Establishing ecological baselines for long-term monitoring of tigers, co-predators and prey species in Dibang Wildlife Sanctuary and its adjoining landscape in Arunachal Pradesh

Final Report

भारतीय वन्यजीव संस्थान
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Front cover: Tiger in community forest

Back cover: Dhole pups in DWLS

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CONTENTS

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Summary

Arunachal Pradesh, the land of the rising sun, is situated between 26° 28′ and 29° 30′ North latitudes and 91° 30′ and 97° 30′ East longitudes, covering an area of 83,743 km^2. It has relatively large intact forest areas with low human population densities in the northeastern state of India. Biogeographically, the state is situated in the Eastern Himalaya Biodiversity Hotspot and is one of the four biodiversity hotspots in India, which is also listed among the 200 Globally Important Eco-regions. The entire topography of Arunachal Pradesh depicts a complex landscape matrix of hills with varying elevations ranging from 50 m above mean sea level at foothills up to 7000 m above mean sea level at high elevations. The diverse topographic and climatic conditions support the growth of luxuriant vegetation, which in turn hosts numerous flora and fauna. Around 34 species of mammalian carnivores with nine species of rare and endangered wild felids are reported from Arunachal Pradesh. Nine felid species *viz*., Bengal tiger (*Panthera tigris tigris*), clouded leopard (*Neofelis nebulosa*), common leopard (*Panthera pardus*), snow leopard (*Panthera uncia*), Asiatic golden cat (*Catopuma temminckii*), marbled cat (*Pardofelis marmorata*), leopard cat (*Parionailurus bengalensis*), jungle cat (*Felis chaus*) and fishing cat (*Prionailurus viverrinus*), and two species of canids such as the Asiatic wild dog (*Cuon alpinus*) and golden jackal (*Canis aureus*) are found in the state. The tiger is charismatic and has become a global priority in wildlife conservation as they act as an umbrella species by virtue of being the top predator.

The tiger is culturally considered as a brother by the local Idu Mishmi community who live in the Dibang Valley district in Arunachal Pradesh. Though the local community has long been claiming about the presence of tigers in the region, unfortunately, no efforts were made by the line departments, academicians, or conservationists to assess and monitor the tigers, their prey, and habitat in Dibang Wildlife Sanctuary, Dibang Valley district of Arunachal Pradesh.

In 2013-14 a preliminary rapid survey was carried out by the Wildlife Institute of India (WII) in collaboration with the National Tiger Conservation Authority (NTCA), which confirmed the presence of tigers, and sizeable diversity and abundance of prey populations. This preliminary study was carried out after the rescue of tiger cubs from the district in Angrim Valley during December 2012. The rescued tiger cubs were the first-ever record of a tiger from the Dibang Wildlife Sanctuary. Subsequently, a three-year study was initiated with the following objectives:

1. To determine the distribution and abundance of tigers, co-predators, and their prey species in different habitat regimes in and around the Dibang Wildlife Sanctuary.

2. To evaluate the effects of environmental features and anthropogenic pressure on their occupancy patterns.
3. To determine the factors governing the niche differentiation among these species.
4. To assess local people's knowledge, attitudes, and perceptions about the conservation of tigers.

Methods: From October 2015 to June 2017, intensive camera trapping exercise was conducted in the Dibang Wildlife Sanctuary and adjoining landscapes to monitor tigers, co-predators, and their prey species. Monitoring was done for six successive sessions during these years in different river valleys of the Dibang Wildlife Sanctuary and its adjoining landscapes. The camera traps were deployed corresponding to the accessibility of the area. The study area was overlaid with 3 km^2 grid cell, and camera traps were placed along the trails or paths that were actively used by target species. In each of the grid, at least one camera trap was placed, wherever evidence from signs as pug/hoof marks, scat/pellets, tracks, rake marks, digging signs, and other signs were obtained. A total of 28 sign surveys were conducted and 104 households were covered in the questionnaire survey to collect data about human-carnivore interaction and the dependency of local communities on forest resources.

Results: The two-year intensive camera trapping exercise covered the central and southern portions of the Dibang Wildlife Sanctuary and its adjoining areas. 90 camera trap stations were set up inside the protected area over an area of about 270 km^2 and 22 camera trap stations were deployed outside the protected area over an area of 66 km^2. Total camera trap locations were 112 with a sampled area of 336 km^2 with the total number of trap nights being 13,761. 83 photographs of tigers were captured, of which 42 are left-sided, 38 were right-sided and 3 were unable to be identified due to poor image quality. From the 42 left-sided tiger photographs, 9 adults and 2 cubs were identified. During the study, the Asiatic wild dog was also photo captured along with tigers. Apart from tiger, many meso and small carnivores and their prey species were cameras trapped. So far 5 forest-dwelling ungulates were photo-captured from our camera traps *viz.* barking deer, red goral, Himalayan serow, Mishmi takin, and wild pig.

Conclusion: Despite several limitations in terms of the vastness of area to be covered and the limited number of camera traps available, this study has documented 11 tigers in a limited surveyed area of 336 km^2. This study has generated baseline information on tiger, co-predators, and prey in Dibang Wildlife Sanctuary and adjoining landscape. Tigers do not necessarily use only the protected areas; they use the community forests outside the protected area as well. Arguably, the Dibang landscape harbors more tigers than designated tiger reserves in the state. Pakke and Namdapha have 9 and 4 tigers, respectively (Jhala et al. 2015).

Species with small populations are prone to extinction and especially tigers in rainforests are at risk due to various factors like low densities of prey, hunting pressures, and habitat fragmentation. Population viability analysis on tigers in other landscapes has revealed that 24 breeding females in a population or a population having at least 68 individuals can persist over the next 100 years. The Dibang Valley District, if surveyed extensively and fully may have a potentially high number of tiger individuals and will meet the above condition. Also, as the Idu Mishmi community has a strong cultural bond with the tigers, the hunting pressure on tigers is not anticipated. Hence, considering the cultural significance and uniqueness of the tigers in the landscape, any proposal for the tiger reserve needs to be done with the consensus of local communities.

CHAPTER 1

INTRODUCTION

1.1 Background

The state of Arunachal Pradesh is known for its immense biological richness, located in the Eastern Himalaya ranges. The Eastern Himalaya is one of the four biodiversity hotspots in India and is also listed among the 200 Globally Important Eco-regions (Olson and Dinerstein 1998, Myers et al. 2000). The topography of Arunachal Pradesh depicts a complex landscape matrix of hills with varying elevations ranging from 50 m at foothills up to 7000 m at high elevations. The diversity of topographical and climatic conditions has supported the growth of luxuriant vegetation, making it an abode to a plethora of flora and fauna. The state is home to many species of endangered, endemic, rare, primitive, and relict flora and fauna. Studies have reported that 54% of threatened mammals in India occur in the northeast region (Choudhury 2006). Nine species of rare and endangered wild felids have been reported from Arunachal Pradesh *viz.*, Bengal tiger (*Panthera tigris tigris)*, common leopard (*Panthera pardus)*, snow leopard (*Panthera uncia)*, clouded leopard (*Neofelis nebulosa)*, Asiatic golden cat (*Catopuma temminckii)*, marbled cat (*Pardofelis marmorata)*, leopard cat (*Parionailurus bengalensis)*, jungle cat (*Felis chaus)* and fishing cat (*Prionailurus viverrinus).* Two species of canids such as the Asiatic wild dog (*Cuon alpinus)* and golden jackal (*Canis aureus)* are also found here (Choudhury 1997b, Hussain 1999, Dada and Hussain, 2006). According to the Forest Survey of India (2017), the state has a relatively large intact forest area of about 66,964 km^2 or 79.96 % of the total geographical area of the state. It supports more than 5000 species of plants which are distributed at varied altitudinal gradients ranging from lowland tropical forest to alpine vegetation (Saikia et al. 2017).

Despite strong conservation laws in India, hunting remains the most serious threat to wildlife in this region. Local communities have a strong tradition of hunting, due to which implementation of wildlife laws is difficult (Dollo et al. 2010). Hunting and rapid land-use change lead to habitat fragmentation and, consequently, impacts the habitat ecology of tigers and other carnivores. Another challenge for wildlife conservation is the illegal trade and poaching of wildlife species, which has been identified as a major driver of extinction (Karanth and Sunqusit 1995).

Tiger is charismatic and has become a global priority in wildlife conservation as they act as umbrella species; plays an important role in maintaining and balancing the ecosystem (Wang and Macdonald 2009). During the past decade, the geographic range of tigers was reduced by 41% (Dinerstein et al. 2007). A futuristic scenario projection considering the current rate of habitat loss in the tiger occurring landscapes for the next decade suggests a further reduction of 43% during the next decade (Wikramanayake et al. 2010). The respective governments of the tiger range countries are working to protect and conserve these “Tiger Conservation Landscapes” (TCLs), prioritizing securing the source population sites having a viable population (Walston et al. 2010). Given that these large carnivores, especially tigers, may require a conservation approach that complements the preservationist programs, generating ecological and genetic baseline information, and understanding the impacts of anthropogenic pressure is essential for their conservation.

1.2 Literature review

Literature suggests that the tiger originated in East Asia (Herrington 1987); from where two major dispersals took place about two million years ago. To the North-West, tigers migrated through woodlands and along with the river systems into South-West Asia. To the South and South-West, tigers moved through continental South-East Asia, some crossing the Indonesian Islands, while others reached India (Nowell and Jackson 1996). The late arrival of the tiger in the Indian sub-continent is supported by its absence in Sri Lanka, which was cut off by rising sea levels at the beginning of the Holocene (Kitchener 1991). Tigers had colonized this area either coming through North-East Asia via Central Asia or through North-West India (Heptner and Sludskii 1992). At present, there are about 160 distinct and fragmented populations of tigers, which have been designated as Tiger Conservation Units (TCUs) (Chundawat et al. 2011). Three main sources of variation can be observed in tigers *viz.* body size, stripe patterns and color of the pelage, and skull characteristics (Kitchener 1991); even within the population's wide variation in coat color and markings can be pointed out (Heptner and Sludskii 1992).

Tiger, leopard, and wild dog are sympatric with each other by competing and coexisting for thousands of years through subtle ecological and behavioral mechanisms such as differential prey selection and spatial-temporal partitioning of the habitat (Johnsingh 1992, Karanth and Sunquist 1995).

1.3 Tigers

Tigers have been studied widely in its distribution range concerning its general ecology, home range, habitat use, prey selection, interactions with humans (Seidensticker et al. 1999). Different aspects of tiger conservation studied in the Indian sub-continent are on general ecology (Schaller 1967, Johnsingh 1983, Seidensticker and McDougal 1993), social organization (Sunquist 1981), land tenure system (Panwar 1979, Smith et al. 1987, Gogate and Chundawat 1997 and Vanak 1997), dispersal and communication and its effect on prey species (Tamang 1983 and Karanth 1993), prey selection (Karanth and Sunquist 1995, Biswas and Sankar 2002, Bagchi et al. 2003 and Majumder et al. 2012), food habits (Schaller 1967, Johnsingh 1983, Stoen 1996, Sankar and Johnsingh 2002, Uma Ramakrishnan et al. 1999 and Andheria et al. 2007), the response of tiger to the removal of anthropogenic disturbances (Harihar et al. 2008), tiger-leopard interaction (Seidensticker 1976), and population estimation (Karanth and Nichols 1998,). Besides these, several natural history accounts and some short-term studies are also available e.g., Corbett (1944), McDougal (1977), Sankhala (1977), Singh (1984), and Thapar (1986, 1989). The above-mentioned studies give an overview of tiger ecology from site-specific habitats where it occurs.

