CHAPTER 04

OBJECTIVE 01

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

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BACKGROUND

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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.

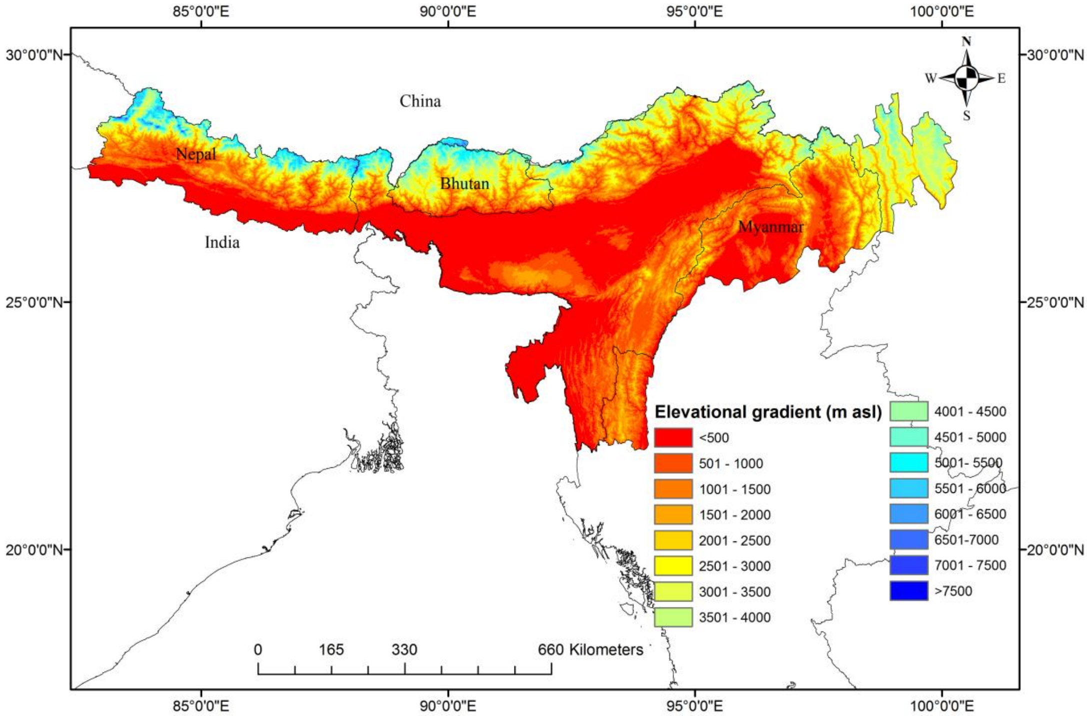

Figure 3.1: Digital elevation model of Eastern Himalaya.

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.

