PATTERNS AND DETERMINANTS OF MAMMALIAN ASSEMBLAGE IN AN EASTERN HIMALAYAN LANDSCAPE UNIT

Thesis submitted for the award of the degree of

DOCTOR OF PHILOSOPHY
IN
WILDLIFE SCIENCE

by

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May - 2025

Citation:

Deepan Chackaravarthy S, Ramesh K, and Gopi G V. (2025). Patterns and Determinants of Mammalian Assemblage in an Eastern Himalayan Landscape Unit. Ph.D. Thesis. Wildlife Institute of India, Dehradun, India and Saurashtra University, Rajkot, India. 191.

Acknowledgments

I express my deepest gratitude to my supervisor, Dr. Gopi G. V., Scientist-F, Wildlife Institute of India, Dehradun, for his invaluable guidance, consistent encouragement, and insightful feedback, which kept me focused and motivated throughout this journey.

I am sincerely thankful to Mr. Ankhyangso Kri and his family for their unwavering support during the execution of my fieldwork. A special thanks to Miss Kushiyali Kri, a member of our research team, and to Grandmother Mukumla Kri, Mother Yampailu Chaitom, and her brother Sirusa Rukhiam Kri, for their kindness and hospitality.

My heartfelt gratitude goes to Dr. Lakshminarayanan, Mr. A.D. Udhayraj of the Elephant Cell, Wildlife Institute of India, and Mr. Vinoth A., Senior Project Officer, WWF, for their valuable support and cooperation.

I am also grateful to Dr. Aisho Sharma Adhikarimayum for his help in exploring the landscapes of Arunachal Pradesh, and to Mr. Ajay Prakash Rawat, Senior Project Associate, and Mr. Vivek Ranjan, Principal Project Associate, Wildlife Institute of India, along with their families, for their encouragement and support.

Special thanks to Mr. Ramesh Kumar A., Proprietor, Red Carpet Enterprises, and Mr. Natarajan Nurani Hariharan, Managing Director, Firebird Technologies Pvt. Ltd., Coimbatore, for their consistent support in various aspects of my research.

I extend my appreciation to Mr. Sivapushanam Karthy, doctoral student at National Sun Yat-sen University, Taiwan, and Mr. Thirumurugan V, Madras Christian College, for their enduring support throughout this journey.

At this cherished moment, I would like to thank Capt. Dr. Parag Nigam, Scientist-G, Wildlife Institute of India, for being a well-wisher and mentor. His support proved crucial during various stages of my thesis work.

I am thankful to Dr. K. Sankar, former Director of SACON, Dr. Justus Joshua, and Dr. Wesley Sundarraj for their valuable suggestions, scientific inputs, and guidance.

I am indebted to the faculty of the Wildlife Institute of India, especially Dr. Ruchi Badola, Dean, Faculty of Wildlife Science, Dr. Samrat Mondal, Scientist-F (NOEA), and Dr. Ramesh Chinnasamy, Scientist-E, for their academic encouragement. I also thank former scientists of the institute Dr. V. P. Uniyal, Dr. Bitapi C. Sinha, Dr. Surendra Prakash Goyal, Dr. Y. V. Jhala, Shri Qamar Qureshi, and Dr. S. A. Hussain—for their lasting influence on the institution and its scholars.

I am deeply grateful to the following friends and fellow researchers for their unwavering support throughout my research career. Dr. Vineet Dubey from the Wildlife Institute of India, M. Naveen, Scientist at the Asian Elephant Conservation Research and Conflict Management Centre, Dr. T. T. Shameer, Project Scientist at the Centre for Conservation Ecology, Advanced Institute for Wildlife Conservation, Tamil Nadu Forest Department, and Dr. B. Navaneethan, Species Coordinator (Elephant) at WWF-India, have been invaluable in offering their guidance and assistance. I also appreciate the support of M. A. Predit, Coordinator – Species Conservation, Western Ghats Nilgiris, WWF-India; Dr. Mirza Ghazanfarullah Ghazi, Project Scientist-I; S. K. Zeeshan Ali from the Wildlife Institute of India; Sayanti Basak, Programme Officer at the IUCN SSC Centre for Species Survival: India; Dr. Naveen Chandra Joshi, Senior Scientific Officer at UCOST; P. Girikaran, Research Scholar at Government Arts College, Ooty; and Joseph Reginald L. and Vinny R. Peter from CUBE Coimbatore, for their continual support and encouragement.

I am especially indebted to Shri M. M. Uniyal for his continuous encouragement and support. I also thank Shri Gyanesh Chibber and Shri Kishan Singh Bhainsora for their assistance in my academic and research development. Special thanks to Mr. A. Madhanraj, Senior Technical Officer, for his kind help and support.

I appreciate the camaraderie and help of my lab colleagues from the GGV Lab—Dr. Frank Sadrack Jabaraj D, Alex Jacob S. S. (PhD Scholar), Rohit Jha, Mr. Karan Kumar (Project Associate-1, Admin), and Mr. Sagar Nawani (Administrative Assistant)—who supported various aspects of my research activities.

I am sincerely thankful to the Forest Department and the Government of Arunachal Pradesh for granting permission to conduct fieldwork in the Kamlang Tiger Reserve. I gratefully acknowledge the National Tiger Conservation Authority (NTCA) for funding support.

Finally, I express my deepest thanks to my family and friends for their unwavering support, understanding, and patience. Their love and encouragement gave me the strength to persevere through challenges.

I dedicate this work to my grandfather, the late R. Seshan, and to my field guru, the late Ajay Desai, the renowned Elephant Scientist, whose legacy continues to inspire me.

List of Publication

1. Deepan Chackaravarthy. S, Ramesh. K and Gopi.G.V. 2025. Diel Activity Pattern and Co-occurrence of Mammal Species in the North-eastern Landscape, Arunachal Pradesh, India, *Asian Journal of Conservation Biology*, Vol. 14 No. 1, pp. 81–97.

Conference and Seminars

1. International Conference on Agro-Ecology, which was held on March 30th, 2018 organized in collaboration with Arulagam held at Bangalore (presented on "Traditional Knowledge in Managing Human-Wildlife Conflicts in Agricultural Areas: Insights from the Northeast Region".)
2. National Seminar on Conservation of Taditional Crops in Himalayan Regions with Special Reference to Cerals and Millets organized by Department of Botany, Soban Singh Jeena University, Campus Almora Uttarakhand (presented on Exploring the utility of the species distribution mdelling to understand habitat availability for select mammalian species in the Eastern Himalayan landscape)

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List of Abbrevation

a.s.l.- Above Sea Level

AUC - Area Under Curve

BRT - Boosted Regression Trees

CART - Classification And Regression Trees

CEPF - Critical Ecosystem Partnership Fund

CR - Critically Endangered

EN - Endangered

FSI- Forest Survey of India

GLM - Generalised Linear Models

GSI- Geological Survey of India

ICIMOD - International Centre for Integrated Mountain Development

IPLC - Indigenous people and local communities

IUCN - International Union for Conservation of Nature

LAC - Line of Actual Control

LBS - Locally-Based Survey

LC - Least Concern

LEK - Local Ecological Knowledge

m - Meter

MARS - Multivariate Adaptive Regression Splines

MaxEnt - Maximum Entropy

MBT - Main Boundary Thrust

Mha - Million Hectares

MSL - Mean Sea Level

NEC - North Eastern Council

NT - Near-Threatened

NTFP – Non-timber Forest Product

PA -Protected Area

RF - Random Forests

RFA - Recorded Forest Area

SDM _ Species Distribution Modelling

TCL - Tiger Conservation Landscapes

TSS - True Skill Statistic

UNCED - United Nations Conference on Environment and Development

VU - Vulnerable species

ZSI- Zoological Survey of India

Table of Contents

Executive summary

This thesis presents a detailed investigation of the mammalian assemblage in a selected landscape unit in the Eastern Himalayan in the Far East region of Arunachal Pradesh. The selected landscape unit is located in a Himalayan biodiversity hotspot, with its mountain ranges are biogeographically well connected to the Indo-Burma biodiversity hotspot. The study unit remains one of the least explored forests for mammalian species, except for a few prior expeditions. The unit is situated between two contiguous tiger reserves, The Kamlang Tiger Reserve and Namdhapa Tiger Reserve to the south, and the state's largest wildlife sanctuary, the Dibang Wildlife Sanctuary, to the north and the Mehao Wildlife Sanctuary to the west. The landscape units encomposses protected areas, including the Kamlang Tiger Reserve and Wildlife Sanctuary, and forest divisions of Lohit, Anjaw, Anini, and Namsai forest divisions. The terrain is rugged and hilly, traversed by various rivers and streams, which are the contributors to the river Brahmaputra. We conducted a reconnaissance survey to fulfil the objective of creating an inventory, and the resulting information guided the deployment of camera traps in locations optimal for effective photo capture of mammals. The objective of the study also examines the perception of the indigenous people towards mammalian, species. A questionnaire survey was conducted in and around the study unit, to assess the perception, which also provides information about species that are not directly captured in the camera-trap monitoring programme.

The study documented several mammalian species in the selected landscape unit, with species, like tigers (*Panthera tigris*) and leopards (*Panthera pardus*), were reported from secondary sources and direct sightings. Dhole (*Cuon alpinus*), clouded leopard (*Neofelis nebulosa*), and Asiatic golden cat (*Catopuma temminckii*) are the top predators recorded using camera traps. Certain species of conservation interest are also reported, such as Alpine musk deer (*Moschus chrysogaster*), Red Panda (*Ailurus fulgens*), and the recent past

distribution of Wild water buffalo (*Bubalus arnee).* This information adds additional credits for reintroduction programs in future. Both bear species, the Asiatic Black Bear (*Ursus thibetanus*) and the Sun Bear (*Helarctos malayanus*), are recorded in this study. The recently segregated species Gongshan Muntjac (*Muntiacus gongshanensis*) and data-deficient species like the Northern Tree Shrew (*Tupaia belangeri)* were also recorded during the study period. Though the study reported flying squirrels at taxa level the region is occupied by species that are listed as endangered and critically endangered. The Critically Endangered Chinese Pangolin (*Manis pentadactyla*) was also recorded with one individual rescued during the study. The habitat suitability prediction for selected species, both at a regional scale and at the landscape unit level provided valuable insights for conservation and management. The analysis using time-stamped camera-trap images shows that the interaction of Dhole and Yellow-Throated Martens with prey is high, possibly due to the lower density of higher Felids. The activity pattern of the Mishmi Takin (*Budorcas taxicolor taxicolor)* offered valuable and additional information about the migratory species which moves across habitats and elevations seasonally.

The questionnaire survey on the people's perception revealed that the people's cultural connectedness to the wilderness remains strong. A community-based participatory approach should be developed in this region to enhance conservation practices. The study also identified an increasing trend of negative interaction with species such as the dhole (*Cuon alpinus*) and crop damage caused by the Asian elephant (*Elephas maximus)* recorded through indirect evidence. Additionally, there are also two least studied rodents: The Asiatic brush-tailed porcupine (*Atherurus macrourus*) and the Indian crested porcupine (*Hystrix indica*), which was noted to requiring further studies on their ecological role in the region. There have been discoveries of new species very recently in this region, underscores the need for a deeper understanding of species distribution in this region. In a landscape where people are deeply connected to culture, tradition and beliefs, there needs to be an inclusive approach for further exploration. A significant proportion of respondents indicated that cultural beliefs and traditional rights interlink with species protection in the region. A successful transfer of knowledge either the stratified sampling of communities and citizens to ensure that only those most apt to conduct science are invited to participate (Fernandez-Gimenez, 2008).

Organisation of the Thesis

The thesis is organised into six chapters. Chapter I deals with the General Introduction about the study and its objectives. Chapter II deals with the description of the study area. Chapter III describes the basic Inventory of mammals, which is one of the core findings of the study. Chapter IV focuses on the suitable habitat modelling of select mammal species recorded in the study unit. Chapter V examines the Diel activity pattern, temporal activity overlap, and spatial co-occurrence of mammal species in the study unit, serving as a representation of the species activity patterns in Eastern Arunachal Pradesh. Chapter VI explores the perception of people on mammalian conservation in the landscape unit, based on a questionnaire survey.

Chapter – I

General Introduction

Understanding biodiversity distribution patterns and their underlying mechanisms is a fundamental and challenging task for ecologists. Patterns of distribution of organisms on islands have served repeatedly as the inductive inspiration for new theory, from Darwin's (1859) theory of evolution by natural selection, to Mayrs, (1942) ideas of speciation due to geographical isolation, to MacArthur & Wilson's (1967) theory of insular species diversity. Determining the factors that generate and maintain patterns of assemblage structure and diversity is a fundamental topic in ecology (MacArthur & MacArthur, 1961; Ricklefs, 1987; Gaston, 2000). Considerable investigation has been conducted on associations between habitat structure and mammal assemblage structure (M'Closkey, 1976; Fox, 1981; August, 1983; Shenbrot *et al*., 1994; Williams & Marsh, 1998; Fox & Fox, 2000). The species assemblage at a regional scale, along with the habitat characteristics (Nieto *et al*., 2005; Rodrıguez *et al*., 2006), is an essential factor for species richness (Ricklefs, 2004). The species assemblage is an artefact of the evolutionary trait of a species to a specific environmental condition (Ricklefs & Schluter, 1993; Hawkins *et al*., 2003a, b; Willig *et al*., 2003; Wiens & Donoghue, 2004). Thomas *et al.* (2001) state that there is a poor understanding of how species of vertebrates are distributed across a mosaic landscape. Indeed, the persistence of these environmentally sensitive and ecologically pivotal species may be indicative of the integrity of entire ecosystems (Noss *et.al*, 1996). The historical biogeography is important for understanding species richness and configuration of the species community (Wiens & Donoghue, 2004). The surge in species richness is an outcome of species dispersal or an '*in-situ* speciation'. The species composition in a community depends upon the regional scale 'species pool' (Ricklefs & Schluter, 1993; Webb *et al*., 2002; McPeek & Brown, 2000) caused by biogeographical processes over a great extent of area. The species pool affects the composition of the local species, and it needs a vibrant understanding for vindicating a locality occupancy of a species (Ricklefs, 2004; 2007). To achieve such goals, monitoring a cumulative species distribution over a greater range of area is vital.

The regional fauna has a long and complicated history of exchange with both the surrounding sclerophyll forests and the rainforests (Schodde & Calaby, 1972; Winter, 1988). Due to the current anthropogenically driven extinction event, biodiversity is being lost at an alarming rate, far more than the geologically normal levels (Pimm *et al*., 1995; Regan *et al*., 2001). Tropical forests support more than 60 % of all known species, but represent only about 7 % of the Earth's land surface. Globally, there is a general deterioration in the status of mammals, and tropical forest mammals are the least studied and the most threatened (Schipper *et al*., 2008) when compared to those of temperate regions (Cayuela *et al.*, 2009). However, the rate of loss faced tropical rainforest was estimated to be as high as 15 Mha annually, and the rate of species loss is also found to be at an escalating rate up to ten thousand times higher than the expected rate at a non-human manifestation state (Bradshaw *et al*., 2009). Yet, several factors caused by both natural and anthropogenic activities negatively affect tropical forest mammals. However, limited and often inconsistent information is available on the status or trends of mammal communities in tropical forests. The local scale pattern of mammalian assemblage structures in wet tropical biogeographic regions shows the highest mammal diversity. The highest mammalian diversity along the environmental gradient of Tropical forests needs to be studied concerning the interactions between habitat structure and the mammal assemblage. (Williams *et al*., 1996). With biodiversity in the tropics being in turmoil, mitigation of human-mediated impacts such as shifting land use or wildlife exploitation continues to be a clear focus for tropical conservation biology (Bradshaw *et al*., 2009).

Proper understanding of species distribution is the cornerstone for any research on community dynamics or conservation biology. Most empirical studies of the determinants of assemblage structure have been at the local scale, probably because of the logistical constraints associated with larger spatial scales and the pervasiveness of competition and niche theory in models of the determinants of species richness in a community. In traditional niche and competition theory, the control of assemblage structure occurs at the local scale and is a bottom-up process. Other models propose that local assemblages are primarily a static subset of the regional assemblage (i.e., proportional sampling), which implies a top-down control of assemblage structure (Cornell & Lawton, 1992; Griffiths, 1997; Caley & Schluter, 1997). Assemblage structure is more likely to be the result of different processes acting at different spatial scales (Ricklefs, 1987; Hughes *et al*., 1999).

Species are a fundamental unit of biodiversity. The patterns of geographical variation in abundance, distribution, and diversity must ultimately be explained by geographical variation (MacArthur, 1972; Brown, 1988; Rosenzweig, 1992; 1995; Brown & Lomolino, 1998) in the Earth's environment. Therefore, the ecological variables that are responsible for the observed patterns of mammalian diversity are an important factor. Patterns of distribution on continents have similar potential, but the theoretical syntheses have been slower to emerge. They are readily recognised, and offer the opportunity to both measure and decipher changes at other levels of complexity (Baillie *et.al*. 2004). As has been emphasized elsewhere (e.g. MacArthur, 1972; Brown, 1988; Rosenzweig, 1992; 1995; Brown & Lomolino, 1998).

Attributes of assemblages are highly dependent on the scale at which they are examined (Whittaker, 1972; Ricklefs, 1987; Caley & Schluter, 1997; Angermeier & Winston, 1998; Hughes *et al*., 1999). Scale is important over a broad range of ecosystems and taxa. It includes terrestrial vertebrates (Robinson *et.al*., 2000), fish (Poizat & Pont 1996), vascular plants (Kohn & Walsh, 1994; Stoms, 1994), insects (Lawton *et al*., 1993, Pearson & Juliano, 1993), mangrove root epibionts (Farnsworth & Ellison, 1996), and coral reefs (Karlson & Hurd 1993).

The role of large mammals in structuring ecosystems is one of the most important factors. The carnivore mammals play an apex role upon the prey species and create a cascading effect on events of the ecosystem (Owen-Smith, 1988; Berger, 2001; Dinerstein, 2003; Terborgh, J., *et al*., 2001; Morrison, 2007). The mammalian communities in a tropical forest system represent the species community richness. Though these forests are proportionally small by area in the landmass of the planet, these habitats are highly influenced by various factors, which accelerate the extinction of the participants of this ecosystem. Such Extinctions are happening at a high rate over vulnerable species and increase the number of vulnerable species (Bradshaw *et al*., 2009). The mammalian carnivores fall victim of vulnerability to local extinction in landscapes that are fragments because of their comparatively large ranges, lower in numbers, and direct persecution by humans (Noss *et al*., 1996; Woodroffe & Ginsberg, 1998). The decline and extirpation of top predators from fragmented systems may generate trophic cascades that alter the structure of ecological communities (Crooks & Soulé, 1999). As such, mammalian carnivores can serve as useful tools for the study of ecological disturbances or for conservation planning and reserve design (Soulé & Terborgh, 1999). As Tutin *et al.* (1995) pointed out, survey data are essential for the conservation and management of the protected areas. The distribution of Ungulates is highly influenced by the combinations of biotic and abiotic factors (Augustine & McNaughton, 1998). The herbivores, which occupy similar habitats, could fall under a similar functional guild and form an assemblage. In such an assemblage, grazers show selective foraging or generalised foraging and will show an overlap among the foraging (Hofmann, 1973; 1985). It is Important to estimate numbers, but it is probably even more important to monitor trends to establish whether the population is stable, declining, or increasing over time. A range of ecological factors, including vegetation (Barnes *et al*., 1991; White, 1994), also influences mammal densities and distribution. The work of mammalian observation in the Indian subcontinent region by Jerdon (1867), Sterndale (1884), and subsequently Blanford (1888) mentions the observations as introductory. Those works show the difference in observation as 242 mammal species (Jerdon, 1867) and 482 mammal species (Sterndale, 1884), then the number dropped to 400 (Blanford, 1888) by re-evaluation of certain species. From then, the need for exploration and extension of the survey was emphasised to understand the distribution of species in a mega biodiverse country like India. Because of its biogeographic history and this ecological complexity, it harbours a stunning diversity of floral and faunal elements (Champion & Seth 1968; Mani 1974). The Eastern Himalayas possess a unique biodiversity assemblage due to various factors (Guangwei, 2002). Firstly, the rivers, which originate from these mountain ranges together, constitute the mighty Brahmaputra, one of the largest rivers in the world by both discharge and length (Intelligence Branch Division of the Chief of the Staff Army Headquarters India 1983). Sharma *et al*., (2015) mentioned 428 species of mammals in India, and approximately 69 % of these species are found in the Indian Himalayan Region (IHR). The distribution gradients in the Himalayan region is not even. The highest species diversity has been identified from the eastern Himalayas with 172 species, followed by the western Himalayas with 102 species, and there are 77 species and 40 species from the north-west Himalaya and Indian trans-Himalaya (Sharma *et al*., 2015), respectively. This is, one of the states of India in the Eastern Himalaya, is a part of the Indo-Myanmar biodiversity hotspot (Myers *et.al.*, 2000) and one among the 200 globally important ecoregions (Olson & Dinerstein, 1998). The state harbours the world's northernmost tropical rainforests. It is estimated that nearly 50 % of the total flowering plant species in India are distributed in the state. Fifty percent of bird species out of 1200 bird species recorded in India have been reported from the state, which is also recognized as an area of avifaunal endemism. The six broad types of forest recognised in Arunachal Pradesh are tropical forests, subtropical forests, temperate forests, Subalpine, alpine meadows, and secondary forests (Kaul & Haridasan, 1987). People belonging to 26 indigenous communities live in the state, 80% of whom depend on agriculture and rely on the shifting cultivation method, as a considerable area of the states land is community-owned. Most tribes in Arunachal Pradesh are site-specific.(Aiyadurai, Singh, & Milner-Gulland, 2010).

Lying in the Eastern Himalayan region, Arunachal Pradesh has remained largely isolated from the rest of India by its geographical position and inaccessible terrain. Arunachal is also home to enthralling species of large herbivores such as the Mishmi takin (*Budorcas taxicolor taxicolor)*, Red goral (*Nemorhaedus baileyi*), and Mainland serow (*Nemorhaedus sumatraensis)*, several species of primates, and carnivores such as the common leopard *Panthera pardus*, clouded leopard (*Neofelis nebulosi)*, tiger (*Panthera tigris)* (Datta and Madhusudan, 2004) and Snow leopard (*Panthera uncia*). Species belonging to seven families, 26 genera, and 55 species represent the order Carnivora in India; of this, the state has a share of nearly 13 species under 10 genera. Fifteen species represent the family Felidae in India, of which the state of Arunachal Pradesh has nine Species, thus constituting nearly 60 ~ of the total Indian species (ZSI).

There are number of surveys on status, and documentations on large and small mammals has been conducted in the state (Choudhury, 1997; Datta, 1999; Datta *et al*., 2008; Jha, 1999, 2000; Dada & Hussain, 2006; Mishra *et al*., 2006, Gopi *et al*., 2009; 2013), red panda (Kakati 1996; Sethy & Chauhan 2011). The wildlife surveys in Arunachal have been considerably limited to low and mid elevation forests, including some of rare species surveys (Kaul & Ahmed, 1993; Athreya & Jhonsingh, 1995; Katti *et al*., 1992, 1990; Kumar & Singh, 1999; Captain & Bhatt, 1997; Selvan *et.al*., 2013) and avifauna (Singh, 1994; 1999; Athreya

1997; Datta *et al*., 1998; Pawar & Birand, 2001). Recent avifaunal and herpetofaunal surveys revealed new species, species range extensions, and first records of species for India (Athreya, 2006). Mammal surveys have resulted in discoveries of three mammals the leaf deer (*Muntiacus putaoensis*), black barking deer (*Muntiacus crinifrons*), Chinese goral (*Nemorhaedus caudatus*) representing new additions to the large mammals of India, apart from a new primate species, the Arunachal macaque, (*Macaca munzala*). The conducted surveys and ecological studies have brought forth certain important ecological discoveries and information, but many areas remain unexplored. The tigers in the region were identified to have a unique genetic makeup based on their evolutionary traits compared to the tiger population in Southeast Asia (Kolipakam *et al.*, 2019; Jhala *et al.*, 2011).

The concepts of hotspot and PA management are considered as one of the effective methods in these regions. The concepts of Protected Area (PA) management (Švara *et al*., 2024) and Biodiversity hotspot (Myers *et al.*, 2000; Orme *et al*., 2005; Prendergast *et al*., 1993) evaluations rationalized that those places can act as a reservoir for species in a changing world. Such criteria can be overridden by species demography. The remaining contiguous forests can act as a refuge for the distribution of mammals (Pillay *et al*., 2011). The species can migrate or disperse to maintain overall demography and resource utilization. The conservation measures can be effectively implemented by considering species occupancy in a 'Source-Sink' model, besides niche and carrying capacity, which is also necessary. Under such circumstances, information about the distribution and assemblage of species in their habitat is crucial, irrespective of the fact that the habitat is continuous or discontinuous (Paula, 1996).

Consequently, conservation science is required to make choices, and must often do so in the context of great ignorance about the species it is looking to conserve, and while human expansion continues to exacerbate the speed and magnitude of biodiversity loss

(Groombridge, 1992; Mace, 1995). Such components of threatened biodiversity suffer availability of resources to undergo conservation measures. When attempting to make inferences about a larger area, it is rarely possible to sample the entire area of interest, and investigators should take care to select locations for sampling arrays that are representative of the area for which inferences need to be achieved. If the investigator wishes to make inferences further than that of an effective sampling area (e.g., extend the inference from a sampling area to an entire park), then rules of stratification or random sampling should apply in determining the location of a sampling array (Cochran, 1997; Thompson, 1992).

The geographical distribution of any species is subject to the progress of knowledge about the distribution and occupancy of a species, along with life history traits. The large mammals are capable of evolving to a state of compromise or altering certain behaviours on a spatio-temporal basis (Gaynor *et al*., 2018; Tucker *et al*., 2018). These traits need to be transferred for generations as a learned behaviour plasticity (Hendry *et al*., 2008; Postma, 2014; Whittaker & Knight, 1998). Several factors, such as hunting, habitat fragmentation, deforestation, and agricultural expansion, are considered the major drivers of spatio-temporal variation (Kinnaird *et al*., 2003; O'Brien *et al*., 2003; Ahumada *et al*., 2011). Therefore, studies should address ecological interactions occurring at the local scale and compile more interconnected local scales to a broader picture, likely to understand the spatial and assemblage variations. It is evident from studies that the animals used to alter their behaviour, such as movement, space use, and activity pattern in response to human interventions (Montgomery *et al*., 2020). In certain cases, the animals are found to be well acclimatised to human presence and higher accumulation of a species can occur near human land use, especially in buffer areas of well-protected forests (Montgomery *et al.,* 2020). In these hilly areas, logging, encroachments, and *jhum* or slash-and-burn shifting farming are the main causes of habitat loss. Then there are the proposed dams, which the large Dibang multipurpose projects would submerge large areas of pristine habitats along the Dibang and Ithun rivers (Choudhury, 2016).

Natural landscapes, i.e., those that are void of human interventions, are becaming cultural landscapes throughout the world (Feranec *et al*., 2010; Foley *et al.,* 2005; Lopez & Sierra, 2010). The indigenous group of people's preference towards wild meat is culturally intertwined (Hilaluddin *et al*., 2005), which also plays an important role in their lives (Elwin, 1959; Furer-Haimendorf, 1982; 1983). Hunting, which is one of the traditional practices in the state of Arunachal Pradesh, was found that 34 mammal species were reported to be prominent victims (Datta, 2002; 2003), which is also observed through various studies that recorded remains of hunting and trophies. The market-based surveys on the sale of wild species were used as an alternative for understanding the impact of hunting on a species when population monitoring is deficient (Nielsen, 2006). In a landscape where there are hunting activities, the animals tend to develop inducible defences (Montgomery *et al*., 2020) due to the presence of human activity. Human intrusion in wilderness cannot able to be avoided in any landscape in the world (Sanderson *et al*., 2002; Sih *et al*., 2011; Woodroffe *et al*., 2005), as the action may be due to various reasons, from exploration to management.

In scientific studies, the conventional animal trapping methods have been overruled by the use of camera trap techniques, as the results produced by the photographic method capture a higher number than the former method (Pei, 1995). The monitoring of large mammals in rainforests and thick canopy forests is not as feasible as in other forests that provide accessible spaces. Especially in the case of species that are elusive and nocturnal is difficult to discern (Burton *et al*., 2015; Wilson *et al*., 1996). In such cases, there is a requirement to adopt an indirect evidence-based survey or a non-invasive method to explore the basic information of species distribution. Camera trap techniques are among the non-invasive sampling methods being recommended (Burton *et al*., 2015; Cutler & Swann, 1999).

The camera traps are also useful in achieving activity pattern-monitoring programmes for small mammals by adopting specific deployment protocols (Pearson, 1959). The study of activity patterns of species without the presence of humans in the wild environment using such photographic observation was well-appreciated (Griffiths & van Schaik, 1993) as it reduces the impact of human presence.

Past environmental changes, especially in climate and geology, play key roles in generating the patterns of biodiversity, while variation in current environments is largely responsible for maintaining the patterns. The patterns of assemblage in a spatial structure fall under three different classifications: i) local ecological interactions, ii) within-habitat dynamics, and iii) the interaction between habitats (Schluter & Ricklefs, 1993). The biodiversity of such remote, inaccessible tropical forests is still in the stage of exploration due to various factors.

Habitat heterogeneity can have many dimensions, but all dimensions affect either the architectural complexity or the spatial and temporal heterogeneity of the habitat (Southwood, 1996). Because the characteristics of land cover have important impacts on climate, biogeochemistry, hydrology, and species diversity, the land cover change has been indicated as one of the high priority concerns for research and the development of strategies for sustainable management (Turner *et al*., 1993; Vitousek, 1994). The mammalian communities are highly associated with the demographic stochasity, suitability of the habitat, and competition arises interspecifically in a landscape (Ziv, 2003).

A species may be smaller or Larger, the habitat utilization range of a species depends chiefly on the availability of suitable habitat and the ecological processes in place in that particular habitat (Wang *et al*., 2023). The habitat evaluation using suitable habitat analysis is widely used for species, particularly in the case of Ungulates (Jun & Ming, 2003). The readily available large sets of species observation data are valuable, as they provide information about species presence in a spatial and temporal scale (Moussa *et al*., 2024; McKinley *et al*., 2015), and certain data provide information about species absence and non-detection, which is valuable in the case of creating an effective predictions of species distribution (Sun *et al*., 2021).

The rationale of biodiversity assemblage in the region is due to the Indo-Malayan realm of South East Asia, Palearctic realm, and complex climatic and topographic composition (Chettri *et al*., 2009). The diversity of habitats in the region includes the Brahmaputra floodplains in Assam to alpine meadows in the upper reaches of the Eastern Himalaya. The Mishmi hill ranges in the state are arguably the richest in terms of biodiversity in the state, where range extensions of flagship species like Tigers have been reported recently (Gopi *et al.*, 2014) and a new subspecies of Hoolock Gibbon, *i.e*., the *Hoolock hoolock mishmiensis* (Chowdhury, 2013). The region that is continuously contributing discoveries to the ecological field demonstrates the wildlife's significance. This, in turn, highlights that there is an essentiality to inflate the attainment for research and conservation initiatives, or else there are chances of not witnessing the loss of species. Indeed, such ignorance of the ecosystem service of any species can also lead to cascading effects (Datta *et al.*, 2008). For instance, carnivores can be affected by prey depletion.

The species information along the large extent of the Himalayan region is from various sources of information from detailed research and short-term observations of ecology and behaviour of species, and most of the information is from status surveys (Agarwal *et al*., 1998). In the case of Arunachal Pradesh, various factors favoured a higher research rate in Western Arunachal Pradesh, not only in the field of biodiversity but also in fields such as Sociology, Pedology, and geology. The exploration of the Far East, Eastern Arunachal Pradesh, was lagging until recently in the early decades of the 21st century (Author's observation). The continuous scientific efforts from various researchers Datta *et al*., 2008;

Kato, 2009; Gopi *et al*., 2014; Adhikarimayum, 2020; Mohanty, 2020; Adhikarimayum, 20018; Aiyadurai, *et al*., 2010; Aiyadurai, 2011;2011 & 2012). The accelerated research interests in all possible landscapes pave the way for the discovery of new species such as Indo-Burmese pangolin (*Manis indoburmanica*) (Wangmo *et al.*, 2025), Sela macaque (*Macaca selai*) (Ghosh, 2022). In such a landscape, the exploration of biodiversity and continuous monitoring is one of the important ecological contributions. Keeping such a goal in mind, the research has been carried out. The present study aims to assess the assemblage of mammalian communities in protected areas and adjoining community-managed lands within the same biophysical landscape in a biodiverse, rich eastern Himalayan landscape unit.

The region comprises the Kamlang Tiger, which the National Tiger Conservation Authority notified as the 50th Tiger reserve of the nation. The landscape of Kamlang Tiger Reserve in Lohit District of Arunachal Pradesh lies in an area that has, to the east and southeast having large tracts of contiguous forest of Hkakaborazi National Park and Hukaung Valley Tiger Reserve in Myanmar, while to the south is the Namdapha Wildlife Sanctuary in India

The study aims to fill the gaps in the mammalian distribution study by identifying the assemblage of mammalian guilds in the landscape, which will pave the way for further research, monitoring, and conservation. The species list plays a major role in Conservation biology and acts as an important measure of biodiversity. Considering the area of representation, logistics and the terrain features, the assemblage study limited to the terrestrial mammals. Considering the apriority observed from the reconnaissance survey and the identification of sites for the survey has been wisely selected, such that adequate information pertaining to the mammalian community can be obtained. Furthermore, such study results may represent this Landscape unit for stimulated studies on tropical forests of this region.

Objectives

1. To assess the inventory and species richness of selected mammalian groups in the landscape.
2. To assess the habitat suitability of selected mammalian species
3. To determine the spatio-temporal activity of selected Mammalian Species
4. To understand perception on wildlife by local communities and implications for conservation objectives

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Chapter II

Study area

The eight states of easternmost part of India - Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland which is commonly called as ‘Land of Seven Sisters’ along with the, Sikkim which is called as their ‘Brother’ (Ministry of Culture) forms the North-Eastern region which is part of the North Eastern Council (NEC). Arunachal Pradesh lies between the latitude 26°28' N to 29°30' N and longitude 91°30' E to 97°30' E is situated in far north east of India. The total area of state is 83743 sq.km. This is the largest state by area of the Northeast region. This hilly state shares an international borders totalling 1630 km with 1030 km along China, 160 km along Bhutan and 440 kms along Myanmar. The boundary between India and China is demarcated by McMohan line under a treaty which is considered as Line of Actual Control (LAC) by India. The state is administered through 26 districts. Arunachal Pradesh is called as ‘Land of the Dawn-lit-Mountains’which a complex hill system which origin from Shiwalik and Himalayas. The criss-cross mountains form the rugged terrains and valleys. These valleys are the route and sources of major rivers and its tributaries. The study area’s administrative forest divisions fall under the Lohit, Anjaw, and Anini forest divisions. The study area includes Kamlang Tiger Reserve and is surrounded by Other protected areas such as Namdhapha Tiger Reserve, Dibang Wildlife Sanctuary and Mehao Wildlife Sanctuary. The extent of area is well connected to all the sanctuaries (Fig. 2.1).

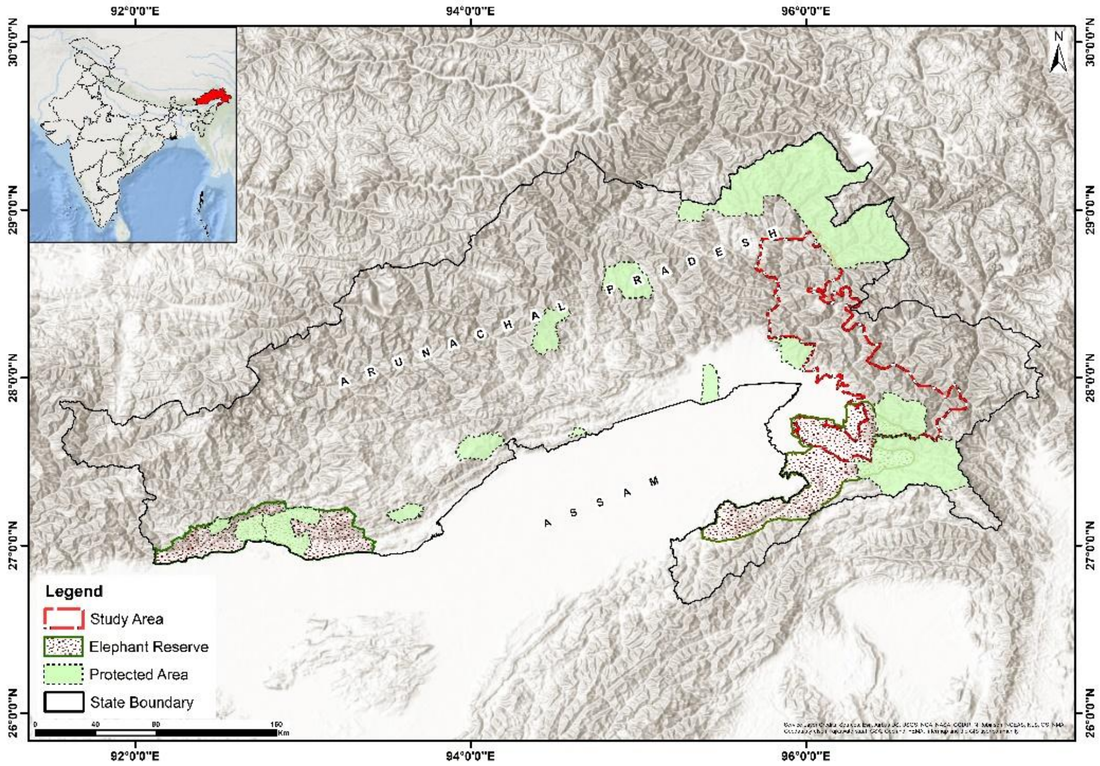

Figure 2.1. The Terrain features, Protected Areas and study area in Arunachal Pradesh

Administration—Ownership History and Legal Perspective on Land

The population of Arunachal Pradesh as per the 2011 census was 13.84 lakhs with a population density of 17 individuals/sq. km. The population density of the study districts Lohit, Lower Dibang, Anjaw, and Dibang Valley is 28, 4, 3, and 1 per square kilometer, respectively. The jurisdictional and legal rights of the people in the state are administered by special policies that support community forests. The Arunachal Pradesh Anchal and Village Forest Reserve (Constitution and Maintenance) Act, 1984, mandates benefit sharing between the state and the people (Ramya, 2024). There are 13 wildlife sanctuaries, of which Dibang Wildlife Sanctuary is the largest, with an area of 4149 km, and Kane Wildlife Sanctuary is the smallest, with 31 sq. km. The Namdapha National Park and the Mouling National Park are two national parks in the state. Nine community reserves range from the smallest, the Wanu Community Reserve of 4.025 sq. km., to the Lal Aane Community Reserve with an area of 37.75 sq. km. There is one biosphere reserve in the state, which includes the Mishmi Hills. This region, comprising an area under Mouling National Park and Dibang Wildlife Sanctuary, is part of the Dihang-Debang Biosphere Reserve (Chaudhry, 2012). There are three tiger reserves in the state: Pakke, Namdhapha, and Kamlang Tiger Reserve. Northern Forest Complex—Namdaph-Royal Manas and Kaziranga—Garampani are the two Tiger Conservation Landscapes (TCL) (Wikramanayake *et al*., 2011). The identified tiger connectivity corridors, Dibru Saikhowa-D'ering-Mehao-Kamlang and Kane Wildlife Sanctuary-Tale Valley Wildlife Sanctuary, are located in the state and also fall within the study unit (Qureshi *et al*., 2014). There are two elephant reserves. There are two elephant reserves in the state: The Kameng Elephant Reserve and the South Arunachal Elephant Reserve. The study unit also included Kamlang Tiger Reserve and South Arunachal Elephant Reserve. (Fig. 2.2)

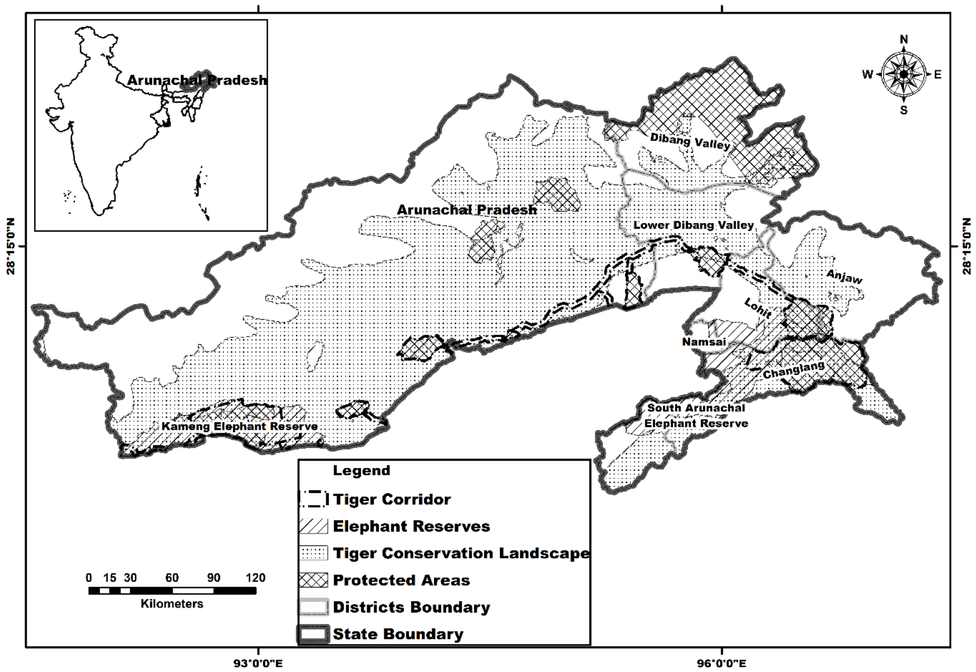

Figure 2.2. The terrain features, protected areas and study area in Arunachal Pradesh

Biogeography

The Himalayan range extends from the Bhutan border to the valleys of the Dibang and Lohit districts for a length of 350 km. This range terminates at the Tidding-Tuting structure, which is oriented towards Indo-Burma.The Himalayan range peaks in elevation between 100 and 1000 asl in the south-north direction. There are certain peaks in the extent that attain a height to 7000 asl. The Himalayas constitute the first division of this range *viz.*, 1. Tibetan Himalayas, 2. Higher Himalayas 3. Lesser Himalayas 4. Sub-Himalayas. The 30 to 40 km long Tibetan Himalayas comprise the highest peak of 7089 asl. The Higher Himalayas is formed of rugged slopes and peaks with the highest elevation up upto 6000 asl. The Lesser Himalayas lie between the Higher Himalayas and the Sub-Himalayas in the north and south, respectively, in the valleys of Lohit and Dibang and the Roing fault. The sub-Himalayas, with longitudinal ridges at an altitude range of 1700 to 2000 asl, support flourishing vegetation.