1.3 (a) Taxonomy

Tigers belong to the genus of big cats known as *Panthera*, the first binomial nomenclature was given by Linnaeus (1758) in the name of *Felis tigris*, synonym(s) of *Panthera tigris* (Pocock 1939). Leu et al. (2004) recognize six sub-species of tigers based on distinctive molecular makers. Recently, the IUCN SSC Cat Specialist Group revised the subspecific taxonomy of tigers through a comprehensive study on several molecular and phylogeography of tiger. Based on the revised study, tigers have been categorized into two sub-species i.e., *Panthera tigris tigris* (Linnaeus, 1758), which includes *P. virgata*, *P. altaica*, *P. amoyensis*, *P. corbetti* and *P. jacksoni*, and *Panthera tigris sondaica* (Temminck, 1844), which includes *P. balica* and *P. sumatrae* (Kitchener et al. 2017).

1.3 (b) Distribution

In the past, the tiger was widely distributed across Asia, Turkey and the Eastern coast of Russia (Nowell and Jackson 1996). However, the first inclusive assessment to define the tiger range was carried out in 1994 (Dinerstein et al. 1997).

This exercise was revised and updated ten years later, and in delineating TCLs, greater emphasis was placed on actual records of tiger presence and breeding (Sanderson et al. 2006). Presently, tigers have lost over 93% of their historic range (Sanderson et al. 2006, Walston et al. 2010). Their resilience, a product of adaptability and high fecundity, has allowed tigers to survive the massive onslaught and habitat loss of the past century (Kawanishi 2002). Currently, tigers are found in 13 Asian range countries *viz.* Bangladesh, Bhutan, Cambodia, China, India, Indonesia, Lao PDR, Malaysia, Myanmar, Nepal, Russia, Thailand, and Vietnam. They may persist in North Korea, although there has been no recent confirmed evidence (Goodrich et al. 2015).

1.3 (c) Feeding and breeding ecology

Carnivore ecology is largely governed by the availability of their prey, and hence understanding the feeding ecology and behavioral flexibility of felids in prey selection is essential to ensure their conservation (Pokheral 2013). Tigers have to hunt large ungulate prey solitarily, as evident from their evolutionary history (Johnsingh & Manjrekar 2013). Since the early 1980's, studies on the feeding ecology of tigers have been conducted in Southern India (Johnsingh 1983, Karanth & Sunquist 1995, Reddy et al. 2004, Andheria 2007, Ramesh T. 2010), Central India (Schaller 1967, Biswas & Sankar 2002, Edgaongar

2008), Northern India (Harihar 2005), Western India (Bagchi et al. 2003, Avinandan et al. 2008) Eastern India (Khan 2008), and Northeast India (Selvan et al. 2013). Similarly, it is also studied in neighboring countries like Nepal (Sunquist 1981, Stoen & Wegg 1996) and Bhutan (Wang 2008).

Tigers can predate large to medium-sized prey. In Southern India, studies reveal that the prey selectivity of tigers was on large-bodied prey (Karanth & Sunquist 1995, Andheria 2007). While in Central India, predation was based on the availability of prey base and their study has also reported the highest predation on chital (Biswas & Sankar 2002). The diet profile of the tiger from the Pakke tiger reserve of Arunachal Pradesh reveals that tigers consumed larger sized prey to smaller sized prey (Selvan et al. 2013). They mate throughout the year; the peak period of birth is between March to June (Sankhala 1977). The gestation period is about 102 to 108 days, and they give birth to a litter of 2 to 5 cubs, usually 3 cubs (Johnsingh & Manjrekar 2013).

1.3 (d) Population ecology

In India, the estimation of a countrywide tiger population started in 1972 through the pugmark method (Choudhary 1970, 1971, Panwar 1979, Sawarkar 1987, Sharma 2001). However, the pugmark method of estimating tiger numbers was later discontinued due to lack of statistical accuracy, as it yielded unreliable results (Karanth 1987, Karanth et al. 2003, TTF 2005). In 1995, the first camera trapping census started in India based on the capture-recapture technique (Karanth 1995). Camera trapping is used to estimate the tiger population precisely (Karanth & Nichols 1998, 2000, 2002, Karanth et al. 2004, Edgaonkar 2008, Jhala et al. 2008, Harihar et al. 2009, Sharma et al. 2009, Wegge et al. 2009, Wang & Macdonald 2009, Ramesh 2011). The All India tiger population estimation within the North-Eastern hills and Brahmaputra plains revealed 100 (84-118) tigers in 2006, 148 (118-178) tigers in 2010, and 201 (174-212) tigers in 2014 (Jhala et al. 2008, Jhala 2011, Jhala et al. 2015). This estimation shows that the tiger population shows an increasing trend in the North-Eastern Hills and Brahmaputra plains from 2006 to 2014. The North-Eastern Hills tiger populations were identified under the conservation priority, based on genetic uniqueness, diversity, and vulnerability.

1.4 Study justification

The tiger is culturally considered as a brother by the local Idu Mishmi community who reside in the Dibang Valley district in Arunachal Pradesh. Though the local community has long been claiming about the presence of tigers in the region, unfortunately, no efforts were made by the line departments, academicians, or conservationists to assess and monitor the tigers, their prey, and habitat in Dibang Wildlife Sanctuary (DWLS), Dibang Valley district of Arunachal Pradesh. A rapid survey-based preliminary study carried out by Wildlife Institute of India (WII), Dehradun in collaboration with the National Tiger Conservation Authority (NTCA) confirmed the presence of tigers and the sizeable diversity and abundance of prey populations in this valley (Gopi et al. 2014). This preliminary study was carried out after the rescue of tiger cubs from the district in Angrim valley in December 2012 (Gopi et al. 2014).

1.5 Objectives

A three-year study was initiated for establishing baselines for tigers, co-predators, and their prey species, to assess the ecological baselines and conservation status. The primary objectives are:

1. To determine the distribution, abundance of tigers, co-predators and their prey species in different habitat regimes in and around the DWLS,
2. To evaluate the effects of the environmental features and anthropogenic pressure on tigers, co-predators and their prey species occupancy patterns,
3. To determine the factors governing the niche differentiation among tigers, co-predators and their prey species,
4. To assess local people's traditional knowledge, attitudes and perceptions about conservation of tigers, co-predators and their prey species, and
5. To identify areas that have high conservation value as well as those that are under threat for tigers, co-predators, and their prey species.

CHAPTER 2

STUDY AREA

2.1 Dibang Wildlife Sanctuary and Dibang Valley District

DWLS is situated in the Dibang Valley district of Arunachal Pradesh. DWLS is the second-largest protected area (PA) in India. This sanctuary was named after the Dibang river. It covers an area of 4,149 km^2 and is situated between 95° 17´ and 96° 38´ East longitudes and 28° 38´ and 29° 27´ North latitudes with altitude varying from 1800 to 5500 m above mean sea level (amsl). It partially falls in Dihang Dibang Biosphere Reserve. The DWLS was notified vide no. CWL/D/42/92/744-844 dated 12th March 1998. The northern part of DWLS shares an international boundary with the Tibet Autonomous Region (China). The district has an area of 9,129 km^2 and is one of the largest districts in Arunachal Pradesh (Fig 2.1). It is the least populated district in India with a population of 8,004 with a population density of less than 1 inhabitant per km^2 (Census 2011). The population growth rate over the decade 2001–2011 was 9.3%, with a sex ratio of 808 females for every 1000 males and a literacy rate of 64.8% (2011 census report). The Dibang valley of Mishmi hills is a unique landscape as it hosts a tiger population at an altitude of over 3630 m amsl in the Indian part of the Eastern Himalaya Biodiversity hotspot (Adhikarimayum and Gopi 2018).

The district is administered under the 1 subdivision, 3 blocks, and 6 circles, with Anini as the district headquarter, which is located at an elevation of 1968 m amsl. It shares international boundaries with Tibet in the North and the East, the western region is bounded by the Upper Siang district, and the southern side is bounded by the Lower Dibang Valley district. Idu Mishmi, the main inhabiting tribe of Dibang valley district, is one of the four sub-tribes of Mishmi; the other three sub-tribes are Digaru Mishmi, Miju Mishmi, and Deng Mishmi. Idu Mishmi are Schedule Tribes (ST) under The Constitution (Scheduled Tribes) Order, 1950; they also inhabit the other three districts of Arunachal Pradesh *viz.* Lower Dibang Valley, East Siang, and Upper Siang districts. The Idu Mishmi tribe follows the religion of animism and believe in the presence of spirits living in the natural surroundings. They have their own culture, languages, and healing practices, and perform traditional ritual ceremonies. The majority of households in this community are subsistence farmers and seasonal hunters, and few are government employees, contractors, and businessmen. They mostly practice shifting or *jhum* cultivation in different seasons for various crops. The *jhum* cultivation is the only practicable way of cultivation in such kind of rugged terrain in the Dibang Valley district. The major harvested crops are rice, buckwheat, maize, millet, and a variety of vegetables. They maintain varieties of fruit orchards and horticulture plantations such as apple, kiwi, orange, plum, pear, cardamom, ginger, etc. for the local consumption and to sell in the local market. To meet the necessary nutritional requirement and have additional income, some villagers hunt wild animals like barking deer, Himalayan serow, Red goral, wild pig, Mishmi takin, musk deer, Asiatic black bear, etc. However, they follow a unique traditional ecological culture and management system to control the overexploitation of wild animals.