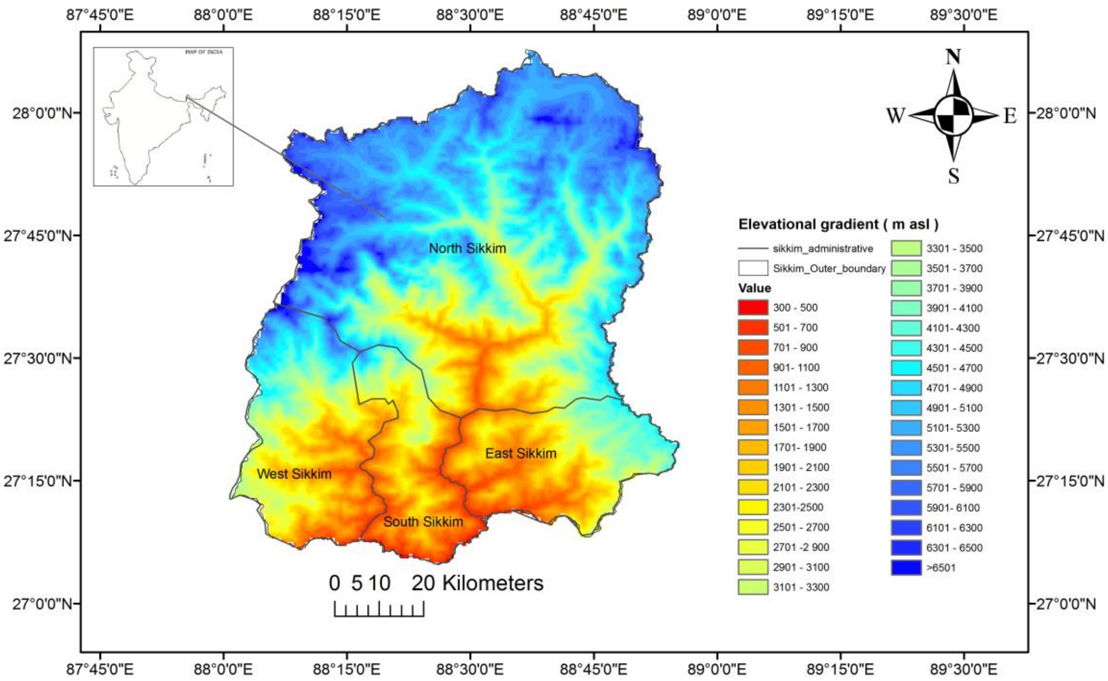

Figure 3.2: Digital elevation model of Sikkim Himalaya.

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).