The Trans-Himalayas in the Mishmi Hills have an elevation range of 2500 to 6000 asl in the Tidding Suture of the Eastern Himalayas. It is composed of two belts, which are west and east of the Lohit thrust. This range meets once at the Naga-Patkoi range along the Mishmi thrust and the second at the Lohit Granitoid complex, which extends up to the Northern Myanmar range in a southeast direction. The Naga-Patkoi range, which holds the highest elevation, up to 3,826 asl. This range is the southernmost limit of the Upper Brahmaputra Plain. This range acts as the border of Assam and Southeast Arunachal Pradesh. The Brahmaputra plain falls in the western region below the Himalayan Range and Mishmi Hills. This range possesses Quaternary sediments of post-Siwalik features. (GSI, 2010). The economic minerals found to be occurring in the state include both metallic and non-metallic compounds. Some of the compounds are coal, iron, gold, platinoids, molybdenite, graphite, asbestos, talc, clay, glass sand, limestone, dolomite, marble, phosphate, mica, etc.

Physical features

The mountainous landscape of Arunachal Pradesh was described as approximately 64% of the total land lying at an elevation above 1200 msl and 13 % of the area is between 300 and 1200 msl of elevation and 8.87 % below 300 msl (Gopalakrishnan, 1994). Several hill passes lie along the stretch of the Himalayas. The regions lie after the Dihang Gorge, which is a part of the Himalayan region, and this area is called the Eastern Himalaya or Purvanchal Hills. There are ten hill regions in the Eastern Himalayas: Daffla, Abor, Mishmi, Patkai Boom, Naga, Manipur, Garo, Khasi, Jaintia, and Mizo Hills (Chaudhry, 2012). The study area lies in a junction of three biogeographies, viz., the Indo-Malayan, the Palearctic, and the Indo-Chinese realms (Bennie *et al*., 2014). This is also a landscape of two biodiversity hotspots: the Himalayan biodiversity hotspot and the Indo-Burma biodiversity hotspot. The Mishmi Hills and adjoining area are a landscape that lies under the transboundary influence from the Yunnan region of China and the northern region of Myanmar (CEPF, 2020; ICIMOD, 2015), embracing a diverse culture and biodiversity on the earth. The trade routes lie in the hill region of the Himalayas between Arunachal and China and Tibet, and another route to Nepal through Sikkim and between Tibet and China is one of the major causes of the transmission of religio-culture (Chakrabarti, 2021; Sen & Chakraborty, 2023) in the province. The study unit, which lies in this region, possesses unique elevation variation and elevation-based measures such as terrain ruggedness and slope and aspect (Fig. 2.3).

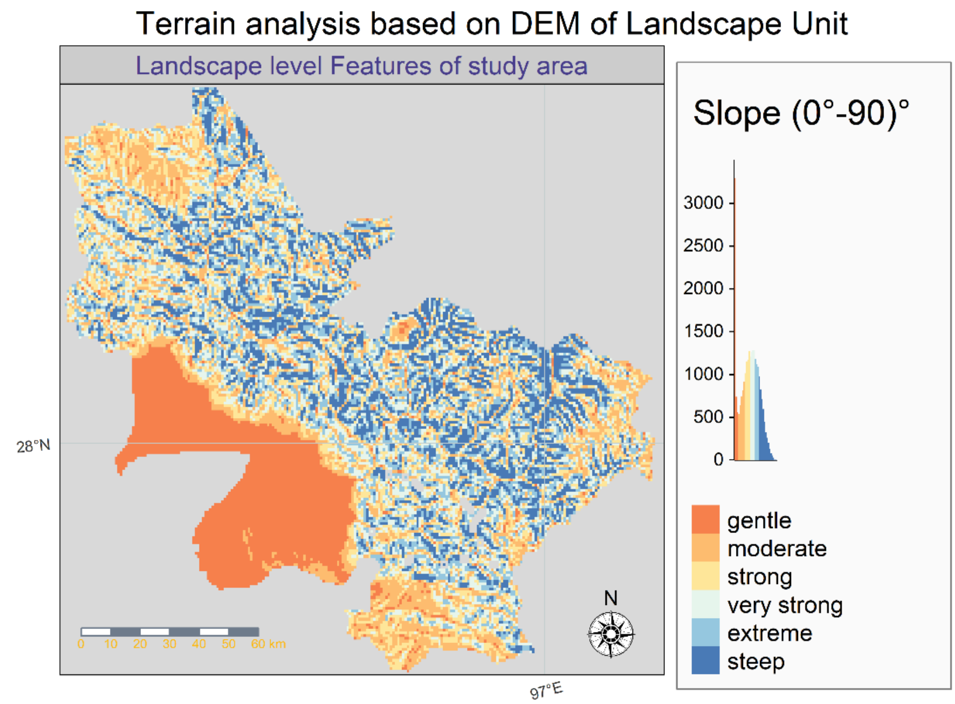

Figure 2.3. The terrain analysis based on DEM in study area

Vegetation—Floristic and Physiognomy

The Forest Survey of India states that Arunachal Pradesh possesses 61.55 % of its area under forests (Fig. 2.4), with a total of 51,540 sq. km identified as Recorded Forest Area (RFA). This forest area includes 12371 km of reserve forest and 11857 sq.km of protected forest. The 27,312-sq.km area of RFA is designated as unclassified forests. The state also has the highest bamboo distributed area and is second in carbon stock, with an amount of 1,021 Mt. The state shows a net increase of 91.17 km of forest from the year 2021 and is the second highest at the national level (FSI, 2023). The increase in the forest cover was found to be maximum outside the RFA, with 45.32 sq. km. In the altitudinal gradient, more than 58 % of forests were recorded in the altitudinal range of 1000 to 3000 msl, of which 33 % occupy elevations between 1000 and 2000 asl. The major invasive floral species found in the states' forests are *Chromolaena odorata, Mikania micrantha, Lantana camara, Imperata cylindrical*, and *Ageratum conyzoides*. Arunachal Pradesh forest is composed of lowland tropical forest to alpine Himalayan vegetation, which harbors 6000 species of plants (Page *et al*., 2022).

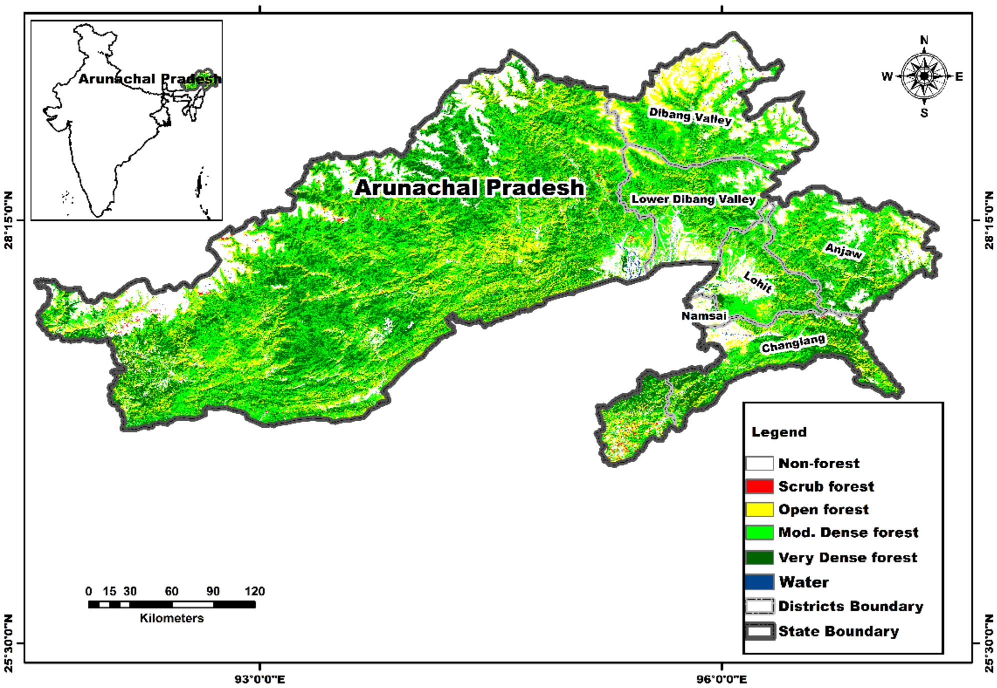

Figure 2.4. The Forest cover in Arunachal Pradesh.

Drainage (Brahmaputra)

The region east of the Ganges was reflected as 'India's ultra Gangem,' which means beyond the Ganges (Ardussi, 1977), by European cartographers like Gerard Mercator. During the earlyly 18th century, the Brahmaputra was considered a mysterious river course among Asiatic society, and it was the only available route (Saikia, 2019) to explore the Northeast region. In the colonial period, the region was not included in the cartography; later, it was included by exploration (Proposed Exploration of the Brahmaputra, 1906). Though the exploration was expected to find the river's origin and ecology, the imperial government also expected to find a possible trade route between Tibet and Assam.

The Tsan-po River in Tibet, which runs along the mountains, becomes the Brahmaputra in India. The 2900 km journey of the Brahmaputra is mostly outside Indian

Territory. It originates in the Tam-chok Khambab at an elevation of 5150 asl in Tibet. It takes an 1100 km parallel journey along the Himalayas as an east-flowing river, like the Hwang-ho, Yangtze-kiang, and Mekong. A 640 km flow at an altitude of 3650 asl is the only high-elevation navigable river in the world. The river system, once it entered Indian Territory, was called the Dihang. Subsequently, the river Dibang and the river Lohit join at the Mishmi Hills of the Eastern Himalayas. The continuous 720 km forms the flow of the Brahmaputra plains. The river passes Garo Hills and runs for 270 km to join the river and form the Padma River (Mani, 1974).

Altitude, Climate, Rainfall, Seasons

The state lies in an altitudinal range from 50 asl to as high as 7000 asl (Fig. 2.5), resulting in diverse environmental conditions. The state experiences three major seasons: summer, rainy, and winter. The temperature reaches as high as 36 degrees Celsius during summer and an average low of 0 degrees Celsius during winter. In the sections of the Lesser Himalayas, it experiences long rainy days and winter seasons. The temperature during winter can drop as low as 0°C. The higher elevation regions remain snowbound throughout the year and experience severe rain and winter. The average rainfall of the state is around 500 cm. The months of monsoon start from the end of March and end in September. The state receives a rainfall range from 1577 mm to 6002 mm (Jhajharia *et al*., 2009).

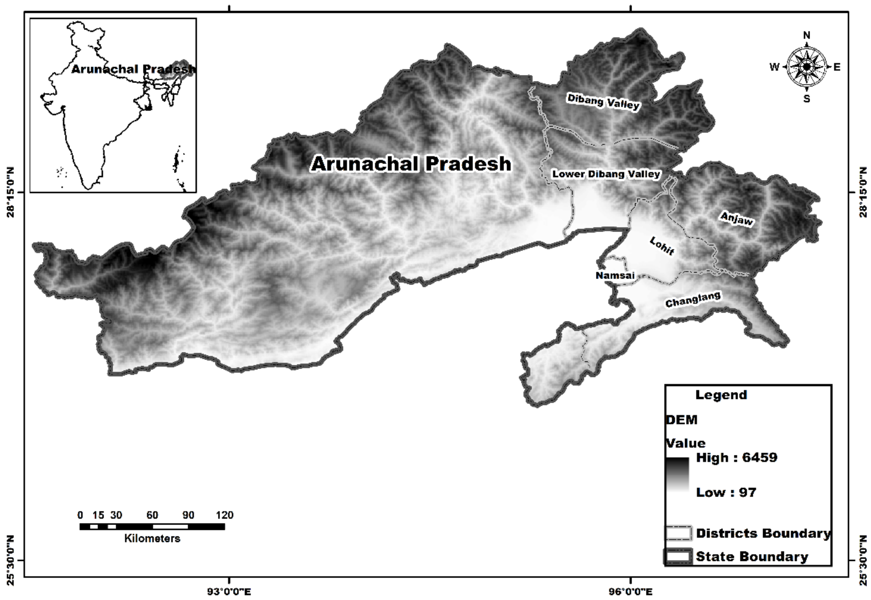

Figure 2.5. Digital Elevation Model of the state Arunachal Pradesh

Faunal groups

There are 700 species of birds (Taro, 2021), 166 species of mammals (Talukdar *et al*., 2021), and 96 species of amphibians (Sinha *et al*., 2022). The state with 700 ha of lentic water resources and 2000 km of lotic water resources. It is composed of a cold-water zone up upto 30-40 %. There are approximately 145 species of fish identified from the state (Ramakrishna & Alfred, 2006).

Local Communities

The state has records of prehistoric settlement, subsequent discoveries of Stone Age tools from the Mishmi hills, and traditions that extend from historic routes (Anderson, 1871; Banerjee, 1924; Pushpa, 2012). The state was identified as home to diverse peoples; there are 25 major ethnic groups and different other subgroups, and based on the distribution of the groups, the state can be considered an ethnic group meeting point (Ashraf, 1990). The people of the state depend on the forest for various resources and adhere to traditional beliefs and *'taboos'* (Aiyadurai, 2009). The agricultural practice is shifting cultivation, which is called

‘*Jhum.’* The primary method of this kind of cultivation involves relocating the cultivation area through forest clearing or forest burning (Tripathi, 2003).

The language diversity of the Northeast region is unique, as it is the only region that possesses all the six families of India language (Das & Abbi, 2023). The Tai-Kadai family languages are spoken predominantly in the regions of Assam and Arunachal Pradesh. The people's culture also has influenced the architecture of their houses, so they will be constructed in a way that the first room of their houses will act as a guest room and ritual place. This is where the mithun skull and trophies collected by hunting will be showcased (Kolkman & Blackburn, 2014).

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Chapter III

Inventory of species recorded in the Eastern Himalayan Landscape Unit

Introduction

The Macroecology and biogeography research mainly depends on a vibrant understanding of patterns of biodiversity and the different scales of influencing factors (Vale *et al*., 2018). Species inventory is one of the essential requirements for such understanding to undergo research and pave the way towards policies (Soroye, 2018). Mammalian species play a major role in any ecosystem (Keesing *et al*., 2010) and can also act as an indicator of ecosystem fitness (Jones, 2009). The ecological communities are significantly impacted by elements of the landscape (Rodas-Trejo *et al*., 2025), which shape the assemblage and process of ecological events. The species distribution and its richness is one of the vital information for understanding the profiles of biodiversity and enhancing monitoring at various levels from community to global scale (Gotelli, 2001; Pereira, 2013). On the other hand, Species richness is considering as one of the important indicators that can be useful in a broad spectrum of Conservation biology in making management decisions Gotelli & Colwell, 2011; Benito, 2013; Rocchini, 2017; Scholes, 2017). However, there is a lack of consistent data about the distribution of species (Rondinini *et al*., 2011) either at the landscape level or within the parts of the landscapes. The species' cryptic nature and elusive behaviour also make assessing the distribution of certain species difficult (Vine *et al*., 2009). There is a requirement to create an applicable population monitoring procedure for better biodiversity management practices (Swan, 2014). Arunachal Pradesh is the state that possesses the richest terrestrial biodiversity, holds a high rate of rare and endemic flora and fauna (Mishra & Datta, 2007) in India. There are around 5000 species of flowering plants recorded in the state. The IUCN Red List states that 47 species are facing extinction, and a higher number of species fall under the Critically Endangered (CR), Endangered (EN), and Vulnerable (VU) categories in the far east landscape of the country (Lily, 2022). Research efforts should be enhanced in data-deficient landscapes, especially in areas of extensive forest cover, such as this region. The locality of the survey region, which lies in the combination of two biodiversity hotspots, possesses a diverse mammalian community. The Himalayan hotspot holds 269 mammal species, of which 7% are endemic. The Indo-Burma is occupied by > 400 mammal species with an endemism rate of 24 %. (Mittermeier, 2011). The topography created a heterogeneous habitat, which in turn created an ecologically diverse ecosystem (Chettri *et al*., 2009).

When working with different models of the distribution of species, the challenges arise due to various reasons, such as accessibility and logistics, can be overcome by using Local people's knowledge. The knowledge of indigenous people about the natural resources is vital information because they are culturally integrated with the people of a particular region (Rival, 2009). The use of Local Ecological Knowledge (LEK) and locally-based survey (LBS), which is experienced as one of the cost-effective methods to provide insights to monitoring and management by community participation (Micaela *et.al.*, 2020; Daniel & Oliver, 2021). The inventory of the list of many taxonomical groups is essential for prioritising the objective of any research. The list of mammals in any selected region may be obtained by available literature, Secondary information, and reconnaissance surveys. The recent studies about the effectiveness of Protected areas found that there is a necessity to consider the regions outside the boundary (Geldmann *et al*., 2019), which also need to be considered.

Study Area

The mountain stretches of the Himalayas extend beyond the Brahmaputra in the northern region, have sequences of faults and thrusts, and the Main Boundary Thrust (MBT) in Arunachal Pradesh reaches an elevation of 7000 asl (Goswami *et al*., 2022). The three biogeographic realms, viz., the Indo-Malayan, Palaearctic, and Sino-Japanese confluences in the Eastern Himalayas, which is the reason for an ecologically diverse altitudinal gradient (Brooks *et al*., 2006; CEPF, 2005; 2007). The study area lies in the landscape, which is a continuous landscape of two biodiversity hotspots: The Himalayan biodiversity hotspot and the Indo-Burma biodiversity hotspots. The Mishmi hills and adjoining area is a landscape which lies under the transboundary influence from the Yunnan region of China and the Northern region of Myanmar (CEPF, 2020; ICIMOD, 2015), embracing a diverse culture and biodiversity on the earth. The distinctive landscapes characteristic of the region includes Plain regions, mountain peaks, snow-covered higher elevations, which hold a diverse forest along the elevation gradients, and favour a weather condition of rainfall moisture (Taher,1993). The diverse tropical taxa are a part of Southeast Asia's Indo-Malayan realm, and the higher elevation floral diversity is due to the Palaearctic realm (Guangwei, 2002). The state is covered with forest more than 60% area under forests, of which 60 % is dense forest. The state-owned forest is only 37%, and the remaining forest falls under the unclassified category, which is designated in different names under traditional rights of the peoples of the state (Pant, 2009). The selected study unit is surrounded by three protected areas 1. Namdapha National Park, 2. Dibang Wildlife Sanctuary, and 3. Mehao Wildlife Sanctuary and a protected area. The study unit is a landscape that falls under different districts, the Lohit, Anjaw, Lower Dibang Valley, and Dibang Valley & Namsai District. The Forests are under the management of Dibang Forest Division, Anjaw Forest Division, Lohit

Forest Division, and Namsai Forest Division, including a protected area, Kamlang Tiger Reserve and Wildlife Sanctuary.

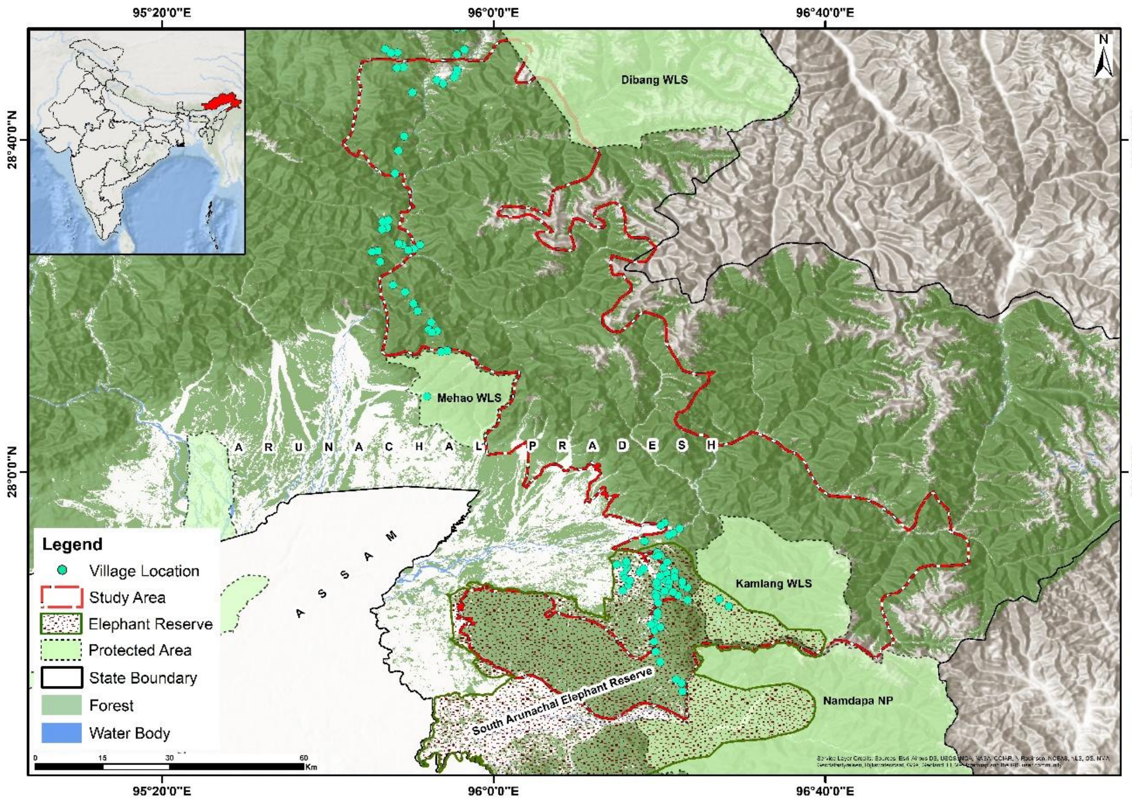

Figure 3.1. The villages where reconnaissance survey was carried out

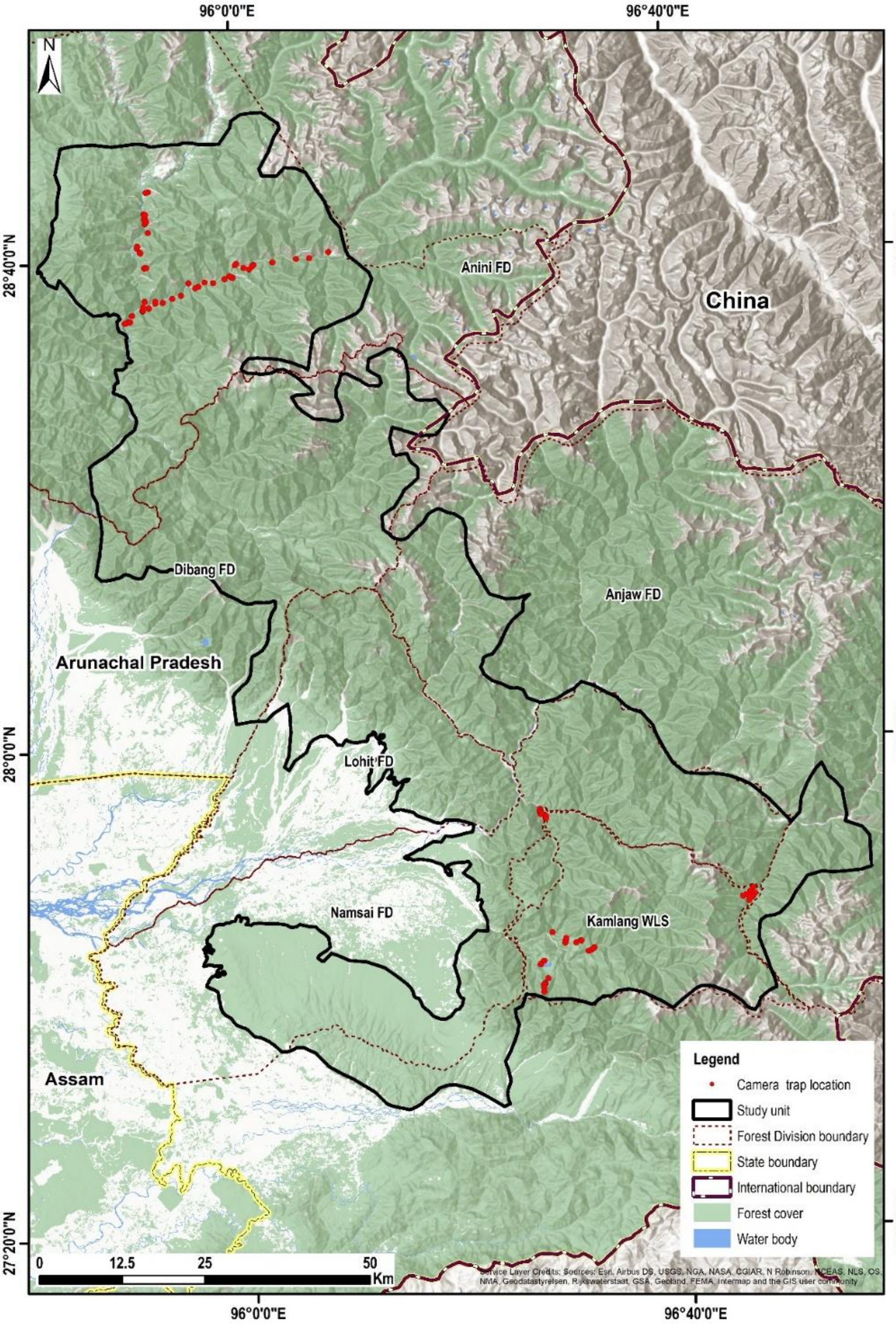

Figure 3.2. The camera trap monitoring stations in the study area

Methodology

Reconnaissance survey and secondary data

Due to difficulty in accessing the terrain features and logistical constraints, a reconnaissance survey was carried out along the villages around the selected landscape unit (Fig. 3.1). The information was collected from the inhabitants (Gary, 1992) who are especially hunters, and the people who have undergone expeditions, and from those who possess deep knowledge of the forest areas in the Landscape. Based on the information, the study area was demarcated and the area for deployment of a Camera trap was decided. The suggestions were also obtained from the experienced field assistants and porters of the field survey teams. The monitoring camera trap stations were deployed in the location where there is the highest possibility of recording the terrestrial mammalian species, and the periodic monitoring of the camera trap status is possible.

Camera trap surveys

Camera traps were deployed in the locations lying between two different identified blocks as representative of the landscape unit. The area was demarcated and selected based on reconnaissance survey and available primary and secondary information, which includes sections inside the Protected Area (PA); The Kamlang Tiger Reserve and the landscape adjoining to it. The 6031-sq.km stretch of area of Potential spots was chosen for maximum possibility of photo capturing of the species of our interest. Cuddeback C1 Day and Night Color 20 MP Xchange Trail Game Cameras were used and fixed in the places like trails, which are frequently used by wild animals, and where there is information about animal signs and usages (Rovero *et al*., 2010). The sites were selected in such a way that there is more possibility of as many species as possible being recorded in the rugged terrain like our study unit. Camera Traps were deployed as a single camera per location and in exceptional cases pair of cameras was deployed to maximise the probability of animal sighting. The study was carried out between 2018 to 2020. There was a total of 92 camera trap locations (Fig. 3.2).

Results

The study was carried out between 2018 and 2020, comprising 4572 trap nights (number of camera traps X no. of operational days of each camera). A total independent capture 2548 events of various species were recorded. The targeted species were recorded in 1110 independent events. The Photographs obtained from each camera trap station were identified using the standard Mammal Field Guides (Menon, 2009; IUCN Website). Forty-one mammal species were recorded in the study, based on Camera traps, direct sightings, and questionnaire-based surveys. The species list includes 40 species of wild mammals and a semi-domesticated species. The species belong to 7 orders (Fig. 3.3), 19 families (Fig. 3.4), and 34 genera (Tables 3.1;3.2;3.3;3.4). The list includes 30 species of mammals, which are recorded by deployment of Camera Trap, and five species Leopard (*Panthera pardus*), Golden Jackal (*Canis aureus*), Pallas's Squirrel (*Callosciurus erythraeus*), Northern Tree shrew (*Tupaia belangeri*) and Flying Squrriel species by direct sighting. The Asian Elephant (*Elephas maximus*) was recorded by indirect evidence. There are four species recorded by the Questionnaire survey, of which Alpine musk deer (*Moschus chrysogaster*), Red Panda (*Ailurus fulgens*), and Snow leopard (*Panthera uncia*) were reported to be identified in the study unit. The Wild water buffalo (*Bubalus arnee*) was reported to be distributed in the study unit in the recent past. Tigers (Panthera tigris), leopards (*Panthera pardus*), dhole (*Cuon alpinus*), Clouded leopard (*Neofelis nebulosi*), and Asiatic Golden Cat (*Catopuma temminckii*) are the top predators recorded among the 18 Carnivora orders recorded by camera trap along the landscape (Table 3.1). Another big cat, the Snow leopard which is reported based on the questionnaire survey. Two species of bear Asiatic Black Bear (*Ursus thibetanus*) and the Sun Bear (*Helarctos malayanus*) are also photo captured. There are 11

Artiodactyl orders recorded in the region by camera trap (Table 3.2), of which semi-domesticated Mithun or Gayal (*Bos frontalis*) is one among the species. There are six primate species belonging to two different families (Table 3.3), with only the Western Hoolock Gibbon (*Hoolock hoolock*) from the family Hylobatidae being recorded through photographic exercises. The Asian elephant is recorded through indirect evidence such as tracks and crop damages in the foothill regions and regions adjoining Elephant reserve areas. The only Scandentia distributed in the region Northern Tree shrew is recorded. There are 4 rodents recorded, of which the Asiatic Brush-tailed Porcupine (*Atherurus macrourus*), Indian crested porcupine (*Hystrix indica*), and Pallas's Squirrel are reported up to the species level by photographs. The Flying squirrels or the gliding squirrels, which are reported by direct sighting, were not identified up to the species level. The Chinese Pangolin (*Manis pentadactyla*) belongs to the Pholidota order and is recorded in camera traps and also in rescue operations (Table 3.4).

The functional guild of the species (numbers of species in parentheses) is as Carnivore (12), Herbivore (16), Omnivore (11), Frugivore (1), and Folivore (1) (Tables, 3.1, 3.2, 3.3, & 3.4). The Tiger, Leopard, Dhole, clouded leopard, and Golden Cat are the top predators of the landscape. There are 13 wild herbivore species belonging to the Artiodactyl order that are found to be major prey species, and one species of semi-domesticated Bovid, Mithun (*Bos frontalis*).

Considering the conservation status as per the IUCN status of the identified wild species falls under eight species are endangered (EN), and one species is a critically endangered (CR) species. There are 13 vulnerable (VU) species and three near-threatened (NT) species recorded in the study unit. 13 species are categorised as least concern (LC) and were also recorded (Fig. 3.5a). As per the Indian Wildlife Protection Act 1972, last updated in April 2023, more than 90 % of the identified species fall under Schedule I - Part A of the act (Fig. 3.5b). Only one species, which was scheduled under Schedule II (Part A), is the Wild Pig (*Sus scrofa*). The species like Gongshan Muntjac, and Northern Tree shrew, which was not defined directly, adheres to the status with its superior taxa Northern Red Muntjac and Nicobar Tree shrew respectively. The IUCN assessment on current population trends found that 80% of the listed species are in a decreasing population trend (Fig. 3.6). The Golden Jackal is the only species that shows increasing trends (Tables, 3.1, 3.2, 3.3 & 3.4). Among the listed species, the population trend of four species was identified as stable, and for two species was unknown (Fig. 3.6). Based on the elevation gradient of distribution as identified by the IUCN assessment for the recorded species ranges from 0 asl to 5800 asl (Fig. 3.7). The snow leopard is the species found to be capable of being distributed at the highest elevation, followed by the Dhole and then by the common leopard. The smooth-coated otter was identified as the species that prefers the least elevation, up to 700 asl. The IUCN identification of habitat preference states 11 different habitats as the preference for the species recorded in the study in various scales from mono habitat to multiple habitats (Fig. 3.8). All the species identified in the study are dependent on forest habitat. There are a higher number of species that depend on scrubland and grasslands. Artificial terrestrial vegetation is also found to be a vital habitat for a considerable number of species. There are several species identified as inhabitants of aquatic habitats (Fig. 3.8).

The Species Accumulation Curve shows the completeness (Gotelli and Colwell 2001) of the possible terrestrial mammalian species record in the study area (Fig. 3.9a; 3.9b). From the curve, it may be inferred an adequate camera trap locations were employed for the objective of the current study. We calculated the relative abundance index (RAI), which is the number of events divided by sampling effort and multiplied by 100. This will represent events per 100 days of camera trapping. The RAI of the species recorded in the region is given in Table 3.5. From the obtained results, Northern Red Muntjac (5.5) shows the highest value, followed by Mainland Serow (4.0) and Stump-tailed Macaque (3.1). The estimated relative abundance of three species, Western Hoolock Gibbon, Common Palm Civet, and Small Indian Mongoose, falls to zero.