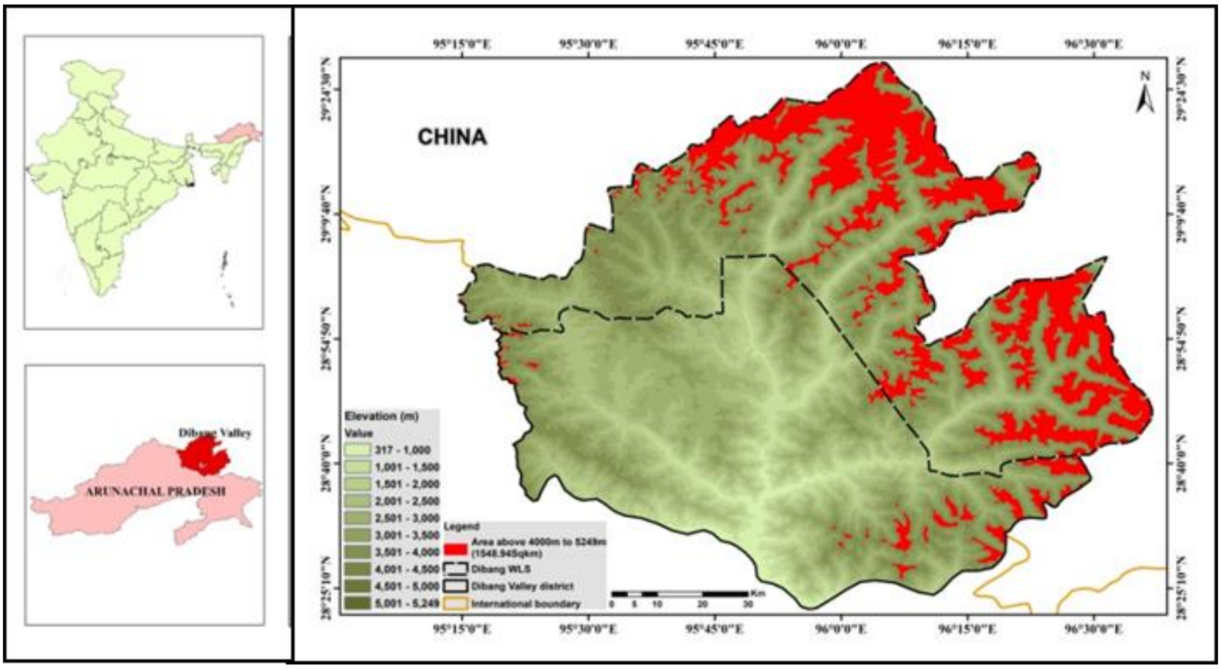


Figure 2.1: Map showing the Dibang Valley district and Dibang Wildlife Sanctuary, Arunachal Pradesh

2.2 Edaphic characters

2.2 (a) Geology and soil

The Arunachal Himalaya extends from the eastern part of Bhutan to the Easternmost part of the Dibang and Lohit valley. The present study area, Dibang valley, lies in the Trans Himalaya on the Eastern limb of the Eastern Himalayan Syntaxis (Gururajan & Choudhuri 2003, 2007), which is occupied by denudational structural hills consisting of diorite, tonalite, granodiorite, hornblende granite, pegmatites, gneiss, schist, marble bands, quartzites, etc. (CGWB 2013). The hills of Dibang valley are highly eroded, fractured with a weathered zone of 5 to 30 m thick, and are geo-dynamically active resulting in many landslides and other mass movements due to high rainfall. The average rainfall in the Dibang Valley (headquarter at Anini) is about 2,866 mm per annum, which promotes chemical alteration in the region (Vyshnavi et al. 2013). The physical, chemical and biological weathering processes have played a major role in the development of the soil profile. Soils of this valley generally contain high humus and nitrogen due to the thick forest cover. In the downstream valleys, it is clayey and rich in organic matter. Generally, the soil is mainly acidic, and the acidity increases with the amount of precipitation and heaviness of the soil (CGWB 2013).

2.2 (b) Terrain

The sanctuary has elements of the lesser and greater Himalayan ranges, having mountainous, gorges, rugged, and steep to very steep terrains. The altitude varies from

1800 to 5500 m amsl and the peaks remain snowcapped throughout the year. The peaks are also interspersed with valleys and natural lakes. Some major river valleys are Dri valley, Mathun valley, Tallon valley, Ahi valley, and Amra valley. All these valleys spread along the riverside; however, the extent of the river valley depends on the narrowest part of the river and mountains that are mainly accessible from the different parts of the sanctuary. All these valleys have their characteristics with distinct geographical and biological features.

2.2 (c) Climate and rainfall

The climate of Arunachal Pradesh is a tropical monsoon type, but some regions at higher elevations like Mishmi Hills have a 'mountain type' climatic condition (Rahmani et al. 2016). During summers, the average maximum temperature goes up to 24˚C, and the average minimum temperature drops to 0˚C. Harsh winter is experienced in the valley from November to March when snowfall becomes quite frequent and as thick as 2m to 6m. Between December and February, the temperature drops to sub-zero level. Pre-monsoon prevails from March to May and is followed by monsoon season from June to October. It receives rainfall from the Southwest monsoon of South Asia (April-October) and the Northeast monsoon of East Asia (December- April) and the average annual rainfall recorded is about 2866 mm, but occasional rains occur throughout the year (Bhuyan et al. 2003, Vyshnavi et al. 2013).

2.2 (d) Rivers

The Dibang River, one of the main tributaries of the mighty Brahmaputra River, originates in the southern slopes of the Adzon Chhu peak situated at the Northernmost point of Arunachal Pradesh and has an altitude 5355 m amsl (Singh et al. 2004). There are numerous southerly flowing small rivers, perennial rivulets, and nullahs that are tributaries to the Dibang River flowing through the sanctuary. The Mathun and Dri rivers flowing from the Northern and Northeastern side of Anini confluence as one at the Western side of Anini and flows as Dibang River from thereon. The Tallon River on the Southeastern side merges with the Dibang river at Etalin. Other tributaries such as Ithun, Deopani, and many small nullahs merge with the Dibang River downstream. Finally, the Dibang River joins the Dihang and Lohit rivers near Laikaghat, about 52 km downstream from Pasighat. Afterward, the combined flow of the three Trans-Himalayan rivers *viz.* Lohit, Dihang, and Dibang are called the Brahmaputra (Singh et al. 2004).

2.3 Ecological attributes

2.3 (a) Floral diversity

The floristic composition of the Mishmi hill ranges of Dibang valley comes under the wet temperate forest type IV/11/IIB/C1, IV/11/IIB/C2, IV/12/C1/3a, IV/12/C/3b, V/C2, VI/ISC3, VI/16/C1, and E1 of vegetation classification of India. Broadly, the vegetation of DWLS is classified into three categories that range from temperate broadleaf, temperate conifers to alpine forests, while the peaks are barren and remain snow-capped for the greater part of the year (Campion & Seth 1968). The temperate broadleaf forest is dominated by *Michelia* spp*., Quercus lamellosa, Quercus* spp*., Magnolia* spp*., Castanopsis indica, Castanopsis* spp., *Acer hookeri*, *Alnus nepalensis, Populus ciliata,* etc., the temperate conifer forest is dominated by *Abies* spp*., Tsuga dumosa, Rhododendron arboretum, Taxus baccata, and Pinus wallichiana*, and the alpine forest is dominated by *Rhododendron* spp*., Saussurea* spp*., Sedum* spp*. Primula, Saxifraga* spp. In the foothills, there is wide coverage of grasslands. Apart from this diverse vegetation, many endemic and rare medicinal plants such as *Coptis teeta, Paris polyphylla, Panax pseudo, Panax sikkimensis, Artemisia nilagirica,* etc. are also reported. Along with diverse forest types, bamboo such as *Phyllostachys bambusoides*, *Arundinaria* spp., *Cephalostachyum* spp. etc., wild banana, cane, and varieties of ferns are grown in this region. Many shrubs and herbs such as *Zanthoxylum acanthodia pyriformis*, *Panax* spp., *Rumex* spp., etc. are also found here. Most of the trees with epiphytic mosses and other epiphytic growth are also abundant. The diverse vegetation composition of the protected area mainly depends on micro-climatic factors *i.e*. topographic, climatic, edaphic, and biotic factors. The varied altitudinal gradient and associated factors have supported diverse forest types such as the temperate broadleaf forests that are distributed at an elevation of 1800 to 2800 m amsl. While temperate conifer forest is confined at elevations of 2800 to 3500 m amsl and the alpine forest is found between 3000 and 5500 m amsl.

2.3 (b) Faunal diversity

DWLS and its adjoining landscapes harbor a high diversity of faunal species, including endangered, rare, endemic, and threatened faunal species like the Bengal tiger (*Panthera tigris tigris*), snow leopard (*Panthera uncia*), clouded leopard (*Neofelis nebulosa*), Asiatic golden cat (*Catopuma temminckii*), marbled cat (*Pardofelis marmorata*), leopard cat (*Prionailurus bengalensis*), fishing cat (*Prionailurus viverrinus*), jungle cat (*Felis chaus*), Asiatic wild dog (*Cuon alpinus*), Mishmi takin (*Budorcas t. taxicolor*), Goral (*Naemorhedus goral*), Musk deer (*Moschus chrysogaster*), barking deer (*Muntiacus muntjak*), Himalayan serow (*Capricornis sumatraensis thar*), and wild pig (*sus scrofa*) (Gopi et al. 2014).

2.4 Study area selection

The study area was chosen based on altitudinal gradient, vegetation type, topography, accessibility, and habitats of expected occurrence of tigers, and its co-predators and prey species. Five river valleys were selected *viz.* Dri valley, Angi-pani valley, Mathun valley, Enjoo valley, and Tallon valley. The accessibility of these river valleys from different parts of the sanctuary is dependent on the width of the riverbank, the existence of walkable human tracks, and the steepness of the mountain.

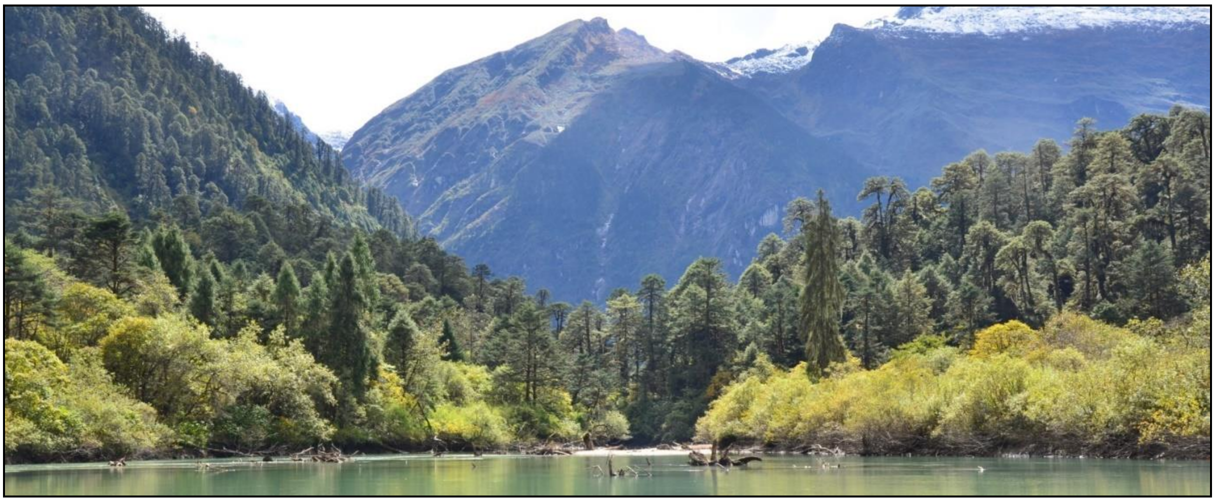
(i) Dri Valley (*Dri-mro*): The Dri valley was named after Dri River, which is formed by the confluence of two tributaries Adjamkho la (Adjamkho River) and Tsang Khang la (Ekka-pani River) at Brueni, which is around 56 km away from Dumbuen. The Dri valley originates at a place called Dumbuen (Achecho village), 3 km from Angrim valley and 29 km away from the district headquarter. The forest type is miscellaneous with thick temperate broad-leaved forest, bamboo forest, riparian forest, and grasslands with hilly and undulating terrain. There is a well-established walkable track; many temporary hunting base camps, built by the local tribes for hunting, were encountered along this track. This valley is one of the identified long-range patrolling route (LRPs), which is mainly used by the Indo-Tibetan Border Police (ITBP) and the Indian Army, and there are four permanent base camps *viz*. Chelo (Chai pani), Chigu (Chigu-pani), Pather-one, and Brueni that are used during patrolling.

