Heritage site (under mixed category) on 17.07.2016 by the UNESCO (Fig 1). The study areas covered the altitudinal gradient around c. 1760 m-4900 m asl in the KBR.

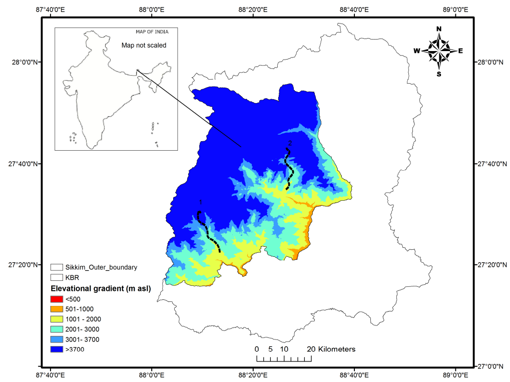

Fig 1 Location of study sites in the Khangchendzonga Biosphere Reserve (1 depicts Yuksom-Black Kabru transect and 2 depicts Tholung- Kisong transect)

Sample design

The two major transects were selected in the core zone of KBR, covering its northern and western parts to reduce the bias of availability of the species in time and space. Depending upon the accessibility in the study area, different sub-transects were laid down at different broad habitats along the elevation gradients in the two transects. Within sub-transacts, the total 680 point grids having 200 m x 200 m were laid down to detect the presence of the Satyr Tragopan at the perpendicular line based on altitude. The minimum 200 m distance between two successive points was maintained.

Distance analysis

Distance program was used (Thomas *et al,* 2005; Anderson *et al,* 2015) to estimate the Satyr Tragopan density, encounter rate, detection probability, mean cluster size and effective strip width (ESW). Distance data were analyzed using the program Distance 7.0, which has four key functions such as uniform, half-normal, hazard rate and negative exponential all with cosine series adjustment. Based on Akaike's Information Criteria (AIC), we used the chi-squared statistics to assess the ‘goodness of fit' of each function (followed by the similar approach by Burnham *et al,* 1981; Buckland *et al,* 1993; Kidwai *et al,* 2011). The pooled data across years were used to increase the number of detection is recommended to estimate density with a reasonable degree of accuracy using program Distance (followed by the similar approach of Scott *et al,* 2006). For small sizes, we applied the Akaike's Information Criterion (AICc) to select the most parsimonious model from all possible combinations that are of uniform, half normal and Hazard Rate models with Cosine, Simple Polynomial and Hermite Polynomial adjustment. The Half Normal function with Cosine adjustment was fitted best in the model to achieve consistent convergence (followed by similar approach Anderson *et al,* 2015). Detection probability of Satyr Tragopan was also modeled using different models and adjustment terms and according to the AIC value, the Half-Normal model without any adjustment terms provided the best fit at the point, i.e. detection function of individuals should be 1.0.

Habitat assessment for Satyr Tragopan

For the habitat assessment of the Satyr Tragopan, we recognized area, the Yuksom- Black Kabru (Dome) or Y-BKD transact (27˚22'32.0" N latitude and 088˚13'29" E longitude to 27˚30'14.2" N latitude and 088˚09'20" Longitude) along 1780 m to 4520 m asl, lies in the Khangchendzonga Biosphere Reserve of Sikkim in its West district, as a case study. Yuksom, a place for the trekkers and trailhead, the trail goes up to Dzongri and Gochela in KBR is designated as tourism zone; the entire targeted transect is approximately a 30 km walk from Yuksom and reaching up to Black Kabru. A long walking distance across temperate to alpine zone passes through Sachen, Bakhim, Tsokha, Phitang, Dzongri and Laxmi Pokhri (lake) reaching to the base of Mt Kabru (dome). The whole transect was surveyed first to understand the habitat range of the Satyr Tragopan and also cross-checked for its presence with former hunters, Himal-Rakshaks, Foresters, Tourist Guides, and Potters, to know the exact habitat range of the species in the region. This transect offers great opportunities to visitors, scientist and nature lovers for its diverse tropical mixed broad-leaved forest, sub-alpine conifer-Rhododendron forest, alpine meadows, cascading streams, sacred lakes, a wide variety of birds, flowering plants as well as medicinal plants and scenery of the World's third highest peak Mount Khangchendzonga presents. The habitat range of the Satyr Tragopan was encountered from 2800 m asl -3400 m asl based on our primary observation in the target site and the indigenous knowledge. As a case study, for understanding the habitat requirements of the Satyr Tragopan in KBR, we focused 2600 m - 3600 m asl range of the Yuksom- Black Kabru (Dome) transect.