Table 3.1. List of Mammal species of order Carnivora recorded in the Landscape unit

S.No.	Source	Classical Order	Family	Common Name	Scientific Names	Functional guild	IWPA(1972)	IUCN Status	Current Population Trend
1	Camera Trap	Carnivora	Ursidae	Asiatic Black Bear	*Ursus thibetanus*	Omnivorus	Sch I (Part A)	VU	Decreasing
2	Camera Trap	Carnivora	Felidae	Mainland Leopard Cat	*Prionailurus bengalensis*	Carnivores	Sch I (Part A)	LC	Stable
3	Camera Trap	Carnivora	Canidae	Dhole	*Cuon alpinus*	Carnivores	Sch I (Part A)	EN	Decreasing
4	Camera Trap	Carnivora	Mustelidae	Yellow-throated Marten	*Martes flavigula*	Omnivorus	Sch I (Part A)	LC	Decreasing
5	Camera Trap	Carnivora	Felidae	Clouded Leopard	*Neofelis nebulosa*	Carnivores	Sch I (Part A)	VU	Decreasing
6	Camera Trap	Carnivora	Viverridae	Masked Palm Civet	*Paguma larvata*	Omnivorus	Sch I (Part A)	LC	Decreasing
7	Camera Trap	Carnivora	Ursidae	Sun Bear	*Helarctos malayanus*	Omnivorus	Sch I (Part A)	VU	Decreasing
8	Camera Trap	Carnivora	Felidae	Marbled Cat	*Pardofelis marmorata*	Carnivores	Sch I (Part A)	NT	Decreasing
9	Camera Trap	Carnivora	Prionodontidae	Spotted Linsang	*Prionodon pardicolor*	Carnivores	Sch I (Part A)	LC	Decreasing
10	Camera Trap	Carnivora	Herpestidae	Small Indian Mongoose	*Urva auropunctata*	Omnivorus	Sch I (Part A)	LC	Unknown
11	Camera Trap	Carnivora	Felidae	Asiatic Golden Cat	*Catopuma temminckii*	Carnivores	Sch I (Part A)	NT	Decreasing
12	Camera Trap	Carnivora	Viverridae	Common Palm Civet	*Paradoxurus hermaphroditus*	Omnivorus	Sch I (Part A)	LC	Decreasing
13	Camera Trap	Carnivora	Mustelidae	Smooth-coated Otter	*Lutrogale perspicillata*	Carnivores	Sch I (Part A)	VU	Decreasing
14	Direct Sighting	Carnivora	Felidae	Leopard	*Panthera pardus*	Carnivores	Sch I (Part A)	VU	Decreasing
15	Camera Trap*	Carnivora	Felidae	Tiger	*Panthera tigris*	Carnivores	Sch I (Part A)	EN	Decreasing

S.No.	Source	Classical Order	Family	Common Name	Scientific Names	Functional guild	IWPA(1972)	IUCN Status	Current Population Trend
16	Direct Sighting	Carnivora	Canidae	Golden Jackal	*Canis aureus*	Carnivores	Sch I (Part A)	LC	Increasing
17	Questionnaire	Carnivora	Ailuridae	Red Panda	*Ailurus fulgens*	Omnivorus	Sch I (Part A)	EN	Decreasing
18	Questionnaire	Carnivora	Felidae	Snow leopard	*Panthera uncia*	Carnivores	Sch I (Part A)	VU	Decreasing

*** recorded in the same monitoring session in Forest department exercises**

Table 3.2. List of Mammal species of Artiodactyla recorded in the Landscape unit

S.No.	Source	Classical Order	Family	Common Name	Scientific Names	Functional guild	IWPA(1972)	IUCN Status	Current Population Trend
1	Camera Trap	Artiodactyla	Bovidae	Mishmi Takin	*Budorcas taxicolor taxicolor*	Herbivore	Sch I (Part A)	VU	Decreasing
2	Camera Trap	Artiodactyla	Bovidae	Mainland Serow	*Capricornis sumatraensis*	Herbivore	Sch I (Part A)	VU	Decreasing
3	Camera Trap	Artiodactyla	Cervidae	Northern Red Muntjack	*Muntiacus vaginalis*	Herbivore	Sch I (Part A)	LC	Decreasing
4	Camera Trap	Artiodactyla	Cervidae	Sambar	*Rusa unicolor*	Herbivore	Sch I (Part A)	VU	Decreasing
5	Camera Trap	Artiodactyla	Suidae	Wild Pig	*Sus scrofa*	Omnivorus	Sch II (Part A)	LC	Unknown
6	Camera Trap	Artiodactyla	Bovidae	Red Goral	*Naemorhedus baileyi*	Herbivore	Sch I (Part A)	VU	Decreasing
7	Camera Trap	Artiodactyla	Cervidae	Gongshan Muntjack	*Muntiacus gongshanensis*	Herbivore	Sch I (Part A)*	DD	Decreasing
8	Questionnaire	Artiodactyla	Moschidae	Alpine musk deer	*Moschus chrysogaster*	Herbivore	Sch I (Part A)	EN	Decreasing
9	Questionnaire	Artiodactyla	Bovidae	Wild Water Buffalo	*Bubalus arnee*	Herbivore	Sch I (Part A)	EN	Decreasing
10	Camera Trap	Artiodactyla	Bovidae	Mithun	*Bos frontalis*	Herbivore	NA*	NA	NA

***Not subject to the provisions of the Convention.**

Table 3.3. List of Mammal species belonging of order Primates recorded in the Landscape unit

S.No.	Source	Classical Order	Family	Common Name	Scientific Names	Functional guild	IWPA(1972)	IUCN Status	Current Population Trend
1	Camera Trap	Primates	Cercopithecidae	Capped Langur	*Trachypithecus pileatus*	Folivorous	Sch I (Part A)	VU	Decreasing
2	Camera Trap	Primates	Cercopithecidae	Stump-tailed Macaque	*Macaca arctoides*	Herbivore	Sch I (Part A)	VU	Decreasing
3	Camera Trap	Primates	Cercopithecidae	Assamese Macaque	*Macaca assamensis*	Herbivore	Sch I (Part A)	NT	Decreasing
4	Camera Trap	Primates	Cercopithecidae	Arunachal Macaque	*Macaca munzala*	Herbivore	Sch I (Part A)	EN	Decreasing
5	Camera Trap	Primates	Hylobatidae	Western Hoolock Gibbon	*Hoolock hoolock*	Frugivorous	Sch I (Part A)	EN	Decreasing
6	Camera Trap	Primates	Cercopithecidae	Northern Pig-tailed Macaque	*Macaca leonina*	Omnivorus	Sch I (Part A)	VU	Decreasing

Table 3.4. List of Mammal species of other orders recorded in the Landscape unit

S.No.	Source	Classical Order	Family	Common Name	Scientific Names	Functional guild	IWPA(1972)	IUCN Status	Current Population Trend
1	Camera Trap	Pholidota	Manidae	Chinese Pangolin	*Manis pentadactyla*[#]	Carnivores	Sch I (Part A)	CR	Decreasing
2	Indirect Signs	Proboscidea	Elephantidae	Asian Elephant	*Elephas maximus*	Herbivore	Sch I (Part A)	EN	Decreasing
3	Camera Trap	Rodentia	Hystricidae	Asiatic Brush-tailed Porcupine	*Atherurus macrourus*	Omnivorus	Sch I (Part A)	LC	Decreasing
4	Camera Trap	Rodentia	Hystricidae	Indian crested porcupine	*Hystrix indica*	Herbivore	Sch I (Part A)	LC	Stable
5	Camera Trap	Rodentia	Sciuridae	Pallas's Squirrel	*Callosciurus erythraeus*	Herbivore	ND	LC	Stable
6	Camera Trap	Scandentia	Tupaiidae	Northern Tree shrew	*Tupaia belangeri*	Omnivorus	Sch I (Part A)*	LC	Stable
7	Direct Sighting	Rodentia	Sciuridae	Flying Squrriel sp	-	Herbivore	Sch I (Part A)	-	-

[#] Recorded in rescue operations ***Same status as superioir taxa**

Table 3.5. List of Mammal species recorded in the study unit and the Relative Abundance Index based on Camera trap captures

S. no	Common Name	Scientific Name	RAI
1	Capped Langur	*Trachypithecus pileatus*	1.5
2	Stump-tailed Macaque	*Macaca arctoides*	3.1
3	Assamese Macaque	*Macaca assamensis*	0.3
4	Arunachal Macaque	*Macaca munzala*	0.2
5	Northern Pig-tailed Macaque	*Macaca leonina*	1.2
6	Western Hoolock Gibbon	*Hoolock hoolock*	0
7	Dhole	*Cuon alpinus*	0.4
8	Mainland Leopard Cat	*Prionailurus bengalensis*	1.2
9	Marbled Cat	*Pardofelis marmorata*	1.3
10	Clouded Leopard	*Neofelis nebulosa*	0.1
11	Asiatic Golden Cat	*Catopuma temminckii*	0.2
12	Sun Bear	*Helarctos malayanus*	0.3
13	Asiatic Black Bear	*Ursus thibetanus*	0.3
14	Common Palm Civet	*Paradoxurus hermaphroditus*	0
15	Masked Palm Civet	*Paguma larvata*	1.5
16	Spotted Linsang	*Prionodon pardicolor*	0.1
17	Smooth-coated Otter	*Lutrogale perspicillata*	0.1
18	Small Indian Mongoose	*Herpestes auropunctatus*	0
19	Yellow-throated Marten	*Martes flavigula*	1.8
20	Mishmi Takin	*Budorcas taxicolor taxicolor*	1.2
21	Mainland Serow	*Capricornis sumatraensis thar*	4
22	Red Goral	*Naemorhedus baileyi*	0.1

S. no	Common Name	Scientific Name	RAI
23	Northern Red Muntjac	*Muntiacus vaginalis*	5.5
24	Sambar	*Rusa unicolor*	0.5
25	Wild Boar	*Sus scrofa*	0.3
26	Gongshan Muntjac	*Muntiacus gongshanensis*	0.3
27	Chinese Pangolin	*Manis pentadactyla*	0.1
28	Northern Treeshrew	*Tupaia belangeri*	0.1
29	Pallas's Squirrel	*Callosciurus erythraeus*	0.1
30	Asiatic Brush-tailed Porcupine	*Atherurus macrourus*	2
31	Indian Crested Porcupine	*Hystrix indica*	0.8

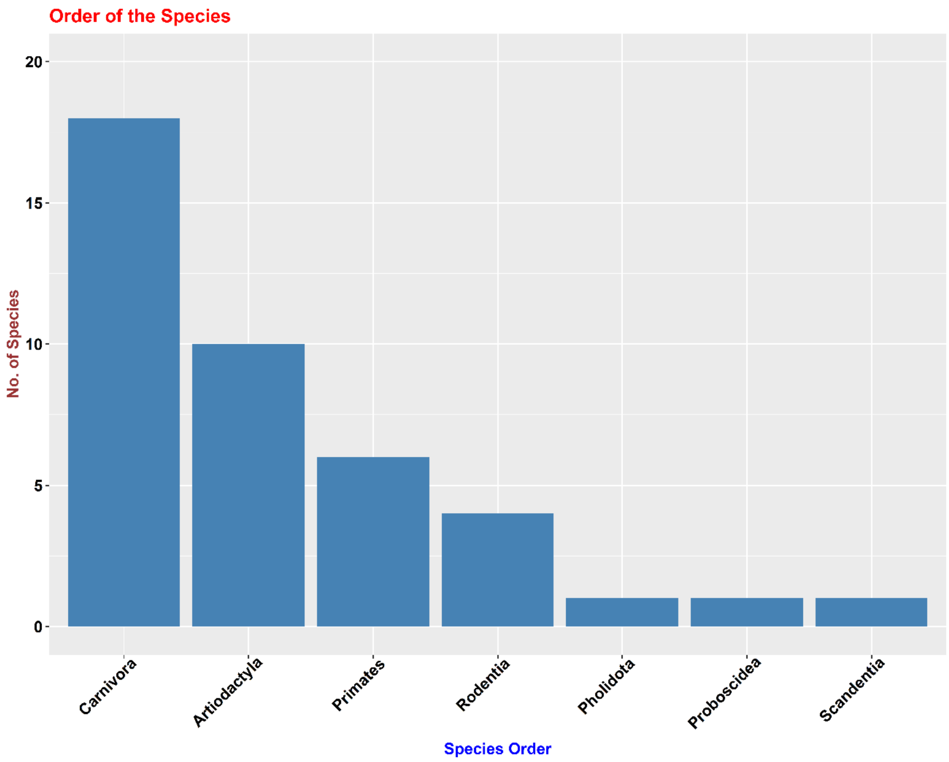

Figure 3.3. Number of species recorded under different Orders in the study unit

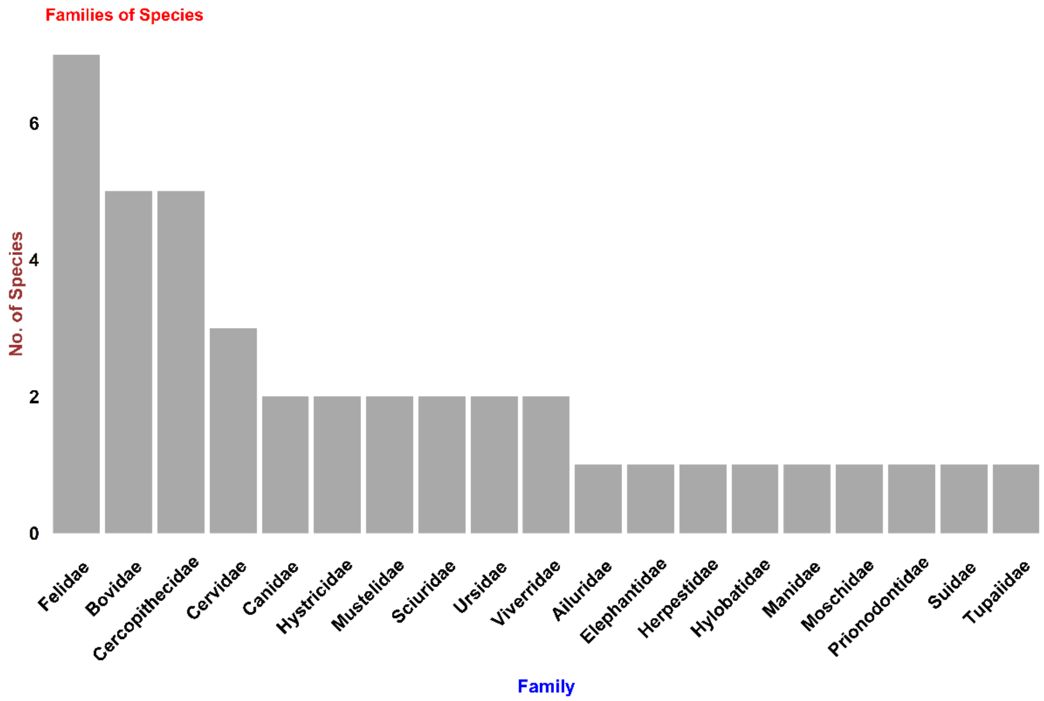

Figure 3.4. Number of species recorded under different Families in the study unit

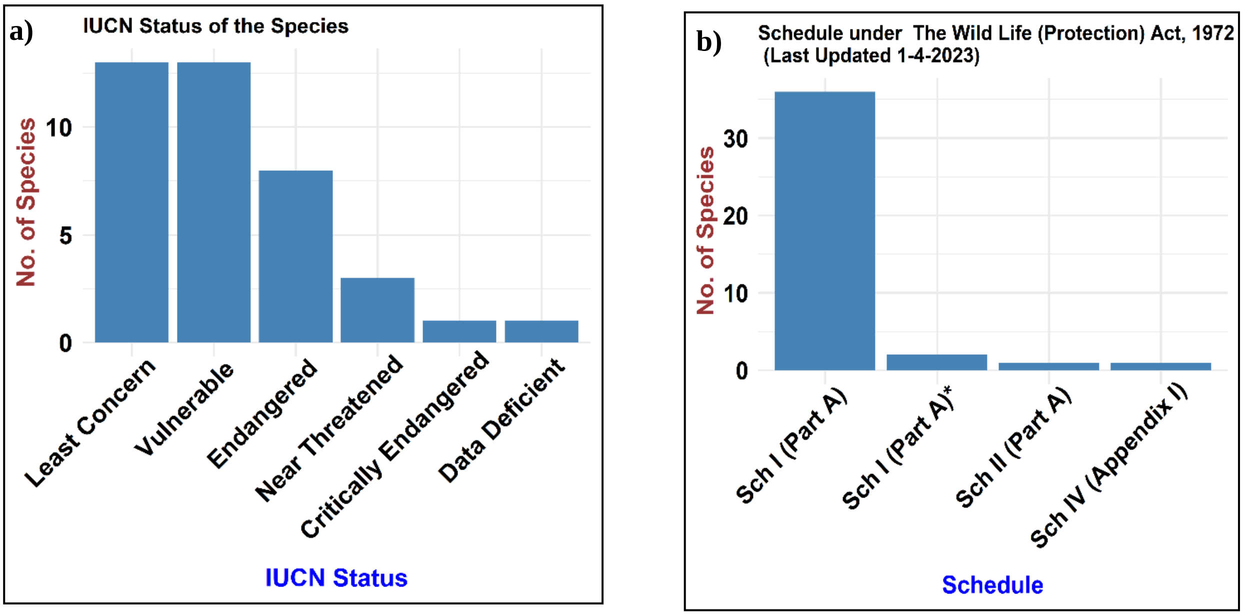

Figure 3.5. a). Number of species under IUCN threatened species categories and b). Number of species under different schedules of the Indian Wildlife Protection Act 1972 (Last Updated 1– 4-2023)

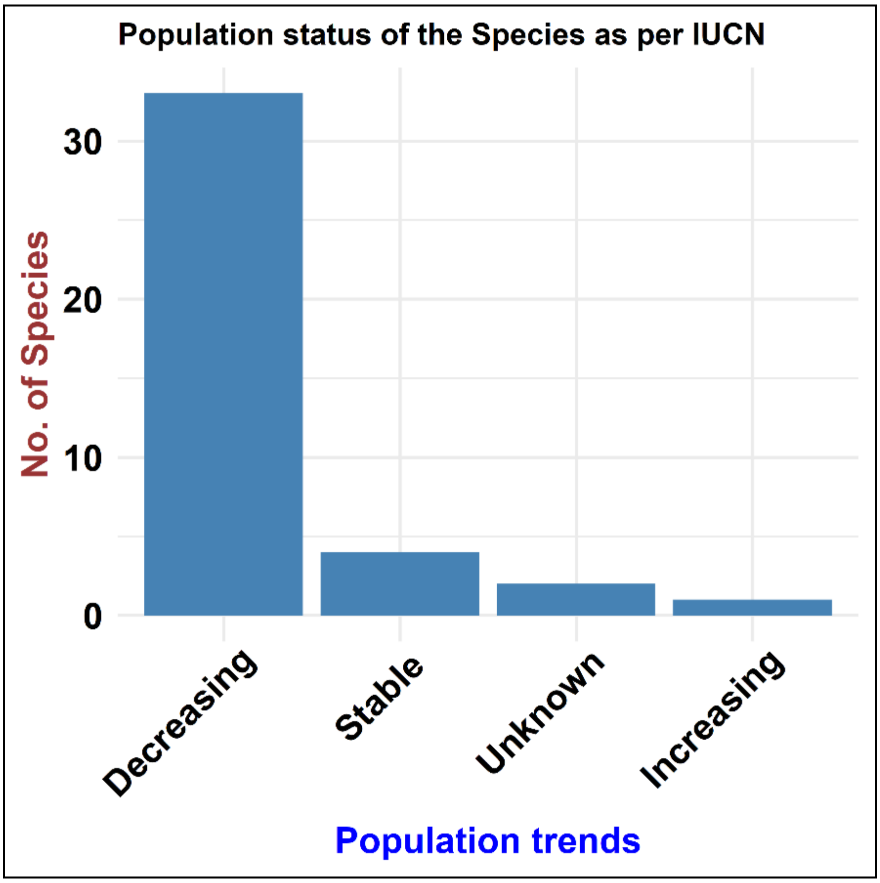

Figure 3.6. Number of species under Population trends as per IUCN

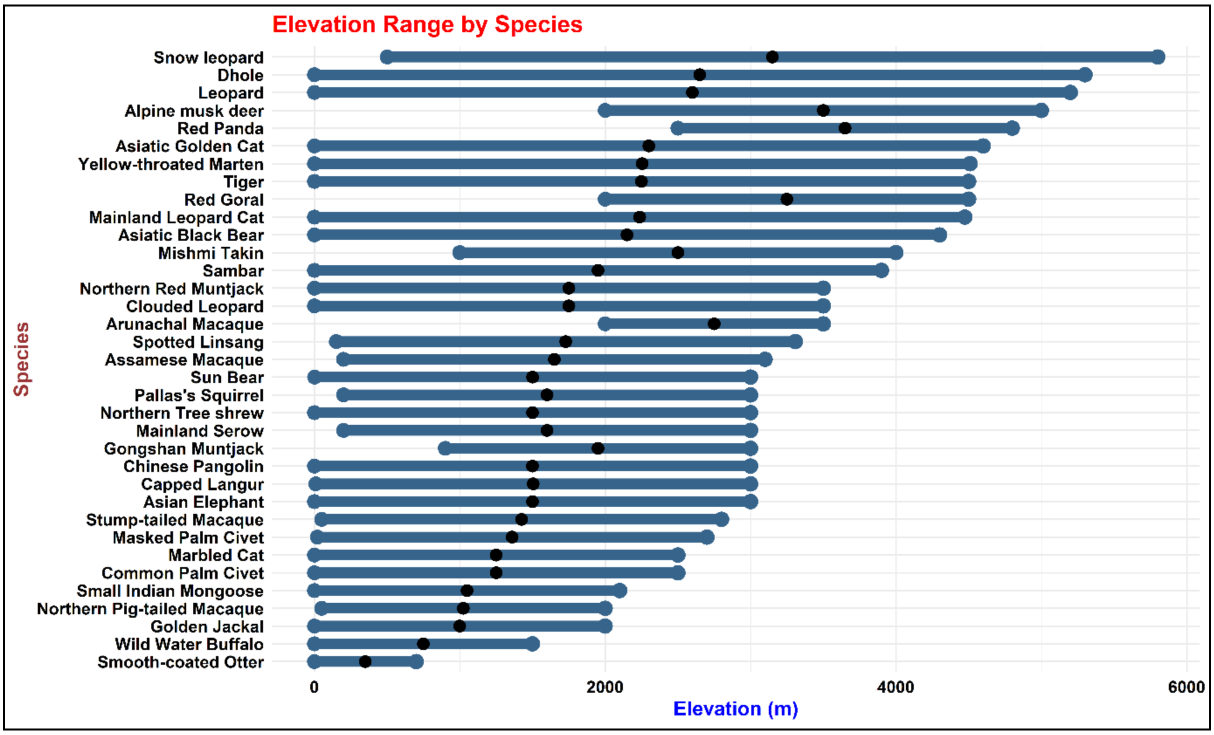

Figure 3.7. Identified Elevation range preferred by each species reported in the study as per IUCN

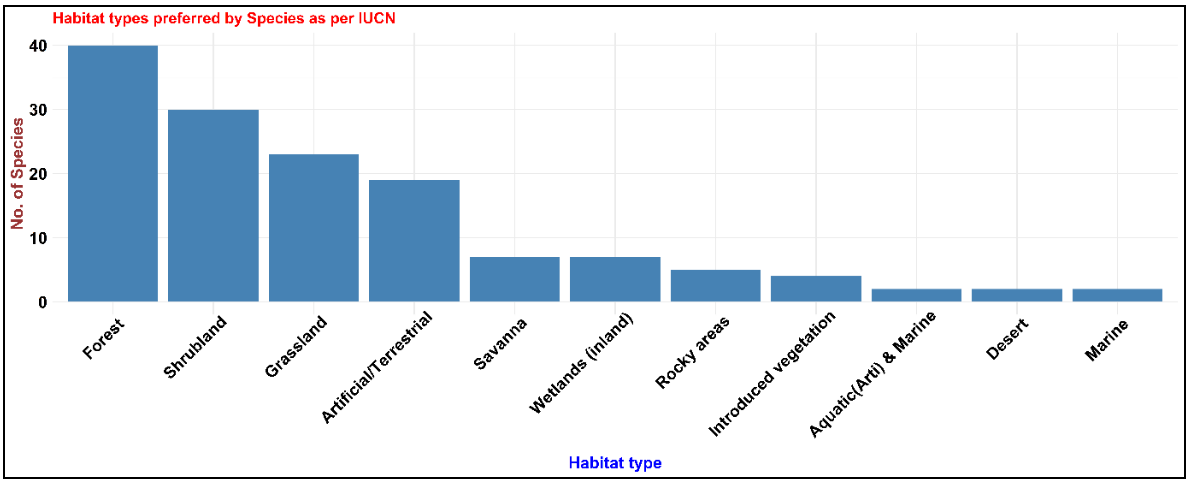

Figure 3.8. Number of species in each Habitat as per habitat preference identified by IUCN

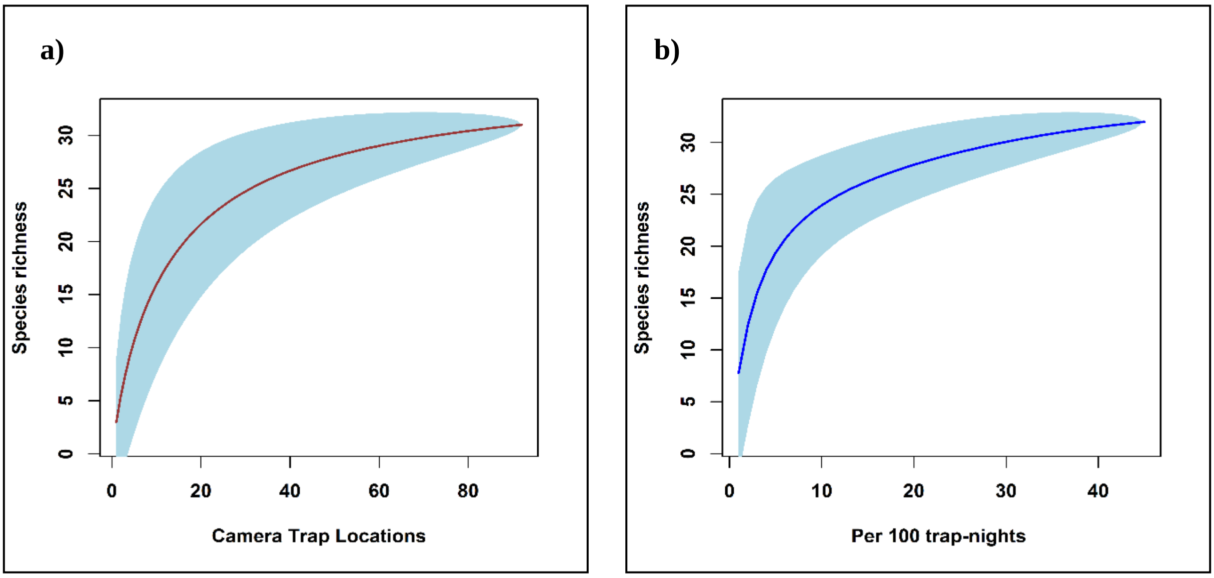

Figure 3.9. a) Species Accumulation Curve showing a) the species richness based on camera trap locations b) the species richness based on trapping days

Discussion

The zoogeography science in ecology and conservation depends on species distribution data (Fjeldsa *etal*., 2004; Lomolino, 1994; Sanderson, 2002). The lack of biodiversity information in various regions (Zarnetske *et al*., 2019; Soto-Navarro, 2020) is one of the reasons for certain species being considered as data deficient or the population status is unknown. Various species are reported to be experiencing contraction of their range and experiencing extinction risks (Cardillo *et al*., 2005). This creates a situation where the studies need to be conducted irrespective of boundaries to reduce the information gaps (Kühl *et al*., 2020; Guralnick, et.al 2007). In any region with an exceptional assemblage of biodiversity, whether it is flora or fauna, it is because of various factors (Guangwei, 2002). The rise in new species description rates from the study region shows the immense importance of species inventories (Hammond, 1992) and the addition of intrinsic information in monitoring a system (Nigel, 2001). The studies using the camera trapping method are found to be one of the compatible methods in biodiversity surveys in the least accessible and rugged terrains (Jiménez *et al*., 2010). The distributional information from a field survey alone cannot fill the gaps about a species' information (Karanth *et al*., 2009); additional sources of information are required. Not only the adopted methods but also the variation in species activity along the landscape also affect the detection probability of any species at a particular time (Zanón-Martínez *et al*., 2016, Jarnemo *et al*., 2017). There are two more species were reported elsewhere in the region and also recorded in the secondary data information and questionnaire survey (Chapter VI): endangered (EN) Alpine Musk Deer (*Moschus chrysogaster*) and Vulnerable (VU) Snow Leopard (*Panthera uncia*). The distribution information obtained from secondary sources can also be used to address hunting (Bertolino *et al*., 2014; Brodie *et al*., 2015; Allen *et al*., 2017).

The species belonging to the order Carnivora are diverse in northeast India (Talukdar, 2021). Forty percent of the 46 species of the order in the region has been reported in our study. All four big cats were identified to being distributed in our region emphasises the landscape's ecosystem viability. The species that are alpha predators, *viz*., the big cats and the Dhole, Jackal, all indicate that the ecosystem is one of the high profile (Natsukawa & Sergio, 2022) terrestrial ecosystems. The extrapolated density of tigers in the Dibang-Kamlang-Namdapha landscape was estimated to be 29, and there is a decrease in tiger density compared to the earlier estimate was also reported from this landscape (Jhala *et al.,* 2020). The leopard population of the state was estimated to be 42 in 2022, which shows an increase from 11 in 2018, as the area of assessment increases, which in turn number. In parts of the study unit, especially in the Kamlang Tiger reserve, there are no evidence identified and no assessment was carried out outside the protected area. During February 2018 there are three people were injured in the Namsai district. In September 2022, a Leopard was captured from the boundary of the Kamalang Tiger reserve (Department of Forest, Arunachal Pradesh). The leopards were observed to use of periphery of the forested area (Seidensticker, 1976) for various reasons like the presence of a dominant predator or easy availability of resources. The presence of snow leopards was expected to be along the snowline of at least ten districts of the state, of which high-altitude regions of Dibang Valley and Kamlang Wildlife Sanctuary are among the identified places (Bhatnagar, 2012). In our study, we reported the snow leopard based on secondary information. The latest statewide assessment based on perception and threat assessment shows a possible higher proportion of occupancy of snow leopard in Anjaw, Lohit, and Dibang districts (Sharma, 2023). Few studies about scattered dholes from the western part of the state (Gopi *et al*., 2010) and their involvement in livestock depredation were identified. The relative abundance of Clouded Leopard in our landscape unit was as low as 0.1, which was also the case in the northeast region (Goswami & Ganesh, 2014). The other two Canid apex predators were not well studied in the far northeast region. The information about the ecology of Dholes is limited in the northeast region (Stewart, 1993; 1994). Few studies about scattered dholes from the western part of the state (Gopi *et.al*, 2010) and their involvement in livestock depredation were identified. The status and ecology of the golden jackal is not explored in the landscape; reports of the species facing threats (Debnath *et al*., 2013) at a higher rate were reported from adjoining landscapes.

The other carnivores, such as the studies on the distribution of the golden cat or the studies special monitoring programme for the species, were not carried out (Dutta, 2022). The species that was recorded as a sympatric species alongside the camera trap exercises conducted for other big cats and other terrestrial mammals. Those observations recorded six morphs (Nijhawan, 2019) of the golden cat from Northeast India. Though the region is diverse in small mammals, especially carnivore species, little information is available about the distribution and abundance of almost all the species (Choudhury, 1997; Datta, 1999). The information about the distribution of small cats such as the Leopard Cat, Marble cat and the threats faced by the species was not addressed due to the lack of ecological information's (Greenspan *et al*., 2025; (Selvan *et al*., 2013). The Yellow-throated marten which is capable of acting as a top predator in forest where there is a less abundant top predator was also found to be poorly known in this region (Appel *et al*., 2014). There are three species of bears among the four in the country, except that the Brown bear is distributed in the Eastern Himalayas. Though there was information available as patch distribution (Garshelis & Steinmetz, 2008) and studies in the thirteen protected areas in the state found the status of the Sloth Bear unknown (Sethy *et al*., 2015). The Asiatic black bear was found to occupy almost all the identified PAs, whereas the sun bear was found in five of them. Of which one of the PAs is part of our study unit, and three of which lie around the study unit. The two species Asiatic Black bear and the Sun bear, are also recorded in the blocks outside the protected area, and were recorded in our study. The available information about sun bears' distribution and population status has been considered unreliable (Garshelis, 2002), such that information on the distribution of such species in all possible regions is considered valuable. The low relative abundance of the bear was due to human interventions along the identified distribution ranges

(Sahu *et al*., 2020). The past distribution information from the study area is crucial for a species as it experiences a decrease in population trend (Choudhury, 1994 & 2010), and various reintroduction initiatives (Bora *et al*., 2024) have been initiated.

The Northeast region holds 26 species of Artiodactyl (Talukdar, 2021). The nine species that belong to four families were identified in our monitoring. The sambar is considered to occupy more of the protected area than the community-managed forest in the region because of various human interventions (Velho, 2016). The barking deer was considered widespread in its distribution range, and this is the only species considered to be capable of present in hunting privileged zones of the distribution range (Timmins *et al*., 2016). Though the species was expected to distribute up to the range of 3500 msl, elevation and terrain ruggedness were identified to negatively influence the occupancy of the species (Chandrama, 2023). The Gongshan muntjack described by Ma *et al*., (1990) was reported to be occupied all along the eastern districts, and also the species was found to share the distributional range with the sister species red muntjack at the range of 1800 to 2000 msl and possibly distributed up to 300 msl (Choudhury 2003 & 2008; Aiyadurai & Meme, 2015). The serow is considered one of the widespread ungulates of the region, but is identified as preferring rugged terrains (Carr *et al*. 2023). Goral and serow, as goat-antelope, share the same habitat resources from food to cover (Awasthi *et al*., 2003), and were reported from the western Himalayan region. As the Goral identified in this study region is the Red goral (Naemorhedus baileyi), there need a community-level examination to identify the association of the species in habitat use. Serow was identified as one of the major prey species for large predators like the tigers and the leopard (Aryal, 2008). The ecological information about both species of Takin distributed in the Eastern Himalayas, the Mishmi takin (*Budorcas taxicolor taxicolor)* and the Bhutan takin (*Budorcas taxicolor whitei*) is still considered deficient (Wang, 2024). The studies found that there needs a completely different approach in ecological practice concerning each of these subspecies, as they possess unique evolutionary characteristics (Yang, 2021). There are also two species were identified to extend their distribution and underwent a range extension (Chatterjee *et al*., 2006), the Leaf deer (*Muntiacus putaoensis*) and Chinese goral (*Nemorhaedatus caudatus*), which emphasise the need for a wide-ranging survey in this Himalayan region. The report of the Leaf deer (*Muntiacus putaoensis)* was reported in Arunachal forests (Datta *et al*., 2003), which was a new species of deer discovered in Myanmar. The Musk deer was reported as a questionnaire which is distributed in alpine and edges of alpine and subalpine habitat where other ungulates are absent (Green, 1985) require a unique set of detection methods (Cook & MacDonald, 2004).

The Mithun, which is a free-ranging semi-domesticated species reported in the region, was linked more to the cultural value and was also found to be one of the prey species for carnivores, especially Tigers and Dholes (Aiyadurai & Varma, 2003; Jhala *et al*., 2020). The studies in this region in the Dibang wildlife sanctuary show Mithun is of a major part of the diet profile of Dholes, but not with tigers to the same extent (Adhikarimayum & Gopi, 2018). Nevertheless, there are chances that livestock acts as a prey buffer for the top predators in rugged terrain with low prey density.

Asian Elephants occupy the Brahmaputra flood plains and the flood plains of the Lohit River. The distribution was at the foothills of the Mishmi hills, which range extends up to the Naga-Patkai Ranges of the international border with Myanmar. The population in the region is considered two sets, where the population Southwest of Dibang Valley in Lohit and Namsai district forest occupies our study unit. There lies the Elephant Reserve, South Arunachal Elephant Reserve. is considered to have been separated during the 1980's (Choudhury 1995; 1999). This is the continuous stretch of population between Assam and Myanmar, with population in Namdhapha National Park (WII, 2022).

Out of 16 primates in the world, seven primates were recorded from this state (Taro, 2021). The northeast of India holds the highest number of primates by diversity, with 13 species. The species lists include one species belonging to the genus Nycticebus, representative of the family Lorisidae. Our study reported four species out of seven belong to the genus Macaca and single species out of three Trachypithecus, which are distributed in the Northeastern region. All the primate species, invariable of current conservation status, experience effects of habitat loss and habitat fragmentation, which is one of the greatest threats to primates (Choudhury, 2001). Though it was not recorded in our study, the distribution of the Slow Loris (*Nycticebus bengalensis*, Lacepede, 1800), as a rare sighting, was reported from the study unit landscape (Radhakrishna *et al*. 2012). There is a new adition of macaque species was also discovered from the state the Sela macaque (*Macaca selai*) as a distinct species which is additional species to the region (Ghosh 2022).

The description of two species of gibbon (Fan *et al*., 2017) and disputes in the separation of Hoolock gibbons into two different species or a single species (Trivedi *et al*., 2021) created a situation to calls for a critical assessment of the population and distribution of species status. Choudhury (2022) described the Mishmi Hills hoolock (*Hoolock hoolock mishmiensis*), which occupies the forest of the lower Dibang and Lohit districts. There is also a distribution of the endangered third species, Skywalker Hoolock Gibbon (*Hoolock tianxing*), which was a separated monotypic taxon (Fan, 2017) from the vulnerable Eastern Hoolock gibbon (*H. leuconedys)* in the adjoining region surrounding the distribution of the gibbons in the Indian region.

The Ailuridae, the red Panda’s fifty percent of habitat, was identified in the Eastern Himalayas, and the distribution is recorded in patch habitats. The species is considered common in the Dibang and Lohit districts (Choudhury, 2001). Gosh *et al*., 2024 mentioned two different species of Red panda in India, viz., Western Red Panda (*Ailurus fulgens* Cuvier, 1825) and Eastern Red Panda (*Ailurus styani* Thomas, 1902). Among the two species, the distribution of Eastern Red Panda is only in the state of Arunachal Pradesh.

Though the study reported flying squirrels to the genus level, the landscape is reported to be occupied by eleven out of fourteen species of Flying squirrels (Kumawat, 2013; Dollo, 2010). The species are Particolored Gliding Squirrel (*Hylopetes alboniger*), Grey Headed Gliding Squirrel (*Petaurista caniceps*), Spotted Giant Gliding Squirrel (*Petaurista elegans*), Hodgson's Giant Gliding Squirrel (*Petaurista magnificus*), Bhutan Giant Gliding Squirrel (*Petaurista nobilis*), Red Giant Gliding Squirrel (*Petaurista petaurista*), Mishmi Hill Giant Gliding Squirrel (*Petaurista mishmiensis*), Indian Giant Gliding Squirrel (*Petaurista philippensis*),Red and White Giant Gliding Squirrel (*Petaurista alborufus*), Namdapha Gliding Squirrel (*Biswamoyopterus biswasi*), and Yunnan Giant Gliding Squirrel (*Petaurista yunanensis*). The species includs endemic and species of conservation importance. Other species, such as Orange-bellied Himalayan Squirrel (Wilson & Reeder, 2005), are also recorded to be distributed in the study unit landscape.

The one among the two species of pangolin Chinese pangolin (*Manis pentadactyla*) was the only species identified from the region until recently, the discovery of the Indo-Burmese pangolin (*Manis indoburmanica*) (Wangmo *et al.*, 2025) from the region. Our observations are based on the camera trap record and an isolated record of the rescue operation, which did not account for taxonomic level identifications. Further adaptation of specialised methods and intensive surveys in the study unit can provide an understanding of the geographic extent and niche association among the species.

The burrowing vertebrates like the Porcupine play a considerable role in the ecosystem and niche requirements (Bhupathy & Haque, 1986) of other mammal species, like the Golden Jackal, and also play a role in resource availability (Lynn & Detling, 2008) of other species. Himalayan Crestless Porcupine (*Hystrix brachyuran* Linnaeus, 1758), Malayan Porcupine (*Hystrix brachyuran bengalensis* Blyth, 1851) are also reported from the state and also from the study region (Chattopadhyay *et al*., 2006; Das *et al*., 1995; De *et al*., 2006; Wilson & Reeder, 2005; Lunde *et al*., 2016).

Certain species are not reported in the study but are reported to be distributed in this region, which are mostly small mammals (Kumar, 2018**).** Yellow-bellied weasel (*Mustela kathiah*), Siberian weasel (*Mustela sibirica*), Stripe-backed Weasel (*Mustela strigidorsa*), Beech Marten (*Martes foina*), Crab-eating mongoose (*Urva urva*) (Choudary, 1999), and Fishing cat (*Prionailurus viverrinus*). There are certain species of conservation importance, such as the Eurasian otter (*Lutra lutra*), which is a Near Threatened (NT) species, and the Asian Small-clawed Otter (*Aonyx cinereus*), and the Binturong (*Arctictis binturong*), which are Vulnerable (VU) species as per IUCN**.** There are certain species which are considered to be distributed only in Arunachal pradesh within India territory. The species are White-cheeked Macaque (*Macaca leucogenys)* , Arunachal Macaque (*Macaca munzala*), Sela Macaque (*Macaca selai*), Namdhapa Flying Squirrel (*Biswamoyopterus biswasi*), Mebo Giant Flying Squirrel (*Petaurista siangensis*) , Chindwin Giant Flying Squirrel (*Petaurista sybilla*), Yunnan Red-backed Vole (*Eothenomys Eleusis*), Yunnan Field Mouse (*Apodemus ilex*), Large-eared Field Mouse (*Apodemus latronum*), Hidden Brown-toothed Shrew (*Episoriculus umbrinus*), Leaf Muntjac (*Muntiacus putaoensis*), and Red Goral (*Naemorhedus baileyi*) (Gosh, 2024; Li *et al.*, 2015; Sinha *et al*., 2005; Ghosh *et al.*, 2022; Saha, 1981; Choudhury, 2013; Thomas & Wroughton, 1916; Thomas, 1911; Thomas, 1922; Thomas, 1911; Allen, 1923; Amato *et al.*, 1999; & Pocock, 1914;). Arunachal Pradesh has been identified with 13 species of Murids, and two species of bamboo rats belonging to Spalacidae. The other rodent species belongs to the family Cricetidae; the Royle's Mountain Vole (*Alticola roylei*), which is a Near Threatened species, was also reported from the state (Kumawat *et al*., 2016). A poorly known species, the hog badger (*Arctonyx collaris*), was reported from the adjoining forests of Namdapha National Park (Datta, 2008).