(ii) Angi-pani Valley (*Angi-mro*): The Angi-pani river is one of the principal tributaries of Dri River that flows from the Northeastern hilly parts of DWLS. To reach the walkable track, which is also the local hunting track along the Angi-pani River in this valley, one has to start from the road point 28° 51' 38.1" North latitude and 95° 58' 50.2" East longitude, which lies approximately 4 km ahead from Angrim village. The valley is at a distance of 20 km from the district headquarter. The forest type is a miscellaneous, thick temperate broad-leaved forest with hilly terrain and highly undulating. Unlike the Dri Valley, this valley is exclusively used by local people.

(iii) Mathun Valley (*Mathun-mro*): Mathun valley is situated on the left side of the central part of the sanctuary. The track here starts from Mipi village, which is 39 km away from Anini town. The Mathun valley is named after the Mathun River, which is joined by Enjoo River before Basam and the sides of Enjoo river are known as Enjoo valley (*Enjoo-mro*). Two more tributaries *viz.* Yonggyap chu and Andra chu joins at Basam and Mipi, respectively, flowing in from west to east. It further flows south to merge with the Dri River, little below Anini town. Mathun valley has hilly and highly undulating terrain and comprises different kinds of forests such as miscellaneous, temperate broad-leaved, bamboo, riparian forests, and grasslands. There are four villages on the way to the sanctuary from Mipi, namely, Engolin basti, Beyanli basti, Adoni basti, and Endulin basti. This valley also has one of the LRPs, which are mainly used by ITBP and the Indian Army.

(iv) Enjoo Valley (*Enjoo-mro*): The Enjoo valley is situated on the right side of the North-central part of the sanctuary, which is adjacent to Mathun valley, the left-wing valley. Enjoo valley is named after the Enjoo River, which flows from the eastern to western direction and joins the Mathun river before Basam (Basam ITBP camp). This valley gets diverted before reaching Basam ITBP camp on the way to Mathun valley. This valley also has a highly undulating terrain with less open areas along the river bank. The major vegetations are a miscellaneous type of forest with thick temperate broad-leaved forest, bamboo forest, riparian forest, and grassland. There are no habitations in this valley. This valley is also used by ITBP and the Indian Army as their LRPs route.

(v) Tallon Valley (*Tallon-mro*): The Tallon valley is situated in the southern part of the sanctuary. The Tallon valley has taken its name from the Tallon River that originates from the east of the DWLS and flows towards the western side. The Edzon and Edza rivers are the main tributaries of the Tallon River. It can be reached from the Maliney side through Etalin town. The Maliney village is situated just on the boundary of the Wildlife Sanctuary, which is around 90 km from the district headquarter on the southern side. Around 8 to 10 km of track is highly undulating from the Maniley village towards the Tallon valley. It has the miscellaneous type of forest with thick temperate broad-leaved forest, bamboo forest, riparian forest, and grassland. There are no habitations inside this valley. Three ITBP camps have been established up to Balua, which is around 38 km from Maliney village. Local people frequently enter the forest mainly for collecting local medicinal plants.



CHAPTER 3

DISTRIBUTION AND ABUNDANCE OF TIGERS, CO-PREDATORS, AND PREY

3.1 Background

The presence of tiger, co-predators, and prey species along the trails, ridges, and rivulet, was confirmed through sign surveys in different valleys which served as travel routes (Smith et al. 1989, Karanth & Nichols 2000, Bennet et al. 1940, Chundawat, 1992, Sathyakumar 1994). Based on the reconnaissance surveys, the intensive study area was selected for the deployment of camera traps (Mackenzie & Royle 2005).

Distance sampling is one of the conventional methods for estimation of ungulate density. Three assumptions are essential in incurring the reliable estimation of density: (a) detection of an object on the transect line or point, (b) initially objects are detected at their location, and (c) accurate measurement of distances and relevant angles (Buckland et al. 1993, 2001). However, the direct counting of ungulate (density estimation) is a challenge due to the dense vegetation along with the rugged terrain, complex geographical features, and varied climatic conditions (Singh and Milner-Gulland 2011). Henceforth, the non-line transect method is conducted for estimation of encounter rates of ungulates and mammalian carnivores.

Camera traps are a non-invasive survey technique that records animals as they pass, typically triggered by a passive infrared motion sensor (Rowcliffe et al. 2011). It is widely used in monitoring the status of wildlife population, relative abundance estimation, and habitat occupancy patterns. The population estimation of individually identifiable species through the mark-recapture method (Miththapala et al. 1989, Mace et al. 1994, Karanth 1995, Karanth et al. 2004, Liu et al. 2013) and relative abundance index (RAI) was used for individually unrecognizable species (Carbone et al. 2001, Royle and Nichols 2003, Nag 2008,). Significantly, it can also be used to gain information on highly cryptic species and in difficult terrain where other field methods are likely to fail (Karanth and Nichols 1998, O'Brien et al. 2003, Rowcliffe et al. 2008). The Indian part of the Eastern Himalayan region has several challenges about adopting the conventional camera trap analytical methods due to the low density of wild animals' population, dense vegetation, thick understoreys, rugged terrain, harsh weather condition, logistic constraints, the existence of very few forest trails or roads, lack of manpower and inadequate financial assistance. With such constraints coupled with less number of images of targeted species obtained from camera traps, relative abundance index (RAI) based on the photographic encounter rates (number of tiger photographs/ 100 traps nights of effort) was used instead of conventional camera trap-based analytical methods such as spatially explicit capture-recapture (SECR), estimation of occupancy or random encounter models, etc.

3.2 Methodology and analytical methods

3.2 (a) Sign survey

Mammalian carnivore and ungulates signs are an index measurable as a correlative of abundance over time and space (Caughley 1977). Indices of relative abundance based on signs such as scat/dung/pellets, pugmark/hoofmark, track, rack mark, scrap, hairs, digging signs, kill, etc. can offer cost-effective and rapid methods for tiger, co-predators, and ungulates abundance estimation (Jhala et al. 2011). The sign surveys were conducted at an imaginary beat level with a minimum of 5 km length along trails, ridges, banks of a dry riverbed, and near rivulets (Fig 3.1). The encounter signs of any indirect evidence of tiger, co-predators, and ungulates were recorded. Each trail was monitored 2-3 times in every session and information on the encountered signs was collected. The coordinates of each encountered signs were recorded in the Global Positioning System (GPS) using GERMIN etrex 20. Besides, covariates such as forest types, canopy cover, shrub density, ground cover, distance from the stream, rivulet or *nullahs,* and anthropogenic activity like tree lopping, human presence, etc. in and around the encountered signs were recorded.

Analytical method

Encounter rates based on sign survey sampling were attained for tiger, co-predators, and ungulates and estimated using the formula:

Encounter rate= n/L

Where **'n'** is the total number of signs encountered belonging to a species during each trail surveys and **'L'** is the length of trail walk in kilometer (km) used as the sampling effort.

The encounter rate is defined as the number of animals seen/encountered per unit effort (Rodgers 1991). On a trial, pooling the number of signs encountered from all the repeats of the trail divided by the total length walked in all the repeats of the trail was used to calculate the average sign encounter rate for tiger, co-predators, and ungulate species. Mean sign encounter rate of tigers, co-predators, and ungulate species at each valley and overall sign encounter rates were calculated. Kruskal-Wallis χ^2 and Mann- Whitney U tests were used to test significant differences among the estimates in-different valleys and seasons.

3.2 (b) Camera trapping

Camera trapping was carried out in a 336 km^2 stratified area of the five potential river valleys and outside the sanctuary. For mammalian carnivores and ungulates species, 3 km^2 (1.73 x 1.73 km) uniform grids were overlaid on a map of the study area. The scale is to match with the other camera trapping surveys conducted elsewhere in Southeast Asia (Grassman Jr. 2003, O'Brien et al. 2003, Kawanishi & Sunquist 2004, Johnson et al. 2006). Mostly, random and logistically accessible grids were chosen to place the camera traps. The effort was made to deploy the camera trap units along the streambeds, animal trails, and in locations that had evidence of animal presence as identified through a sign survey. A single-sided camera tarp, Cuddeback Model C, was deployed in a grid perpendicular to the expected direction of the animal movement (Fig 3.2). The parameters around the camera trap such as types of vegetation, altitude, other habitat parameters, etc. and GPS coordinates were recorded. The camera trap was placed at a height of 30-40 cm above the ground, with a minimum distance of 500 m between two consecutive camera traps. The trap occasions were calculated from the date of deployment until the date of the final photo was taken. An average of 55 to 65 trap nights was deployed without leaving any gaps, which is large enough to photo-capture the tiger, co-predators, and prey species movements in the area during the sampling period (Karanth 1998).

Analytical method

The photographic rate is defined as the number of camera days (24 hours) per study species (>1-year-old) photograph summed across all camera traps (Carbone et al. 2001). Captured images of the targeted mammalian carnivores and their prey species were used to calculate an index of relative abundance (RAI). The number of photographs of a species divided by the total number of trap days of sampling efforts at per site and expressed per 100 trap days was estimated (Kawanishi et al. 1999, Carbone et al. 2001, O'Brien et al. 2003).

The independent pictures of the target species were used to calculate and estimate the relative abundance index (RAI). Each photograph was identified at the species level and rated as a dependent or independent event, with an independent capture event defined as (i) consecutive photographs of different individuals of the same or different species, (ii) consecutive photographs of individuals of the same species taken more than 0.5 hrs apart, and (iii) non-consecutive photos of individuals of the same species (O'Brien et al. 2003).