Field Sample collection

Woody vegetation composition structures were studied using stratified random sampling in the target site to know the habitat composition of the Satyr Tragopan. The potential transact for vegetation was laid down random stratification, and depending upon the requirements different sites were identified, based on homogeneity composition of forest and altitude. For the trees, 10 quadrates of 10 m x10 m size at each site were laid down. Within each 10 m x10 m quadrate, 5 m x5 m size was taken for the shrubs and the saplings, whereas, the seedlings were observed under 10 quadrates of 1m x1m size. Due care was taken to sample the most representative area of each site.

Data Analysis

The procured data of woody vegetation were quantitatively analyzed for density, relative density, frequency, relative frequency dominance and relative dominance using formulae given by Misra (1968). The Important vegetation Index was also quantified by summing of relative density, relative frequency and relative Dominance of the woody species in the forest. To evaluate species diversity for each site the Shannon and Wiener Index (1963) and Simpson Index (1949) were applied, which is given as,

$$H' = -\sum_{i=1} (ni/N) \log_2 (ni/N)$$

Where ni represents a total number of individuals of particular species and N represents a total number of individuals of all species.

The Index of Species Evenness was determined by Shannon Index of Evenness, which can be expressed as, E=H'/ln(S); where, H = Shannon's Index of Diversity, and S = number of species in the sample; species dominance was quantified by Simpson's Index (1949), as,

$$D = \sum_{i=1} (ni/N)^2$$

Where ni represents a total number of individuals of particular species and N represents a total number of individuals of all species.

Species richness was quantified by using Margalef's Index I= (S-1)/ ln (N); Where, S = the number of species in the sample; and N = the total number of individuals in the sample.

RESULTS

Population assessment

The Satyr Tragopan was sighted of 54 individuals on 21 occasions with aggregations ranged from 1- 5 individuals. Based on Distance 7.0, the detection probability of the Satyr Tragopan in the targeted site was estimated at 0.75 (CV% 21.9). The overall density of the Satyr Tragopan in the target landscape in the Khangchendzonga Biosphere Reserve was estimated at 0.79±0.35/sq.km with an overall encounter rate of 0.079±0.02 for the Satyr Tragopan. The probability of detecting the Satyr Tragopan first decreased initially and after certain distance then again the detection probability increased and thereafter decreased with increasing distance from the observer (Fig 2).

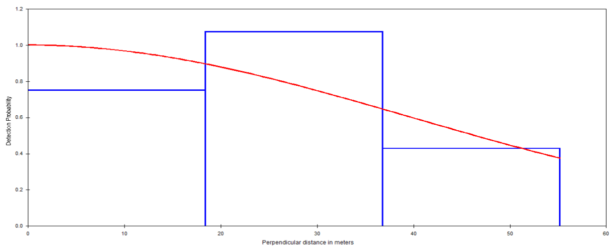

Fig 2 The best fit detection function model generated by DISTANCE analysis considering all Satyr Tragopan in the Khangchendzonga Biosphere Reserve during the study period (20014-2017).

Habitat assessment

The total 7 sites were identified as a habitat range of the Satyr Tragopan for the habitat assessment based on homogeneity of species and altitude in the cold temperate forest and subalpine region of the Yuksom-Black Kabru transect. The total 34 woody species were identified along 2600-3600 m asl range under 12 families. The Ericaceae followed by Sapindaceae and Rosaceae emerged as the most dominant family. The individuals of adult, sapling, and seedling per hectare also quantified. The maximum number of individuals of adult woody species were recorded at 3600 m asl (15200/ha) and the minimum at 2600 m asl (5400/ha). It seemed a trend that the number of individuals of adult woody species was increasing with altitude in the study sites. The maximum number of saplings of woody species was found at 3100 m asl (3000/ha) and the maximum number of seedlings was found at 3400 m asl (2100/ha) (Fig 3).