There are certain species lost over time in the study unit landscape, of which the recent past distribution information from the study area is crucial for a species as it experiences a decrease in population trend (Choudhury, 1994 & 2010), and various reintroduction initiatives (Bora *et al*., 024) have been initiated. The Asian two-horned Rhinoceros (*Dicerorhinus sumatrensis*) was historically present in Lohit district and adjoining Changlang later experienced regional extinction (Shebbeare 1953, Choudhury 1997; Rookmaaker 2024).

Our study documented as much as possible species of terrestrial mammals. As we are dependent on Camera trap procedures, mainly focused on methods used for large-bodied mammals, the probability of detection of certain small mammals and arboreal mammals becomes low. That is also the reason some groups of species are represented below par. The difficulty in assessing the distribution of certain species (Vine *et al*., 2009), which are elusive by behaviour and cryptic by activity, requires a large-scale monitoring program (Barea-Azcon *et al*., 2007). There exists a huge gap in the discovery of species to understanding of the species biology among the scientific community (Novotny *et al*., 2002).

In the rugged terrain like our study unit, it is not unexpected that the carnivore species, which are elusive in behaviour, due to which there is extremely difficult to find and also require an intense survey effort (Nowell & Jackson, 1996; Sillero-Zubiri *et al*., 2004). Determining the status of conservation of most of the species found to be problematic; Old World mammals are more threatened than New World mammal species (Russell, 1994). The need for assessing the geographical distribution of species and subspecies arises critical aspect in such a highly diverse landscape. The geographical boundary and subspecies divergence can be understood through the development of as much information all along the possible extents. For ex, in these peculiar hotspot landscapes the species like Gibbons, Red Panda, Goral, Musk deer, Pangolins, barking deer, etc., all the species have parallel distributions of similar species with unique evolutionary backgrounds.

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Chapter IV

Exploring the utility of the species distribution modelling to understand habitat availability for select mammalian species in the Eastern Himalayan Landscape

Introduction

Wildlife conservation is one of the pressing challenges in an era of accelerated human population growth; increasing environmental degradation, and rapid climate change (Heller and Zavaleta, 2009; Rands *et al*., 2010). In present, prediction the synergistic impacts of global change on various species in different ecoregions remains the mainstay in applied ecology (Hickling *et al*., 2006; Bellard *et al*., 2012). Thus, the importance of baseline field data to understand species distribution is paramount for both conservation and management (Collins & Crump, 2009). The baseline information on distribution of a species can be obtained through direct ecological surveys and further augmented by developing ecologial models that can use sparce information on species locations to reliably predict distribution over large spatial scales (Neto *et al*., 2020). The niche-based studies focusing on realized niche (actual occupancy) with the fundamental niche (potential habitat) typically use the nested model focusing on the populations, community, landscape and the ecosystem (Baker 1992, Scavia & Robertson, 1979). These nested models are among the myriad quantitative models used by ecologists in decision-making. Soberón (2007) and Jackson & Blois (2015) use the idea of environmental assembly to develop models of how species or taxonomic groups are spread out. This idea is based on basic niches that overlap and the environmental conditions of the area.

Forest cover or green cover on its own may not represent the distribution and existence of wild fauna or a community of species as an interplay of biotic interactions and human factors can have an overwhelming effect on species occurrence (Redford, 1992). The "eco-field hypothesis" (Farina *et al.*, 2006) states that the function of any species is a response to specific spatial configurations and cognitive reactions. Cayuela *et al*. (2009) elucidate that figuring out the likely geographical range of a species can be done by carefully describing the environmental conditions that the species needs in an area. Environmental variables can predict a species' environmental niche, translating climatic space into geographical space (Coelho, 2003). Recent advancements in the readily available climatic data sets such as precipitation and temperature and their subtle variants are often the overarching factors influencing species distribution (Kearney *et al*., 2014). Further, the use of landscape positioning arises from elevation variation; elevation-based measures such as terrain ruggedness, slope, and aspect are useful in modelling (Wilson & Gallant, 2000). While comparison of presence and absence elucidate the effect of certain variables in determining species occurrence in a location, because absence locations are rarely available, presence-only models have gained prominence in species distribution modelling. Using the presence-only locations at the landscape level and correlating the spatial information with environmental variables can describe and predict the habitats of the target species quantitatively (Phillips *et al*., 2006; Elith & Leathwick, 2006; Newbold, 2010; Elith *et al*., 2011). It is often easy to access location information from various easily available online resources and published literature, which will enable creating modelling for larger areas (Chapman *et al*., 2020, Anderson *et al*., 2016; Fletcher *et al*., 2019; Chapman *et al*., 2020; Valavi *et al*., 2021).

In the Eastern Himalayan region, the combination of topographic features, soil, and rainfall, along with unique climatic conditions support tropical evergreen, especially wet evergreen forests over the mountains terrain transitioning to temperate forests at higher elevations (Singh, 2001). The forests were occupied by diverse flora and fauna. With a forest cover of more than 61 %, in the eastern Himalayan landscape account for approximately 78% lies in the hilly region (Wikramanayake *et. al*., 2011). The landscape is at the junction of two biogeographic realms and three biodiversity hotspots (Olson *et al*., 2001), and it is physically connected and covered by more extensive forest cover. There are two identified tiger conservation landscapes: namely the Northern Forest Complex with 'Namdapha – Royal Manas, and the Kaziranga – Garampani landscape complex' (Wikramanayake *et al*., 2011). Mammalian species are known to have a wider distribution occuring both inside and outside the designated protected areas. The sporadic new discovery of mammalian species from the region illustrates the richness of mammals in the region. Thus, scientific studies at the landscape level are often needed to comprehensively understand landscapes from time to time so as to devise adaptive management strategies (Uddin *et al*., 2020; Nzei, 2022). Terrestrial large mammals, in general have a disproportionately high effect on the ecosystem processes, and they also have a cascading effect on the mesocarnivores (Jarvie & Svenning, 2018; Ripple *et al*., 2014; Malhi *et al*., 2016; Doughty *et al*., 2016). Therefore, the knowledge of distribution of the species guilds at the trophic level would elucidate the details of habitat available for managing the species. The study area and the surrounding landscapes, although inherently rich, have also been regarded "empty forests" due to relatively high hunting pressures (Datta *et al*., 2008). Assessments carried out in the adjoining Namdapha landscape revealed that the animal numbers were precariously low (Datta, 2008). Given this, surveys based on direct site assessments are not very useful and camera trapping can potentially identify most species in the region.

The primary aim of our study is to understand species assemblage in the identified landscape, which till date remains one of the least surveyed forested regions in India. As detailed in chapter-1, this study has recorded 36 mammal species in the landscape unit. Among them 32 species were recorded in camera traps with geo-coordinates. Given these captures, there is a pressing need to assess fundamental niche (suitable habitat) at the regional scale (comprising a larger landscape elucidated in the following section) for the identified species using robust statistical approaches such as the species distribution modelling (SDM).

Study Area

We selected the biodiversity hotspot area in the Indian boundary for our regional distribution prediction. The area falls under two different biodiversity hotspots: The Himalayan and Indo-Burma biodiversity hotspots (Hoffman *et al*., 2013). The regions lie from the Dihang Gorge and form part of the Eastern Himalaya or Purvanchal Hills. There are a total of 10 hill regions in the Eastern Himalayas: Daffla, Abro, Mishmi, Patkai Boom, Naga, Manipur, Gaora, Khasi, Jaintia, and Mizo Hills. This region, known as the Dihang-Debang biosphere encompasses an area under Mouling National Park and Dibang Wildlife Sanctuary (Chaudhry, 2012). There are about 145 Protected Areas (PAs henceforth) distributed over different hotspot regions across 8 states in the country's northeastern region, including national parks, wildlife sanctuaries, and community reserves. This hotspot region possesses one of the highest number of rare and endangered species and there are continuing new discoveries this region (Sinha, 2018). In the whole of India, the Northeast region possesses 22.35% of the total threatened species as identified by IUCN. In particular, the faunal diversity of the region is high, with around 14,838 species identified (Kailash *et al*., 2021). The states of Meghalaya, Assam, the Brahmaputra valleys, the Manipur, Nagaland, Tripura, and Mizoram follow in terms of faunal diversity (Kailash *et al*., 2021). The Indo-Burma biodiversity hotspot, which lies above 6000 meters a.s.l harbours different types of habitats and thus, supports a rich biodiversity composition (Davis *et al*., 1995). This geographical region is one of the largest biodiversity hotspots in the world. Within India, this hotspot includes specific regions: Assam, Meghalaya, Manipur, Nagaland, Tripura, and a considerable area in Arunachal Pradesh. According to Stephen *et al*., (2015), this hotspot ranks among the top irretrievable biodiversity regions, having lost 95% of its natural habitat. There are several hill passes that lie along the stretch of the Himalayas. In our study area, there is Dihang-Debang, which connects the region with Myanmar. The intensive study area comprises 6408-square-kilometre (Fig. 4.1) area of forests in the state of Arunachal Pradesh.

It is known as a "biodiversity mine" (Rao, 1994; Baishya, 2001; Borang, 2001) and is in the hotspot region between Namdhapha National Park in the far east and Dibang Wildlife Sanctuary in the north. The state lies in an altitudinal range from 50 m to as high as 7000 m asl (Fig. 4.2), resulting in diverse environmental conditions. The state possesses various forest types and has approximately 25% very dense forest, approximately 36% moderate dense forest, and approximately 17% open forests (ISFR, 2019). The administrative forest divisions fall under the Lohit, Anjaw, and Anini forest divisions. The study area includes Kamlang Tiger Reserve and is surrounded by other protected areas such as Namdhapha Tiger Reserve, Dibang Wildlife Sanctuary, and Mehao Wildlife Sanctuary. The extent of the area is well connected to all the sanctuaries.

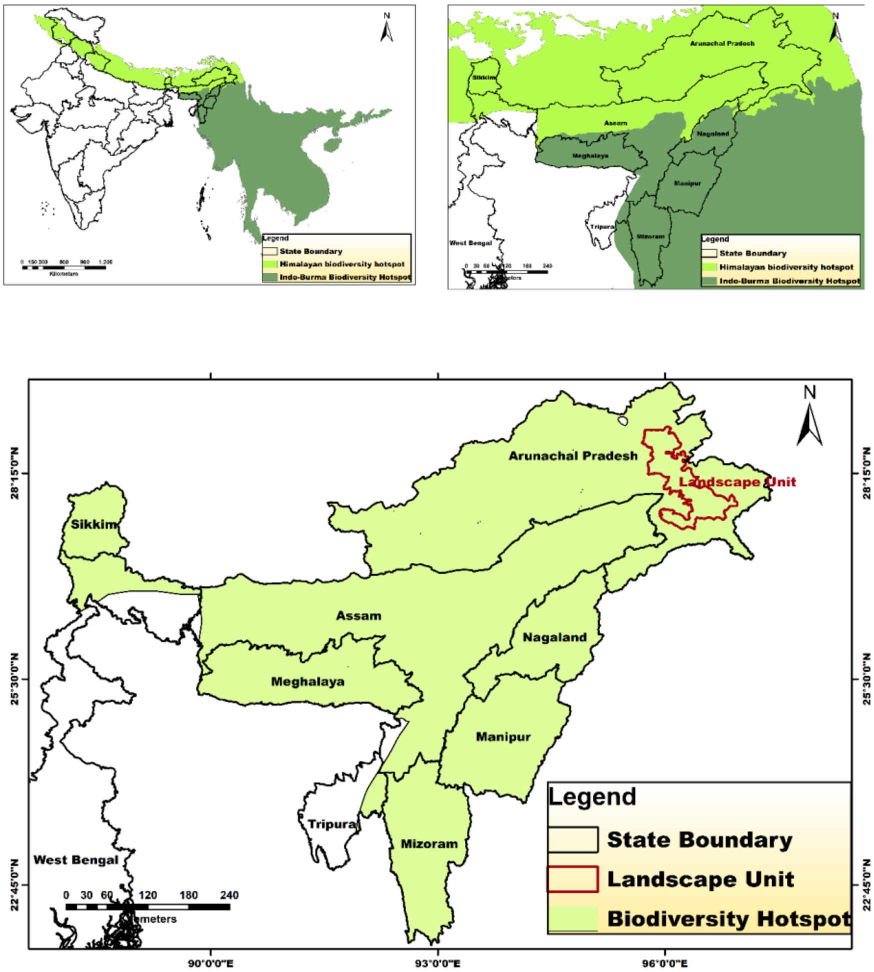

Figure 4.1. The Hotspot region and Landscape unit selected for Species Distribution Modelling in Northeast India.

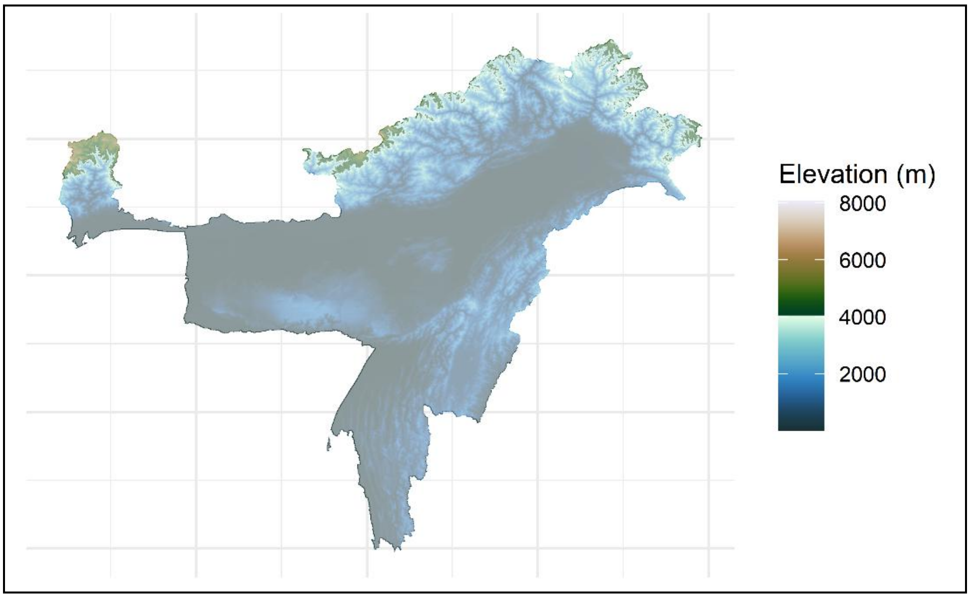

Figure 4.2. The Digital Elevation Model of the Hotspot region

Species Occurrence Data

The species presence locations recorded through camera trapping along with location data from the Global Biodiversity Information Facility (GBIF, https://www.gbif.org) database were collated. Along with the first two sources (Sujata, 2021; Gouda *et al*., 2019), the locations for Mishmi Takin and Sun Bear came from published literature to get a substantial number of locations (Table. 4.1). The published literature for SDM was analysed to find more locations for species with fewer records than those recommended for the first stage of the study and to find out what habitats might be available (Proosdij *et al*., 2016). Based on what other studies have said and how common the species is in the area, a sample size of 20 (Stockwell & Peterson, 2002) and a further smaller number of 15 (Papeş & Gaubert, 2007) were chosen so that the number of locations wouldn't drop below these numbers. The other species weren't taken into account for prediction within the chosen areas, which can show the whole hotspot region in the Eastern Himalayas and the Northeast (Fig. 4.3 & Fig. 4.4). enhance the independence of the data and to avoid spatial dependency of the points The spThin package in R Core 4.1.1's spatial thinning procedure spreads out the locations, according to James *et al*., 2013. This arrangement makes the locations about 5 km apart (Pinto, 2021). The species exercised in distribution modelling belongs to three different tropical guilds: carnivores, herbivores, and mesocarnivores. The two Carnivore species, the Asiatic Black Bear and the Sun Bear, are both under the Omnivore functional guild, and the Asiatic Golden Cat is a carnivore by functional association. Four species belong to herbivorous functional and tropical guilds, which are the major prey species distributed in the region. The two meso-carnivores, the mainland leopard cat and the yellow-throated marten, are identified as carnivores and omnivores, respectively (Table. 4.3). The IUCN data suggest that eight out of nine species are in a state where their numbers are declining (Table. 4.2 & 4.3) (Timmins *et al*., 2015; Garshelis *et al*., 2020; Sotson *et al.,* 2017; McCarthy *et al*., 2015;

Song *et al*., 2008; Phan *et al*., 2020; Timmins *et al*., 2016; Ghimirey *et al*., 2023; Chutipong, 2024).

Table 4.1. The source of presence location collected for Species distribution modelling at the regional scale

S.No.	Common Name	Source of Distribution locations
1	Asiatic black bear	Current study and GBIF
2	Sun bear	Current study, GBIF,and Gouda et.al 2019
3	Asiatic golden cat	Current study, GBIF
4	Mishmi takin	Current study, GBIF, Sujata, 2021
5	Mainland Serow	Current study and GBIF
6	Northern red muntjac	Current study and GBIF
7	Sambar	Current study and GBIF
8	Mainland leopard cat	Current study and GBIF
9	Yellow-throated marten	Current study and GBIF

Table 4.2. List of Mammalian species selected for current study for distribution models

S. no	Classical Order	Family	Common Name	Scientific Name	IUCN Status
1	Carnivora	Ursidae	Asiatic black bear	*Ursus thibetanus*	VU
2	Carnivora	Ursidae	Sun bear	*Helarctos malayanus*	VU
3	Carnivora	Felidae	Asiatic golden cat	*Catopuma temminckii*	NT
4	Artiodactyla	Bovidae	Mishmi takin	*Budorcas taxicolor taxicolor*	VU
5	Artiodactyla	Bovidae	Mainland Serow	*Capricornis sumatraensis thar*	VU
6	Artiodactyla	Cervidae	Northern red muntjac	*Muntiacus vaginalis*	LC
7	Artiodactyla	Cervidae	Sambar	*Rusa unicolor*	VU
8	Carnivora	Felidae	Mainland leopard cat	*Prionailurus bengalensis*	LC
9	Carnivora	Mustelidae	Yellow-throated marten	*Martes flavigula*	LC

Table.4.3. The Tropical and functional guilds of species and its population trends as per IUCN assessments

Tropic Guild	Common Name	Scientific Name	Functional guild	Current Population Trend
Carnivore	Asiatic Black Bear	*Ursus thibetanus*	Omnivorus	Decreasing
	Sun Bear	*Helarctos malayanus*	Omnivorus	Decreasing
	Asiatic Golden Cat	*Catopuma temminckii*	Carnivores	Decreasing
Herbivore	Mishmi Takin	*Budorcas taxicolor taxicolor*	Herbivore	Decreasing
	Mainland Serow	*Capricornis sumatraensis thar*	Herbivore	Decreasing
	Northern Red Muntjack	*Muntiacus muntjak*	Herbivore	Decreasing
	Sambar	*Rusa unicolor*	Herbivore	Decreasing
Mesocarnivore	Mainland Leopard Cat	*Prionailurus bengalensis*	Carnivores	Stable
	Yellow-throated Marten	*Martes flavigula*	Omnivorus	Decreasing

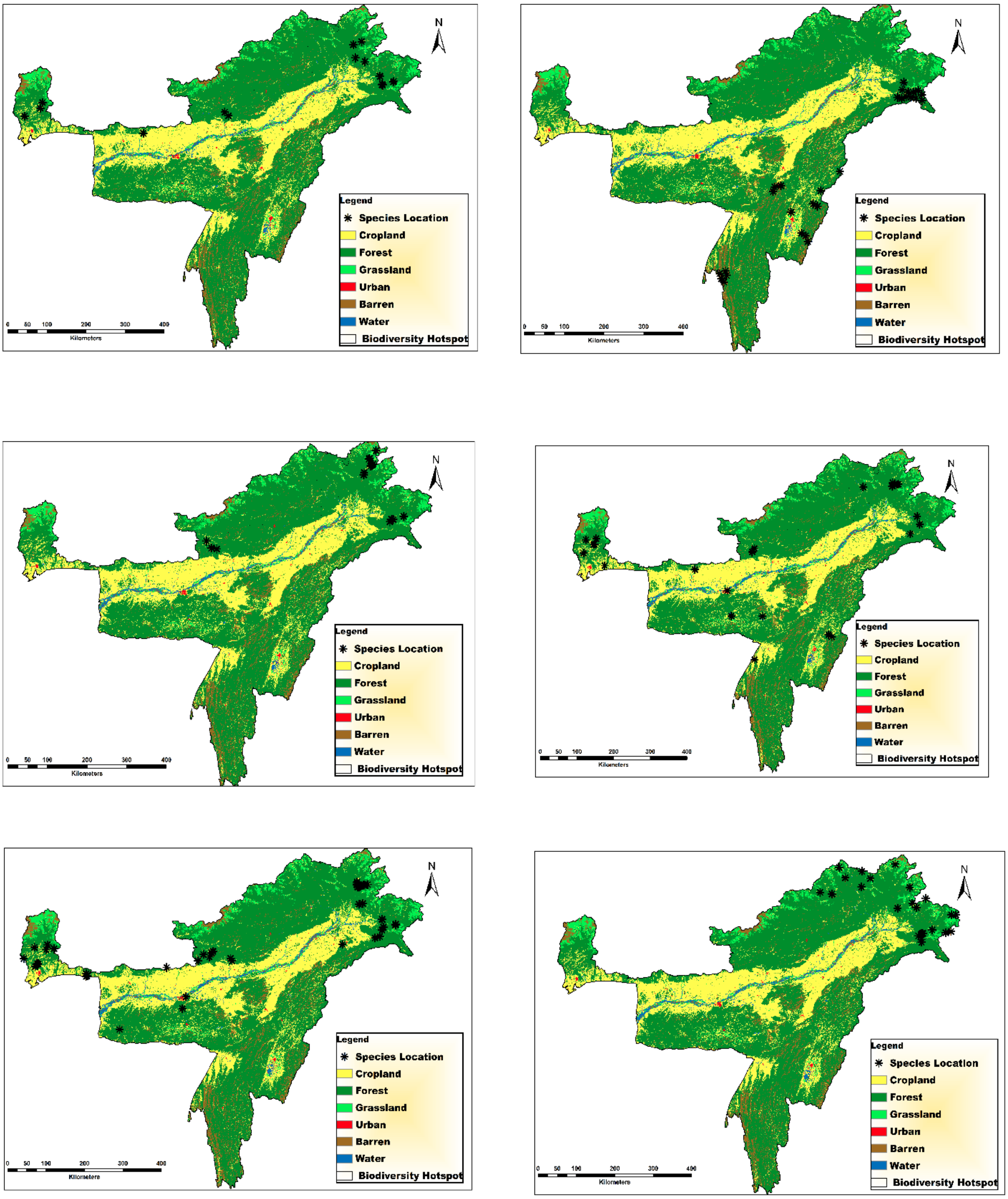

Figure. 4.3. Distribution of locations used for Species Distribution Modelling in the selected region of Biodiversity Hotspots for each species (Left to right horizontally) Asiatic Black bear, Sun Bear, Asiatic golden cat, Mainland leopard cat, Yellow-throated Marten, and Mishmi Takin.

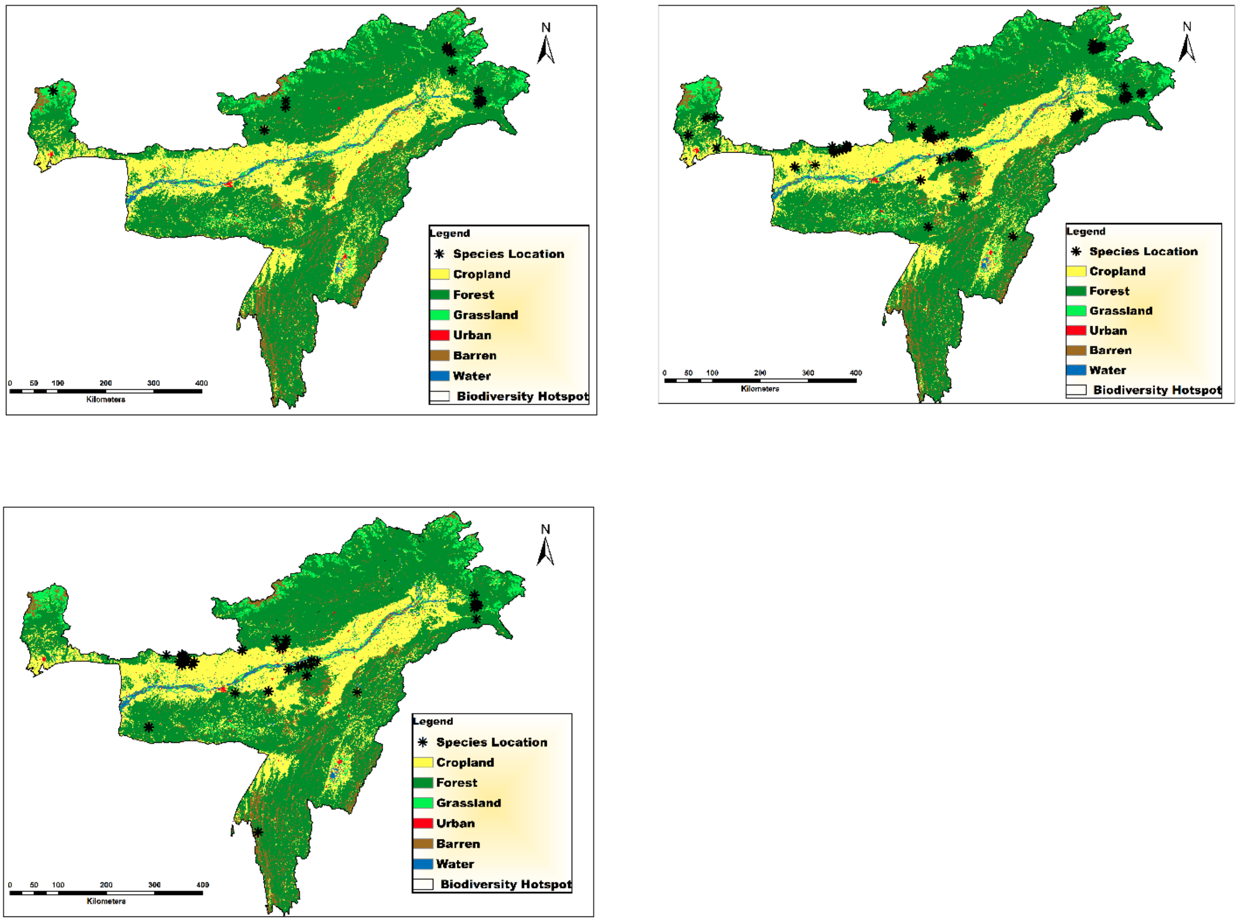

Figure 4.4. Distribution of locations used for Species Distribution Modelling in the selected region of Biodiversity Hotspots for each species (Left to right horizontally) Mainland Serow, Northern red muntjac, and Sambar.

Environmental Variables

By literation, it means the components of an environment surrounding the animal at any particular temporal scale may be considered as the habitat (Dinsmore, 2007). The researchers identified the physical characteristics of the environment as highly persistent in the distribution of species (Grinnell, 1904). Studies (Aititu *et al*., 2022; Lannuzel, 2020) have shown that topographical variables and their effects on biotic and abiotic factors can change where species inhibit. We used 19 bioclimatic variables from Worldclim (https://www.worldclim.org/data/worldclim21.html) as climatic predictor variables and topographic variables such as elevation, slope, aspect, and terrain ruggedness index. also incorporated landuse and Landcover (Zhang *et al*., 2023; Zhang *et al*., 2017; Collins, 2009;

Neto, 2020) as predictor variables for the modelling (Table. 4.4). The land uses include six broad classes: 1. cropped, 2. forest, 3. grassland, 4. urban, 5. barren, and 6. water. Pearson's correlation was used to check for collinearity between the 19 bioclimatic variables. We excluded variables with a correlation coefficient of > 0.7 from the analysis (Dormann *et al*., 2013). We calculated the collinearity for individual species and used specific climatic variables in the modelling (Table. 4.5). The distribution of maximum and minimum values of the variables is given in Table 4.6.

Table. 4.4. List of Variables used for Habitat used predictions

Variable		**Code**	**Source**	**Type**
Climate	BIO1 = Annual Mean Temperature	BIO1	Worldclim	Continuous
	BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	BIO2		
	BIO3 = Isothermality (BIO2/BIO7) (×100)	BIO3		
	BIO4 = Temperature Seasonality (standard deviation ×100)	BIO4		
	BIO5 = Max Temperature of Warmest Month			
	BIO6 = Min Temperature of Coldest Month			
	BIO7 = Temperature Annual Range (BIO5-BIO6)	BIO7		
	BIO8 = Mean Temperature of Wettest Quarter			
	BIO9 = Mean Temperature of Driest Quarter			
	BIO10 = Mean Temperature of Warmest Quarter	BIO10		
	BIO11 = Mean Temperature of Coldest Quarter	BIO11		
	BIO12 = Annual Precipitation	BIO12		
	BIO13 = Precipitation of Wettest Month			

	BIO14 = Precipitation of Driest Month	BIO14		
	BIO15 = Precipitation Seasonality (Coefficient of Variation)	BIO15		
	BIO16 = Precipitation of Wettest Quarter			
	BIO17 = Precipitation of Driest Quarter			
	BIO18 = Precipitation of Warmest Quarter	BIO18		
	BIO19 = Precipitation of Coldest Quarter			
Altitude		DEM	USGS	Continuous
Slope			Derived from DEM	Continuous
Aspect			USGS	Continuous
Terrain Ruggedness Index		TRI	USGS	Continuous
Landuse Landcover		LULC	Zhang *et al.*, 2023	Categorical

Table. 4.5. Climatic variables used for prediction for species in distribution modelling

S.No.	Common Name	Bioclimatic Predictor variables used predictions
1	Asiatic black bear	BIO2, BIO3, BIO7, BIO18
2	Sun bear	BIO2, BIO11, BIO15, BIO18
3	Asiatic golden cat	BIO1, BIO2, BIO3, BIO7, BIO10, BIO18
4	Mishmi takin	BIO3, BIO4, BIO7
5	Mainland Serow	BIO2, BIO7, BIO11, BIO15, BIO18
6	Northern red muntjac	BIO2, BIO3, BIO7, BIO11, BIO18
7	Sambar	BIO3, BIO7, BIO10, BIO11, BIO14, BIO15, BIO18
8	Mainland leopard cat	BIO2, BIO3, BIO7, BIO11, BIO13, BIO15, BIO18
9	Yellow-throated marten	BIO2, BIO7, BIO10, BIO11, BIO15, BIO18

Table. 4.6. The Maximum and Minimum value of the variables used in the Species Distribution Model in the Hotspot region

BIO1 = Annual Mean Temperature	-19 to 26 °C
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	7 to 15 °C
BIO3 = Isothermality (BIO2/BIO7) (×100)	34 to 52 %
BIO4 = Temperature Seasonality (standard deviation ×100)	261 to 691 °C
BIO7 = Temperature Annual Range (BIO5-BIO6)	16 to 32 °C
BIO9 = Mean Temperature of Driest Quarter	-20 to 22 °C
BIO10 = Mean Temperature of Warmest Quarter	-11 to 29 °C
BIO11 = Mean Temperature of Coldest Quarter	-18 to 21 °C
BIO13 = Precipitation of Wettest Month	66 to 2825 mm
BIO14 = Precipitation of Driest Month	0 to 28 mm
BIO15 = Precipitation Seasonality (Coefficient of Variation)	63 to 142 mm
BIO18 = Precipitation of Warmest Quarter	142 to 6124 mm
Elevation	14 to 8081 m

Model Fitting

We used the SDM package in R, Core 4.1.1, with a training and testing data set with 10 per cent of data kept as test data. Since we only use location presence, the package created 000 background points for presence using random applications. We tested the species distribution model using multiple bootstrapping methods. We used bootstrapping methods such as GLM (Generalised Linear Models), BRT (Boosted Regression Trees), RF (Random Forests), MaxEnt (Maximum Entropy), MARS (Multivariate Adaptive Regression Splines), and CART (Classification And Regression Trees). We created the variable importance with confidence intervals using the mean value of the variable's contribution. Response curves fitted the species' response to the range of its predictor variable. We created ensemble models with a weighted average and then used AUC predictions to create a raster.

Result

The use of AUC (Area Under Curve) along with TSS (True Skill Statistic) is one of the useful methods to measure the performance of the created distribution models (Shabani et al., 2018). The estimated AUC value for various models and TS ranges from 0.97 to 0.62.

The TSS value ranges from 0.93 to 0.25 (Table 4.7). The higher AUC scores indicate that the predictions outperform the random distribution. The Maxent model performed well for predicting Asiatic Black Bear (AUC = 0.79, TSS = 0.68), Sun Bear (AUC = 0.85, TSS = 0.68), Mishmi Takin (AUC = 0.93, TSS = 0.85) and Sambar (AUC = 0.91, TSS = 0.77). The case of the Asiatic golden cat (AUC = 0.96; TSS = 0.91), the mainland leopard cat (AUC = 0.76; TSS = 0.55), the yellow-throated marten (AUC = 0.96; TSS = 0.85), the mainland serow (AUC = 0.97; TSS = 0.93) and the northern muntjac (AUC = 0.91; TSS = 0.77) were estimated by the random forest model.

Variable contribution

Table 4.8 displays the relative variable contribution of the climate variables in the model's prediction. It was found that the mean annual temperature in the coldest quarter (100%) had the most impact on the model's prediction of the Asiatic black bear suitability area. This value was followed by the mean annual temperature in the driest quarter (49.9%), the elevation (34.40%), and the mean annual temperature in the driest quarter (46%) (Fig. 4.5a). Slopes (33.70%) contributed to the prediction of sun bear habitats, while the mean diurnal range (14.40%) followed (Fig. 4.5b). The three main variables figure out habitat occupancy of the Asiatic golden cat (Fig. 4.5c). The first is the mean diurnal range, which is the average of the monthly highest and lowest temperatures (6.64%). The second and third are the mean temperature for the warmest quarter (30.80%) and the annual temperature range (22.70%). We discovered a strong link (88% of the time) between the Mishmi Takin's ability to survive in certain types of habitats and changes in temperature throughout the year, which had a considerable effect on the models (Fig. 4.5d). The slope (47.90%) plays a major role in our models as a variable for the prediction of the mainland serow, followed by elevation (26.80) and the mean altitudinal range (17.50), which also shows a considerable participation (Fig. 4. 6a). The elevation (37.50%) plays a major role in prediction as a variable for the northern red muntjac (Fig. 4.5e). If you want to guess what the potential distribution will be, you can use the mean annual diurnal range (23%), the mean annual temperature range (30.90%), the mean annual temperature for the coldest quarter (31.50%), and the mean annual precipitation for the wettest month (27.80%). Our models of Sambar distribution (Fig. 4.5f) took into account the role of elevation (43.50%) and the seasonality of rainfall (25.70%) at higher values. We made predictions about the mainland leopard cat and the yellow-throated marten, two mesocarnivores, based on the amount of rain that fell in the warmest quarter (40.80%) and the average daily range (40.20%). The former species (Fig. 4.6b) benefitted more from the annual temperature range (30.90%), while the latter species benefitted more from the mean temperature (°C) in the coldest quarter (89.20%) and the annual temperature range (25.80%) (Fig. 4.6c).