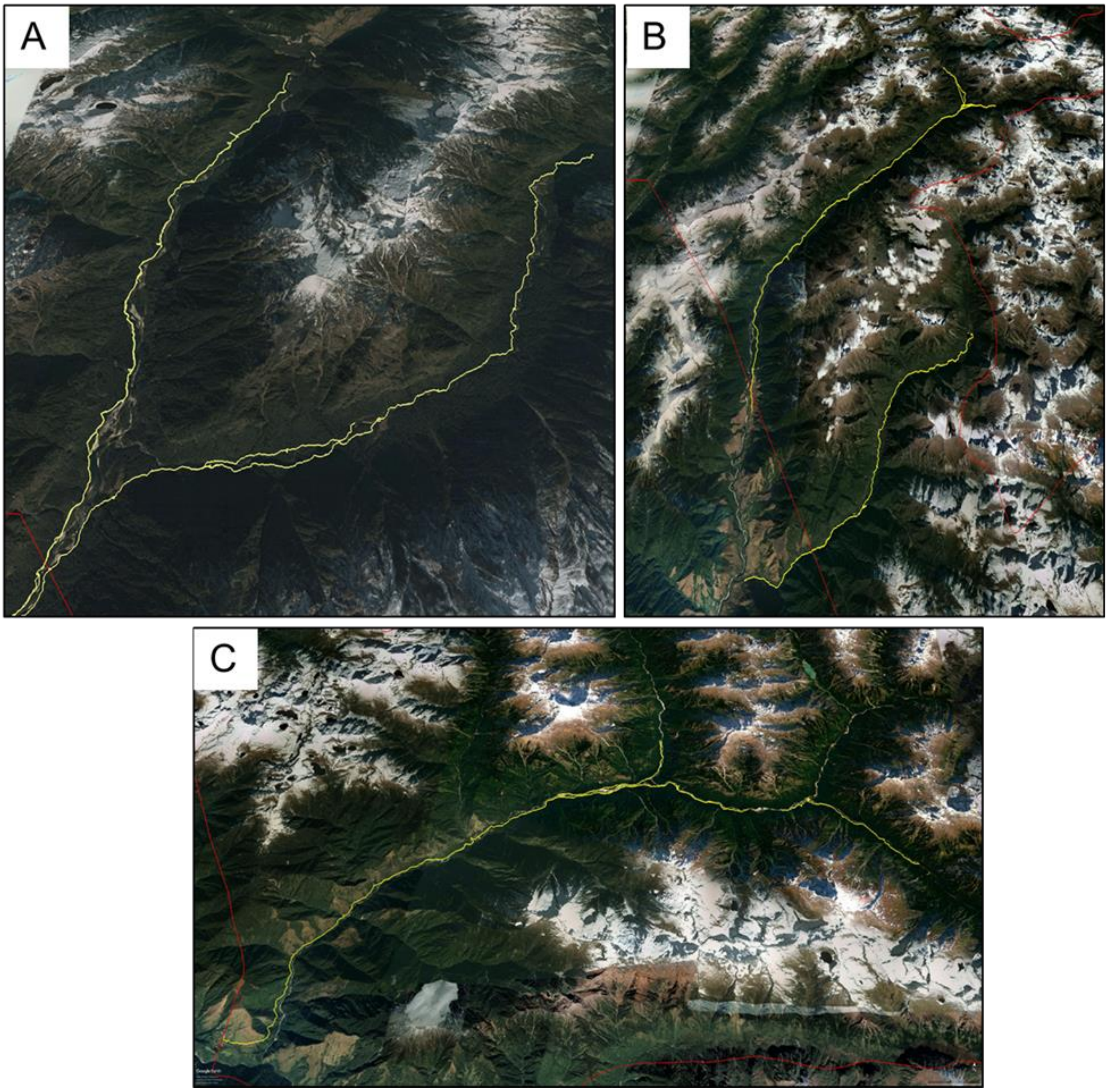


Figure 3.1: Sign survey trails at (A) Mathun and Enjoo Valleys; (B) Dri and Angi-pani Valleys and (C) Tallon Valley in Dibang Wildlife Sanctuary during 2015-2017

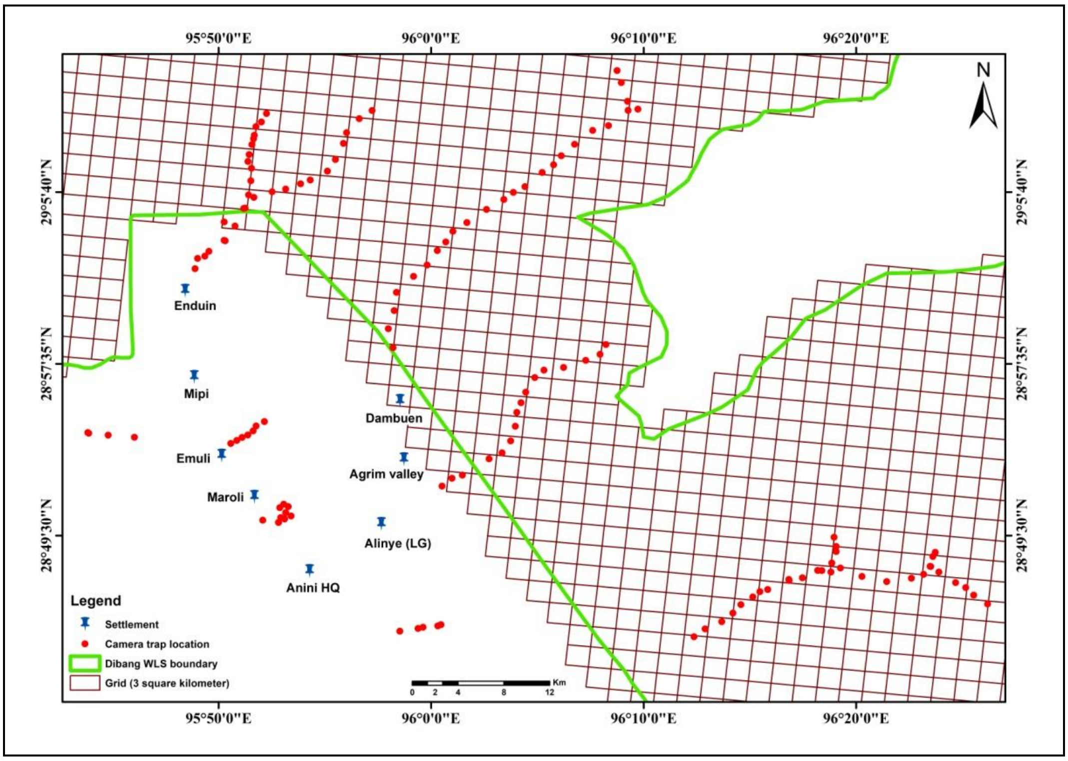


Figure 3.2: Camera traps locations both inside and outside the protected area in Dibang Valley district during 2015-2017

3.3 Camera trap parameters

10 m radius plots around the camera trap locations were sampled for vegetation type and its characteristics i.e. tree density, phenology, and canopy. Canopy cover within each circular plot was measured by using a densitometer on four sides and in the center of the circular plot. For shrub density, 5 m radius plots were laid and monitored in percentage, phenology, etc. and the average height of most dominated shrub cover was measured by a calibrated pole. The number of trees (>20 cm at breast height) within the circular plot were counted and their vernacular names were noted. Ground cover percentage such as grass density, dry grass percentage, dry leaves percentage, and open ground were monitored within a 1 m radius plot. Human presence and disturbance factors were recorded around the sampling plots. A 2x20 m plot was randomly overlaid within the sampled plots for the pellet counts.

3.4 Results

3.4.1 Sign survey: Tiger, co-predators, and ungulate species sign encounter rates

In five river valleys of the protected area, 28 sign surveys of mammalian carnivores and ungulate species were carried out with a total effort length of 231.85 km (Table 3.1). The overall signs encounter rate of the small carnivores (0.276 $km^{-1)}$ was highest followed by tiger (0.099 km^{-1}), wild dog (0.069 km^{-1}), Asiatic black bear (0.039 km^{-1}), and yellow-throated marten (0.013 km^{-1}). For ungulate species, the barking deer sign encounter rate (0.125 km^{-1})

was the highest followed by the wild pig (0.06 km^{-1}), Himalayan serow (0.06 km^{-1}), and Mishmi takin (0.022 km^{-1}), and lowest was for the goral (0.009 km^{-1}) (Table 3.2).

Table 3.1: Mammalian carnivore and ungulates sign survey inside DWLS

Sl. No.	Name of valley	# of sign survey	Total efforts length (km)
1	Dri valley	8	79.39
2	Angi pani valley	3	21.3
3	Mathun valley	5	32.00
4	Enjoo valley	5	41.9
5	Tallon valley	7	57.26
	Total	**28**	**231.85**

Table 3.2: Mammalian carnivore and ungulates sign encounter rate inside DWLS

Mammalian Species	Total effort length (km) (L)	Total # of encounter (n)	Mean	SE	Encounter rate (km^{-1})
Tiger	231.85	23	4.6	2.36	0.099
Wild dog	231.85	16	3.2	1.56	0.069
Asiatic black bear	231.85	9	1.8	0.58	0.039
Small carnivore	231.85	64	12.8	3.50	0.276
Yellow throated marten	231.85	3	0.6	0.40	0.013
Barking deer	231.85	29	5.8	1.88	0.125
Goral	231.85	2	0.4	0.24	0.009
Himalayan serow	231.85	14	2.8	0.97	0.060
Mishmi takin	231.85	5	1	0.45	0.022
Wild pig	231.85	14	2.8	0.86	0.060

Average sign encounter rates (the number of sign encountered/total effort length) of mammalian carnivores and forest-dwelling ungulate species in the different valleys in different seasons were estimated. Kruskal-Wallis χ^2 revealed that across the surveyed valleys, the mean sign encounter rates of wild dogs (p = 0.00), small cats (p = 0.00), and barking deer (p = 0.04) were significant, whereas they were not significant for the remaining mammalian carnivores and ungulate species. The mean sign encounter rate of all mammalian carnivores and forest-dwelling ungulates was associated with high standard error (SE), which is due to the high degree of variability in signs encountered (Table 3.3).

Table 3.3: Mean sign encounter rates of carnivore and ungulate species at different valley and seasons

Mammalian Species	Year 1 (2015-2016)			Year 2 (2016-2017)			K-W che ^{2}	*df*	*P*
	Autumn Dri & Angi valleys	Winter Mathun & Enjoo valleys	Spring Tallon valley	Autumn Mathun & Enjoo valleys	Winter Tallon valley	Spring Dri & Angi valleys			
Tiger	0.04 (±0.01)	0.03 (±0.02)	0.03 (±0.02)	0.002 (±0.002)	0.02 (±0.01)	0.004 (±0.002)	9.6	5	0.09
Wild dog	0	0	0	0.007 (±0.004)	0.03 (±0.01)	0.008 (±0.004)	61.9	5	**0.00**
Black bear	0.02 (±0.01)	0.01 (±0.01)	0	0.01 (±0.01)	0.002 (±0.002)	0	6.25	5	0.28
Small cats	0.44 (±0.16)	0.11 (±0.03)	0.10 (±0.02)	0.03 (±0.01)	0.03 (±0.01)	0.02 (±0.01)	20.79	5	**0.00**
Yellow T. marten	0	0	0	0	0.01 (±0.01)	0.002 (±0.002)	4.82	5	0.44
Barking deer	0.014 (±0.008)	0	0	0.02 (±0.007)	0.015 (±0.009)	0.035 (±0.008)	11.45	5	**0.04**
Goral	0	0	0	0	0.003 (±0.003)	0.002 (±0.002)	3.57	5	0.6
Serow	0.024 (±0.01)	0	0	0.02 (±0.01)	0.008 (±0.008)	0.008 (±0.005)	7.90	5	0.16
Takin	0	0	0	0	0.005 (±0.003)	0.007 (±0.004)	6.0	5	0.3
Wild pig	0.005 (±0.005)	0	0	0.04 (±0.02)	0	0.01 (±0.005)	7.96	5	0.16

The mean sign encounter rates of carnivores and ungulate species in different seasonal temporal scales at the same valleys were calculated using the Mann-Whitney U test and tested for significant difference (Table 3.4).