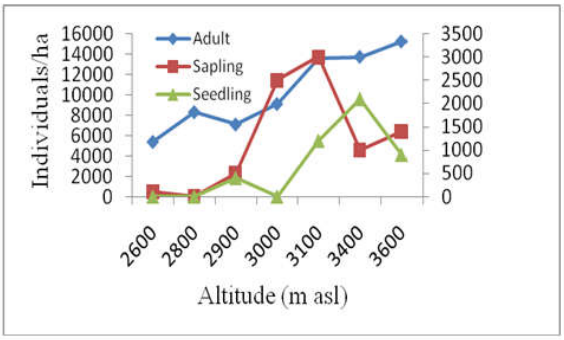

Fig 3 Abundance of woody species of the habitat of the Satyr Tragopan in the Khangchendzonga Biosphere Reserve

The basal area cover of woody species in meter per hectare of the study area was also quantified. We encountered the maximum basal area cover of adults at 3400 m asl (3386.56 sq. m/ha) and the minimum area cover of adults at 3600 m asl (562.11 sq. m/ha). The maximum basal area cover of sapling was found at 3000 m asl (5.29 sq. m/ha) and similarly, the highest basal area cover of seedling was found at 3400 m asl (0.23 sq. m/ha) (Fig 4).

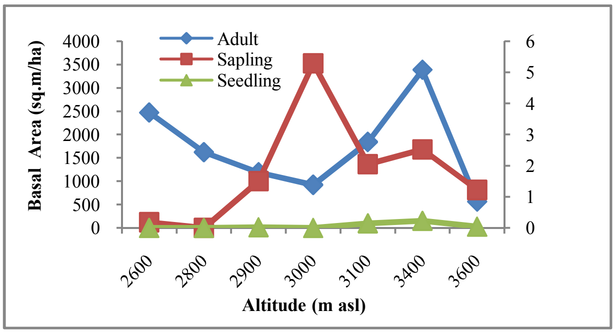

Fig 4 Basal area of woody species of the habitat of the Satyr Tragopan in the Khangchendzonga Biosphere Reserve

The ecological indices of the habitat of the Satyr Tragopan were also quantified such as Margalef's Index of Species richness (range from 5.80-10.76), Simpson's index of Dominance (range from 1.41E+00-1.67E-01), Shannon-Weiner Diversity Index (range from 2.082-1.18), and Shannon Index of Species Evenness (range from 0.87-0.64). Overall, all the ecological indices appeared to be negatively correlated with altitude using the regression line (Fig 5).

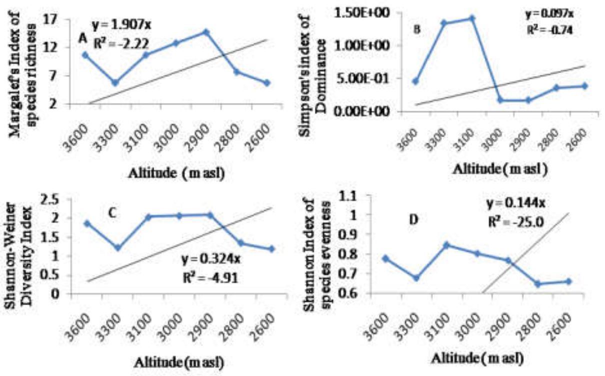

Fig 5 Ecological indices of the habitat range of the Satyr Tragopan in the Khangchendzonga Biosphere Reserve

Based on the relative density, relative frequency and relative dominance of woody species, the Important Vegetation Index (IVI) of the Satyr Tragopan's habitat range was also quantified. As per IVI, *Rhododendron hodgsonii* (Ericaceae), *Abies densa* (Pinaceae) and *Rhododendron campylocarpum* (Ericaceae) had the highest IVI at 3600 m asl. Similarly, *Abies densa, Rhododendron falconeri* (Ericaceae), *Betula alnoides* (Betulaceae) and *Rhododendron barbatum* (Ericaceae) at 3400 m asl, *Rhododendron falconeria, Rhododendron arboreum* (Ericaceae) and *Abies densa* at 3100 m asl, *Abies densa, Rhododendron falconeria, Rhododendron arboreum* at 3000 m asl, *Rhododendron arboreum* and *Magnolia campbellii* (Magnoliaceae) at 2900 m asl, *Rhododendron arboreum, Magnolia campbellii,* and *Quercus pachyphylla* (Fagaceae) at 2800 m asl, and *Quercus pachyphylla* and *Rhododendron arboreum* in the site at 2600 m asl were the dominant species of the Satyr Tragopan habitat range. Overall, it seemed that the Satyr Tragopan habitat range was confined in a very narrow stretch of cold temperate and sub-alpine zones of the Khangchendzonga Biosphere Reserve. It was seen that the Satyr Tragopan dwelling mainly restricted in the dense undergrowth and bamboos of the ecotone of the cold temperate-subalpine forest in the Khangchendzonga Biosphere Reserve.