Table. 4.7. Predicted AUC (Area Under Curve) and TSS (True Skill Statistic) calculated for each species using different methods (highest values are given in bold)

Species	Models	AUC	TSS
Asiatic Black bear	GLM	0.75	0.63
	BRT	0.71	0.56
	RF	0.74	0.61
	MAXENT	**0.79**	**0.68**
	MARS	0.63	0.32
	CART	0.62	0.25
Sun Bear	GLM	0.72	0.51
	BRT	0.84	0.62
	RF	0.83	0.65
	MAXENT	**0.85**	**0.68**
	MARS	0.82	0.61
	CART	0.75	0.51
Asiatic golden cat	GLM	0.86	0.71
	BRT	0.94	0.86
	RF	**0.96**	**0.91**
	MAXENT	0.91	0.81
	MARS	0.89	0.79
	CART	0.65	0.33
Mainland leopard cat	GLM	0.7	0.48
	BRT	0.73	0.5
	RF	**0.76**	**0.55**
	MAXENT	0.73	0.54
	MARS	0.68	0.48
	CART	0.7	0.36
Yellow-throated Marten	GLM	0.89	0.7

	BRT	0.91	0.74
	RF	**0.96**	**0.85**
	MAXENT	0.94	0.76
	MARS	0.92	0.75
	CART	0.81	0.59
Mishmi Takin	GLM	0.92	0.85
	BRT	0.92	0.86
	RF	0.91	0.85
	MAXENT	**0.93**	**0.85**
	MARS	0.78	0.72
	CART	0.66	0.41
Mainland Serow	GLM	0.92	0.83
	BRT	0.96	0.88
	RF	**0.97**	**0.93**
	MAXENT	0.96	0.88
	MARS	0.93	0.84
	CART	0.83	0.69
Northern red muntjac	GLM	0.68	0.41
	BRT	0.82	0.58
	RF	**0.91**	**0.77**
	MAXENT	0.83	0.6
	MARS	0.82	0.61
	CART	0.76	0.52
Sambar	GLM	0.73	0.51
	BRT	0.85	0.66
	RF	0.86	0.73
	MAXENT	**0.91**	**0.77**
	MARS	0.88	0.71
	CART	0.7	0.4

Table 4.8. Relative variable importance in performing model

Variable	Species								
	Asiatic black bear	Sun bear	Asiatic golden cat	Mishmi takin	Mainland Serow	Northern red muntjac	Sambar	Mainland leopard cat	Yellow-throated marten
	Relative variable importance								
Bio1	-	-	13%	-	-	-	-	-	-
Bio2	-	14.40%	64.10%	-	17.50%	23%	-	40.20%	0.10%
Bio3	-	-	96%	3.80%	-	-	12.60%	19.80%	-
Bio4	-	-	-	88%	-	-	-	-	-
Bio5	-	-	-	-	-	-	-	-	-
Bio6	-	-	-	-	-	-	-	-	-
Bio7	46%	-	22.70%	6.90%	19.70%	23.40%	-	30.90%	25.80%
Bio8	-	-	-	-	-	-	-	-	-
Bio9	49.90%	-	-	-	-	-	-	-	-
Bio10	51%	-	30.80%	-	-	-	10.90%	-	50.80%
Bio11	100%	4.50%	-	-	32.20%	22.40%	15.20%	31.50%	89.20%
Bio12	-	-	-	-	-	-	-	-	-
Bio13	-	-	-	-	-	27.80%	-	23.70%	-
Bio14	-	-	-	-	-	-	1%	-	-
Bio15	5.10%	2.70%	-	-	4.10%	-	25.70%	13.80%	16.40%
Bio16	-	-	-	-	-	-	-	-	-
Bio17	-	-	-	-	-	-	-	-	-

Bio18	0.70%	0.60%	2.20%	-	1.10%	0.20%	6.90%	40.80%	0.30%
Bio19	-	-	-	-	-	-	-	-	-
Elevation	34.40%	5.60%	9.70%	0.20%	26.80%	37.50%	43.50%	22.10%	14.50%
Aspect	1%	0.30%	1.20%	0.70%	0.10%	0.10%	1.10%	5.70%	1%
Slope	0.40%	34.70%	35.7	18%	47.90%	0.80%	0.30%	21.40%	19.60%
Terrain Ruggedness Index	0%	4.70%	0.30%	0.40%	0.60%	0.40%	0.20%	0.80%	0.20%
Landuse Landcover	0.50%	5.90%	3.80%	5%	1.80%	0.90%	2.40%	6.60%	3.30%

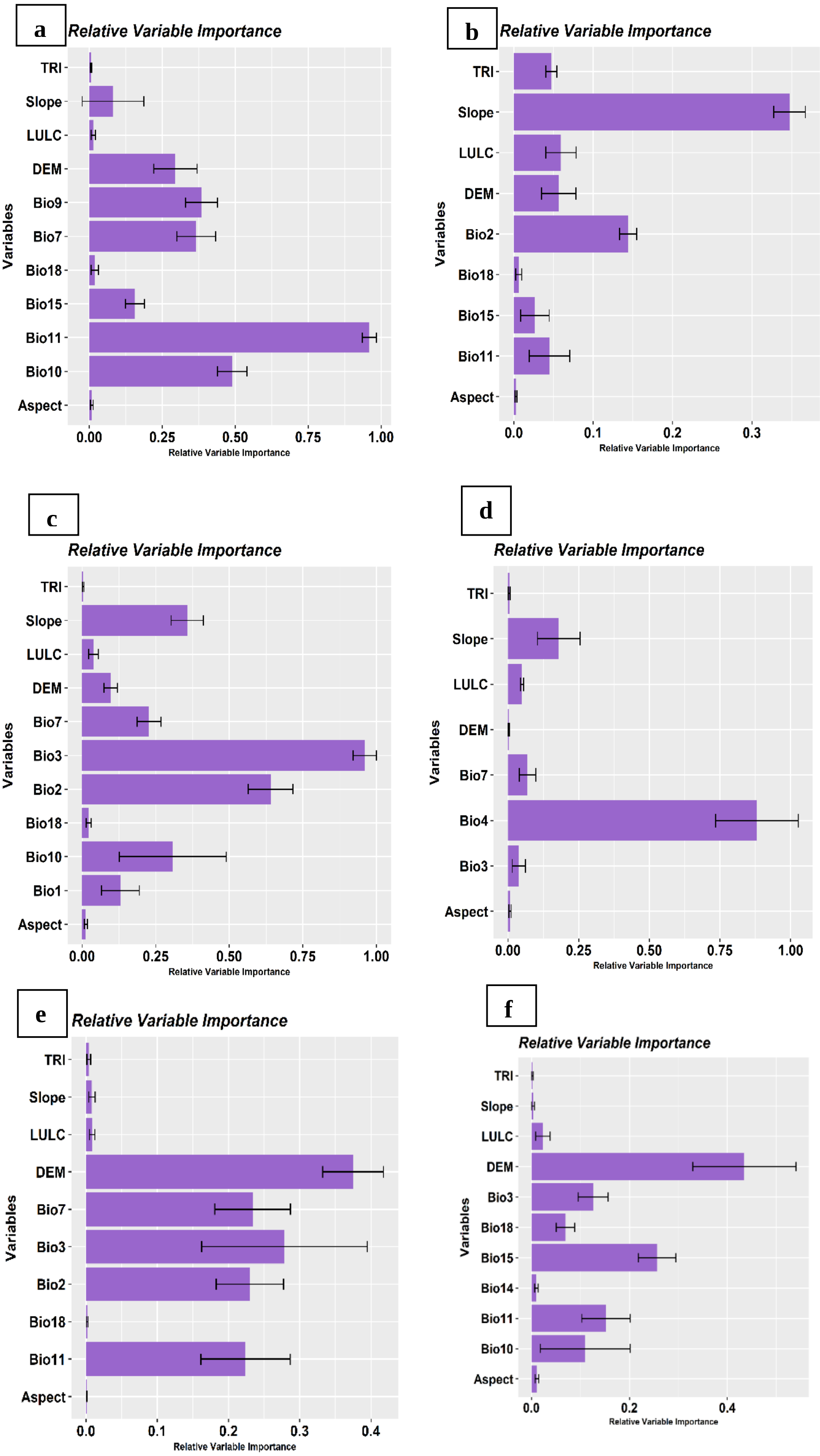

Figure 4.5. Species-wise Relative Variable Importance of different variables in modelling (a) Asiatic Black bear, (b) Sun Bear, (c) Asiatic golden cat, (d) Mishmi Takin, (e) Northern red muntjac, and (f) Sambar.

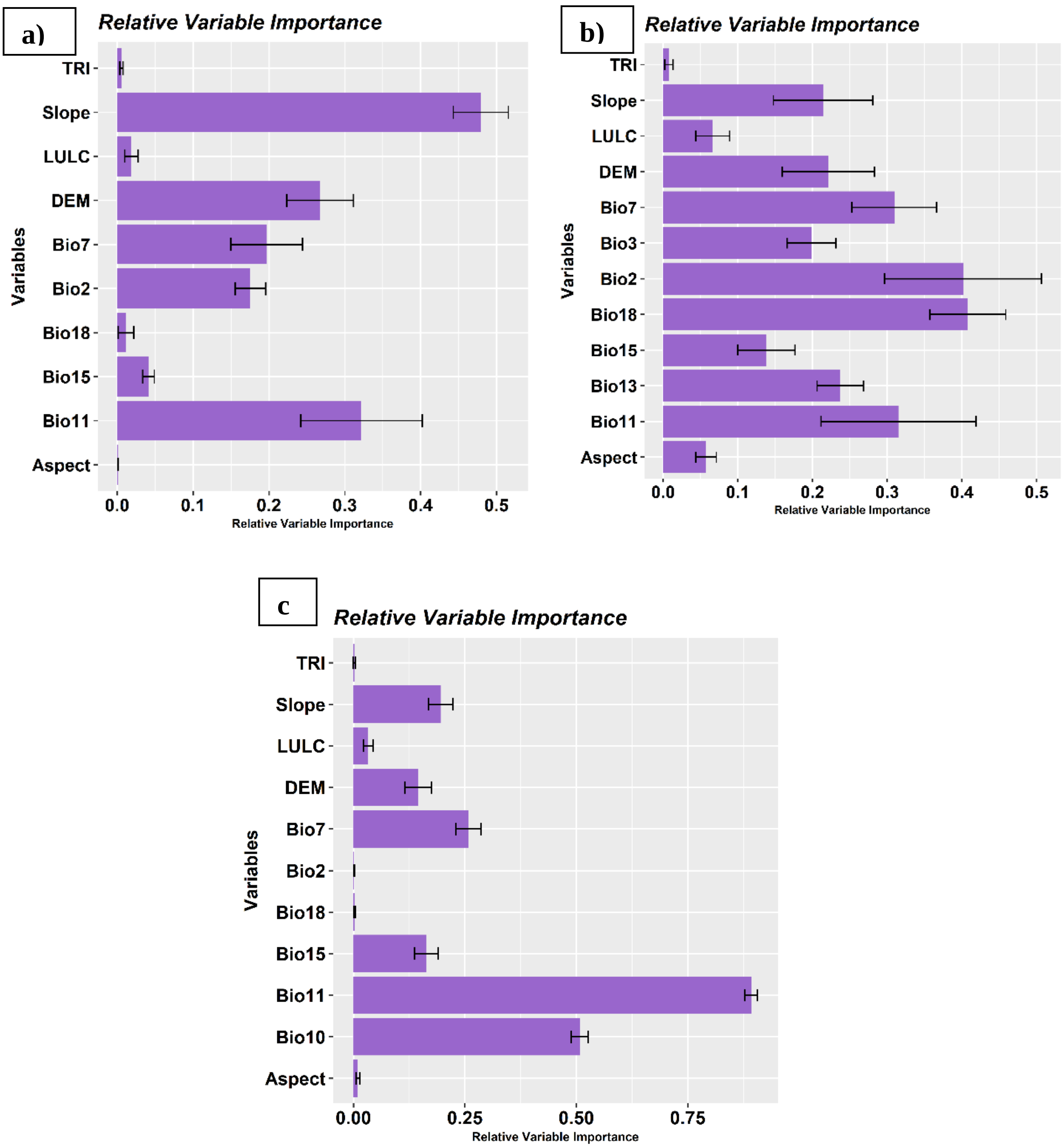

Figure 4.6. Species-wise Relative Variable Importance of different variables in modelling a) Himalayan serow, (b) Mainland leopard cat, and (c) Yellow-throated Marten

The environmental variables used to create a partial response curve to show how different variables affect the likelihood of where the Asiatic black bear occupancy show that black bears may be able to find a home in areas that get a lot of rain. These variables are Bio15 (Precipitation Seasonality) and Bio18 (Precipitation of Warmest Quarter). The distribution map also identifies a marginal rise in the elevation curve between 2000 and 3000.

It also shows areas with the coldest quarters, and the range with negative temperatures is probably not suitable for the distribution of black bears (Fig. 4.7). Elevation, slopes, and rainfall (Bio18: Precipitation in Warmest Quarter) also influence the likelihood of a sun bear distribution. The forest and grassland cover are most favourable for sunbear distribution. The increase in Bio15 (precipitation seasonality) shows a negative impact (Fig. 4.8). The Asiatic golden cat prediction indicates that the area likely has excellent habitats with a Bio18 (precipitation warmest quarter) distribution. The higher the elevation, the more likely it is that there will be habitats available. Predictions also show that habitats with steep slopes are likely to be good habitats (Fig. 4.9). Bio4 (temperature seasonality) demonstrates that habitats with high yearly temperature variability are suitable for the distribution of Mishmi Takin. It was also noteworthy that Takins found suitable habitat at elevations above 4000 m (Fig. 4.10). The chance that a mainland serow will be able to find a habitat to occupy goes up as the Bio7 temperature (annual range) goes up. The chances also increase at elevations above 4000 meters, and steep slopes can be favorable for distribution (Fig. 4.11). The Northern Red Muntjac's Bio2 (mean diurnal range) was found to be an important variable in its habitat occupancy, which is related to temperature changes. The sharp drop in response to Bio3 (isothermality) shows that the animal can't adapt to places where the temperature changes from day to night are too small. The range below 100 shows less variation with the monthly average (Fig. 4.12). Bio15 (Precipitation Seasonality) indicates that an increase in rainfall increases the likelihood of finding the Sambar in more locations. However, in terms of vegetation and land use, there is a sharp drop in the probability distribution, which is also indicated by a peak in the forest category (Fig. 4.13). Leopard cats prefer habitats with specific precipitation conditions, as indicated by the variables Bio18 (precipitation in the warmest quarter) and Bio15 (precipitation seasonality). Besides that, Bio3 (isothermality), which is temperature, also has an effect on this mesocarnivorous leopard cat as it gets bigger

(Fig. 4.14). The yellow-throated marten's habitat suitability will also likely be affected by the Bio15 variable for seasonality of precipitation; and followed by slopes (Fig. 4.15).

Regional Habitat Suitability

The predicted distribution of Asiatic black bears covers an area with elevation ranges from above 2000 m to 4000 m. All the regions of Arunachal Pradesh have a continuous distribution probability of bears, with areas predicted to have marginal, moderate, and high suitability. These areas reveal that moderate areas act as buffers to highly suitable habitats. This conclusion suggests that a good availability of habitat that could serve as a connecting habitat is available. The availability also subjected to various other factors (Fig. 4.16a). The suitable habitat predicted for the sun bear also overlaps with that for the black bear. The Himalayan region and the higher elevations of the Indo-Burma Hotspot offer highly suitable areas (Fig. 4.16b). The habitat above 3000 m of elevation is found to be suitable for the Asiatic golden cat, and all along the high altitudes favour the habitat availability (Fig. 4.16c). The range of most of the suitable regions is expected to be marginally suitable for mesocarnivores, like the mainland leopard (Fig. 4.16d), and all high-altitude regions are expected to be very suitable for the yellow-throated marten (Fig. 4.16e). The mountain-dwelling species such as Mishmi takin and Serow are likely to be able to find suitable habitat in mountainous areas on the edges of both hotspot regions (Fig. 4.16f & Fig. 4.17a). The Mishmi Takin shows that there may be continuous habitat all along the Himalayan region and the Indo-Burma region. This evidence indicates that the species will be able to move from China to these areas where habitat is available (Fig. 4.16f). Most of the forested areas of the region serve as habitats for the other two ungulates, Sambar and Red Muntjac (Fig. 4.17b &Fig. 4.17c). However, the prediction indicates only marginal suitability. The availability is evident to a greater extent in the prediction.

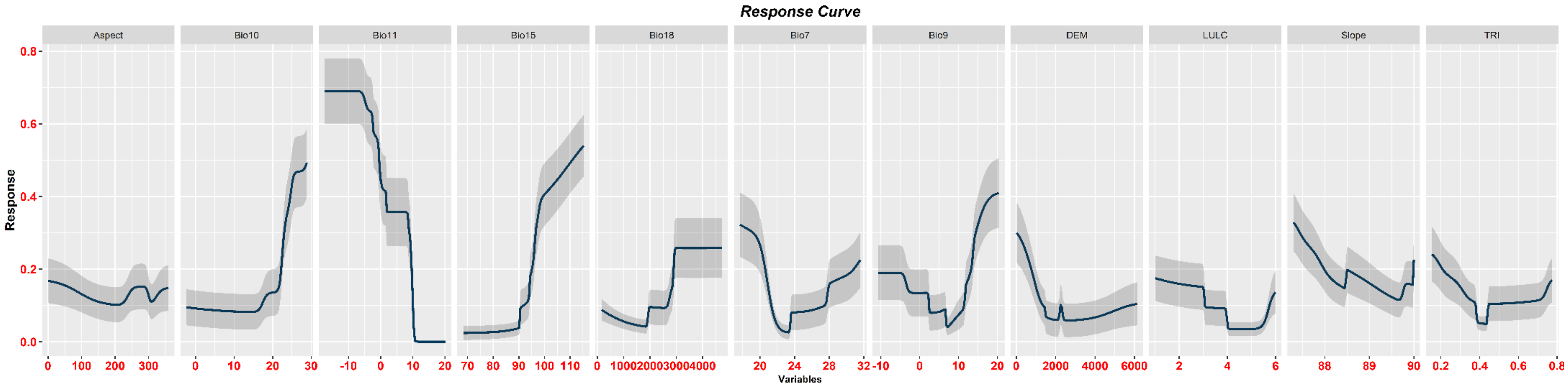

Figure 4.7. The Response curve of the variables in Model Prediction for Asiatic Black Bear (Variables from left to right Aspect, Bio10, Bio11, Bio15, Bio18, Bio7, DEM, LULC, Slope, and TRI)

Figure 4.8. The Response curve of the variables in Model Prediction for Sun Bear (Variables from left to right Aspect, Bio11, Bio15, Bio18, Bio 2, DEM, LULC, Slope, and TRI)

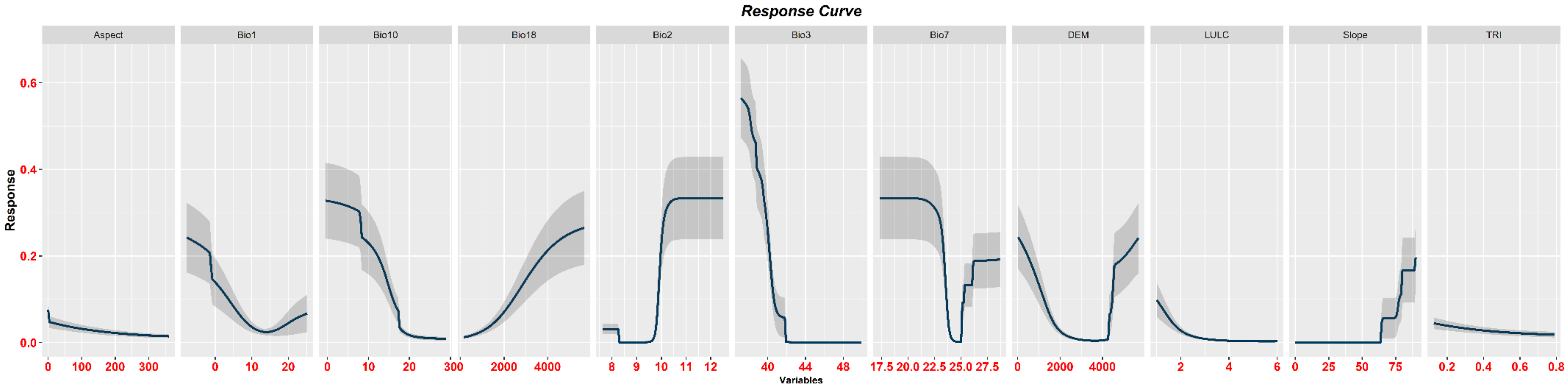

Figure 4.9. The Response curve of the variables in Model Prediction for Asiatic Golden Cat (Variables from left to right Aspect, Bio1, Bio10, Bio18, Bio 2, Bio3, Bio7, DEM, LULC, Slope, and TRI)

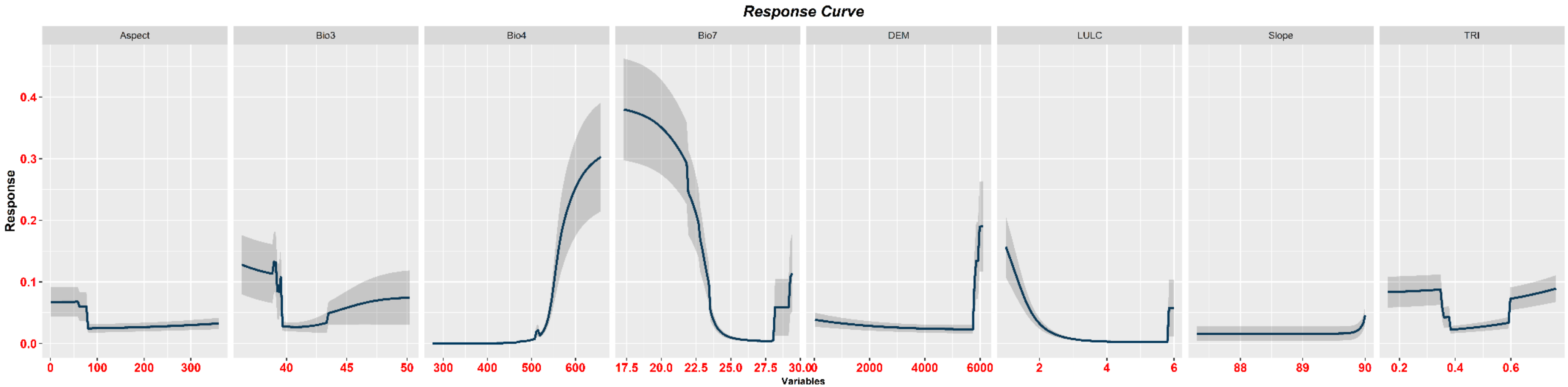

Figure 4.10. The Response curve of the variables in Model Prediction for Mishmi Takin (Variables from left to right Aspect, Bio3, Bio4, Bio7, DEM, LULC, Slope, and TRI)

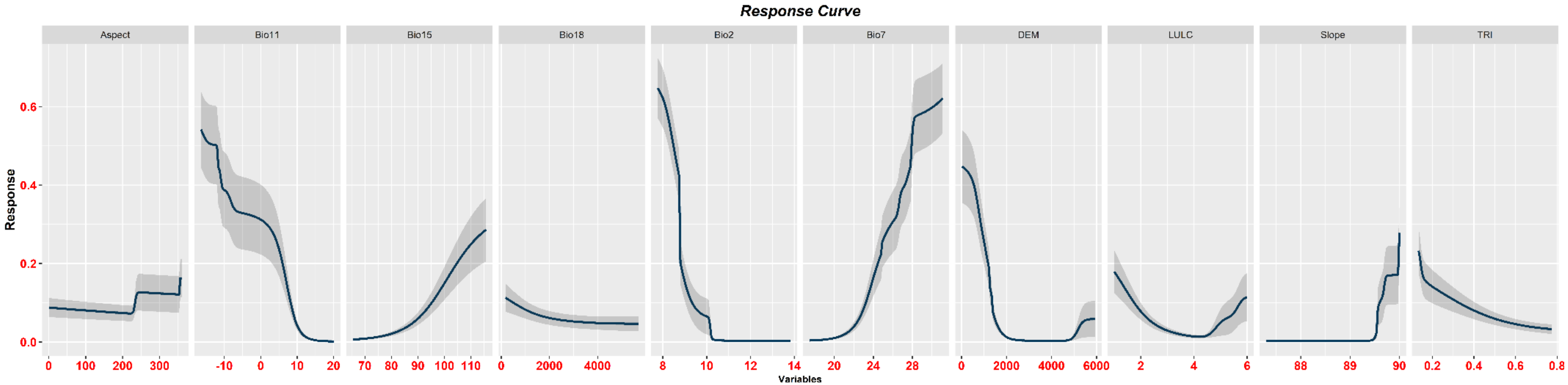

Figure 4.11. The Response curve of the variables in Model Prediction for Mainland Serow(Variables from left to right Aspect, Bio11, Bio15, Bio18, Bio2, Bio7, DEM, LULC, Slope, and TRI)

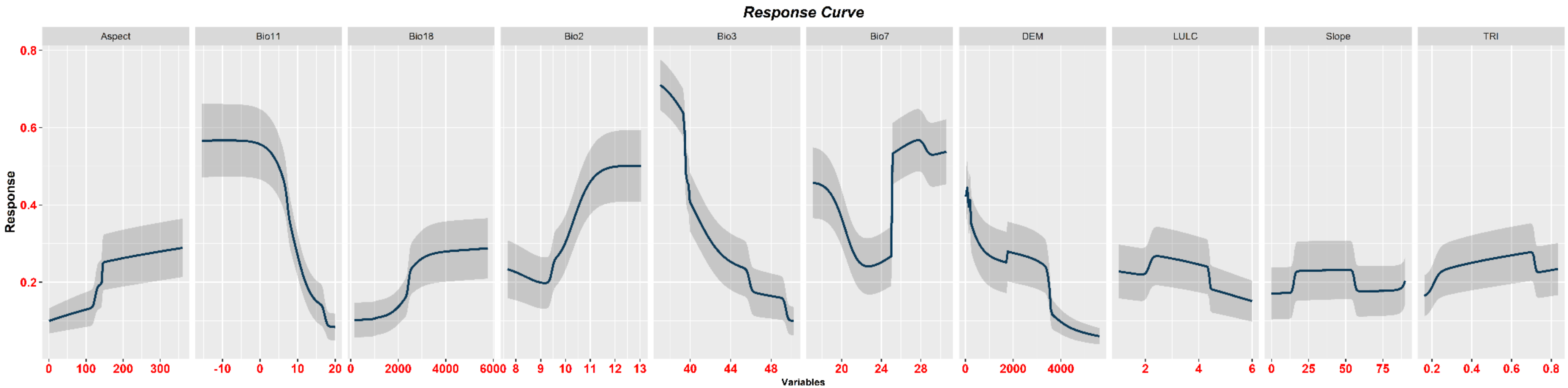

Figure 4.12. The Response curve of the variables in Model Prediction for Northern Red Muntjac (Variables from left to right Aspect, Bio11, Bio18, Bio12, Bio3, Bio7, DEM, LULC, Slope, and TRI)

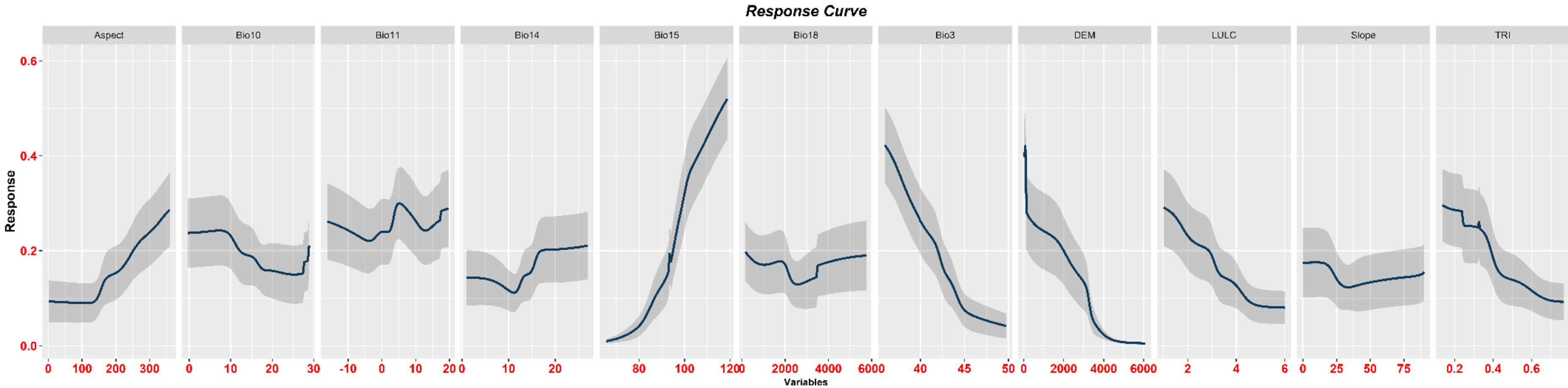

Figure 4.13. The Response curve of the variables in Model Prediction for Sambar (Variables from left to right Aspect, Bio10, Bio11, Bio14, Bio15, Bio18, Bio3, DEM, LULC, Slope, and TRI)

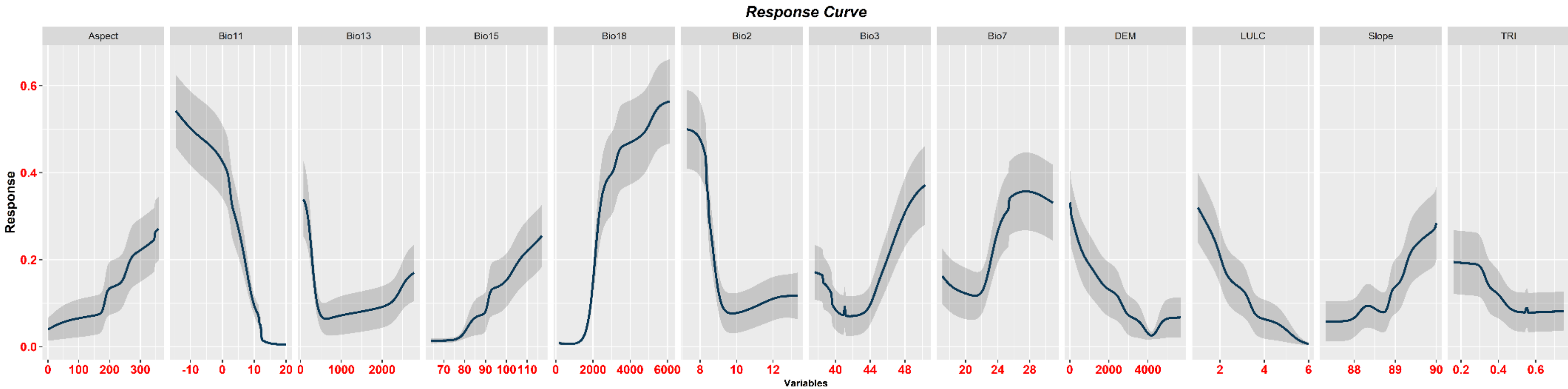

Figure 4.14. The Response curve of the variables in Model Prediction for Leopard Cat (Variables from left to right Aspect, Bio11, Bio13, Bio15, Bio18, Bio2, Bio3, Bio7, DEM, LULC, Slope, and TRI)

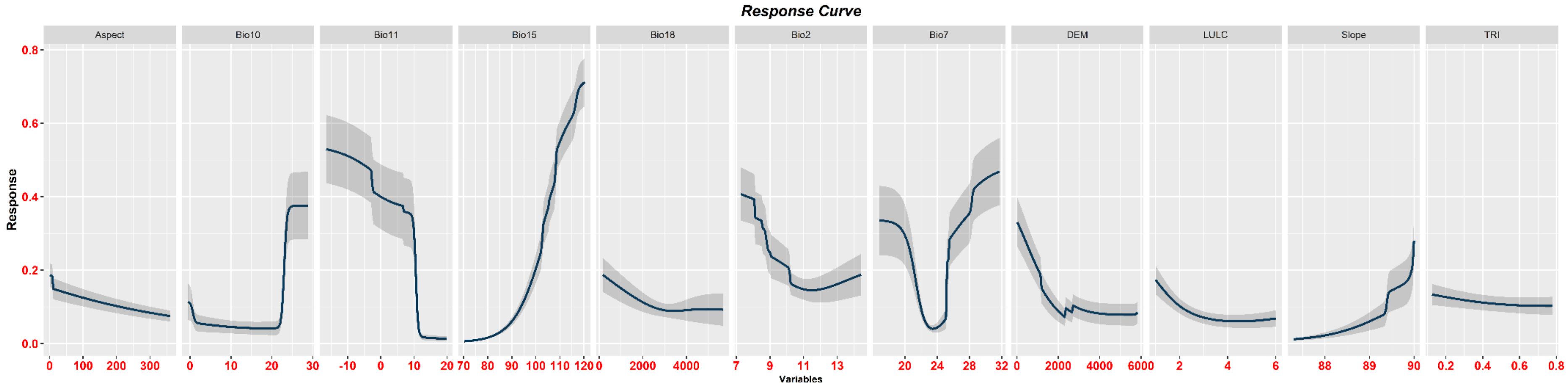

Figure 4.15. The Response curve of the variables in Model Prediction for Yellow-Throated Matren (Variables from left to right Aspect, Bio10, Bio11, Bio15, Bio18, Bio2, Bio7, DEM, LULC, Slope, and TRI)

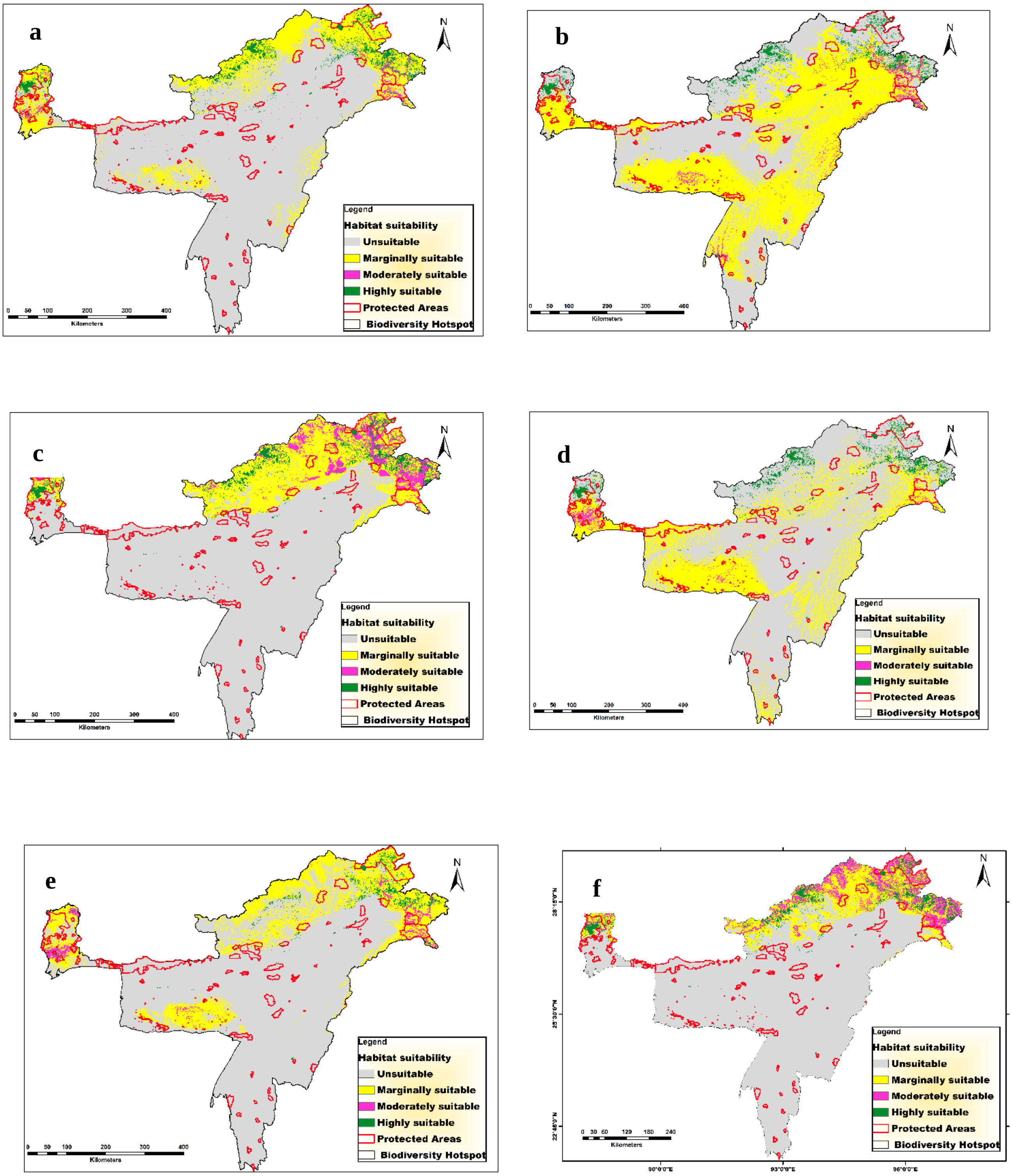

Figure 4.16. The potential distribution of each species predicted by Species Distribution Modelling in the Biodiversity hotspot region (a) Asiatic Black bear, (b) Sun Bear, (c) Asiatic golden cat, (d) Mainland leopard cat, (e) Yellow-throated Marten, and (f) Mishmi Takin.

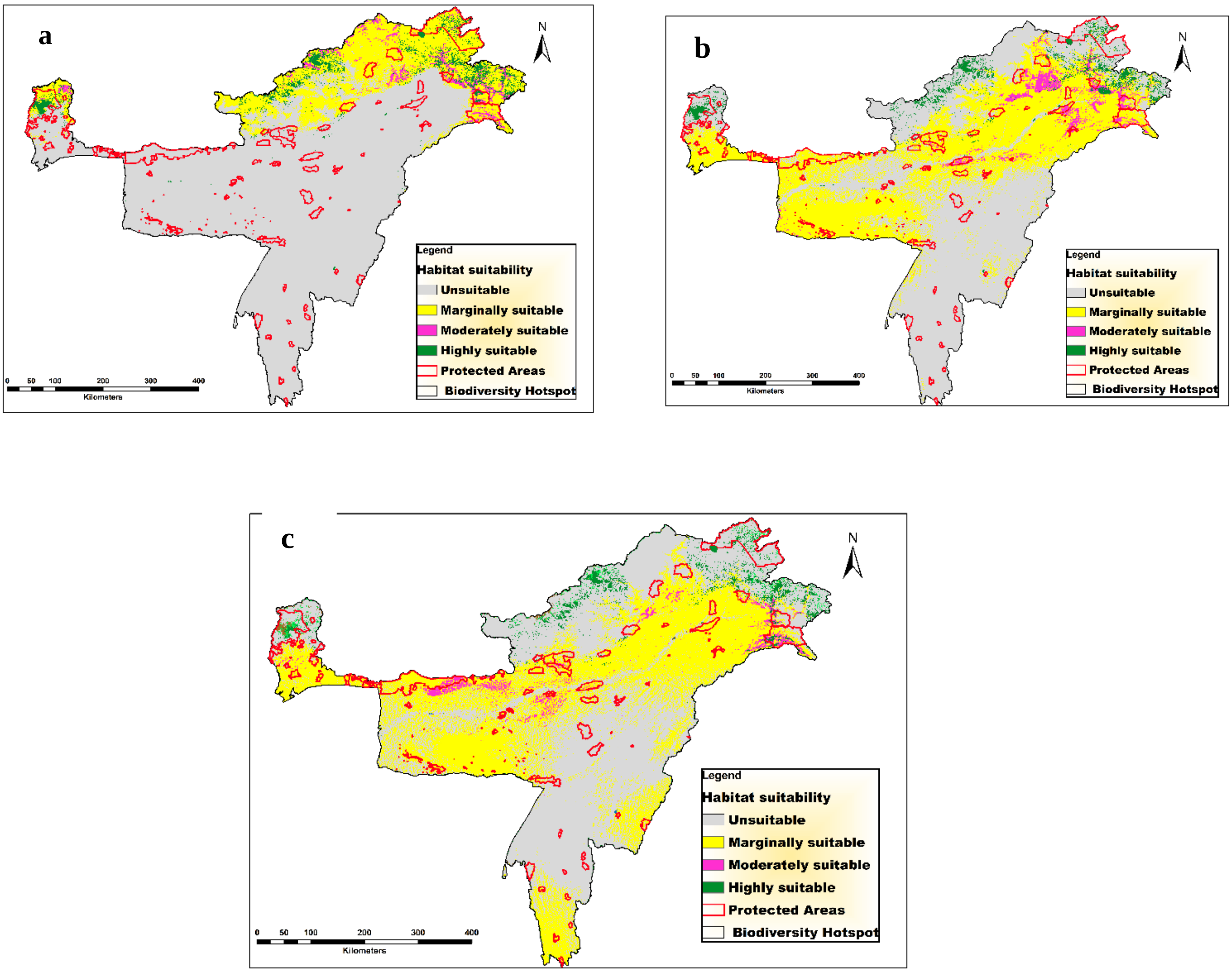

Figure 4.17. The potential distribution of each species predicted by Species Distribution Modelling in the Biodiversity hotspot region a) Mainland serow, b) Northern red muntjac, and c) Sambar

Predicted Habitat Suitability in Landscape Unit

The intensive study area was found to be a favourable habitat for the chosen species based on the habitat suitability prediction for that species in that region. We predict that the entire area is suitable for the distribution of Asiatic black bears, northern muntjacs, and mainland leopard cats (Table. 4.9). The mainland serow and the yellow-throated marten are the only species whose predicted habitat suitability is less than 50%. This means that the unsuitable area is greater than 50% (Fig. 4.15). More than 5000 sq.km of the area is identified to have available habitat for distribution, of which more than 1000 sq.km are predicted to have a threshold of more than a viable habitat. More than 1000 sq. km of area is predicted to be suitable for the distribution of the golden cat, which is near threatened (Table. 4.9). Habitat suitability was predicted for large mammals, such as the sambar, as well as for small mammals, such as the yellow-throated marten (Table. 4.9). These results shows that the landscape unit is one of the viable habitat for the mammalian community and it also capable of acting as buffer to the protected areas situated in the region for Habitat Use and Population dynamics (Fig. 4.18).