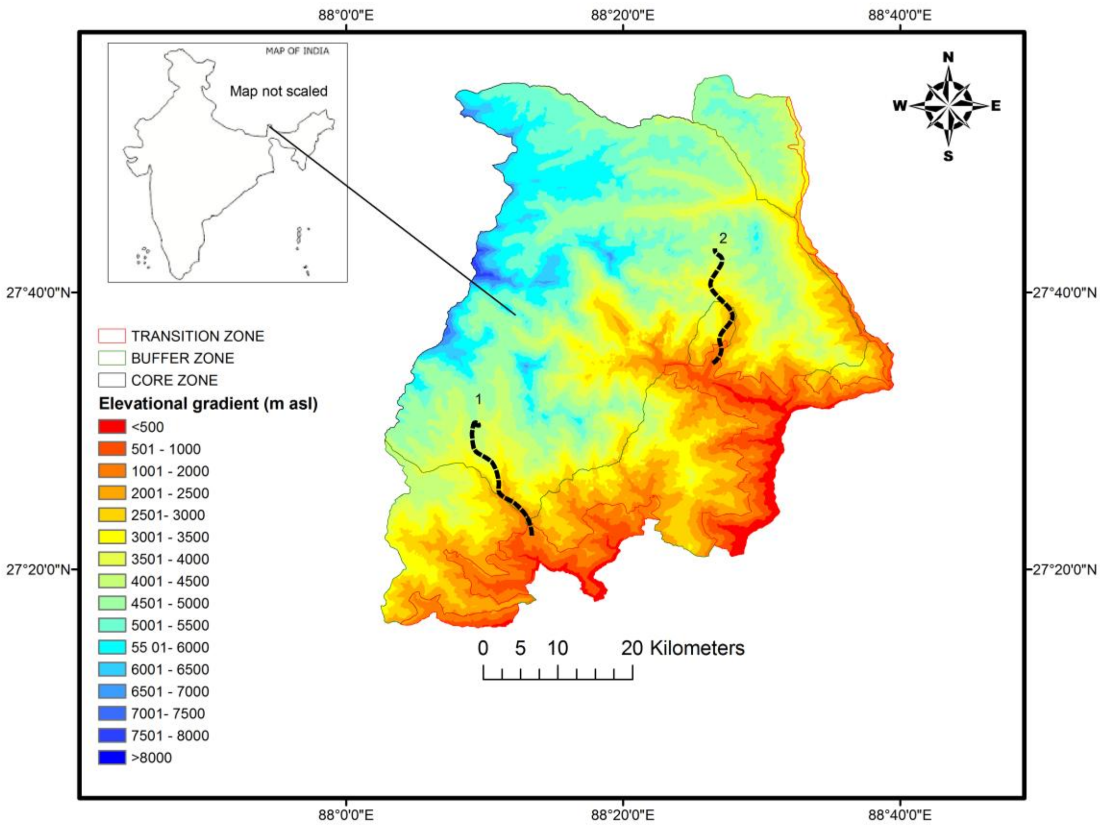

Figure 3.3: Digital elevation model of Khangchendzonga Biosphere Reserve (1 depicts Yuksom-Black Kabru (Dome) transect and 2 depicts Tholung-Kisong transect of the study area).

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).

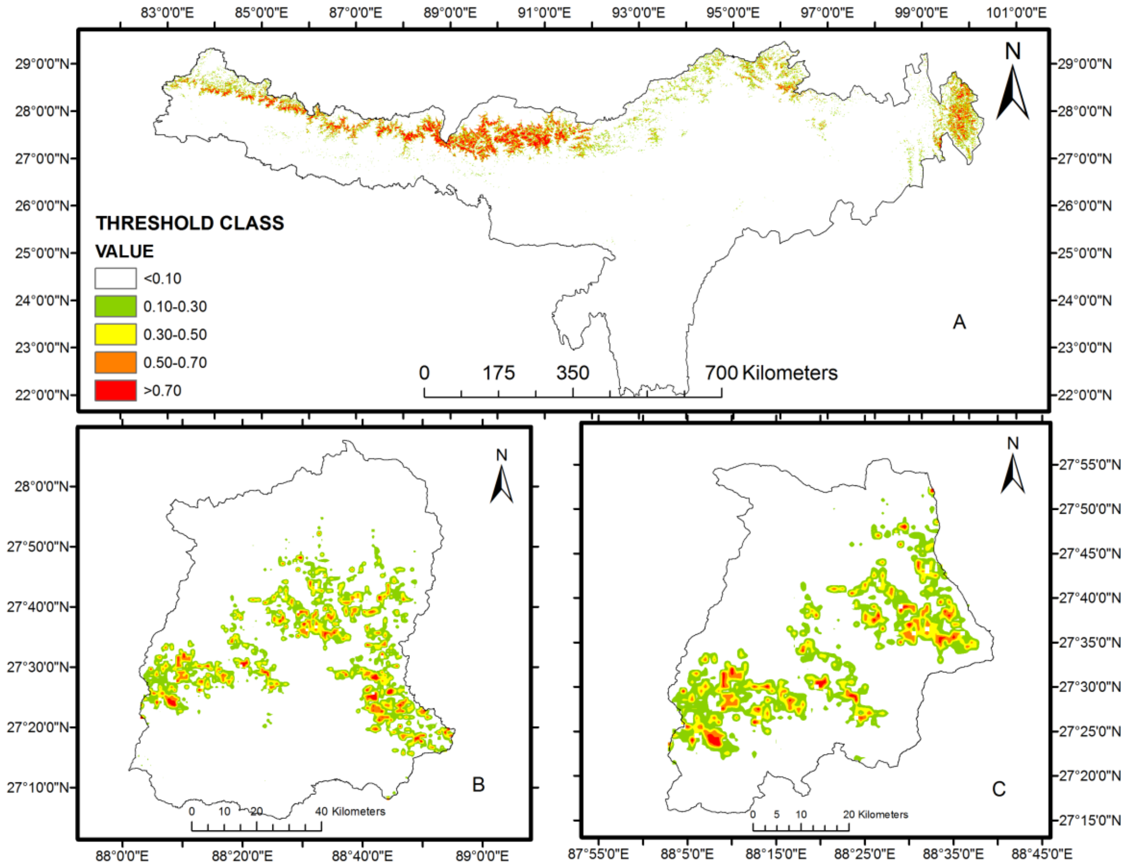

Figure 3.4: SDM of Blood Pheasant depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential 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)