a) Dri and Angi pani valleys were monitored in two seasons i.e. autumn and spring. The mean sign encounter rates of small cats (0.44 ± 0.16) were highest and followed by tiger (0.04 ± 0.01) and Asiatic black bear (0.02 ± 0.01), whereas wild dog and yellow-throated marten signs were not encountered during autumn. In the following spring season, all the listed carnivore species of the preceding season were recorded, except Asiatic black bear, and the sign encounter rates were low as compared to autumn. For ungulates, barking deer signs were highest in spring (0.014 ± 0.008) and followed by serow in autumn (0.024 ± 0.01). Goral and Mishmi takin signs were not encountered during autumn from these valleys. However, there were direct sightings of Mishmi takin in a group of around 25 to 30 individuals at Angi pani valley, which was excluded from the analysis. The encounter rates for tiger, small cats, and barking deer were found to be significant. Tiger and barking deer were the only species that showed significantly high encounter rates (Table 3.4).

b) **Mathun and Enjoo** valleys were monitored in two seasons i.e. winter and autumn. The mean sign encounter rates of small cats (0.11 ± 0.03) were highest, followed by tiger (0.03 ± 0.02) and Asiatic black bear (0.01 ± 0.01) whereas wild dog and yellow-throated marten signs were not encountered in the winter season. During the spring season, Asiatic black bear signs encountered were highest followed by wild dog and tiger, no yellow-throated marten signs were encountered. No ungulate signs were encountered during winter in these valleys. Only the signs of barking deer, serow, and wild pig were encountered during autumn. Among these, the wild pig (0.04 ± 0.02) had the highest mean sign encounter rates. In these valleys, there were no significant seasonal differences in mean sign encounter rates except for small cats (Table 3.4).

c) Tallon valley was monitored during the spring and winter seasons. Only tiger (0.03 ± 0.02) and small cats (0.10 ± 0.02) signs were encountered during the spring season. In winter, sign encounter rates were highest for wild dogs (0.03 ± 0.01) and small cats (0.03 ± 0.01) followed by tiger **(**0.02 ± 0.01). No ungulate signs were encountered during the spring season. In the winter season, the mean sign encounter rates were highest for barking deer (0.015 ± 0.009) followed by serow (0.008 ± 0.008) and Mishmi takin (0.005 ± 0.003). No significant seasonal difference was observed from this valley for encounter rates of other species except for small cats which showed significant seasonal difference (Table 3.4).

Table 3.4: Mean sign encounter rates for carnivores and ungulates across different seasonal temporal scales in the different valleys within the protected area

Species	**Dri & Angi Valleys**		**Mann-Whitney U test**	**Significance**
	Autumn (2015-16)	**Spring (2016-17)**		
Tiger	0.04 (±0.01)	0.004 (±0.002)	0	**0.02**
Wild dog	0	0.008 (±0.004)	0	0.11
Black bear	0.02 (±0.01)	0	0	0.08
Small cat	0.44 (±0.16)	0.02 (±0.01)	15	**0.01**
Yellow T. Marten	0	0.002 (±0.002)	0	0.32
Barking deer	0.014 (±0.008)	0.035 (±0.008)	0	**0.002**
Goral	0	0.002 (±0.002)	0	0.3
Serow	0.024 (±0.01)	0.008 (±0.005)	3	0.25
Mishmi Takin	0	0.007 (±0.004)	0	0.5
Wild pig	0.005 (±0.005)	0.01 (±0.005)	0	0.4
Species	**Mathun & Enjoo Valleys**		**Mann-Whitney U test**	**Significance**
	Winter (2015-16)	**Autumn (2016-17)**		
Tiger	0.03 (±0.02)	0.002 (±0.002)	0	0.16
Wild dog	0	0.007 (±0.004)	0	0.19
Black bear	0.01 (±0.01)	0.01 (±0.01)	1	0.48
Small cat	0.11 (±0.03)	0.03 (±0.01)	15	**0.01**
Yellow T. Marten	0	0	-	-
Barking deer	0	0.02 (±0.007)	0	0.25
Goral	0	0	-	**-**
Serow	0	0.02 (±0.01)	1	0.06
Mishmi Takin	0	0	-	-
Wild pig	0	0.04 (±0.02)	0	0.25

Species	Tallon Valley (Maliney)		Mann-Whitney U test	Significance
	Spring (2015-16)	Winter (2016-17)		
Tiger	0.03 (±0.02)	0.02 (±0.01)	2	0.18
Wild dog	0	0.03 (±0.01)	0	0.09
Black bear	0	0.002 (±0.002)	0	0.32
Small cat	0.10 (±0.02)	0.03 (±0.01)	7	**0.00**
Yellow T. Marten	0	0.01 (±0.01)	0	0.22
Barking deer	0	0.015 (±0.009)	0	0.40
Goral	0	0.003 (±0.003)	0	0.30
Serow	0	0.008 (±0.008)	0	0.30
Mishmi Takin	0	0.005 (±0.003)	0	0.60
Wild pig	0	0	-	-

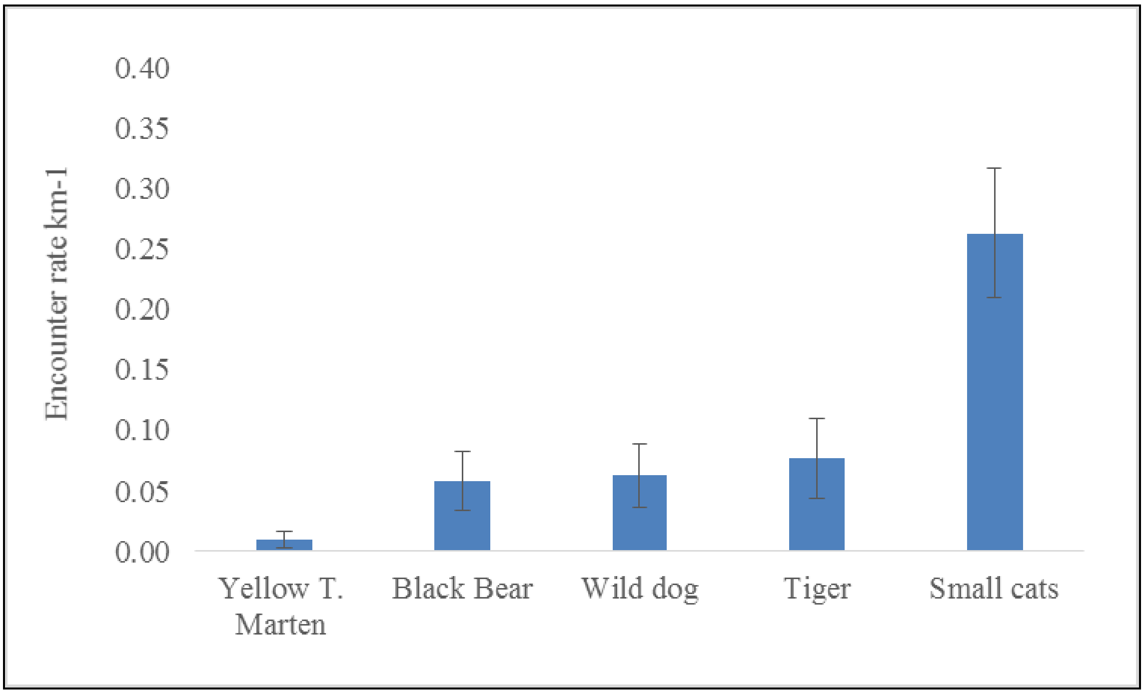


Figure 3.3: Mean sign encounter rate of mammalian carnivores at DWLS

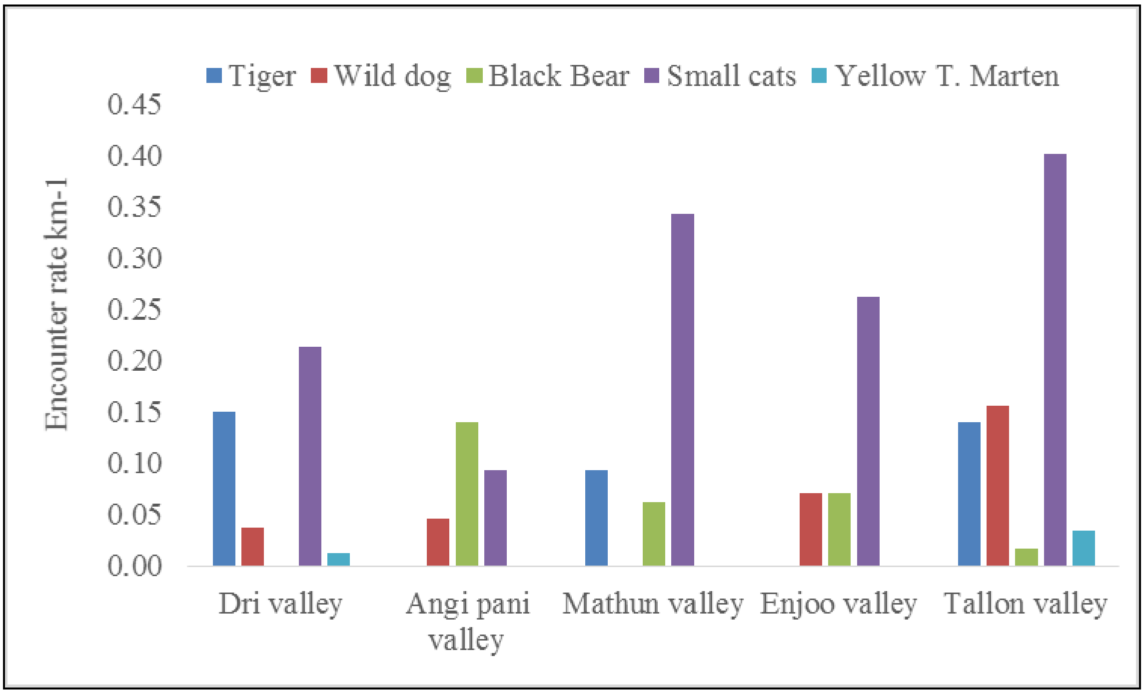


Figure 3.4: Mammalian carnivore sign encounter rates along the five potential major river valleys of DWLS