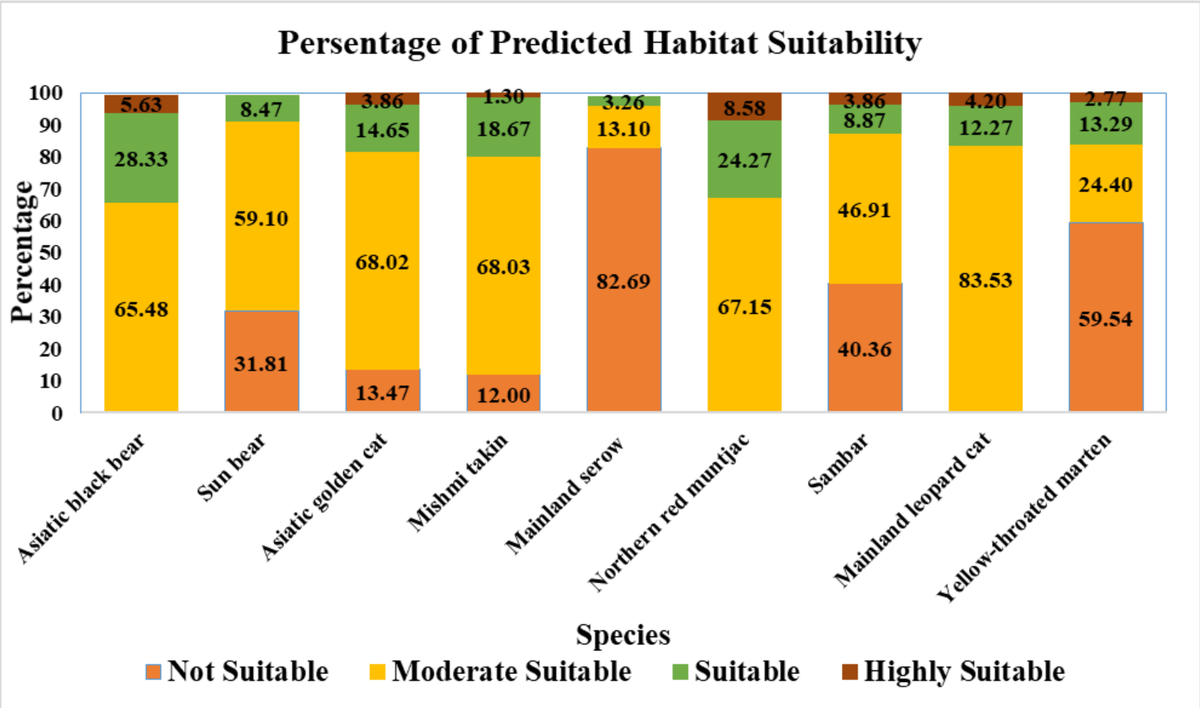

Figure 4.18. Percentage of Area of habitat suitability predicted for different mammal species in the Landscape unit

Table 4.9. Area of Habitat Suitability pPredicted for different mammal species in the Landscape unit

Predicted Habitat Suitability	Asiatic Black bear	Sun Bear	Asiatic golden cat	Mishmi Takin	Mainland Serow	Northern red muntjac	Sambar	Mainland leopard cat	Yellow-throated Marten
	Area in Sq. km								
Not Suitable	34.78	1952.23	826.73	736.63	5075.80	0.00	2477.04	0.00	3654.71
Marginally Suitable	4019.07	3627.83	4174.77	4175.56	803.81	4121.82	2879.35	5127.18	1497.77
Moderate Suitable	1738.83	520.07	899.45	1146.05	199.97	1489.86	544.57	753.23	815.67
Highly Suitable	345.39	37.94	237.11	79.83	58.49	526.39	237.11	257.66	169.93

Discussion

Species distribution is often profoundly influenced by landscape metrics (Turner, 1989), and thus, the use of modelling tools can be useful in species identification in landscapes in the past, present, and future (Semeniuk, 2011). The species distribution models (SDMs) were created using the fundamental ideas of ecology and biogeography. The SDMs show how species of interest interacts with its environment (Holdridge, 1947; Whittaker *et al*., 1973). The influencing factors could be biotic, abiotic or any factors which are considered non-influencing the very existence of a species in its niche. We must take into account the limitations of SDM when attempting to provide a minimum occurrence location for effective predictions. It is possible for our prediction models to select only 1% of the species recorded in our total study. This is because the occurrence location of the species meets the minimum required location for a basic prediction. We have included species of which five are Vulnerable (VU) categories, one species is Near Threatened (NT), and three are Least Concern (LC) as per IUCN. Our study focuses on the identification of the probable distribution of species. The current study only examined other factors, not PA networks, so adding these variables could make it even more important to find the best places for different mammals to occur. Systematic ground surveys can confirm the presence of species in an area, which can help make information about where they distribute more clear and add value to the distribution model (Greaves *et al*., 2006).

The state of Arunachal Pradesh has confirmed presence of two bear species namely the Sun bear and the Asiatic black bear. The presence of the Asiatic black bear was confirmed in 14 PAs and the Sun bear in five PA's from the same list and was unknown in others (Sathyakumar & Anwarrudin, 2007). The Asiatic black bear, which occurs from Central to South Asia was expected to have a population decline of 30% to 40% as a consequence of various negative impacts (Waqar *et al*., 2024). Understanding the possible availability of a habitat will favour its management implications (Bista *et al*. 2018). The presence of black bears was recorded at elevations as low as 75 m, which was reported recently from Assam in Kaziranga National Park (Borah, 2022). The distribution of Asiatic black bears is reported at an elevation range from 1200 to 3000 asl across 83 PAs from Jammu and Kashmir to the northeastern states (Sathyakumar, 1998). The information about the status of the species is still scarce (Sethy, 2015). However, the incidences of black bear-man conflict are escalating (Sunar, 2012), which further necessitates comprehensive evaluation of possible distribution. Studies in the Himalayan region also reported the influence of precipitation and elevation on predicting the distribution of the Asiatic black bear (Babar, 2021). The patchy distribution of sun bears is reported from the northeastern states of Arunachal Pradesh, Nagaland, Manipur, Mizoram, and Meghalaya (Higgins, 1932; Blanford, 1891; Choudhry, 1989). The species range along mainland Southeast Asia was recently mapped (Chauhan, 2009), and the photo of the sun bear from Namdhapa National Park was also a rare event, even though it was known that the species occur in these forests (Karanth & Nichols, 2000). In Namdapha National Park (Sethy, 2016), it is found that the the sun bear used slopes in different types of forests as habitat. This also corroborates with our findings.

We found that the prediction on distribution of Asiatic golden cat was influenced by variables, like heights, slopes, and rainfall, Previous studies have reported the species' distribution across an elevation range exceeding 4000 asl (Yongdrup, 2024). The presence of Asiatic golden cats was reported in Arunachal Pradesh (Datta *et al*., 2008), Sikkim (Bashir *et al*., 2011), Assam (Choudhury, 2007), Mizoram (Gouda *et al*., 2019), and Nagaland (Longchar, 2024) and also recently reported from Neora Valley of West Bengal (Chatterjee, 2018). Given the inherent scope to identify more potential areas for the golden cats, our study predicts almost all the continuous regions of mid to high elevation as marginally suitable to highly suitable for possible distribution of the species.

The distribution of the mainland serow was identified at an altitudinal range from 2000 to 3000 asl (IUCN). The species shifted from Near Threatened (NT) in the year 2010 to Vulnerable (VU) by 2020 and was still considered one of the elusive Asiatic ungulates distributed in the scattered habitats of its historical ranges (Prakesh, 2012). Our prediction also states the distribution probability above such elevation, and elevation also contributed to modelling and distribution. The barking deer were found to be common in the entire landscape (Steinmetz *et al*., 2008). In general, the population of species like the barking deer is expected to be lesser compared to gregarious ungulates (Barrette, 2004). Our models predicted that the species will occupy most of the forests in the hotspot region. The SDMs predicted sambar distribution well suggesting the species occurs over a very large area as the species in generally highly adaptable (Schaller, 1967, Timmins, 2015).

The leopard cat inhabits elevations above 3000 m and the five states of Northeast India (Ghimirey, 2022). The lack of critical evaluation and uncertainty about the species suitability in regional predictions are major concerns for a species with an unevaluated distribution status. Researchers found the species inhabiting rugged terrains and river valleys at altitudes ranging from above 500 m msl to 4500 m msl (Mallick, 2020; Hutipong, 2024). Despite being present in various habitats; diurnal species will transition to nocturnal behaviours in human-dominated regions. Prediction shows the temperature range plays a major role in habitat prediction; the species distribution was predicted to lose most of its habitat in future climate scenarios (Ritam, 2022). Mishmi takin's distribution ranges from 1750 to 4100 m (Wen-Bin, 2019) a range that aligns with our own predictions. The species was also reported to use higher elevation habitats in summer and autumn and move towards lower elevations during winter and spring, which we also found habitats with temperature seasonality are suitable habitats (Guan, 2013).

Our prediction indicates that the Protected Areas are functioning as reasonably suitable habitats. Adding variables, such as protection and other management activities that are being practiced in the PAs, might include factors that explicitly predict the possibility of distribution. The range extent map provided by IUCN, is also on par with the prediction created by our models. As our model shows, suitability ranges from not suitable to marginal, moderate, and highly suitable; these can help you understand the probabilistic distribution of the species. Our goal is to obtain an insight into the distribution probability of the species of interest within our selected landscape unit. The predictions show that the selected landscape unit is one of the high-priority areas that can provide a viable habitat for the species. Migratory species, like the Mishmi takin, are known to shuttle or move between habitats across three different biogeographic regions. Our predictions also indicate that there is additional potential habitat for this subspecies. This region also encompasses the areas shared by another endangered species, the Bhutan takin.

In our study, we found that precipitation inflenced most of the models make predictions. Yusefi (2021) has found that precipitation significantly influences ecological factors such as species richness. Especially in hotspots located in mountainous regions, mammalian species at various trophic levels, and particularly large mammals, experience greater impact (Heffelfinger, 2018; Ogutu & Owen, 2020). The evaluation of the impact on the distribution of smaller mammals still exists as a complicated process for scientific communities (Beissinger, 2000). We have made predictions exclusively for the selected species within the landscape selected for prediction. These predictions would be useful to understand the community-level interactions with other species. The top predators, such as the tiger *(Panthera tigris*), leopard *(Panthera pardus*), and dhole (*Cuon alpinus*) have been recorded in these regions. High elevations exceeding 3600 m a.s.l. also had recent records of tigers (Adhikarimayum & Gopi, 2018). Novel understanding such as this at the community level would provide important insights and perspectives useful for adaptive management. Sambar is one of the more important prey for umbrella species like the tigers, and thus constitutes the mainstay in large mammal conservation. Previous research identified the Mishmi takin as one of the important prey species for tigers, highlighting the need to examine their habitat use in this landscape (Ajith, 2019). Researches identified the mainland serow as a major prey for the clouded leopard, a species also distributed in this region (Rasphone, 2022). Our study area is surrounded by tiger reserves and wildlife sanctuaries, so it's clear that the continuous lands outside of the PAs can also be beneficial homes for top predators.

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Chapter –V

Diel Activity Pattern and Co-occurrence of Mammal Species in the North-eastern Landscape, Arunachal Pradesh, India

Abstract

Diel activity of mammals reflects inter and intraspecific behavior with implications for spatial planning towards conservation management. The assemblage of mammalian species in an Eastern Himalayan landscape unit was generated from 2018 to 2020 using camera traps. We used timestamp photographs to understand the circadian rhythms of the species through activity patterns, temporal overlap with respect to sunrise - sunset and spatial co-occurrence using R core. Among the recorded predators, Dhole was observed to be cathemeral. Most primate species show activity close to sunrise; however, the Arunachal Macaque was active during midday. The Wild Pig, which is nocturnal, also shows an activity peak before sunset. Temporal overlap among primates shows higher paired coefficients between stump-tailed macaque and capped langur with $\Delta = 0.76$. The Marbled Cat exhibits a higher intergroup overlap with Serow, Red Muntjac, and Sambar, with coefficients of 0.84, 0.82, and 0.72, respectively. Dhole has activity overlap with all the prey species (higher with Takin ($\Delta = 0.59$) and goral ($\Delta = 0.62$)). Within the Artiodactyl guild, temporal overlap was higher between the Serow and Red Muntjac ($\Delta = 0.81$). The probabilistic model of species co-occurrence shows species interactions among 16 out of 24 species. The black bear and sun bear show different diurnal activity peaks but no overlap or co-occurrence. The ethological information about Takin and few other small mammals are one of the prominent findings of the present study. A long-term study will reveal the spatiotemporal relationships among the species and aid management and conservation practices.

Introduction

Understanding the distribution and dynamics of vertebrate communities across a mosaic of landscapes in changing times is vital for conservation management (Thomas *et al*., 2001). Such community dynamics can be influenced by myriad forms of interspecific interactions amongst the species involved (Shameer *et al.*, 2022). Looking at how different species interact can give us important information about population changes. Conversely, it is possible to predict the composition and distribution of species involved by studying interactions. These interactions can provide insights on predation, parasitism, support, and cooperation. Despite its utility, assessing species interactions among free-ranging vertebrates is often challenging, particularly in forest environments (Caro, 2007). In such forested habitats, direct observations are difficult to make, and ad libitum observations often do not meet sample size requirements to carry out statistical analyses. To circumvent these challenges, in recent years, camera trapping has gained popularity as a reliable method of digital sampling in ecology (Wearn & Glover-Kapfer, 2019). Camera traps have revolutionised the unravelling of rare aspects of wildlife over the last few decades (Di Bitetti *et al*., 2009; Foster *et al*., 2013; Tambling *et al*., 2015; Cusack *et al*., 2017; Mori *et al*., 2020; Swan *et al*., 2004). To illustrate, for instance, we can characterise the activity pattern of a species in the wild using the time-stamped photo captures generated from camera traps. Despite the challenges, it is now possible to quantify species interactions involving rare and cryptic wildlife even in remote and rugged terrains.

In the twentieth century, methods for analysing data to understand the timing of species interactions improved due to progress in studying biological clocks (Sollberger, 1965). Animal activity in nature usually depends on their internal body processes and outside factors during the 24-hour daily cycle (Aschoff, 1963). The activity rhythms analysis provides an insight into community structure and co-existence in a forest ecosystem (Zhou *et* *al*., 2014; Liu *et al.*, 2013). One important part of niche selection for any species is how active it is at different times of the day (Norris *et al*., 2010; Pianka, 1973). We broadly classify the species' activity pattern as diurnal and nocturnal. Further information gleaned from activity patterns can be useful in elucidating whether a species is crepuscular or cathemeral in activity (Tattersall, 1988; Jacobs, 1993).

The Indo-Burma region is among the 25 global biodiversity hotspots with a high level of endemism and thus requires continuous focus for advancing conservation (Myers, 2000). Within the Indo-Burma region, northeast India (NE region henceforth) harbours disproportionately high biodiversity (Jain & Das, 2022). The NE region comprises mountain ranges of the Himalaya extending into Upper Burma, the Daphabum termination of the Patkoi range. Brooks *et al.,* (2006) identified the Eastern Himalayas as "crisis ecoregions," "biodiversity hotspots," "endemic bird areas," "megadiversity countries," and "global 200 ecoregions." This landscape is identified as a biodiversity hotspot that possesses a higher human population than all the other biodiversity hotspots (Mittermeier *et al*., 2004). The Eastern Himalayas possess a unique biodiversity assemblage due to various factors such as geological history, adaptive radiation, etc. (Guangwei, 2002). The Eastern Himalayas have one of the largest remaining intact evergreen forests in the whole of Asia (Ashton & Zhu, 2020). These evergreen forests act as habitats for diverse biodiversity. This NE region has identified more than 65% of mammals reported in the Indian subcontinent (Choudhury, 2013; Sharma, 2015). In the Eastern Himalayan landscape, there exists a gap in ecological knowledge and a need for enhancing research areas to create efficient biodiversity and conservation for the future (Kandel, 2016). IUCN states the region is composed of approximately 20% of species, which fall under the Vulnerable, Endangered, and Critically Endangered categories (Shrestha, 2022).

Ecological studies and expeditions in the recent past have discovered new mammalian species from the region (Talukdar, 2021; Gogoi, 2020). The variety of taxa in the area is influenced by the Indo-Malayan region of Southeast Asia, the Palearctic region, and the area's complicated climate and landscape. The biodiversity of such remote, inaccessible tropical forests is still in the stage of exploration. There are still gaps in research about how species interact in the junction of China, India, and Myanmar.

In recent years, camera trapping has gained popularity as a reliable method of digital sampling in ecology (Wearn & Glover-Kapfer, 2019). The camera trapping was identified as one of the feasible ways to characterise a species activity pattern in the wild. Time stamping on camera trap images records the temporal availability of any species in space (Frey *et al*., 2017; Sollmann, 2018). Also, improvements in circular data analysis methods (Ridout & Linkie, 2009; Rowcliffe *et al*., 2014) make it easier to learn about the activities of many species that are hard to sight (Frey *et al*., 2017). The present study focuses on mammalian species activity pattern and interaction within the species community in the study area. In this study, we have used temporal activity overlap and spatial co-occurrence as measure to understand species interaction within the species community.

Study area

The extreme northeast land mass of India lies in the state of Arunachal Pradesh which lies in the trans-Himalayas region with an area of greater than 83740 sq.km. The mountainous state possesses the north-south-running Himalayan Mountains and forms five major valleys of the state: (1) the Lohit, (2) the Kameng, (3) the Subansiri, (4) the Siang, and (5) the Tirap. The Tsangpo River of Tibet, when it reaches the region of Arunachal Pradesh, joins the river Dibang and the river Lohit and runs as the Brahmaputra in the Assam Plains. (Jain & Das, 2022). The state has more than 70 % of the area under forest cover. The major forest types fall under very dense forest, moist deciduous forest, and open forest (FSI, 2021). These comprise even more types of forests, including subtropical broad-leaved forests, subtropical pine forests, long stretches of temperate forest, and subalpine and alpine forests, which make up the forest floors (Kaul & Haridasan, 1987). The protected area network of the state includes 13 wildlife sanctuaries, 2 national parks, and 9 community reserves. Also three tiger reserves and two elephant reserves were declared in the state. The selected landscape unit falls in a region that is a continuous stretch of tropical forest landscape from the Hkawang Wildlife Sanctuary of Myanmar to the Dibang Wildlife Sanctuary of Arunachal Pradesh.

We conducted the study within this highly ecological network of forests. The unit includes regions of Kamlang Wildlife Sanctuary, which is also a Tiger Reserve; Anjaw Forest Division; Lohith Forest Division; and Dibang Forest Division. The area is surrounded by three protected areas: Dibang Wildlife Sanctuary, Namdapha National Park, and Tiger Reserve in the longitudinal ends, and Namai Forest Division and Nampong Forest Division in the latitudinal end in the Indian border. It shares the other end with the international boundaries of the Republic of China. Though the area falls under different administrative blocks, it is a continuous stretch of forest along the crisscrossed river valleys of the tributaries of the Dibang and Lohit Rivers (Fig. 5.1).

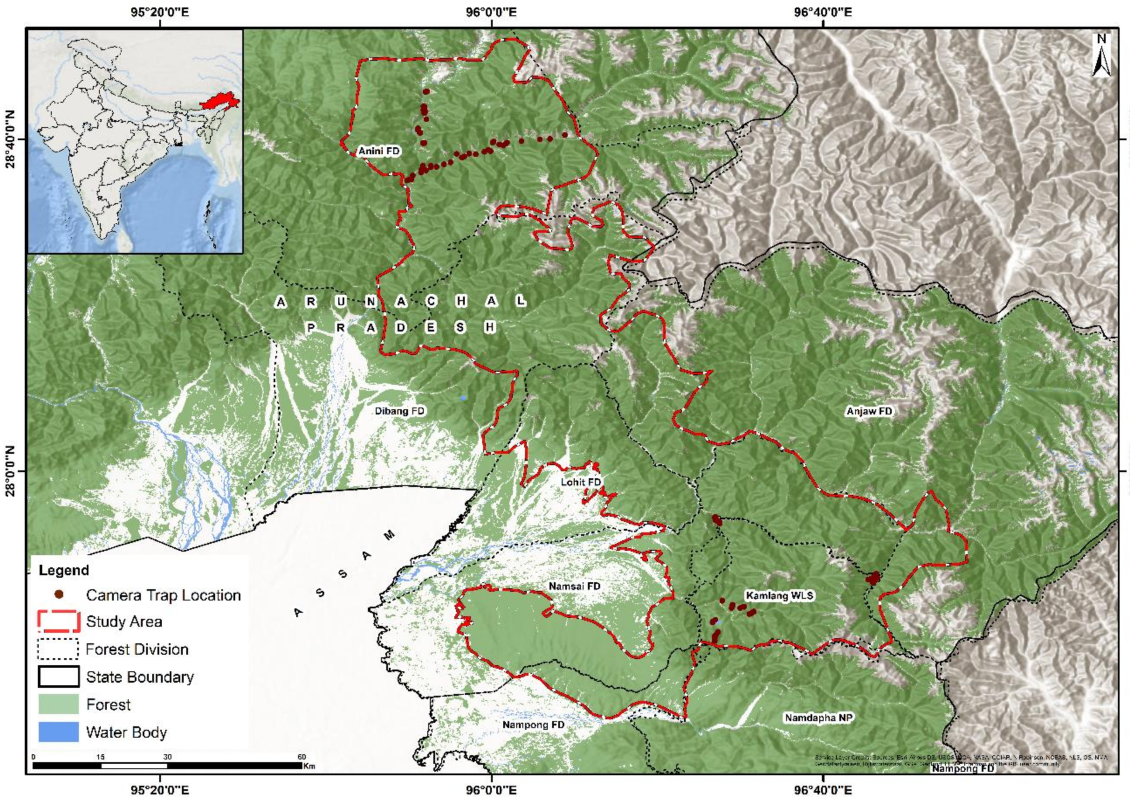

Figure 5.1. The study area and Camera trap monitoring stations

Methodology

Camera trap surveys

A reconnaissance survey was carried out along the identified and accessible locations in the landscape based on available literature information and secondary information. We also obtained information from the indigenous peoples of the region about possible locations to deploy camera traps, which is one of the cost-effective method of monitoring programs (Micaela *et al*, 2020; Daniel & Oliver, 2021). For monitoring we demarcated the area into blocks based on logistic feasibility. We deployed camera traps at the designated locations within the blocks. Cuddeback C1 Day and Night Colour 20 MP Xchange Trail Game Cameras were used and the camera traps were deployed along trails, which were frequently used by wild animals based on prior reconnaissance surveys (Rovero *et al*., 2010). We selected the sites with high capture probabilities for potential species presence in the area.

Camera traps were deployed as single cameras per location in most locations, and in a few locations, a pair of cameras were deployed to maximise the probability of animal captures. A total of 92 camera traps were deployed at different locations during the years 2018-2020 (Fig. 5.1).

Analysis of Activity Pattern and Overlap

A total of 2548 independent captures of various species were recorded and the targeted species in 1110 independent events. We looked at the time overlap of the mammal species caught on camera traps that belonged to the orders Primates, Carnivora, Artiodactyla, and Rodentia (Table 5.1; Fig. 5.2 & Fig. 5.3). Using the overlap package in R (Version 4.4.1) (Meredith & Ridout, 2020), the activity patterns and temporal overlap were calculated based on the time when the different species were active. Diurnal periods were considered as the time duration between an hour after sunrise and an hour before sunset, whereas the nocturnal is the time period between an hour after sunset and an hour before sunrise and crepuscular is the period of an hour before and after sunrise and sunset (Theuerkauf *et al*., 2003; Ross *et al*., 2013). We used species with approximately 15 photo captures to analyse the activity patterns (Nakabayashi, 2021).

Activity patterns among the species may overlap during interactions, including those with predators and prey, and during resource competition as well. We used the coefficient of overlap, a natural measure that facilitates geometrical interpretation, to determine temporal overlap. We chose these estimators based on the sample size, following the advice of Ridout and Linkie (2009). If the smaller sample size is less than 50, we used $Dhat_1$. If the sample size is greater than 75, we used $Dhat_4$. The Dhat Δ value is in unit intervals ranging between 0 (no overlap) to 1 (complete overlap) (Ridout & Linkie, 2009). We calculated the overlap patterns between the carnivores, each with their own prey species, and between the two carnivore species.

Table 5.1. The Mammalian species identified in the camera trap and analysed for activity pattern.

S. no	Classical Order	Family	Common Name	Scientific Name
1	Primates	Cercopithecidae	Capped Langur	*Trachypithecus pileatus*
2	Primates	Cercopithecidae	Stump-tailed Macaque	*Macaca arctoides*
3	Primates	Cercopithecidae	Assamese Macaque	*Macaca assamensis*
4	Primates	Cercopithecidae	Arunachal Macaque	*Macaca munzala*
5	Primates	Cercopithecidae	Northern Pig-tailed macaque	*Macaca leonina*
6	Carnivora	Canidae	Dhole	*Cuon alpinus*
7	Carnivora	Felidae	Mainland Leopard cat	*Prionailurus bengalensis*
8	Carnivora	Felidae	Marbled Cat	*Pardofelis marmorata*
9	Carnivora	Felidae	Clouded leopard	*Neofelis nebulosa*
10	Carnivora	Felidae	Asiatic golden cat	*Catopuma temminckii*
11	Carnivora	Ursidae	Sun bear	*Helarctos malayanus*
12	Carnivora	Ursidae	Asiatic Black Bear	*Ursus thibetanus*
13	Carnivora	Viverridae	Masked Palm Civet	*Paguma larvata*
14	Carnivora	Mustelidae	Yellow-throated marten	*Martes flavigula*
15	Artiodactyla	Bovidae	Mishmi Takin	*Budorcas taxicolor taxicolor*
16	Artiodactyla	Bovidae	Mainland Serow	*Capricornis sumatraensis thar*
17	Artiodactyla	Bovidae	Red Goral	*Naemorhedus baileyi*
18	Artiodactyla	Cervidae	Northern Red Muntjac	*Muntiacus vaginalis*
19	Artiodactyla	Cervidae	Sambar	*Rusa unicolor*
20	Artiodactyla	Cervidae	Gongshan muntjac	*Muntiacus gongshanensis*
21	Artiodactyla	Suidae	Wild Pig	*Sus scrofa*
22	Rodentia	Hystricidae	Asiatic brush-tailed porcupine	*Atherurus macrourus*
23	Rodentia	Hystricidae	Indian crested porcupine	*Hystrix indica*

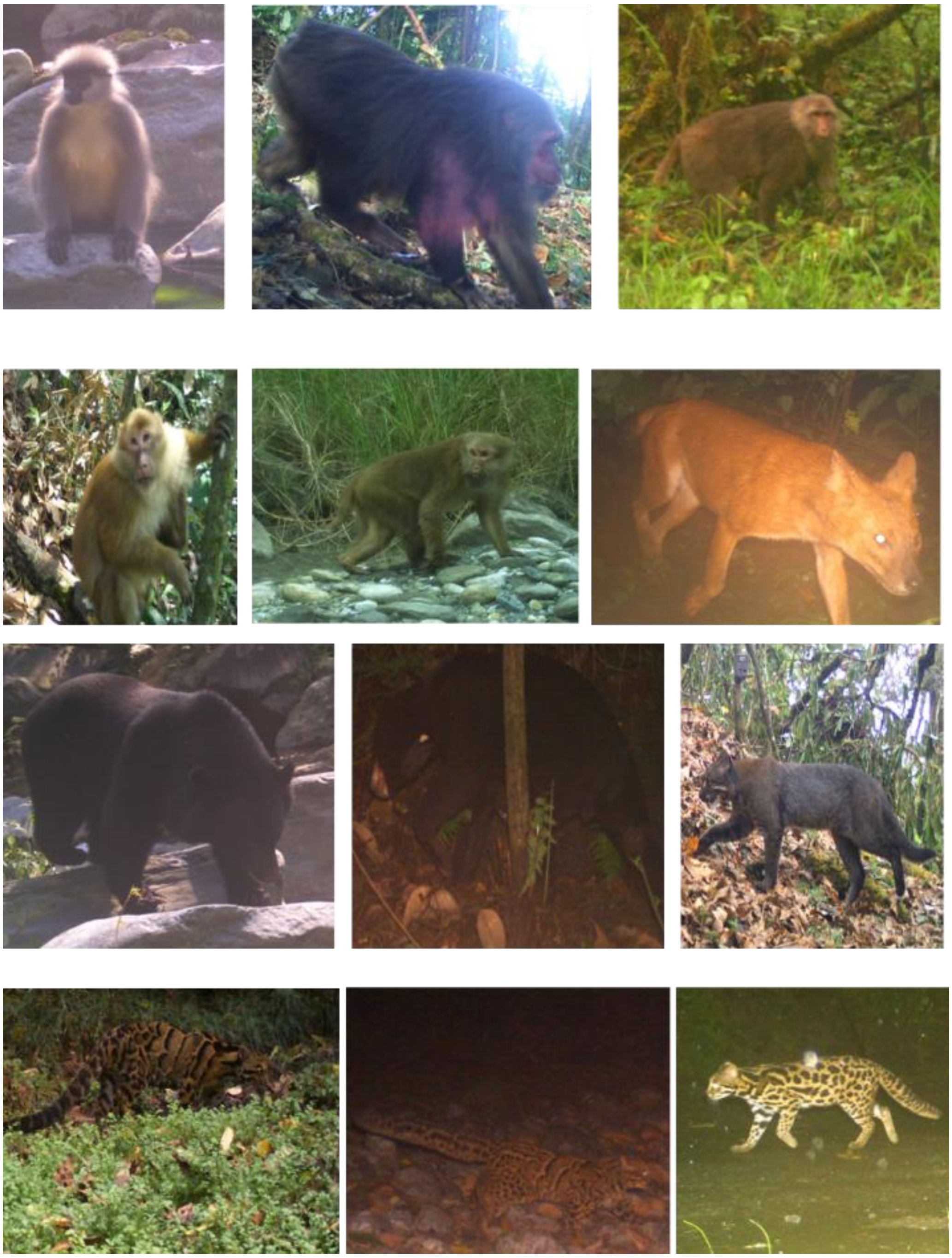

Figure 5.2. (From left to right horizontally) Camera Trap Images of Capped Langur, Stump-tailed Macaque, Assamese Macaque, Arunachal Macaque, Northern Pig-tailed Macaque, Dhole, Asiatic Black Bear, Sun Bear, Asiatic Golden Cat, Clouded Leopard, Marbled Cat, Mainland Leopard Cat recorded in the study area.

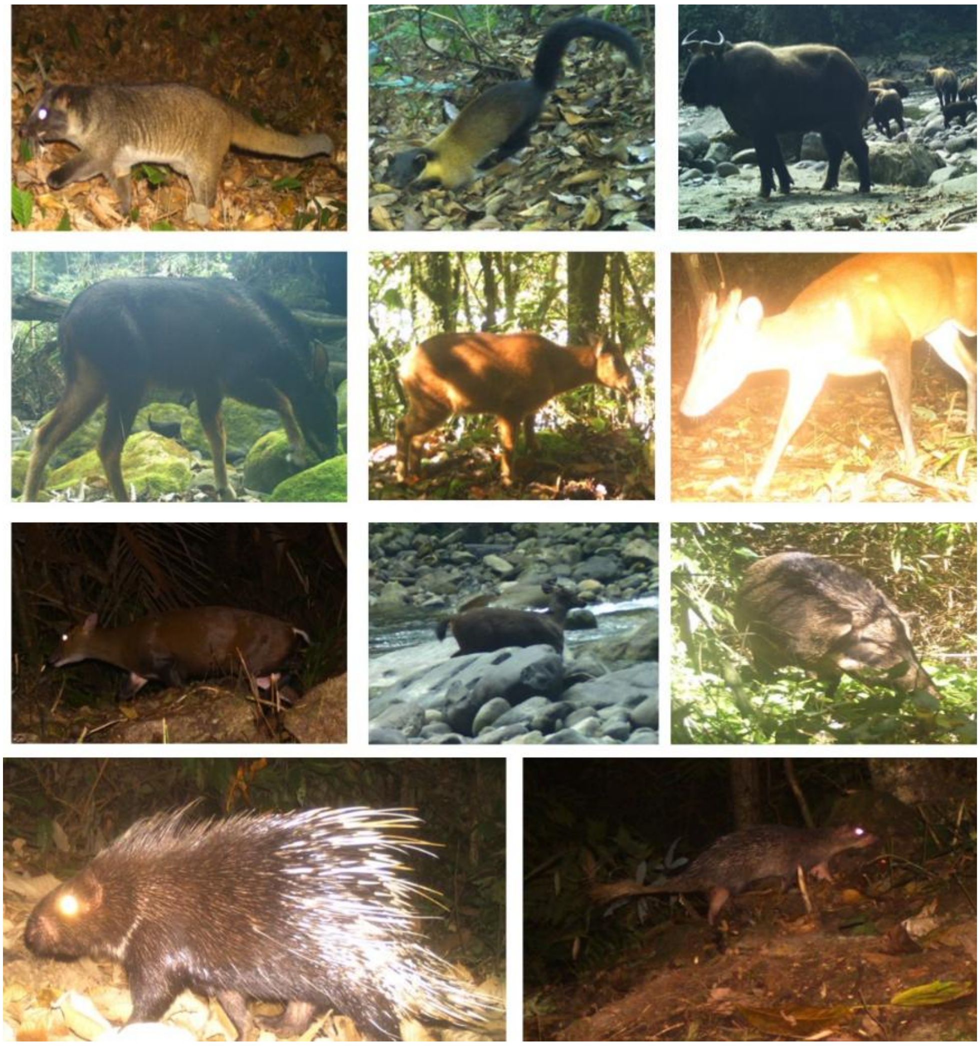

Figure 5.3. (From left to right horizontally) Camera Trap Images of Masked Palm Civet, Yellow-throated Marten, Mishmi Takin, Mainland Serow, Red Goral, Northern Red Muntjac, Gongshan Muntjac, Sambar, Wild Pig, Indian Crested Porcupine, Asiatic Brush-tailed Porcupine recorded in the study area.

Analysis of Species Co-occurrence

We used the "Co-occur" package in R (Version 4.4.1) and pairwise probabilistic co-occurrence (Veech, 2013) analysis (Griffith *et al*., 2016) to understand the spatial interaction among the selected mammalian species. Based on calculated probabilities (Pj), like Pgt and Plt, which had a low frequency, and other factors, the relationships found were categorised as either positive, negative, or random.

Results

The activity patterns of the species were given as a density plot using the method suggested by Ridout and Linkie (2009) (Fig. 5.4 & 5.5). The activity of the Sun Bear showed peak diurnal activity, while the Marbled Cat showed two-peak diurnal activity (Fig. 5.4). The Clouded Leopard showed activity patterns that resembled crepuscular behaviour (Fig. 5.4). The Mainland Leopard Cat was found to be active after sunset, exhibiting nocturnal behaviour. The Dhole showed activity throughout the day as a cathemeral activity species. Among the herbivores, Northern red muntjac, Red Goral, Mishmi Takin, Sambar, and Mainland Serow showed diurnal activity peaks. The Sambar exhibited activity between sunset and sunrise as crepuscular (Fig. 5.5). The Wild Pig showed activity before and after the sunset, with peak activity more of a nocturnal species. The three primates, Capped Langur, Northern Pig-tailed Macaque, and Stump-tailed Macaque, showed diurnal activity patterns, with Northern Pig-tailed Macaque being more active in the early hours, close to sunrise. The two lesser carnivores, the Masked Palm Civet and the Yellow-throated Marten, showed contrasting activity patterns, with the palm civet being active around sunrise and sunset while the Yellow-throated Marten is diurnal.