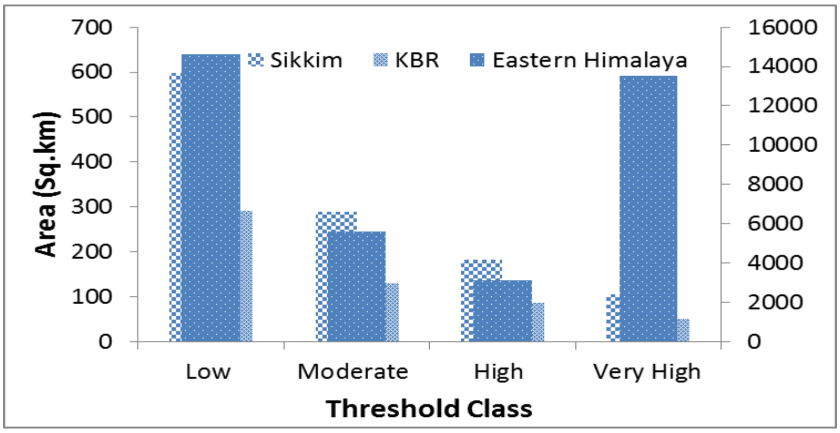

Figure 3.5: Area of potential threshold class of Blood Pheasant in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR).

4.3.1.2. Current habitat distribution model of Himalayan Monal

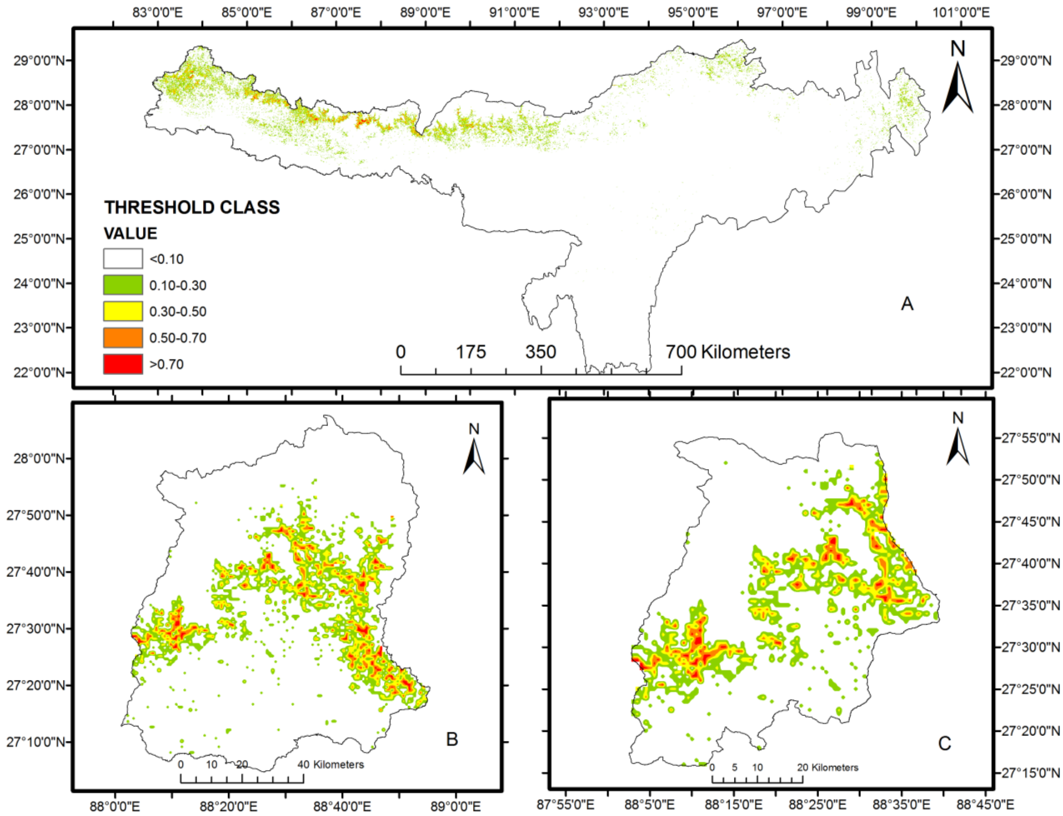

Figure 3.6: SDM of Himalayan Monal depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential 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)