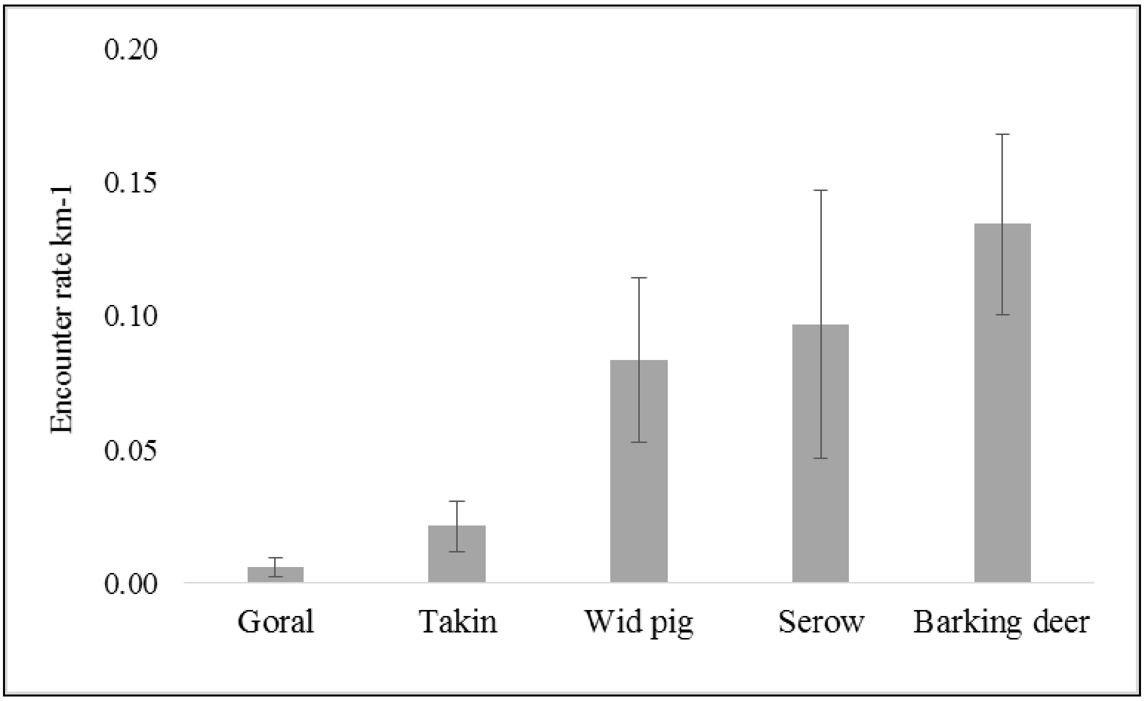


Figure 3.5: Ungulates sign mean encounter rate inside the DWLS

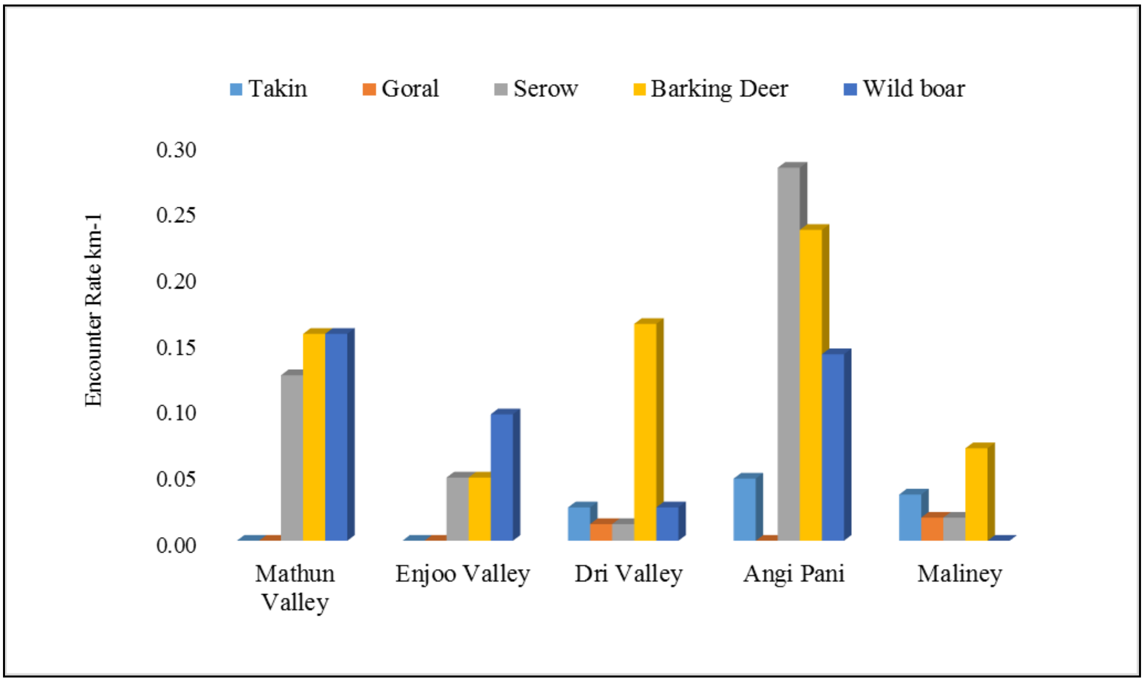


Figure 3.6: Ungulate sign encounter rates along the five major river valleys of DWLS

3.4.2 Camera traps:

Determination of distribution and relative abundance of tiger, co-predator and ungulate species:

This ecological baseline study covers DWLS and its adjoining landscape of community forests during 2015-2017. Camera trapping exercise was conducted for twenty-eight months and covered six sessions with three sessions in each year (Table 3.5). Overall, there were 112 camera trapping locations with 13761 trap nights, covering an area of 336 km^2. Within the protected area, camera traps were set up in 90 locations covering an area of 270 km^2 in five river valleys *viz*. Dri, Angi pani, Mathun, Enjoo, and Tallon. Outside the protected area, a total of 22 camera trap locations covering an area of 66 km^2 were monitored, with 1809 trap nights in community forests (Table 3.6).

Table 3.5: Comprehensive camera traps sessions both inside & outside DWLS

Sampling Session	Sampling period	Sampling valley
2015-2016		
First Session	October (First week) to December (First week)	Dri & Angi
Second Session	December (Last week) to March (First week)	Mathun & Enjoo
Third Session	March (Last week) to June (Last week)	Tallon
2016-2017		
First Session	November (First week) to January (Last week)	Mathun & Enjoo
Second Session	February (First week) to April (First week)	Tallon
Third Session	April (Last week) to July (First week)	Dri & Angi

Table 3.6: Comprehensive camera taps locations both inside & outside DWLS

Name of valley	Camera traps	Area covers (km^2)	Trap nights
Inside PA			
Dri valley	28	84	3274
Angi pani	14	42	1822
Mathun valley	13	39	2176
Enjoo valley	13	39	2067
Tallon valley	22	66	2613
Total (A)	90	270	11952
Outside PA	22	66	1809
Total (B)	22	66	1809
Grand total (A+B)	**112**	**336**	**13761**

Table 3.7: Comparative photo-captures of different taxa within and outside DWLS

Sampling area	Total photo captures	Wild/Semi domestic animals/Humans							
		Carnivores	Ungulates	Birds	Mithun	Non-human primates	Others	Local People	Domestic dogs
Inside PA	23831	1383	856	77	0	273	14077	6322	843
Outside PA	4018	135	115	101	1458	1	0	2208	0
Total	**27849**	**1518**	**971**	**178**	**1458**	**274**	**14077**	**8530**	**843**

Photo-capture rate as indices of tigers, co-predators and ungulate species:

Camera traps photographed a total of 27 mammalian species, specifically 15 mammalian carnivores, 5 ungulate species, 1 primate, 4 pheasant species, and 2 rodent species, in and around DWLS (Table 3.8). The photo-capture rates (photographs/100 days) were estimated for tigers, co-predators, and forest-dwelling ungulate species present only inside the protected area. The photo-capture rates of these mammalian species captured outside the protected area were excluded from analysis due to the inconvenience in following the 3 km^2 grid system. Further, the camera traps were installed opportunistically, and hence data was not collected season and session wise like in the protected area. Consequently, it leads to low trap nights when compared to the photo-capture rates from inside the sanctuary. Additionally, many cameras were disturbed by human activities and even the installed camera traps were lost from outside the PA.

Overall, the mean photo-capture rates of tiger, wild dog and Asiatic black bear were 0.34 ± 0.06 (SE), 1.19 ± 0.20 (SE) and 0.39 ± 0.06 (SE), respectively. Among other mammalian carnivores, overall mean photo rates was comparatively high for yellow-throated marten (2.16 ± 0.43) followed by leopard cat (2.13 ± 0.30), golden cat (0.83 ± 0.16), spotted linsang (0.16 ± 0.05), stone marten (0.08 ± 0.03), clouded leopard (0.03 ± 0.01), marbled cat (0.03 ±

0.02), otter species (0.03 ± 0.02), Masked palm civet (0.02 ± 0.01), red panda (0.01 ± 0.01), Siberian weasel (0.01 ± 0.01), and yellow-bellied weasel (0.01 ± 0.01).

On the other hand, the mean photo-capture rates of barking deer (2.99 ± 0.47) were highest among the ungulates followed by Mishmi takin (0.62 ± 0.26), red goral (0.61 ± 0.13), Himalayan serow (0.50 ± 0.08), and wild pig (0.49 ± 0.18). In primates, the mean photo-capture rate of the Assamese macaque was 3.35 ± 1.24. Additionally, in the pheasant family, khalij pheasant (0.63 ± 0.19) had the highest mean photo-capture rates, followed by temminck's tragopan (0.01 ± 0.01), sclater's monal (0.01 ± 0.01) and hill partridge (0.01 ± 0.01). In the rodent family, mean photo capture rates were comparatively high for rat spp. (0.37 ± 0.13) followed by pallas's squirrel (0.05 ± 0.04) (Table 3.8).

Table 3.8: Overall mean photo-capture rates of tiger, co-predators and their prey species (photographs /100 days) inside DWLS

Sl. No.	Mammalian Species	N	Mean photo-capture rate	SE
Carnivore				
1	Tiger	42	0.34	0.06
2	Wild dog	140	1.19	0.20
3	Asiatic black bear	46	0.39	0.06
4	Clouded leopard	4	0.03	0.01
5	Golden cat	104	0.83	0.16
6	Marbled cat	4	0.03	0.02
7	Leopard cat	214	2.13	0.30
8	Spotted linsang	23	0.16	0.05
9	Masked palm civet	3	0.02	0.01
10	Red Panda	2	0.01	0.01
11	Stone marten	10	0.08	0.03
12	Yellow-throated marten	297	2.16	0.43
13	Otter species	3	0.03	0.02
14	Siberian weasel	1	0.01	0.01
15	Yellow-bellied weasel	1	0.01	0.01
Ungulate				
1	Barking deer	349	2.99	0.47
2	Red goral	67	0.61	0.13
3	Himalayan serow	55	0.50	0.08
4	Mishmi takin	82	0.62	0.26
5	Wild pig	58	0.49	0.18
Primate				
1	Assamese macaque	394	3.35	1.24
Pheasant				
1	Kalij pheasant	77	0.63	0.19
2	Temminck's Tragopan	1	0.01	0.01
3	Sclater's Monal	1	0.01	0.01

Sl. No.	Mammalian Species	N	Mean photo-capture rate	SE
4	Hill partridge	1	0.01	0.01
Rodent				
1	Palla’s squirrel	6	0.05	0.04
2	Rat spp.	37	0.37	0.13

The mean photo-capture rates (the number of photographs/100 days) of tigers, wild dogs, Asiatic black bears, golden cat, leopard cat, yellow-throated marten, and forest-dwelling ungulate species in different seasons were estimated and tested for significance by using the Kruskal-Wallis χ^2 test (Table 3.9).