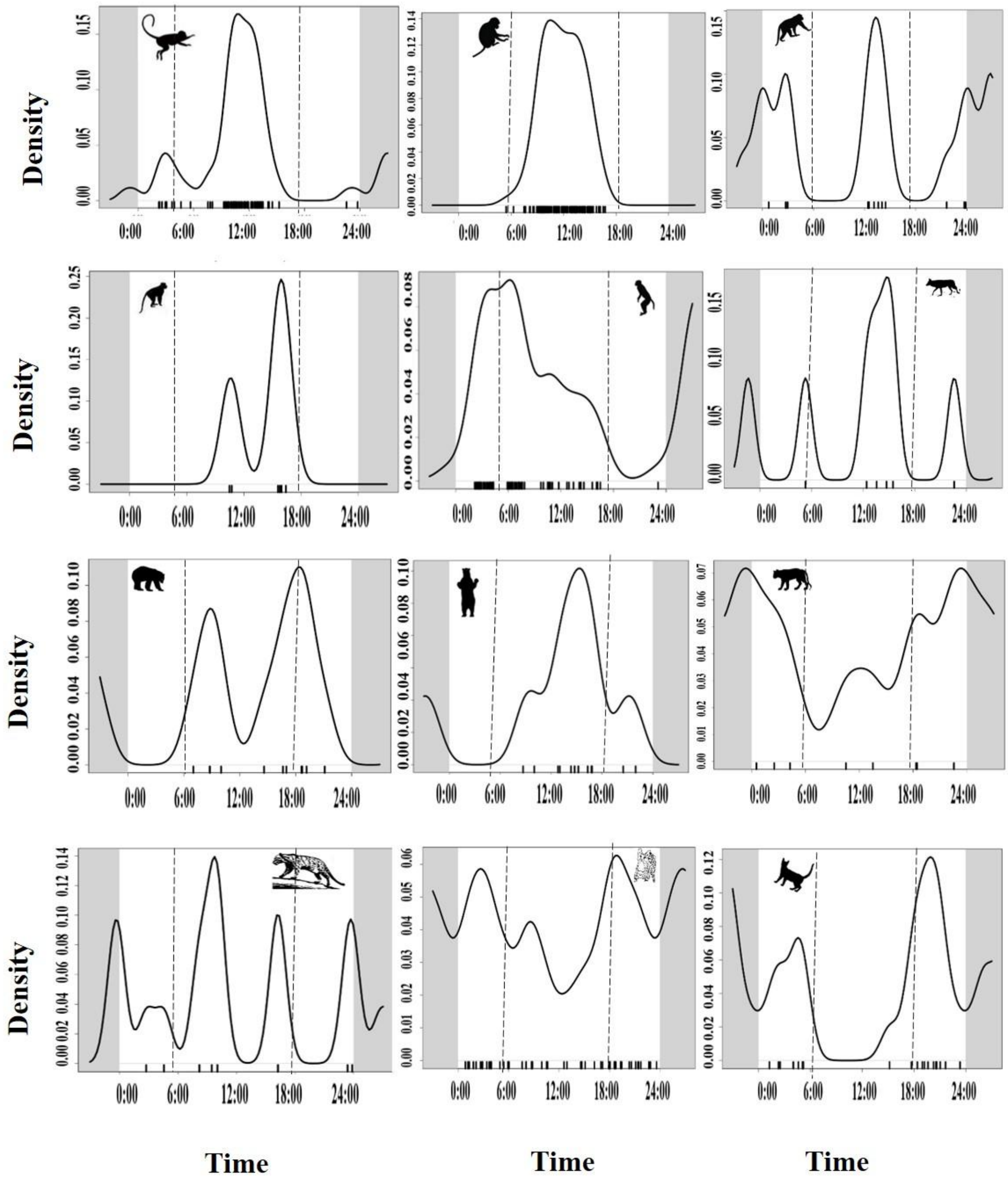

Figure 5.4. Temporal activity pattern of Capped Langur, Stump-tailed Macaque, Assamese Macaque, Arunachal Macaque and Northern Pig-tailed Macaque, Dhole, Asiatic Black Bear, Sun bear, Asiatic Golden Cat, Clouded Leopard, Marbled cat and Leopard cat (from top left horizontally)

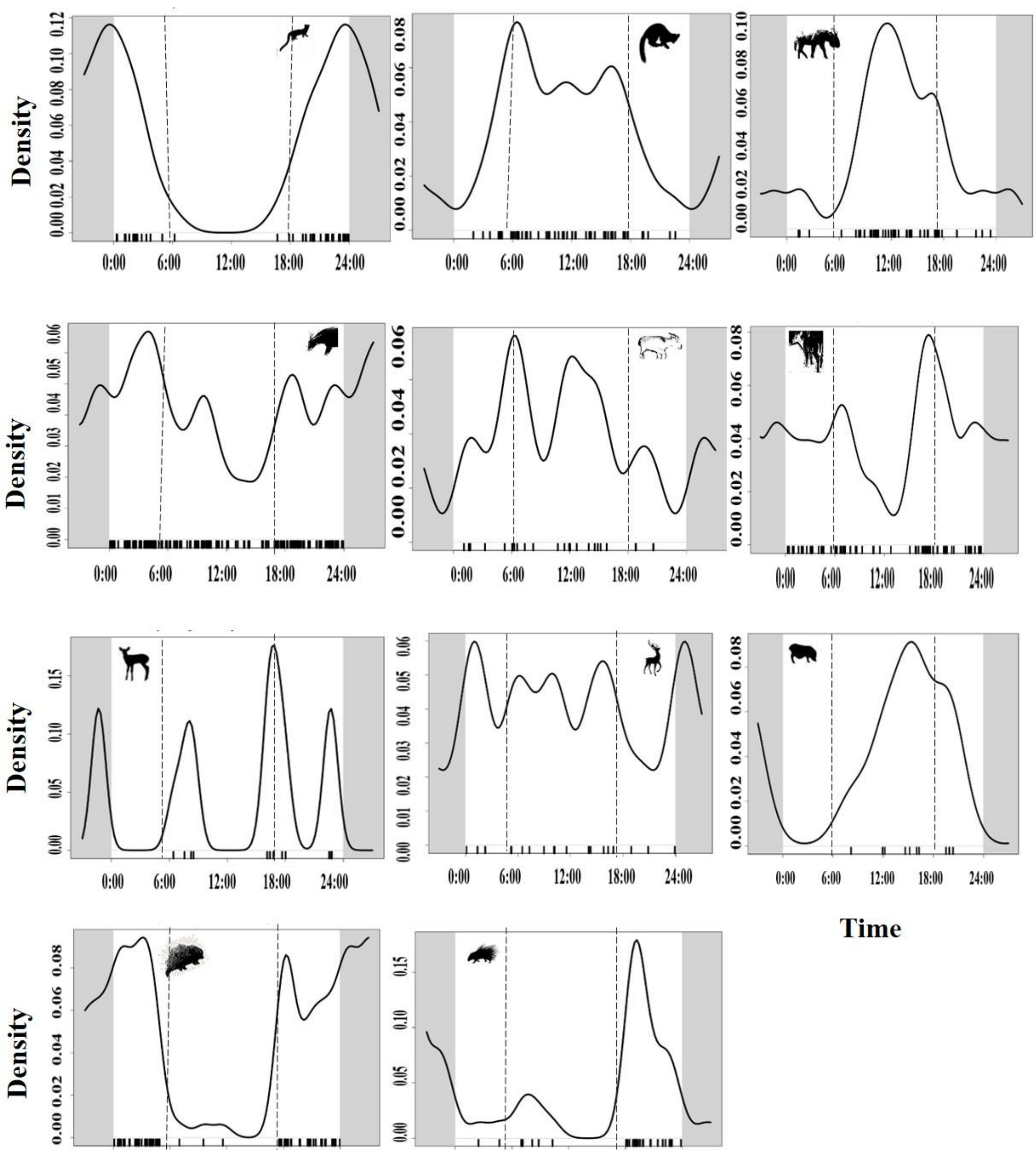

Figure 5.5. Temporal activity pattern of Masked Palm Civet, Yellow-throated Marten, Mishmi Takin, Mainland Serow, Red Goral, Northern Red Muntjac, Gongshan Muntjac, Sambar, Wild Pig, Asiatic Brush-tailed Porcupine, and Indian Crested Porcupine

The overlap analysis reveals different rates of temporal activity overlap coefficients, illustrating how the species in the community interact with one another. Among the primate guild, Stump-tailed Macaque and Capped Langurs showed high temporal overlap with Δ = 0.76 (Table 5.2)**.** Similarly, the Northern Pig-tailed Macaque and Red Goral exhibited relatively high temporal overlap of Δ = 0.72 (Table 5.2). Among the three carnivores, the overlap was considerable between Dhole and Sun Bears with Δ = 0.72 (Table 5.1). Regarding the prey-predator interactions, Dhole showed significant overlap with all five selected prey species, with a maximum overlap coefficient (Δ = 0.59) with Mishmi takin. In the case of lesser carnivores, palm civets and yellow-throated martens showed a low temporal overlap coefficient (Δ = 0.33) (Table 5.2). The Marbled Cat had more interguild time overlap with the Mainland Serow, the Northern Red Muntjac, and the sambar (Δ = 0.84, Δ = 0.82, and Δ = 0.72, respectively), as shown in Table 5.3. Yellow-throated Marten had a high overlap with the Red goral (Δ = 0.77) and a low overlap with the Mishmi Takin (Δ = 0.74) and the sambar (Δ = 0.70) (Table 5.3). As shown in Table 5.4, the Mainland Serow and the Northern Red Muntjac had the most time-overlapping activities (Δ = 0.81 vs. Δ = 0.75 vs. 0.72 for Red Goral and Sambar. The temporal activity overlap activity with a value of 0.70 was observed for sambar with Northern Red Muntjac and Red Goral (Table 5.4). The Gongshan Muntjac shows considerable overlap with all the other ungulates, in which a higher coefficient was observed with its closely related species, the Northern Red Muntjac. The two species of order Rodentia, Asiatic Brush-tailed Porcupine and Indian Crested Porcupine, that show complete nocturnal and crepuscular activity, respectively, didn’t show any overlap in activity (Fig. 5.5).

Table 5.2. Temporal overlaps between the species of the Primate guild pairs with overlap coefficient values given on top of the cell and the values given in the parentheses in each cell denotes 95 % confidence intervals [estimator used Dhat1 (Δ1)]

	Capped Langur	**Stump-tailed Macaque**	**Assamese Macaque**	**Arunachal Macaque**	**Northern Pig-tailed Macaque**
Stump-tailed Macaque	**0.76 (0.67- 0.86)**				
Assamese Macaque	0.44 (0.27- 0.65)	0.42 (0.24 - 0.63)			
Arunachal Macaque	0.43 (0.05 - 0.69)	0.56 (0.19 - 0.83)	0.30 (0 - 0.45)		
Northern Pig-tailed Macaque	0.54 (0.36 - 0.64)	0.47 (0.32 - 0.56)	0.39 (0.19 - 0.52)	0.32 (0.08 - 0.50)	
Dhole	0.54 (0.33 - 0.72)	0.58 (0.42 - 0.80)	0.47 (0.31 - 0.73)	0.45 (0.09 - 0.67)	0.57 (0.38 - 0.80)
Mainland Leopard Cat	0.23 (0.09 - 0.30)	0.13 (0.02 - 0.17)	0.39 (0.16 - 0.57)	0.18 (0 - 0.27)	0.49 (0.36 - 0.62)
Marbled Cat	0.42 (0.28 - 0.54)	0.35 (0.21 - 0.43)	0.49 (0.25 - 0.65)	0.33 (0.11 - 0.45)	0.63 (0.50 - 0.76)
Clouded Leopard	0.30 (0.10 - 0.68)	0.35 (0.18 - 0.78)	NA	NA	0.31 (0.15 - 0.61)
Asiatic Golden Cat	0.37 (0.17 - 0.64)	0.31 (0.05 - 0.56)	0.51 (0.33 - 0.82)	0.29 (0.04 - 0.56)	0.50 (0.31 - 0.79)
Sun Bear	0.45 (0.25 - 0.67)	0.58 (0.37 - 0.81)	0.48 (0.26 - 0.69)	NA	0.41 (0.25 - 0.62)
Asiatic Black Bear	0.33 (0.10 - 0.47)	0.41 (0.19 - 0.61)	0.28 (0 - 0.41)	0.46 (0.15 - 0.65)	0.40 (0.21 - 0.58)
Masked Palm Civet	0.20 (0.10 - 0.28)	0.09 (0.01 - 0.13)	0.52 (0.33 - 0.76)	NA	0.37 (0.20 - 0.45)
Yellow-throated Marten	0.59 (0.43 - 0.67)	0.60 (0.45 - 0.68)	0.42 (0.21 - 0.53)	0.47 (0.17 - 0.64)	**0.72 (0.60 - 0.86)**

	Capped Langur	**Stump-tailed Macaque**	**Assamese Macaque**	**Arunachal Macaque**	**Northern Pig-tailed Macaque**
Mishmi Takin	0.66 (0.54 - 0.78)	0.70 (0.58 - 0.81)	0.49 (0.29 - 0.65)	0.54 (0.19 - 0.76)	0.57 (0.40 - 0.68)
Mainland Serow	0.43 (0.31 - 0.54)	0.34 (0.23 - 0.39)	0.46 (0.22 - 0.60)	0.28 (0.07 - 0.40)	0.69 (0.56 - 0.78)
Red Goral	NA	NA	NA	NA	**0.72 (0.59 - 0.89)**
Northern Red Muntjac	0.37 (0.25 - 0.45)	0.33 (0.23 - 0.36)	0.48 (0.25 - 0.63)	0.34 (0.15 - 0.46)	0.55 (0.41 - 0.63)
Sambar	0.50 (0.33 - 0.67)	0.47 (0.27 - 0.62)	0.47 (0.23 - 0.66)	0.38 (0.16 - 0.62)	0.67 (0.51 - 0.85)
Wild Pig	0.43 (0.22 - 0.67)	0.52 (0.31 - 0.79)	0.46 (0.24 - 0.68)	0.52 (0.23 - 0.78)	0.42 (0.22 - 0.62)
Gongshan Muntjac	0.22 (0.05 - 0.31)	0.30 (0.11 - 0.37)	0.29 (0.04 - 0.42)	0.39 (0.14 - 0.59)	0.38 (0.18 - 0.51)

The values are expressed as mean with approximate 95% bootstrap confidence intervals are given in parentheses. Bold values indicate a high degree of temporal overlap (≥ 0.70).

Table 5.3. Temporal overlaps between the species of the Carnivora guild with its Prey species pairs with overlap coefficient values given on top of the cell and the values given in the parentheses in each cell denotes 95 % confidence intervals [estimator used Dhat1 (Δ_1)]

	Dhole	**Mainland Leopard Cat**	**Marbled Cat**	**Clouded Leopard**	**Asiatic Golden Cat**	**Sun Bear**	**Asiatic Black Bear**	**Masked Palm Civet**	**Yellow-throated Marten**
Mainland Leopard Cat	0.34 (0.14 - 0.52)								
Marbled Cat	0.49 (0.27 - 0.66)	0.69 (0.59 - 0.83)							
Clouded Leopard	0.42 (0.16 - 0.60)	0.40 (0.14 - 0.53)	0.55 (0.33 - 0.71)						
Asiatic Golden Cat	0.42 (0.18 - 0.71)	0.60 (0.43 - 0.86)	0.66 (0.61 - 1.02)	0.47 (0.25 - 0.74)					
Sun Bear	0.56 (0.42 - 0.85)	0.36 (0.14 - 0.53)	0.51 (0.35 - 0.72)	0.41 (0.19 - 0.64)	0.46 (0.26 - 0.78)				
Asiatic Black Bear	0.39 (0.11 - 0.56)	0.45 (0.26 - 0.64)	0.54 (0.40 - 0.76)	0.44 (0.24 - 0.68)	0.44 (0.20 - 0.71)	0.56 (0.34 - 0.82)			
Masked Palm Civet	0.26 (0.06 - 0.38)	0.68 (0.53 - 0.81)	0.63 (0.48 - 0.75)	0.41 (0.18 - 0.61)	0.62 (0.47 - 0.92)	0.29 (0.08 - 0.49)	0.33 (0.11 - 0.49)		
Yellow-throated Marten	0.64 (0.46 - 0.85)	0.42 (0.25 - 0.49)	0.64 (0.46 - 0.75)	0.57 (0.36 - 0.71)	0.50 (0.28 - 0.77)	0.60 (0.42 - 0.81)	0.55 (0.34 - 0.78)	0.33 (0.16 - 0.38)	
Mishmi Takin	0.59 (0.38 - 0.76)	0.39 (0.22 - 0.49)	0.59 (0.44 - 0.73)	0.54 (0.36 - 0.68)	0.51 (0.28 - 0.78)	0.67 (0.49 - 0.88)	0.55 (0.38 - 0.78)	0.32 (0.16 - 0.41)	**0.74 (0.62 - 0.85)**
Mainland Serow	0.50 (0.30 - 0.68)	0.68 (0.56 - 0.79)	**0.84 (0.79 - 0.98)**	0.55 (0.29 - 0.72)	0.65 (0.61 - 1.01)	0.48 (0.32 - 0.69)	0.49 (0.34 - 0.68)	0.62 (0.48 - 0.71)	0.66 (0.51 - 0.73)
Red Goral	0.62 (0.45 - 0.84)	0.51 (0.30 - 0.64)	0.69 (0.52 -0.84)	0.54 (0.24 - 0.65)	0.56 (0.40 - 0.86)	0.57 (0.40 - 0.79)	0.50 (0.26 - 0.70)	0.42 (0.23 - 0.57)	**0.77 (0.68 - 0.95)**

Northern Red Muntjac	0.48 (0.29 - 0.66)	0.68 (0.52 - 0.76)	**0.82 (0.74 - 0.94)**	0.54 (0.38 - 0.73)	0.66 (0.56 - 0.98)	0.55 (0.37 - 0.77)	0.58 (0.42 - 0.77)	0.62 (0.47 - 0.71)	0.61 (0.49 - 0.71)
Sambar	0.53 (0.31 - 0.74)	0.54 (0.33 - 0.68)	**0.72 (0.61 - 0.92)**	0.59 (0.42 - 0.81)	0.59 (0.49 - 0.94)	0.52 (0.33 - 0.76)	0.50 (0.35 - 0.76)	0.50 (0.28 - 0.67)	**0.70 (0.60 - 0.92)**
Wild Pig	0.52 (0.37 - 0.81)	0.43 (0.23 - 0.65)	0.55 (0.39 - 0.80)	0.41 (0.15 - 0.61)	0.49 (0.29 - 0.84)	0.67 (0.60 - 1)	0.60 (0.39 - 0.87)	0.35 (0.16 - 0.56)	0.58 (0.39 - 0.83)
Gongshan Muntjac	0.36 (0.14 - 0.51)	0.41 (0.14 - 0.52)	0.50 (0.27 - 0.63)	0.48 (0.29 - 0.72)	0.42 (0.15 - 0.62)	0.48 (0.26 - 0.67)	0.55 (0.36 - 0.79)	0.39 (0.12 - 0.54)	0.48 (0.29 - 0.63)

Table 5.4. Temporal overlaps between the species of the Ungulate guild pairs with overlap coefficient values given on top of the cell and the values given in the parentheses in each cell denotes 95 % confidence intervals [estimator used Dhat1 (Δ_1)]

	Mishmi Takin	**Mainland Serow**	**Red Goral**	**Northern Red Muntjac**	**Sambar**	**Wild Pig**
Mainland Serow	0.58 (0.44 - 0.69)					
Red Goral	0.69 (0.52 - 0.85)	**0.72 (0.56 - 0.84)**				
Northern Red Muntjac	0.60 (0.46 - 0.70)	**0.81 (0.72 - 0.89)**	0.66 (0.50 - 0.80)			
Sambar	0.65 (0.50 - 0.86)	**0.75 (0.63 - 0.92)**	**0.70 (0.56 - 0.92)**	**0.70 (0.59 - 0.88)**		
Wild Pig	0.65 (0.48 - 0.91)	0.53 (0.36 - 0.73)	0.57 (0.41 - 0.83)	0.60 (0.47 - 0.83)	0.52 (0.34 - 0.76)	
Gongshan Muntjac	0.45 (0.27 - 0.56)	0.48 (0.27 - 0.60)	0.44 (0.19 - 0.54)	0.56 (0.37 - 0.71)	0.47 (0.27 - 0.63)	0.47 (0.21 - 0.66)

The values are expressed as mean with approximate 95% bootstrap confidence intervals are given in parentheses. Bold values indicate a high degree of temporal overlap (≥ 0.70).

The evaluated probabilistic model of species co-occurrence in the sampling unit for species recorded to be distributed in the study unit is given in Figure 5.6. We removed 362 pairs (77.85%) from the analysis of 465 species pairing combinations because the expected co-occurrence was less than 1, and we subsequently analysed 103 pairs. A total of 16 species show co-occurrence based on camera trap history, and the probability of co-occurrence is listed in Table 5.4. We found significant co-occurrence between Northern Red Muntjac and Clouded leopard, Indian crested porcupine, Sambar, and Sun bear. Similarly, we identified Sambar with Asiatic Brush-Tailed Porcupine and Sun Bear with Stump-Tailed Macaque (Table 4). Other species show random co-occurrence, and there was no negative association identified in the study (Fig. 5.6).

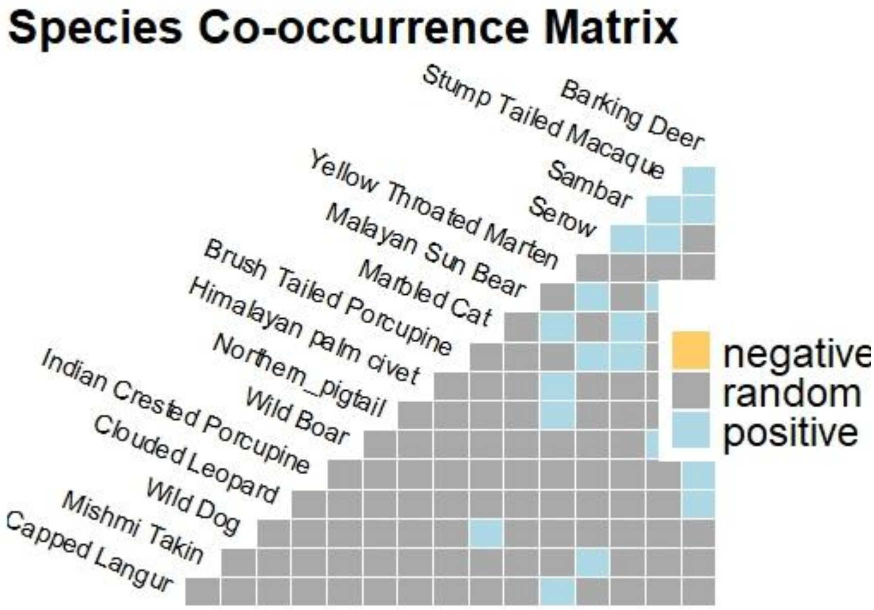

Figure 5.6. The co-occurrence Matrix created from the Camera Trap Capture data using package co-occur in R core.

Table 5.5. Pairwise spatial co-occurrence probability

S.no.	Species A	Species B	No. of sites having Species A	No. of sites having Species B	Observed Co-occurrence of A & B	Observed Co-occurrence probability of A & B	Expected Co-occurrence of A & B	p_lt	p_gt
1	Capped Langur	Yellow-throated Marten	7	36	6	0.03	2.7	0.9991	0.01
2	Mishmi Takin	Mainland Serow	5	22	4	0.013	1.2	0.9995	0.01
3	Mainland Serow	Sambar	22	10	7	0.026	2.4	0.9999	0.00
4	Mainland Serow	Stump-tailed Macaque	22	19	9	0.049	4.5	0.9978	0.01
5	Mainland Serow	Brush Tailed Porcupine	22	13	8	0.034	3.1	0.9998	0.00
6	Mainland Serow	Sun Bear	22	6	4	0.016	1.4	0.9973	0.03
7	Wild Dog	Marbled Cat	9	11	5	0.012	1.1	1	0.00
8	Yellow-throated Marten	Marbled Cat	36	11	9	0.047	4.3	0.9997	0.00
9	Yellow-throated Marten	Himalayan palm civet	36	17	13	0.072	6.7	0.9999	0.00
10	Yellow-throated Marten	Northern Pig-tailed Macaque	36	7	6	0.03	2.7	0.9991	0.01
11	Northern Red Muntjac	Clouded Leopard	37	4	4	0.017	1.6	1	0.02
12	Northern Red Muntjac	Indian Crested Porcupine	37	5	5	0.022	2	1	0.01
13	Northern Red Muntjac	Sambar	37	10	10	0.044	4	1	0.00
14	Northern Red Muntjac	Stump Tailed Macaque	37	19	15	0.083	7.6	1	0.00

S.no.	Species A	Species B	No. of sites having Species A	No. of sites having Species B	Observed Co-occurrence of A & B	Observed Co-occurrence probability of A & B	Expected Co-occurrence of A & B	p_lt	p_gt
15	Northern Red Muntjac	Brush Tailed Porcupine	37	13	11	0.057	5.2	1	0.00
16	Northern Red Muntjac	Masked Palm Civet	37	17	13	0.074	6.8	0.9999	0.00
17	Northern Red Muntjac	Sun Bear	37	6	6	0.026	2.4	1	0.00
18	Sambar	Stump Tailed Macaque	10	19	6	0.022	2.1	0.9995	0.00
19	Sambar	Brush Tailed Porcupine	10	13	7	0.015	1.4	1	0.00
20	Sambar	Marbled Cat	10	11	4	0.013	1.2	0.9983	0.02
21	Stump-tailed Macaque	Wild Pig	19	7	4	0.016	1.4	0.9963	0.03
22	Stump-tailed Macaque	Sun Bear	19	6	6	0.013	1.2	1	0.00

Pit < 0.05 and *Pgt* < 0.05 indicate spatial segregation and positive association, respectively. The species A & B indicates the species of comparison. All the species show a positive co-occurrence as shows a Probability of co-occurrence at a frequency greater than the observed frequency.

Discussion

Our study-generated information about different mammal species activity and their interactions with each other using the time stamp information obtained from camera traps and animal diel activity based on sunrise and sunset. Generally, species interactions were evaluated for priority flagship species, like the Tiger, in Tropical forests. Not much information is available about how different species interact in evergreen forests compared to what we know about tropical forests (Vargas *et al.,* 2022). Though population information remains uncertain from this region (WII, 2018), the activity related information coming from this region provides supplementary information about the species.

The temporal pattern of animal activity is species-specific*;* it may show only a single peak or more than two peaks in 24 hours, but the common pattern observed in most of the studies was two activity peaks per day (Mrosovsky, 2003; Mrosovsky & Hattar, 2005). The circadian rhythms identified in the present study among primates, Capped langurs, show an increase in activity during the dawn as the sunrise and another peak during the noon, which is similar to the two peak activity patterns reported in captivity (Monirujjaman & Khan, 2017). Peak daily activity patterns of Stump-tailed Macaques and Assamese Macaques were the same as those observed in studies from both zoos and the wild (Nigam *et al*., 2014; Li*, et al.,* 2019*).* The Arunachal Macaque activity during the late morning and inactivity during midday by sleeping was observed in other studies (Kumar *et al.,* 2007), which differs from the present study. Our observation shows a mid-day peak and more active capture towards dusk, which may be due to the movement of species to roosting sites away from foraging locations where more camera trap captures might have occurred. Gippoliti (2001) and Feeroz (2012), have identified Northern Pig-tailed Macaques as primarily arboreal and diurnal. The species shows a single peak activity in the early hours of sunrise and does not overlap with other primates; this might be due to its peculiar behaviour, spending most of the time in movement and keeping niche breadth with other sympatric macaques, like stump-tailed macaques (Sharma & Sinha, 2022).

Among the Carnivora, the observations of the current study show similarity with other studies. The dhole shows activity peaks both in the day and also during the night, wherein the species is capable of adjusting its diel activity depending on the habitat where it is distributed. The diurnal activity of dholes and their relation to its prey activity were well studied in low-elevation and mid-elevation parts from other parts of India (Palei, 2016). In Southeast Asia, the diurnal activity of the Dhole shows two peaks (Havmøller *et al*., 2004), while in central India, movement mostly happens around dawn and dusk because of other predators (Ghaskadbi *et al*, 2016). The area doesn't have as many tigers and leopards as other areas (Qureshi *et al*., 2022; Singh *et al*., 2014), which could be the reason why Dholes show cathemeral activity patterns. The species with identical diet preferences might show contrasting time preferences, which also play a major role in the continuous ecosystem process (Charles, 1975). Our study findings provide more information about the species in this particular landscape.

Asiatic Black Bears, which are active throughout the year, exhibit high bimodal activity close to dawn and dusk, as observed in various other studies (Sunar, 2012). In most of the distribution regions, peak activity at night was observed. In China more diurnal activity in regions where brown bears coexist (Ji *et al.*, 2022) were observed. Since there is no den behaviour by Black Bear during winter, significant variation in activity in different seasons and activity over time was observed in Taiwan (Hwang *et al.*, 2007). The sun bear studied in the Dumpa Tiger Reserve in the hotspot region of the Northeast shows crepuscular activity (Gouda, 2020), which is almost similar to late evening and nocturnal activity recorded in the study. Kawanishi (2009) observed the Asiatic Golden Cat's mostly showing nocturnal activity, as well as some activity during the day. Clouded leopards are most active during mid-to-late evenings (Can, 2020), and our observations show there is also activity during the early hours of the day. Such an extended behaviour for cryptic species needs further examination to understand the diel cycles. Another study (Rufino *et al.*, 2010) also observed that some animals are active at night and during dusk. The leopard cat's nighttime activity (Singh, 2017) and the mixed activity during both night and day (Can, 2020) in the Himalayan region were found to be similar to what we observed. The semi-arboreal Marbled Cat species showed crepuscular and more nocturnal behaviour in the study, differing from a few earlier reports as being diurnal (Hendry *et al.*, 2023; Singh, 2017).

Mishmi Takin shows activity peaks during daytime and was found to be active in the morning and evening and reduced activity toward darkness (Wang *et al.*, 2024), which may be due to various environmental and ecological factors. There are reports that Dhole and Clouded Leopards prey on the Mishmi Takin herd because of which Takin prefers being active during the day, particularly to keep their calves safe (Calhim *et al*., 2006; Kamler *et al*., 2007). Fluctuation activity was observed in Mainland Serow throughout the day (Paudel, 2012), and Red Goral was active close to sunrise and during the daytime, and also the Sambar was recorded with cathemeral activity in the Himalayan region (Bhattacharya *et al.*, 2012) is evident from our observations. The Northern Red Muntjac is active during the day in two main periods (Singh, 2022). In contrast, the Gongshan Muntjac is active at different times throughout the day and night. The lack of studies on this species necessitates further research. The current observations will enhance ecological knowledge about the recently described species (Choudhury, 2009). Wild Pigs are mostly nocturnal and more active around midnight as they are influenced by light (Gordigiani *et al.* 2022; Hazlerigg & Tyler, 2019). In our observations, they were found to increase their activity around dusk, which may be due to this region facing a light fall earlier than the actual sunset. Studies have reported that the Masked Palm Civet is active at night, while the Yellow-throated Marten is busy during the day with two peak times reported, and these small carnivores did not show much difference in activity from other regions. Asiatic brush-tailed porcupine studies showed a single peak activity at midnight and also found to be influenced by the phases of the moon (Wen *et al.*, 2016). Our study shows two activity peaks with a crepuscular rhythm during dawn and dusk. The nocturnal activity of Indian crested porcupines exhibits a greater preference for darkness (Mukherjee *et al.*, 2018; Shameer & Ninad, 2021), which aligns with our observations.The species might possess varying activity pattern lengths and states, which can keep interacting species in different associations of stature (Cords, 1987). Pebsworth & LaFleur (2014) launched the camera trap study on primates to investigate their 'geophagy' activity, and for other kinds of activity analysis, specific procedures have been developed in due course. We explore the diel activity of primate species as effectively as possible; yet, from the observation, it can be noted that the temporal and spatial interaction examination has not reached the expected level. This is because we didn't adopt a specific camera trapping recommendation by primatology research (Matsubayashi et al. 2007). There is a need to design and employ specialised techniques in activity monitoring to attain a holistic goal (Hanya *et al*., 2018) about understanding the effects of various factors on primate activity patterns.

A dominant predator such as the tiger and the leopard (Vernes, 2022) will influence the activity pattern of the dhole. There is a need to assess the influence of both the top predators, which are estimated to be less abundant in the region (Qureshi *et al*., 2023; Qureshi *et al*., 2022), to identify the interaction with other species. Sambar was considered important prey for Dholes in the NE region (Singh, 2020), but our finding shows random spatial co-occurrence and a low temporal overlap coefficient. Dhole didn't show either positive or random in our analysis, but negative interaction with the Asiatic Black bear in the eastern Himalayan region (Vernes, 2022). The dholes are not considered predators of sun bears, like tigers and leopards (Naing, 2020). They do exhibit a moderate temporal overlap with other prey species. This overlap is particularly high with Takin, as Takin exhibits activity throughout the day, like the dholes. Some studies found that dholes are seen more often with smaller prey, like wild Pig and barking deer, than with larger prey like gaur and sambar. However, they do still share space with the larger animals (Shameer *et al.*, 2021). Our study did not observe the temporal overlap between dholes and large felids, as reported in the previous study by Singh, 2017 from the region. The moderate overlap between prey species indicates there is an influence of various ecological and environmental variables. Xiang *et al.*, (2024) reported that the association of sympatric ungulates may or may not be influenced by various factors like altitude and season. Information that suggests activity overlaps between prey and predators is crucial for understanding the ecosystem and planning conservation strategies (Havmiller *et al*., 2020). There was a random pattern of co-occurrence between the mammal species. This could be because sympatric prey-predator species use different spatial scales and form different associations in the study areas (Padie *et al*., 2015; Makin *et al*., 2017). This may require further investigation at a finer ecological scale. The NE region possesses three of the four bear species, of which the distribution of the sloth bear is limited to the Indian region, and the sun bear distribution is not found in the peninsular region (Garshelis *et al*., 2022). In such a distribution range, the Asiatic black bear and the sun bear coexist (Steinmetz *et al*., 2013) but don't show temporal overlap or spatial co-occurrence, as both species possess a difference in resource use. The sun bear is more of an insect-diet-preferring species, and the Asiatic black bear depends on a frugivorous diet (Steinmetz *et al*., 2021). The Marble Cat and Mainland Leopard Cat are identified to be temporally segregated (Mukherjee, 2019), and there is a need to create a specific monitoring protocol for small cats rather than utilising data obtained from methods adopted for other large-bodied species (Borries *et al*., 2014).

The Marble Cat and Mainland Leopard Cat are identified to be temporally segregated (Mukherjee, 2019), and there is a need to create a specific monitoring protocol for small cats rather than utilising data obtained from methods adopted for other large-bodied species (Borries *et al*., 2014). The yellow-throated marten, which is capable of acting as a top predator in forests where there is a less abundant top predator (Appel *et al*., 2014) also the reason for the species shows a higher rate of temporal overlap, mostly with the prey species. The diurnal yellow-throated marten shows positive spatial co-occurrence with arboreal species. The masked palm civet is a nocturnal species (Li *et al.*, 2022) that shares its habitat with the Northern Pig-tailed Macaque. The species, such as the clouded leopard and the Asiatic golden cat, were identified as temporally overlapping species (Lynam *et al*., 2013) in the Southeast Asia distribution range. Our estimation was unable to identify such an association, which might be an artefact of site-specific activity. The Asiatic golden cat and leopard cat's difference in temporal activity was observed in other distribution ranges (Kamler, 2020). Environmental factors also played a significant role in the establishment of these elusive felids (Choki *et al*., 2025).

Though the distribution of goral and serow was reported to be in close habitats based on some of the ecological studies. Red goral was found to prefer open area habitats and steep slopes with greater than 30^0 slopes (Green, 1985; 1987). As they have escape behaviours, they prefer cliff-occupied forests (Johnsingh & Manjrekar, 2013). However, there isn't much overlap between the serow and red goral. This could be because serows like to inhabit areas with lots of scrub (Green, 1985), while gorals stay away from these kinds of understory habitats. Gorals inhabit limited areas in NE region, whereas serows are more common in this region. Red Goral, Northern Red Muntjac, Sambar, and Mainland Serow show high temporal overlap, but the activity peak varies among the species at various rates, which might be due to differences in feeding preferences (Ribeiro, 2016). The sambar shows positive spatial co-occurrence with serow and red muntjac but not with goral. The distinction may be due to the feeding behaviour, as sambar and the other two species are browsers, whereas goral are grazers (Green 1987). Though there appears to be a considerable temporal overlap of Takin with all the ungulate species, the species is expected to be capable of maintaining niche separation with other large and medium-sized mammals (Zhang *et al*., 2021). The activity pattern of Takin shows a unimodal peak, differing from other species. Additionally, there is a positive spatial co-occurrence with Serow. Both species are browsers and engage in seasonal movement between altitudinal gradients (Li *et al.*, 2022). The Gongshan Muntjac was considered to be a syntopic with other species of muntjac (Ma *et al.,* 1994) which was not observed in the study unit either temporally of spatially. The existence of separation of niche among the sister species based on elevation was observed in the evaluated habitats (Schaller & Rabinowitz, 2004) which need an extended assessment. Scientists have observed the mutually beneficial group association among species, particularly between ungulates and primates (Newton, 1989; Stensland *et al*., 2003). The Temporal association of various other combinations between Prey-predator and among the similar guild did not show considerable overlap as per our analysis. For example, though the species shows bimodal and unimodal activity peaks, the goral and Northern pig-tailed macaque show temporal overlap but not spatial co-occurrence. In contrast, some species, such as barking deer, serow, and sambar, show spatial co-occurrence but not temporal overlap. The scale of risk, which in turn also influences space uses (Hebblewhite & Merrill, 2008; Kohl *et al*., 2018), influences the activity variation at a finer scale among the ungulates. To understand the rhythms of species that are primary consumers, there needs to be an extensive study, monitoring, and large-scale information.

Conclusion

The mammalian species show various circadian rhythms during different life stages; e.g., the activity during the initial days following birth is not consolidated around the clock during the postpartum period (Bloch *et al*., 2013). Mammal communities are closely linked to random population changes, the quality of their habitat, and competition between different species in an area (Ziv, 2003). When species migrate, the availability of food and their energy reserves affect how active they are at night and during the day. More long-term studies that focus on specific species and communities would give useful insights for conserving and managing biodiversity in this area. Direct observation in the least accessible habitats can contextually explain animal behavior. This camera trap-based activity information helps achieve behavioural ecology and species interaction. As the study area lies in a junction of three biogeography *viz.*, Indo-Malayan, the Palearctic, and Indo-Chinese realms. The timing pattern also varies considerably such that the extension of such monitoring can provide insights about the influence of biogeography and geographic gradients in determining the activity pattern of the species of interests (Bennie *et al*. 2014). The assessment activity pattern from the NE region is being considered preliminary (Mukherjee, 2019). We need to integrate other aspects, such as dietary preferences and spatial use patterns, further examine this activity information. The estimated spatial co-occurrences show a majority of associations as random and some of the species associations as positive; there may be various influencing factors in the environment (Brazeau & Schamp, 2019). The above observation in our study of the circadian activity of species like Dhole, Clouded Leopard, and Marbled Cat shows certain differences from other distribution areas. We need to conduct more research on the competition between different species within a community. This should involve ongoing observation over a long time, along with developing new ideas about how species coexist (Chesson, 2000). This information about activity patterns and the spatial-temporal use of individual species is very important for the management and conservation of biodiversity in the rugged terrain of this valley. The co-occurrence of the analysed species shows a possible favourable probability frequency. As such, species space use, movement, strata, and other factors (Pellissier *et al*., 2010; García-Girón *et al*., 2020) can influence spatial interaction. Currently available co-occurrence results provide valuable information for scientific management. There is a requirement for other species-related information, like population, behaviour, and life history traits, such as movement and migration, which require a long-term study (Alves, 2023).

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Chapter – VI

People's Perception of Forest Resources and their Association with Mammalian Species in an Eastern Himalayan Landscape Unit, Arunachal Pradesh

Abstract

The social-ecological system-based approach to natural resource management has undergone significant developments. Northeast India is home to a high diversity of flora, fauna, and a diverse group of Indigenous people. There have been discoveries of new species very recently in this region, showing the need for a profound understanding of species distribution in this region. The study unit lies in a biodiversity hotspot region of Arunachal Pradesh. The people in this region depend on the forest for a shifting cultivation practice called '*jhum*', as well as other products such as NTFP, firewood, timber, medicinal products, and hunting. The dependency on firewood and hunting rates was found to be high, at 82% and 70 %, respectively. There are 37 fauna species reported as sightings, depredations, hunting, and trophy. The sighting information of endangered species Musk Deer and Red Panda, and further the Water Buffalo reported as trophies, provide recent past distribution of endangered species. The hunting of critically endangered species like the Namdapha Gliding Squirrel and vulnerable species, such as Sambar and Mishmi takin, poses a significant threat to conservation efforts. Hunting practices involve not only the pursuit of meat but also cultural beliefs and adherence to rules known as 'taboos'. We found no statistically significant association between hunting practice and professional status ($P > 0.05$). Negative interactions, such as crop damage by endangered elephants and livestock depredation by vulnerable dhole, were reported. Cultural beliefs and traditional rights interlink with species protection in the region, according to a high percentage of respondents.

Introduction

The core concept of conservation biology as represented by Soulé (1986) and Wilson (1992) exists unchanged, but there is an alternate or additional requirement of approach being developed (Soulé, 1985). This development is based on experiences, i.e., nature and people's relationships (Mace, 2014). The 'social-ecological' system-based approach in natural resource management (Folke *et al*., 2016) and the involvement of social groups directly or indirectly in natural resource and environment management have been aggregated in recent decades (Aracely *et al*., 2022). The attitude of humans, especially Indigenous people, towards nature is not indifferent to the complex social structure of human society. Understanding the differences between Indigenous communities and Western societies is crucial when addressing nature-related issues in areas where community and nature are closely interconnected (Morris, 1991; 2000; 2004; & 2014). The Indigenous people, who are defined as the pioneers in the claim of a territory (Béteille, 1998), developed a continuous process of survival by creating their own culture, tradition, and beliefs that were found to possess a basis of sustainable floral and faunal dependencies (Saini, 2011). Certain policies have also been developed to sustain eco-social aspects, recognising the aesthetic and spiritual values of Indigenous peoples (UNCED, 1992). The interaction with forests by forest use and reliance on forests periodically are the two broad strategies of livelihood associated with forests (Lauren *et al*., 2020; Newton *et al*., 2016).

The North-Eastern region boasts one of the highest levels of forest cover in the country. The state of Arunachal Pradesh boasts a forest cover that exceeds 60% (Dikshit & Dikshit, 2014). The state has records of prehistoric settlement, subsequent discoveries of Stone Age tools from the Mishmi hills, and traditions that extend from historic routes (Anderson, 1871; Banerjee, 1924; Pushpa, 2012). The people of the state depend on the forest for various resources and adhere to traditional beliefs and *'Taboos'* (Aiyadurai, 2009). The agricultural practice is shifting cultivation, which is called '*Jhum'*. The primary method of this kind of cultivation involves relocating the cultivation area through forest clearing or forest burning (Tripathi, 2003). The region is known for new species discoveries that persist in the scientific community; these species are already familiar to the Indigenous people, particularly hunters who understand their distribution and seasonal patterns. There is a need to understand the people's perception to attain the conservation goal, and it was recently recognised, whereas the earlier approach was indigenous people's exclusive approach (Kideghesho *et al*., 2007; Mutanga *et al*., 2015, 2016; Bennett, 2016). To understand the perception of the people in and around the study unit, a semi-structured questionnaire survey was carried out among all the possible stakeholders.