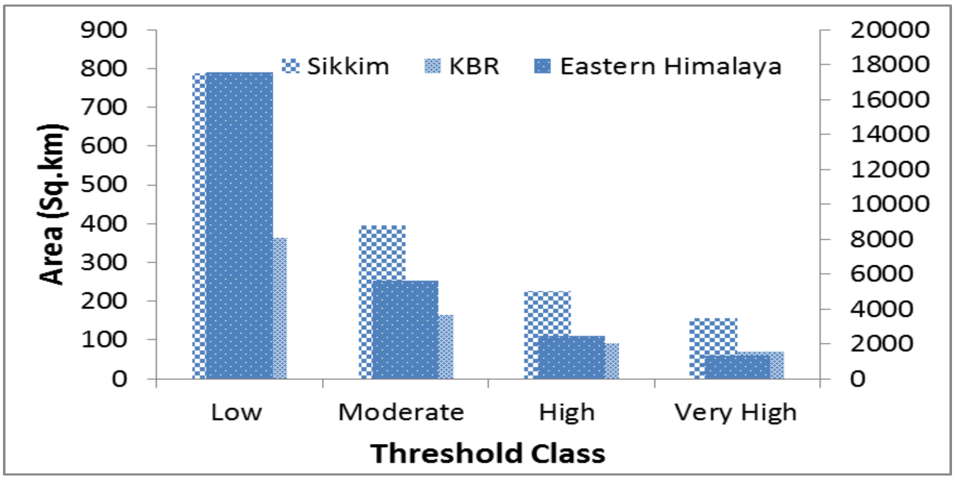

Figure 3.7: Area of potential threshold class of Himalayan Monal in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR)