DISCUSSION

The results indicate that the Satyr Tragopan is confined in a narrow stretch of habitat range from 2800 m -3400 m asl of cold temperate and subalpine regions in the Khangchendzonga Biosphere Reserve. Whereas, Grimmett *et al* (1998) have reported that the Satyr Tragopan was found along 2590-3800 m asl (in winter at 2000 m asl). Similarly, studies in Annapurna Himal in Nepal (Lelliott and Yonzon, 1980) and in Singhalila National Park in Darjeeling (Khaling, 1997) showed Satyr Tragopan distribution in similar habitat and elevation range. The results also indicate that the overall density of the Satyr Tragopan was at 0.79±0.35/sq.km and encounter rate was at 0.079±0.02 in the Khangchendzonga Biosphere Reserve. Although, the habitat loss and fragmentation is a profound impact on declining population of threatened and endemic birds in the Himalayas and elsewhere (Crosby, 1996; Mauro and Vercruysse, 2000; Bird International, 2001; Chettri *et al,* 2001, 2005; Pandit *et al,* 2007; Dunn *et al,* 2016). It has been reported that the endemic birds are unable to cope with non-native habitats resulting from deforestation and land use pattern (Vijayan and Gokula, 2006; Clark *et al,* 2013). The main cause of extinction of endemic species is driven by the loss of potential breeding habitat (Mauro and Vercruysse, 2000; BirdLife International, 2001). Our finding also suggests that the Satyr Tragopan is confined in the ecotone of the cold temperate forest and subalpine region of the Khangchendzonga Biosphere Reserve and their habitats are under threat due to the fragile community composition in the ecotone zone which may easily come under the impact of climate change. Further, it seemed that the species richness of woody species is higher in the ecotone zone, i.e. the middle of the altitude of the habitat range of the Satyr Tragopan and also indication that the lower region of the woody species is shifting towards the higher region. Gaire *et al* (2014) have reported that the timberline tree, *Abies spectabilis* has been shifting towards higher altitude at the rate of 2.61m/per year since 1850, and phenology shifting (Badola,

2010) is evident in Himalaya due to climate change. However, the temperature is increasing generally at 0.01 to 0.04°C per year (Sharma *et al*., 2009); whereas, the rainfall is uncertain (Goswami *et al*, 2006) due to climate change in Himalaya. Additionally, due to anthropogenic pressures and habitat fragmentation, Himalayan birds are becoming more sensitive within restricted range and hence, the immediate task is needed for their improved conservation and management practices, especially in the protected areas (Basnet and Badola, 2012; Clark *et al*, 2013). Scientific data are required on the ecological status, distribution, diversity of bird species and associated habitats, which may offer vital clues on the disturbance level for the effective implementation of conservation management of the same (Chettri, 2000; Nawaz *et al*, 2000; Klerka *et al*, 2004; Fernández-Juricica *et al*, 2004; Basnet and Badola 2012).Therefore, the study on pheasants' diversity and abundance alone without understanding their habitat relationships would be inadequate for a complete and quality research assessment because either is ecologically inter-related. However, Mountain range of the eastern Himalayas is considered as an endemic bird area (BirdLife International, 2001), which supports 22 restricted-range bird species, out of which 22 species 19 are endemic to the Eastern Himalayas (Stattersfield *et al*, 1998; Jathar and Rahmani, 2006). The principal threat to the avian fauna of Himalaya is the loss of habitat; particularly tropical lowland, subtropical and temperate forests (Crosby, 1996). Although, monitoring the Himalayan Pheasants are largely ignored for its conservation and habitat management due to their habitats which mostly confined to sloppy mountain landscape where the climate is unbearable with difficult landscape topography to carry out the study. Therefore, conservation directives should focus on Himalayan Pheasants for their priority conservation and appropriate habitat management in the Himalayas before they are forced to go through the doors of extinction. The authors highly recommend for the long-term data and monitoring mechanism in the Himalayan landscape to allow interpretation of the changes in ecology interaction of Himalayan Pheasants along with climate change, and associated habitats to strengthen their conservation management by involving policymakers, community people, government and non-governmental organizations.

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