Study area

The study area lies in the state of Arunachal Pradesh, which is the farthest eastern territory of India. The state shares three international boundaries. The state is one of the regions with the highest indigenous community populations in the country. The state was identified as home to diverse peoples; there are 25 major ethnic groups and different other subgroups, and based on the distribution of the groups, the state can be considered an ethnic group meeting point (Ashraf, 1990). Two biodiversity hotspot regions, the Himalayan and the Indo-Burma, compose the region. We selected the occupants of the settlements in and around the demarcated landscape unit in the Mishmi Hills, which falls under the Lohit, Anjaw, and Dibang Valley districts and is part of the Namsai districts. The landscape stretch lies between the Namdhapha National Park and Dibang Wildlife Sanctuary; both share international boundaries with Myanmar and China's autonomous region of Tibet, respectively (Fig. 6.1). The study unit also includes a part of the South Arunachal Elephant Reserve. People from the Idu Mishmi in the Dibang Valley and the Miju and Digaru Mishmi in the Lohit and Anjaw districts inhabit the region.

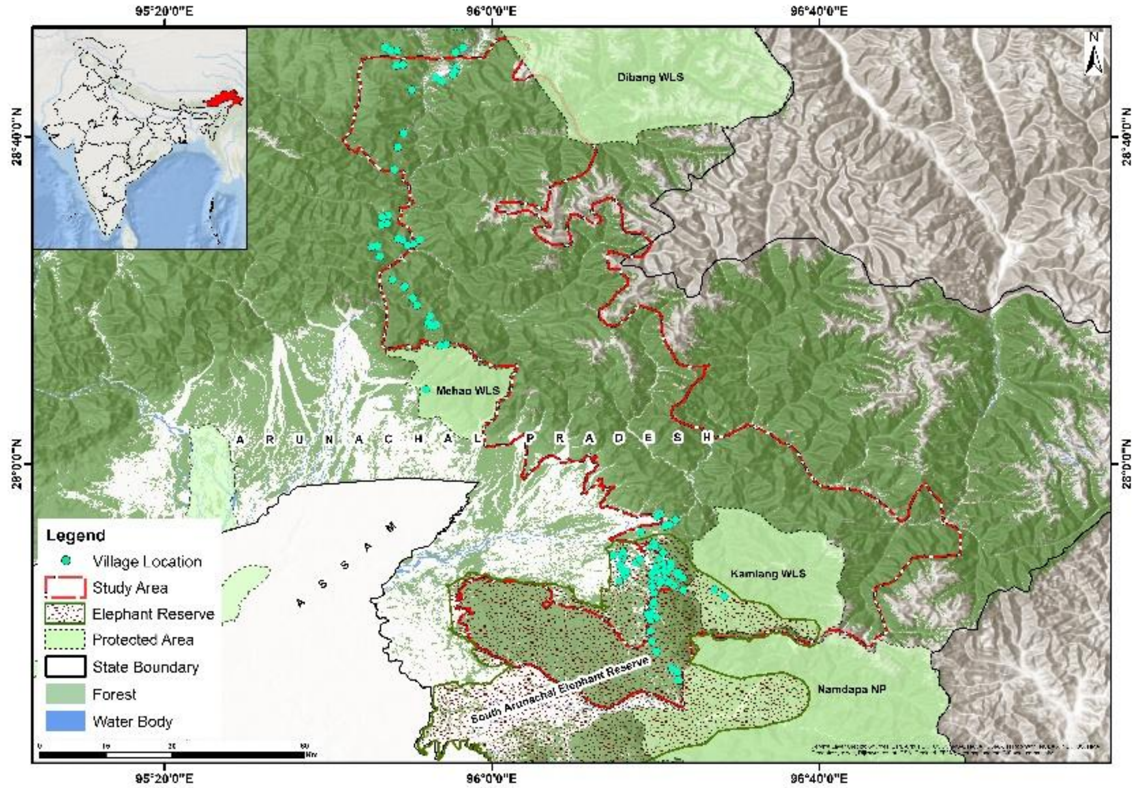

Figure 6.1. The study area for the People's perception component

Methods and Data Collection

To understand the perception of the people in and around the study unit, a semi-structured questionnaire survey was carried out among all the possible stakeholders. A standard questionnaire was prepared to collect information about the local people's association with the forest and their traditional knowledge and dependency on it. We collected information about the interaction between humans and wildlife, particularly mammalian species. The questionnaire was designed (Vaus, 2002) such that we can acquire possible information about the distribution and dependency of forest resources and the interaction with wild animals. The trained research personnel collected the information in the native language of the participants. The data were collected as a part of understanding the determinants of mammalian assemblage in the selected landscape unit. Understanding is crucial. People's attitudes and perceptions are important factors that can influence mammalian distribution. We identified human settlements within the unit. There are constraints at the landscape level to reach a considerable high number of samples (Bryman, 2012) among and within the group level. To overcome such an issue, we didn’t consider the difference between the group of people and their perspective (Kindsiko & Poltimae, 2019) at the selected landscape unit level. We adopted a simple random sampling approach across the identified villages (Fig. 6.1). The respondents in the interview were preferred to be a head man or a secondary-stage adult who might provide better interpretation regarding the information related to the tradition and the association to the forest. We collected demographic information on gender, age, household income source, fuel use, crop cultivation, and livestock. The age class was considered as three different groups (Zhaoyang, 2018): young adults (20 to 39 yrs), middle-aged adults (40 to 59 yrs), and older adults (> 60 yrs). To understand and evaluate the participants' association with natural resources, we collected information related to their dependency on them in various ways, such as NTFP, fuel, timber, medicinal plants, cultural values, conflict with wild animals, hunting practices, animal parts used in medicine, and trophy holdings. As our study area falls in a region surrounded by protected areas, we also recorded their attitude towards the creation of PAs, which includes the respondent's acceptance and their view for natural resource protection, as one of the options.

Ethics

We clearly explained the study's objective to the participants and the value of their information in the current research. We assure respondents that the collected information is strictly for biodiversity knowledge, fostering their confidence and maintaining their voluntary nature. We also guarantee the confidentiality of the respondent's identity details and sensitive information.

Results

The social and demographic data of the respondents, along with their dependency on the forest for various resources recorded for each respondent, are given in Table 6.1. The employment status of respondents falls under seven major classes. The dependency on forest resources varies among the respondents, with the majority of respondents depending on the forest for firewood and hunting.

Table 6.1. Socio-demographic status and forest dependency of respondents

Gender	
Male (Female)	80 (6)
Age range	21 - 80
Mean age	48
Employment status (%)	
Government employee	18.60
Agriculture & Unskilled Labour	54.65
Head man	13.95
Businessman	3.49
Student	4.65
Housewife	2.33
Hunting	2.33
Forest dependency (No. of Respondents)	
Not dependent	8
Moderately dependent	59
High dependency	14
Very High dependency	5

% of respondents depend on firewood from the forest	82
% of respondents depends on NTFP from forest	30
% of respondents depend on medicinal products from forests	36
% of respondents depend on hunting from forests	70
% of respondents depend on timber from forests	26
Creation of Protected area	
Supporting	30%
Not Supporting	31%
Neutral	1%
Conservation by Culture	37%
Trophy	
Years of possession	1 to > 20
Hunting Purpose	
Food	67%
Sales	23%
Cultural	5%
Others	5%
Distance travelled for hunting (km)	15 to 150

Based on the information collected using the questionnaire survey and the interaction with the respondents in the region. During the interview, participants referred to a collection of NTFP and medicinal products as 43 different species. We found it challenging to identify the exact species for all the lists based on the collected names. A few familiar species identified as NTFP products include wild ginger, mushrooms, bamboo, plantain flowers, fodder, cane shoots, bamboo, grass for hut roofs, and honey, among others, which are identified as being collected for medicinal purposes. The respondents have reported in local dialects the use of timber-related products such as pine, bamboo, and 51 other tree species.

We figured out there are 37 faunal species (Table 6.2) from the region with various types of association, viz., direct sightings, agricultural damage, livestock depredation, hunted, and possession of trophies. There are 27 species reported as directly sighted wild animals, 14 species involved in crop damages, and 11 species reported to be the livestock depredation species. The people in this region have reported hunting 21 species. There are 12 different wild animals that were recorded as trophies; additionally, the trophy includes remains of mithun and cows. The species list includes all the top predators, such as the tiger (*Panthera tigris*), the leopard (*Panthera pardus*), the dhole (*Cuon alpinus*), and the snow leopard (*Panthera uncia*). We also identified the Asiatic black bear *(Ursus thibetanus)* and the sun bear *(Helarctos malayanus).* The participants also reported species such as the Alpine Musk Deer *(Moschus chrysogaster)* and the Red Panda *(Ailurus fulgens).* He The respondents also provided information about the use of animal products for medicinal purposes. There are six species reported to be used for various purposes: bear sp., flying squirrel, monitor lizard, porcupine sps., hornbills, and jackal. They are being used for medicinal purposes in various combinations and for different ailments.

The damage to the agricultural crops was reported to be due to 14 different species, which include 13 wild species and one semi-domesticated species belonging to 6 different taxa. The crop depredation by elephants used to happen in the foothill croplands. The crop loss due to natural calamities was also reported to be one of the major causes. Fig. 6.2 identifies the wild pig as a major cause of crop damage, with the bear species following closely behind. The crop damage caused by avifauna and carnivores is equal to the loss created by natural calamities. There are 10 species involved in livestock depredation, of which top predators such as tigers, leopards, and dholes are involved in the depredation of mithun and cattle.

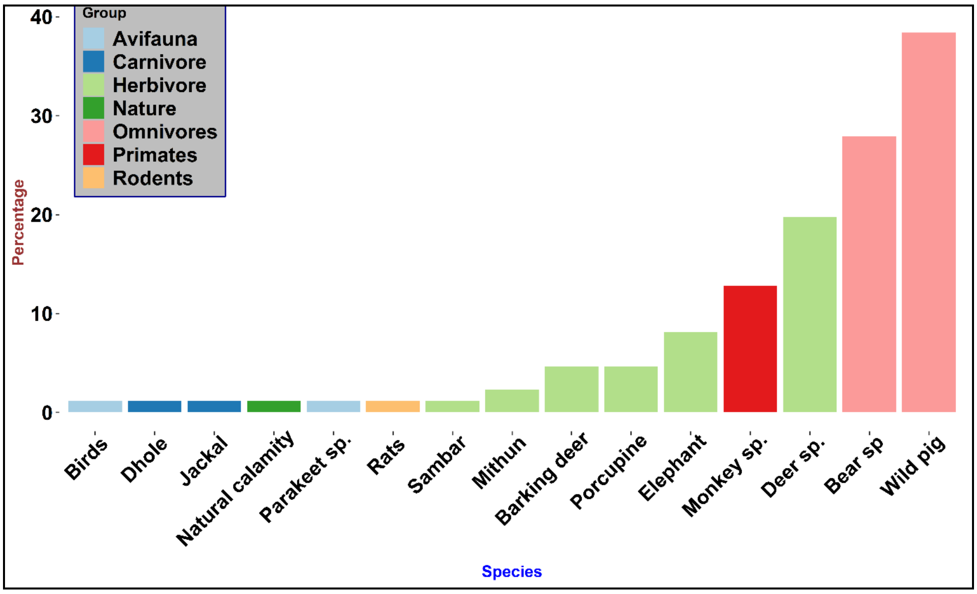

Figure 6.2. The causes of Crop damage and proportion of respondents affected by the species

Table 6.2 List of species reported by respondents of the questionnaire survey and the nature of association

S. No.	Species	Sightings	Crop damage	Livestock depredation	Hunting	Trophy
1	Barking deer	+	+	-	+	+
2	Bear sp.	+	+	-	+	+
3	Bird sp.	-	+	+	+	-
4	Asiatic Black bear	+	-	-	-	-
5	Civet sp.	+	-	+	+	-
6	Deer sp.	+	+	-	+	-
7	Dhole	+	+	+	+	-
8	Elephant	+	+	-	-	-
9	Fish sp.	-	-	-	+	-
10	Flying squirrel	+	-	-	+	-
11	Goral	-	-	-	+	+
12	Hoolock Gibbon	+	-	-	-	-

13	Hornbill sp.	-	-	-	-	+
14	Jackal	+	+	+	-	-
15	Leopard	+	-	+	-	-
16	Leopard cat	-	-	+	-	-
17	Mishmi Takin	+	-	-	+	+
18	Mongoose	+	-	-	-	-
19	Monitor Lizard	+	-	-	+	-
20	Monkey sp.	+	+	-	+	+
21	Musk Deer	+	-	-	+	+
22	Otter sp.	+	-	-	+	-
23	Parakeet sp.	-	+	-	-	-
24	Porcupine	+	+	-	+	-
25	Rats	-	+	-	-	-
26	Red panda	+	-	-	-	-
27	Sambar	+	+	-	+	+
28	Serow	-	-	-	+	+
29	Small cats sps	+	-	+	-	-
30	Snake	+	-	+	-	-
31	Snow leopard	+	-	-	-	-
32	Squirrel sp.	+	-	-	+	-
33	Sun Bear	-	-	-	-	+
34	Tiger	+	-	+	+	-
35	Water Buffalo	-	-	-	-	+
36	Wild pig	+	+	-	+	+
37	Yellow-throated Marten	+	-	+	-	-

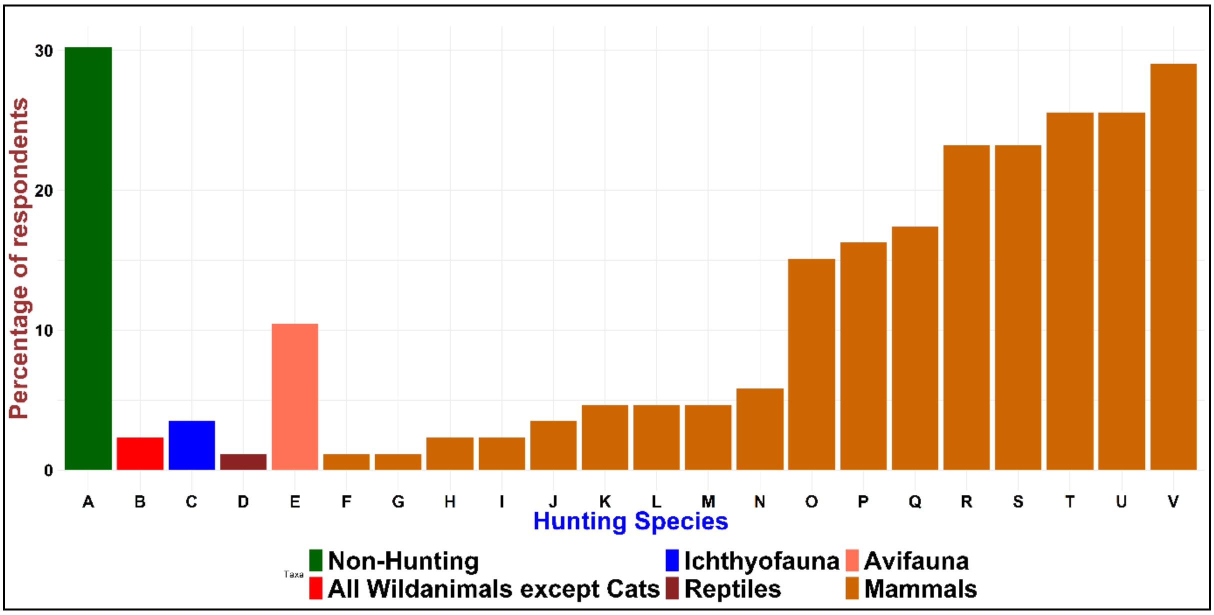

Figure 6.3. Proportion of respondent hunting record of species [A-Not Hunting; B- All except cats; C-Fish sp.; D -Monitor Lizard; E -Birds sp; F- Civet sp.; G -Flying squirrel; H - Otter sp.; I- Tiger; J- Porcupine; K-Dhole; L- Monkey sp.; M- Squirrel sp.; N- Sambar; O - Musk Deer; P- Goral; Q- Serow; R-Barking Deer; S-Wild pig; T-Bear sp.; U-Mishmi Takin; V-Deer sp.]

Among the respondents, around 30 % were not interested in hunting. The respondents who are involved in hunting practice reported consumption of fish and wild meats, which includes 21 different species (Fig. 6.3). The list includes fish, reptiles, birds, and mammals. The respondents rely more on mammals for meat than other animal groups. More people hunt the deer species than any other. The respondents reported moving from 5 km to greater than 100 km for the purpose of hunting. The species' interest, purpose, and season also play a major role in determining the distance required to travel. The information revealed that hunting primarily targets mammal species. The rate of reported hunted species are the deer species (~29 %) and those who mentioned specific species stated barking deer (23.26 %), goral (16.28 %), musk deer (15.12 %), sambar (5.81 %) Mishmi takin (25.58 %). The highest percentage of reported hunted species was the wild pig (23.26 %). The killing of Tiger, reported by two of the respondents, was completely accidental and self-defence. However, the purpose of killing the dhole was to protect domestic animals, particularly mithun, from attack. About 25% of the respondents practiced bear hunting. The respondents reported they used to hunt any species for various reasons, except cat species (Fig. 3). The trophies also revealed the presence of the Wild water buffalo *(Bubalus arnee).* The trophies also identified four species of hornbills. (i.) Great Hornbill (*Buceros bicornis*), (ii.) Rufous Necked Hornbill (*Aceros nipalensis*), and (iii.) Wreathed Hornbill (*Rhyticeros undulates*), which are Vulnerable as per IUCN, and the fourth species is the (iv.) Oriental Pied Hornbill (*Anthracoceros albirostris*), which is a Least Concern (LC) species, were identified from the trophies. T The respondents also reported the hunting of monals. One respondent mentioned Golden Masheer (*Tor putitora*). Observations clearly show that the association of trophies extends beyond mere display, becoming an integral part of their daily lifestyle (Fig. 6.4a;b;c;d). The non-parametric Kruskal-Wallis test for rank sums was used to see if forest use depends on employment (p-value = 0.1306), age group (p-value = 0.3501), and income level (p-value = 0.4274). In all three cases, the df (2) and P value were less than 0.05, indicating a lack of evidence to suggest that either age, income range, or employment status influence hunting practices.

The people's views on setting up protected areas under the Wildlife Protection Act for saving wild animals indicate that they feel more responsible for protecting species because of their cultural beliefs and traditional rights (Fig. 6.5) rather than because of any laws. Those who were positive about the creation of protected areas also emphasised the importance of cultural rights. Conversely, those who oppose the creation of protected areas asserted that its enforcement would infringe upon their communal rights and contradict their beliefs.

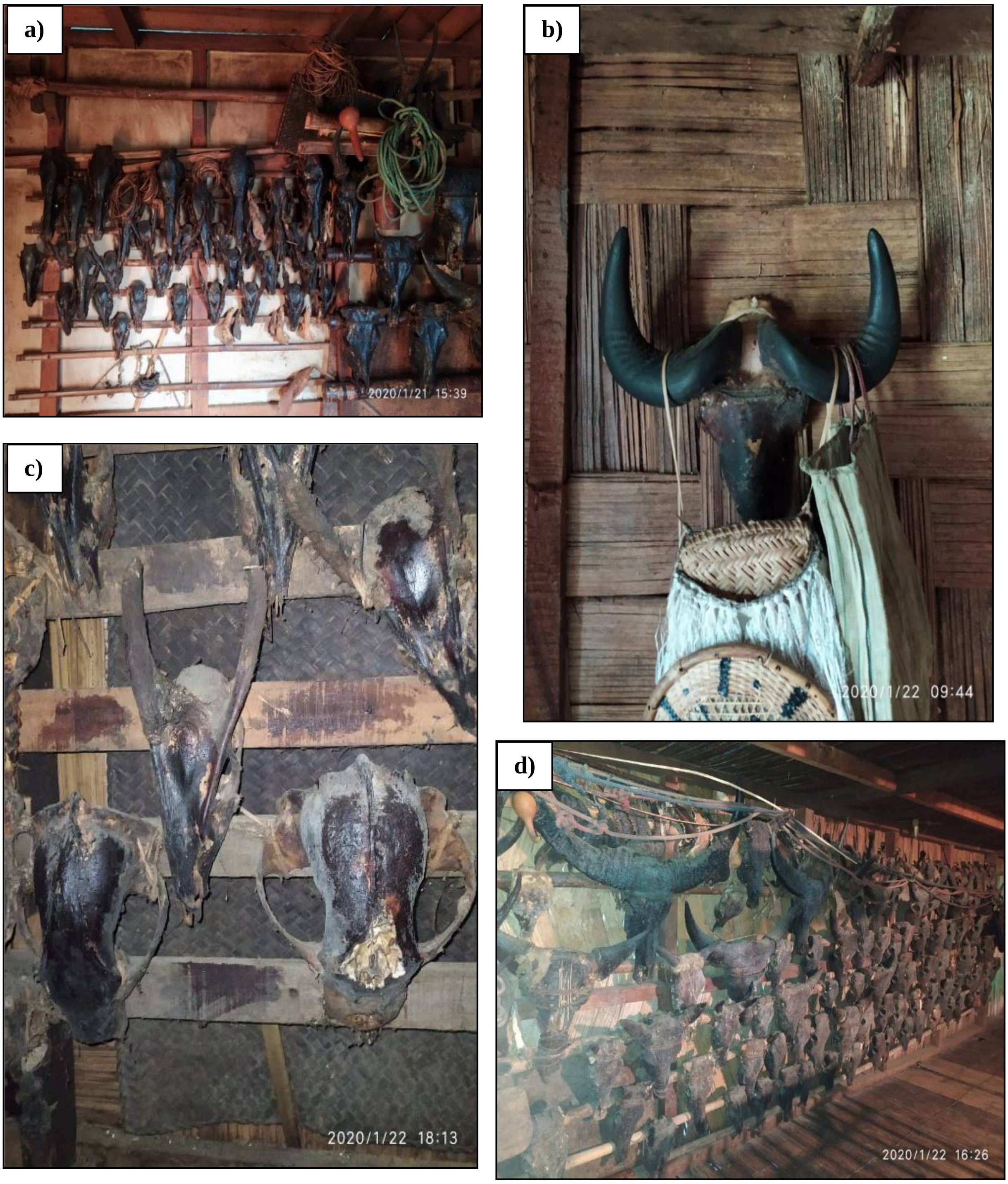

Figure 6.4. Wild animal trophies recorded during the survey, a). A typical trophy arrangement; b). A Takin head trophy and associate use; c). Wild Boar and Barking deer skulls Trophy; d). Trophy with various species including Wild water buffalo

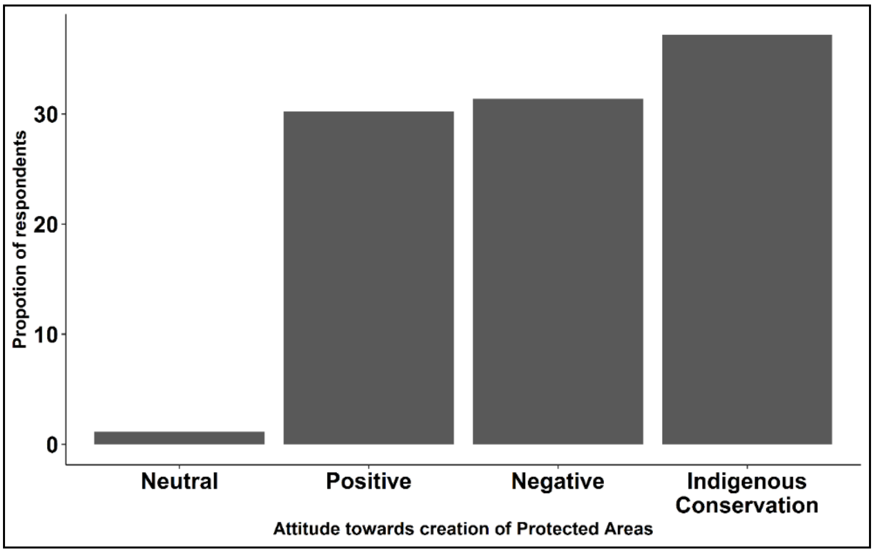

Figure 6.5. Attitude towards creation of Protected areas in the region for conservation of species

Discussion

The close connection between humans and animals is part of the ecological process, as they are deeply connected to the biological and social systems that have developed over time, creating a shared space for different species (Baynes, 2013). Information narrated by Indigenous people, recognised as Indigenous intelligence (Rival, 2009), is important because it provides location-based knowledge. Such knowledge occurs all over the planet and is valuable because it represents adaptations that may be either successful or unsuccessful. Studies on people's attitudes and perceptions are crucial for effectively implementing conservation and management of natural resources. The northeast region is considered one of the highest mammal species diversity regions in India, which is expected to possess 65 % of mammal species in the country (Choudhury, 2013).

In an ethnolinguistic diversity region (Grewal, 1997), identification of flora species by local names is quite difficult. We used the collected information to assess the people's level of forest dependency. That is the case with other plant-based products such as NTFP and medicinal extracts. Respondents directly report popular products and well-documented species. The endemic species, like *Coptis teeta* (Hegde, 1988), was mentioned by respondents. According to Haridasan (2003), this study region's medicinal plants of importance include *Aconitum, Chelidonium, Fritillaria, Caultheria, Taxus, and Hypericum.* Another 101 plant-related products, such as leaves, barks, and even whole plants, are reported to be used for medicinal purposes in the state (Choudhury *et al*., 2015). The studies conducted on the conservation status of such medicinal plants found that these flora species are facing a higher rate of pressure due to overexploitation without evaluation. We need to monitor this practice and develop artificial propagation methods for such species (Hussain *et al.*, 2008). Almost all respondents report using bamboo for various purposes in this region, either directly harvesting it or obtaining it from secondary sources. Bamboo plays a crucial role in the northeastern region, serving various purposes such as house construction and economic contribution (Bahar, 2014). The majority of the rural population's dependency upon natural resources is one of the inbound social phenomena, especially Non-Timber Forest Products (NTFP). The NTFP plays a major role in the socioeconomic support system (Talukdar, 2021).

The associations of mammalian species distributed in the regions listed by the respondents include endangered species such as Asian elephants, tigers, dhole, alpine musk deer, and red pandas, which are recorded in various studies. There are records of high-altitude tigers (Gopi *et al*., 2014; Aiyadurai, 2016) and the distribution of elephants, as there is an elephant reserve in the study area. The current status of two endangered species, the musk deer and the red panda, is unknown in this region. Musk deer species distribution is facing threats due to illegal trade for its musk products value in cosmetics in the state (Wangdi *et al*., 2019; Harris, 2016). Dorjee, (2014) reported scattered information about the status and distribution of red pandas in the state. The species was recently reported from the Lower

Dibang Valley (Hub Network, 2024) in the study area, which was also reported by the respondents.

Although scattered information is available, it still requires assessment. There are various costumed cultural practices in which people participate in group hunting, and the attitude of individual hunting can be carried out at any time of the year (Marak & Kalita, 2013). The association and importance of hunting among the poor people in rural regions are common across the tropics because of greater dependency on such resources for the economy and food (Coad *et al*. 2019; Milner-Gulland *et al*., 2003). There is a uniqueness in evolutionary history, and genetic structure was identified among tigers in this low-abundant distribution region (Kolipakam *et al*. 2019; Jhala *et al*. 2011). The Mishmi people consider tigers their brothers. Two of the respondents reported the killing of the tiger as a precautionary measure. The hunting of small cats, big cats, and martens is restricted by the taboos, which prevent the threat to the species unless they are under threat (Aiyadurai, 2016). The status of leopards in the state itself is unknown except in the tiger reserves. It is required to evaluate the distribution of the leopards (Qureshi, 2024) as the species was reported to be involved in livestock depredation. The bear species are hunted to extract bile from the gall bladder and other products (Bhatt, 2019).

The indigenous peoples of this region hunt flying squirrels and believe they have medicinal value (Adhikarimayum, 2020). There are 14 species of flying squirrels distributed in the state, of which 11 species are reported to be distributed in this region, which includes the Critically Endangered Namdapha Gliding Squirrel (*Biswamoyopterus biswasi*) and the Endangered (EN) Bhutan Giant Gliding Squirrel (*Petaurista nobilis*). There are seven other least-concerning flying squirrels also reported in this region. The IUCN has not yet assessed two species of flying squirrels (Murali *et al*., 2016). The Malayan Giant Squirrel, which is at risk, and the Orange-bellied Himalayan Squirrel, which is not at risk, are important to the local culture and are studied in relation to animals and their uses. The hoary-bellied squirrel, Himalayan striped squirrel, Pallas's squirrel, orange-bellied Himalayan squirrel, and particoloured flying squirrel are reported to be hunted throughout the year (Adhikarimayum *et al*. 2021).

The dependency on these groups of species raises concern to prevent the loss of species population, as the hunting practice creates vulnerability to various species (Velho & Laurance, 2013; Mazumdar & Gupta, 2014). The squirrel species are also considered pests because of the damage caused to orchards and croplands (Kumawat, 2016). Four species of squirrel were reported to be subjected to hunting by the indigenous people at a high rate (Aisho et al. 2021) in the study region. The respondents reported hunting deer species, which directly impacts the prey base of large carnivores (Jhala *et al*. 2021). Concerns exist regarding other vulnerable species and a few species that remain unevaluated. The Mishmi takin is one of the species subjected to a higher proportion of respondents involved in hunting Mishmi takin, and a considerable number of trophies were also recorded, which was one of the major threats to the endangered species (Barman *et al*., 2024). The study reported Wild water buffalo as trophies for hunting, which is now restricted to a confined population status in Assam and Chhattisgarh (Qureshi, 2022), which shows the past distribution and habitat availability in the study area for the species. The eastern hoolock gibbon (*Hoolock leuconedys*) was reported in the lower Dibang district (Chetry, 2011), and the western hoolock gibbon (*Hoolock hoolock*) in the Kamlang Tiger Reserve (Molur, 2005). Adi tribes pose a threat to Hoolock gibbons for their meat consumption, as Idhu beliefs forbid hunting. The species also faces threats from dogs near human habitation in the region (Kumar *et al*., 2014). Reports from this region also indicate that monitor lizards prey on gibbons (Kumar *et al*., 2014). In a developing, mega-diverse country like India, where the population growth rate is high, there is a need to understand the protected area and community land interface (Velho, 2013). There is a need to consider the connectivity of the landscape for the movement and dispersal of species in a protected area and community land complex (Goswami, 2014). The region faces numerous geographical challenges, including rugged terrain, rainfall, river course, poor drainage, and low levels of developmental activities due to various geological and political factors (Piku, 2022). Recent studies indicate that engaging Indigenous peoples and local communities (IPLCs) in biodiversity conservation is possible and should be considered at a regional scale for holistic outcomes. (Mcleod *et al*., 2019; Garnett *et al*., 2018; Schleicher *et al*., 2017; Blackman *et al*., 2017; Oldekop *et al*., 2016; Bridgewater *et al*., 2015; Persha *et al*., 2011). This survey's data and the people's views make it a valuable source for species management and conservation.

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Synthesis

The mammalian species assemblage, diel activity patterns, species cooccurrence patterns, habitat suitability and people's perception were investigated in an Eastern Himalayan landscape unit from 2018 to 2020. The inventory is based on camera trap records, questionnaire surveys and direct observations. Forty-one species were documented during the study, of which 40 species are wild mammals and one semi-domesticated species. The species includes eight endangered species and one critically endangered species; 13 species are vulnerable, and three species are near threatened as per the IUCN Red List data. The examination of species accumulation also indicates sampling adequacy in terms of both effort and the number of camera trap nights. Modelling the species distribution based on available location coordinates is one of the well-recognised techniques to understand the suitable habitat for selected species. Landscape-level modelling at the regional scale in the biodiversity hotspot region in Indian Territory was carried out for select mammalian species identified in the study unit. Combining the camera trap-based locations along with GBIF and geo-coordinates, literature-based secondary sources the species, which fulfils the minimum recommended number of locations for distribution modelling, was selected for prediction. Environmental variables and the positioning variables, such as topographic variables and land cover, were used for prediction. Each species underwent the removal of correlated climatic variables. There are nine species that were selected, of which three carnivores, four herbivores and two meso-carnivore species were analysed for suitable habitat. The predicted habitat suitability shows that the landscape unit is a viable habitat for the selected species, showing highly suitable habitat available for most of the species and suitable habitat for all the selected species.

Diel activity of mammals reflects inter- and intraspecific behaviour with implications for spatial planning towards conservation management. We used timestamp photographs to understand the circadian rhythms of the species through activity patterns, temporal overlap for sunrise and sunset, and spatial co-occurrence using R Core. We observed the dhole to be a cathemeral predator among the recorded species. Most primate species show activity close to sunrise. Temporal overlap among primates shows higher paired coefficients between the stump-tailed macaque and the capped langur. The Marbled Cat exhibits a higher intergroup overlap with Serow, Red Muntjac, and Sambar. Dole's activity overlaps with all the prey species. Within the Artiodactyl guild, temporal overlap was higher between the Serow and Red Muntjac. The probabilistic model of species co-occurrence shows species interactions among 16 out of 24 species. The diurnal activity peaks of the black bear and sun bear are distinct, but they do not overlap or occur together. The ethological information about Takin and a few other small mammals are one of the prominent findings of the present study. A long-term study will reveal the spatiotemporal relationships among the species and aid management and conservation practices.

Northeast India is home to a high diversity of flora, fauna, and a diverse group of Indigenous people. The people in this region depend on the forest for a shifting cultivation practice called '*jhum*', as well as other products such as NTFP, firewood, timber, medicinal products, and hunting. We found high dependency rates on firewood and hunting. During the sociology survey, 37 fauna species were reported as sightings, depredations, hunting, and trophies. Information about musk deer, red pandas, and snow leopards is valuable. The recent distribution of endangered species related to the Water Buffalo is concerning. The hunting of critically endangered species like the Namdapha Gliding Squirrel and vulnerable species, such as Sambar and Mishmi takin, poses a significant threat to conservation efforts. Hunting practices involve not only the pursuit of meat but also cultural beliefs and adherence to rules known as 'taboos'. We found no statistically significant association between hunting practice and professional status. Negative interactions, such as crop damage by endangered elephants and livestock depredation by vulnerable dhole, were reported. Cultural beliefs and traditional rights are still persistent in the region, which need consideration to achieve community participation in conservation.

Recommendations

The study has highlighted the rich assemblage of several rare and threatened mammalian species in the region, emphasizing the need for a long-term ecological and conservation-monitoring program. In this northeast Indian landscape of high conservation significance, global conservation approaches such as 'umbrella fleets' or the use of surrogate species, taking into account the topographic features and resource availability, can help prioritize management strategies. Species such as the Tiger, the Hoolock Gibbons, and the Red Panda can be considered, which can indirectly secure habitat for other species. For lasting conservation efforts, long-term monitoring of select species would be required in this landscape encompassing areas that fall outside the PA network and continuous forests stretch as well, since wildlife ranges spread across the landscape regardless of the administrative boundaries. Here, and in the transboundary regions of the northeastern landscape in general, the researchers has identified the phenomenon of 'Empty Forest Syndrome,' which indicates large-scale defaunation of all forms of faunal taxa. Given this, it is critical to periodically assess the status of habitat and wildlife populations in the area using simple, but robust population metrics such as occupancy, relative abundance, and even absolute abundance of umbrella species. This is particularly the case for implementing adaptive management strategies, given that the forest occurs under diverse administrative regimes. This study indicates widespread occurrence of three species—namely the Sambar, the Clouded Leopard, and the Sun Bear, which can act as keystone (for sambar as it constitutes an important prey for carnivores), and clouded leopard and sunbar (which could act as flagship species due to their appeal) and thus can be chosen for long-term monitoring. Additionally, the Red Panda and Snow Leopard also occur in the landscape in their respective habitats. The red pandas are patchily distributed in the northeast region, occurring scatteredly over Arunachal Pradesh. On the other hand, the snow leopard habitats are limited along the snowline and trans-Himalayan region and thus may not be chosen for region-scale biodiversity monitoring. The only species of the Order Scandentia (the treeshrews) occuring in the region is Northern Tree Shrew. This is a data-deficient species and being the sole species in the Order, it is pertinent to carry out intensive assessment of its fine-scale distribution patterns. The critically endangered Chinese pangolin was rescued during the study, and a new ecotype, the Indo-Burmese pangolin, was recently discovered in this region. Systematic monitoring of the species as a whole is necessary, along with a scientific understanding of species distribution and niche breadth. The smooth-coated otter, a semi-aquatic mammal, was recorded as an ally in the camera trap exercise, but the other species of the group were not recorded. Adopting a specific monitoring protocol and monitoring the species is one of the essential requirements in these largest river networks. Species-specific methods should further explore the data-deficient species, especially small mammals like chiroptera, rodents, and flying squirrels. The suitability model shows a highly suitable area for the takin and the Asiatic black bear, and less suitable areas are found to buffer such localities to enhance habitat connectivity. The prediction also shows continuous habitat connectivity for species like Mishmi Takin, which need an integrated approach for understanding seasonal migration, habitat use, and habitat viability. The Asiatic golden cat, which shows high suitability in higher elevations, is one of the important considerations. The important prey species, such as sambar, serow, and takin, indirectly indicate that the habitats possess high potential for top predators and umbrella species.

Overall, at the landsape-scale and even at a regional scale there is clear paucity of information even on aspects like distribution for most species. Our study underscores the importance of monitoring and we have demonstrated easy presence-location based approach to understand broader patterns of distribution. Surveys such as ours, if carried out periodically can provide critical insights to gauge the landscape, its environmental and anthropogenic stressors and incorporate adaptive management strategies.

Furthermore, as elaborated in the study, the difference in activity patterns between top predators, such as the dhole, and elusive species, like the clouded leopard provide interesting insights circadian rhythms in a landscape, which has a different astronomical day length compared to other Southeast Asian regions. Assessing circadian rythms can provide clue on how the species is responding to both human-induced landscape modifications and also the threats posed by people in the form of hunting. Changes in circadian rythms of functionally important species can potentially alter the entire faunal community structure and thus, justifies approaches such as camera trap monitoring, which enables fine-scale assessment of spatio-temporal behavior of cryptic and elusive animals.

Lastly, our observation about the perception of the people in the landscape clearly shows that the local communities have strong cultural affinity towards wildlife conservation. This can be effectively used to increase community participation in conservation planning, particularly in areas that fall outside the protected areas. Similarly, recording indigenous knowledge and natural history observations in a systematic way can complement scientific interventions, if appropriately used. Hitherto minimal, there are signs that human-wildlife conflicts are emerging and could potentially escalate in some pockets of the landscape necessitating early interventions such as evaluation and monitoring. The human-wildlife conflict (HWC) in the study area mainly involves elephants and occassional livestock depredation. Given that both elephants and large carnivores are species of high global conservation concern, focussing on elephant monitoring in the altitudes spanning 400 – 1500m and focussing on large carnivores in relatively higher altitudes seem to be the most pragmatic biodiversity monitoring approach in the study area.

Annexure