4.3.1.3. Current habitat distribution model of Kalij Pheasant

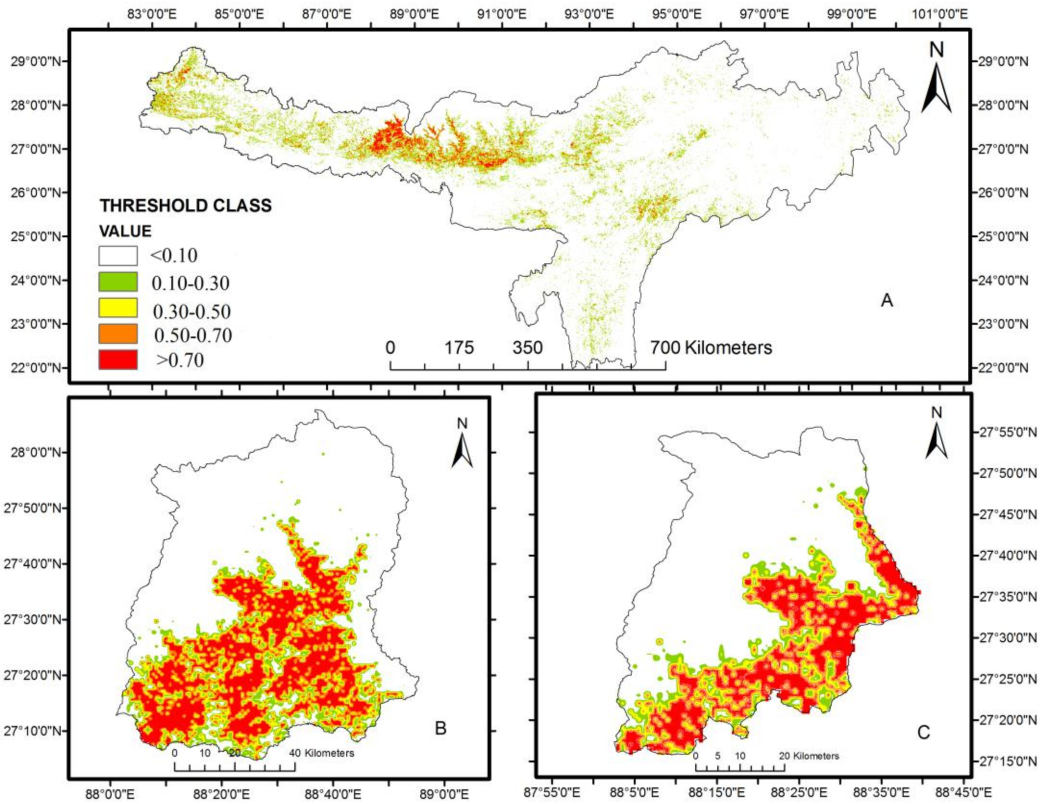

Figure 3.8: SDM of Kalij Pheasant depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential 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].

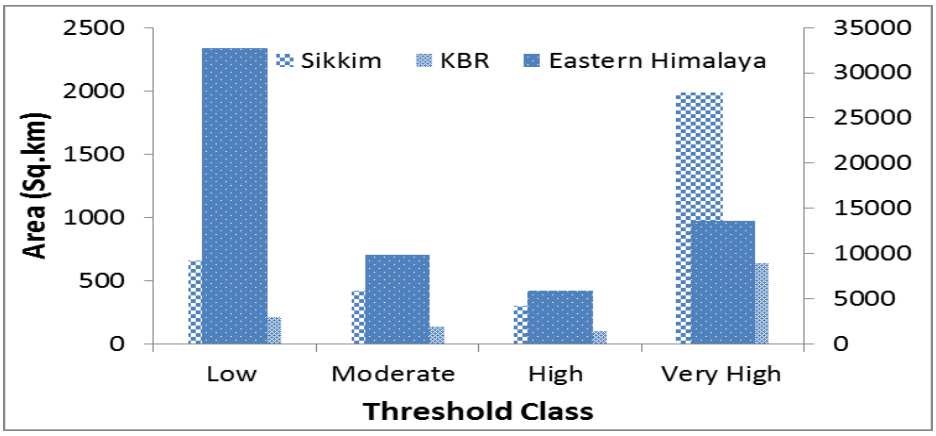

Figure 3.9: Area of potential threshold class of Kalij Pheasant in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR).

4.3.1.4. Current habitat distribution model of Satyr Tragopan

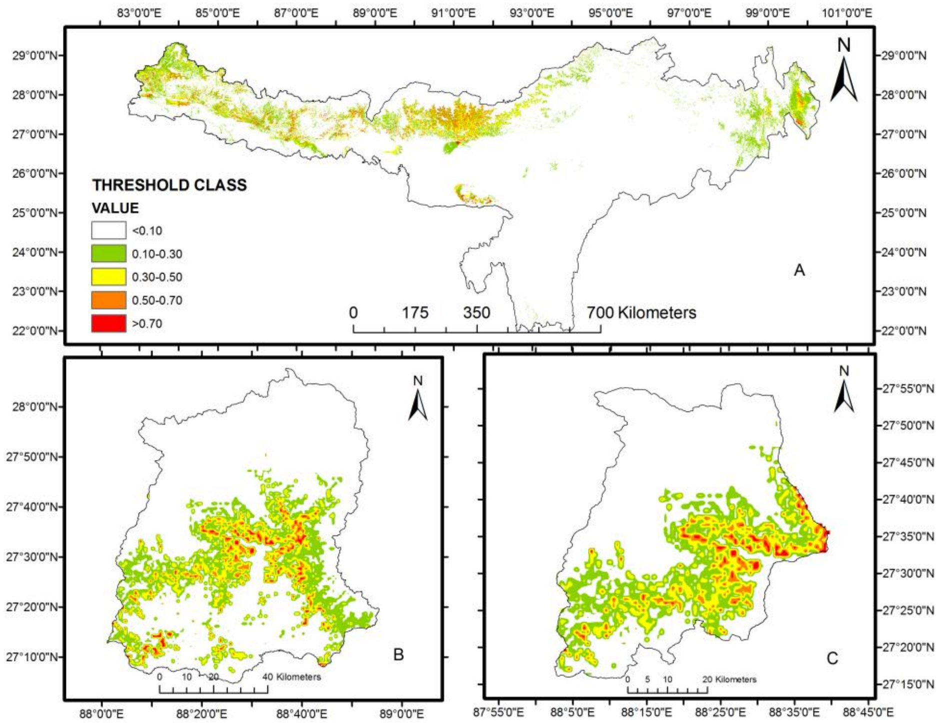

Figure 3.10: SDM of Satyr Tragopan depicts threshold class value, <0.10 as a very low potential habitat suitability, 0.10-0.30 as a low potential habitat suitability, 0.30-0.50 as a moderate potential habitat suitability, 0.50-0.70 as a high potential habitat suitability and >0.70 as a very high potential 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).

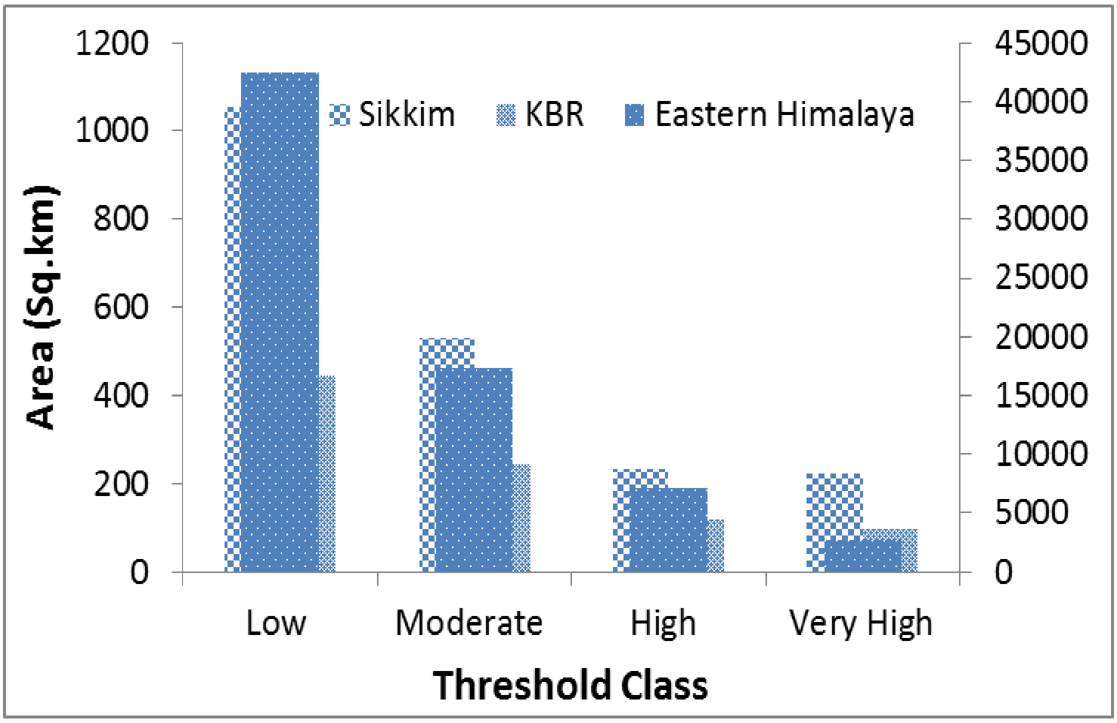

Figure 3.11: Area of potential threshold class of Satyr Tragopan in Eastern Himalaya, Sikkim, and Khangchendzonga Biosphere Reserve (KBR).

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).