The mean photo-capture rate of the tiger was high in Tallon valley during winter (1.09 ±0.27) and in Mathun and Enjoo valleys in autumn (0.49 ± 0.18). The wild dog had the highest mean photo-capture rates in Mathun and Enjoo valleys during both winter (2.04 ± 0.63) and autumn (2.09 ± 0.58). Asiatic black bear had the highest mean photo-capture rate only during autumn in Dri-Angi pani (0.70 ± 0.18) and Mathun-Enjoo (0.75 ± 0.20) valleys. The mean photo-capture rate of the golden cat was high only in Mathun and Enjoo valleys during both autumn (1.91 ± 0.51) and winter (1.48 ± 0.64), while the leopard cat had highest the mean photo-capture rate in Talon valley in spring (4.64 ± 2.00) followed by Dri and Angi pani valleys during autumn (2.65 ± 0.74). Yellow-throated marten had the highest mean photo capture rate only during autumn in Dri and Angi pani (4.87 ± 1.06) followed by Mathun and Enjoo (4.80 ± 1.78) valleys. Kruskal-Wallis χ^2 revealed that the photo-capture rates of the tiger, golden cat, leopard cat, and yellow-throated marten were significant along the different valleys in different seasons, while the photo-capture rates of Asiatic black bear and wild dog were not significant. The Asiatic black bear and wild dog had high standard errors (SE) indicating a high degree of variability in photo-captures (Table 3.9).

Among the forest-dwelling ungulates species, the mean photo-captures rate of barking deer was significantly high in Dri and Angi pani valleys in autumn (3.56 ± 1.05) and spring (5.98 ± 1.61), followed by red goral, which was significantly high in Dri and Angi pani valleys in autumn (1.69 ± 0.42). Mishmi takin photo capture rate was also significantly higher in Mathun and Enjoo valleys in autumn (1.46 ± 1.03) and winter (1.19 ± 0.42).

The photo capture rate for the Himalayan Serow and the wild pig was not significant across the valley in the different seasons. Among all the ungulate species, Mishmi takin and wild pig have very high standard error (SE) indicating the high degree of variability in photo-capture in the Dri, Angi pani, and Mathun valleys (Table 3.9).

Table 3.9: Valley and season wise mean photo-capture rates with SE of carnivore inside DWLS

Mammalian species	**Year 1 (2015-2016)**			**Year 2 (2016-2017)**			**K-W che [2]**	***df***	***p***
	Autumn Dri&Angi valleys	**Winter** Mathun & Enjoo valleys	**Spring** Tallon valley	**Autumn** Mathun & Enjoo valleys	**Winter** Tallon valley	**Spring** Dri & Angi valleys			
Tiger	0.11 (±0.06)	0.30 (±0.10)	0	0.49 (±0.18)	1.09 (±0.27)	0.12 (±0.07)	13.7	5	**0.02**
Wild dog	0.58 (±0.30)	2.04 (±0.63)	1.60 (±1.29)	2.09 (±0.58)	0.11 (±0.11)	1.19 (±0.35)	6.96	5	0.22
A. Black bear	0.70 (±0.18)	0.49 (±0.16)	0.10 (±0.10)	0.75 (±0.20)	0.05 (±0.05)	0.04 (±0.04)	10.71	5	0.06
Golden cat	0.56 (±0.22)	1.48 (±0.64)	0.10 (±0.10)	1.91 (±0.51)	0.81 (±0.27)	0.14 (±0.07)	14.67	5	**0.01**
Leopard cat	2.65 (±0.74)	0.77 (±0.21)	4.64 (±2.00)	1.10 (±0.42)	2.08 (±0.63)	2.41 (±0.57)	20.05	5	**0.00**
Yellow T. marten	4.87 (±1.06)	2.01 (±0.68)	0.89 (±0.36)	4.80 (±1.78)	1.09 (±0.36)	0.41 (±0.22)	18.32	5	**0.00**
Barking deer	3.56 (±1.05)	0.90 (±0.29)	1.53 (±0.67)	1.81 (±0.51)	1.99 (±0.86)	5.98 (±1.61)	12.33	5	**0.03**
Red goral	1.69 (±0.42)	0.09 (±0.06)	0	0.91 (±0.32)	0.06 (±0.06)	0.07 (±0.05)	21.83	5	**0.00**
H. serow	0.90 (±0.21)	0.36 (±0.14)	0.27 (±0.20)	0.40 (±0.14)	0.47 (±0.26)	0.29 (±0.12)	8.63	2	0.12
M. takin	0.06 (±0.06)	1.19 (±0.42)	0	1.46 (±1.03)	0	0.88 (±0.88)	30.2	5	**0.00**
Wild pig	0.48 (±0.48)	0.19 (±0.15)	0.19 (±0.13)	0.20 (±0.12)	1.77 (±1.10)	0.14 (±0.11)	5.00	5	0.42

The mean photo-capture rates of tiger, co-predators and ungulate species in different seasonal temporal scales across the different valleys were also estimated and tested for significant differences (Table 3.10)

a) Dri and Angi pani valleys: Photocapture rates of tiger ($p = 0.05$), golden cat ($p = 0.01$), yellow-throated marten ($p = 0.01$) and goral ($p = 0.02$) had significant seasonal differences.

b) Mathun and Enjoo valleys: Photocapture rates of tiger ($p = 0.00$), leopard cat ($p = 0.03$), barking deer ($p = 0.01$) and goral ($p = 0.03$) had significant seasonal differences.

c) Tallon valley: Only Wild pig's photocapture rates ($p = 0.04$) showed significant seasonal differences whereas other mammalian carnivores and forest dwelling ungulate species photocapture rates were not significant across seasons.

Table 3.10: Seasonal photo-capture rates of carnivore and ungulates species inside PA

Mammalian species	**Dri & Angi pani valleys**		**Mann-Whitney U test**	***p***
	Autumn (2015-16)	**Spring (2016-17)**		
Tiger	0.11 (±0.06)	0.12 (±0.07)	0.00	**0.05**
Wild dog	0.58 (±0.30)	1.19 (±0.35)	16.00	0.06
A. black bear	0.70 (±0.18)	0.04 (±0.04)	0.00	0.11
Golden cat	0.56 (±0.22)	0.14 (±0.07)	4.00	**0.01**
Leopard cat	2.65 (±0.74)	2.41 (±0.57)	174.0	0.69
Yellow T. marten	4.87 (±1.06)	0.41 (±0.22)	26.00	**0.01**
Barking deer	3.56 (±1.05)	5.98 (±1.61)	228	0.96
Red goral	1.69 (±0.42)	0.07 (±0.05)	0	**0.02**
H. serow	0.90 (±0.21)	0.29 (±0.12)	26	0.07
M. takin	0.06 (±0.06)	0.88 (±0.88)	0	0.32
Wild pig	0.48 (±0.48)	0.14 (±0.11)	4	0.50
Mammalian species	**Mathun & Enjoo valleys**		**Mann-Whitney U test**	***P***
	Winter (2015-16)	**Autumn (2016-17)**		
Tiger	0.30 (±0.10)	0.49 (±0.18)	0.00	**0.00**
Wild dog	2.04 (±0.63)	2.09 (±0.58)	70.00	0.66
A. black bear	0.30 (±0.10)	0.75 (±0.20)	21.00	0.06
Golden cat	1.48 (±0.64)	1.91 (±0.51)	73.00	0.35
Leopard cat	0.77 (±0.21)	1.10 (±0.42)	26.00	**0.03**
Yellow T. marten	2.01 (±0.68)	4.80 (±1.78)	121.0	0.25
Barking deer	0.90 (±0.29)	1.81 (±0.51)	25	**0.01**
Red goral	0.09 (±0.06)	0.91 (±0.32)	0	**0.03**
H. serow	0.36 (±0.14)	0.40 (±0.14)	12	0.19
M. takin	1.91 (±0.42)	1.46 (±1.03)	10	0.21
Wild pig	0.19 (±0.15)	0.20 (±0.12)	3	1.00
Mammalian species	**Tallon valley (Maliney)**		**Mann-Whitney U test**	***P***
	Spring (2015-16)	**Winter (2016-17)**		
Tiger	0	1.09 (±0.27)	-	-
Wild dog	1.60 (±1.29)	0.11 (±0.11)	0.00	0.22
A. black bear	0.10 (±0.10)	0.05 (±0.05)	0.00	0.32
Golden cat	0.10 (±0.10)	0.81 (±0.27)	1.00	0.06
Leopard cat	4.64 (±2.00)	2.08 (±0.63)	53.00	0.67
Yellow T. marten	0.89 (±0.36)	1.09 (±0.36)	29.00	0.73
Barking deer	1.53 (±0.67)	1.99 (±0.86)	21	0.62
Red goral	0	0.06 (±0.06)	0	0.31
H. serow	0.27 (±0.20)	0.47 (±0.26)	4	0.68
M. takin	0	0	--	--
Wild pig	0.19 (±0.13)	1.77 (±1.10)	0	**0.04**

The mammalian species richness in DWLS was elucidated from total camera trap efforts and photo-captures of mammalian species. Overall photo-captures of the mammalian species reached asymptote after 45 trap nights during the study (Fig 3.13).

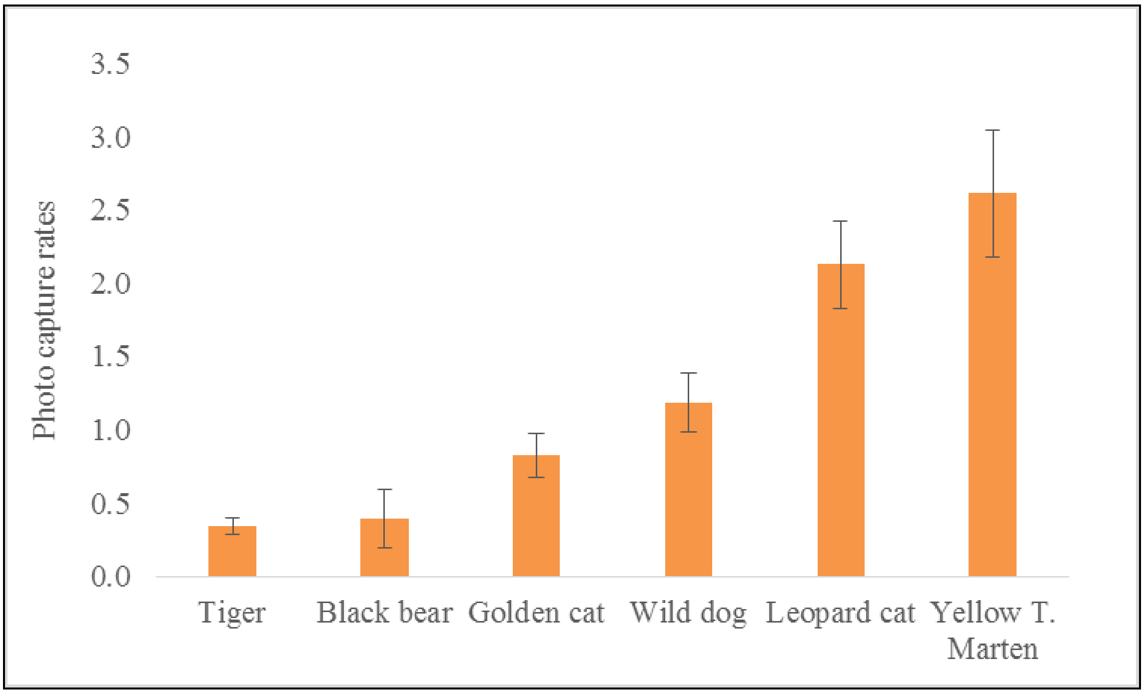


Figure 3.7: Overall photo-capture rates of mammalian carnivore inside DWLS

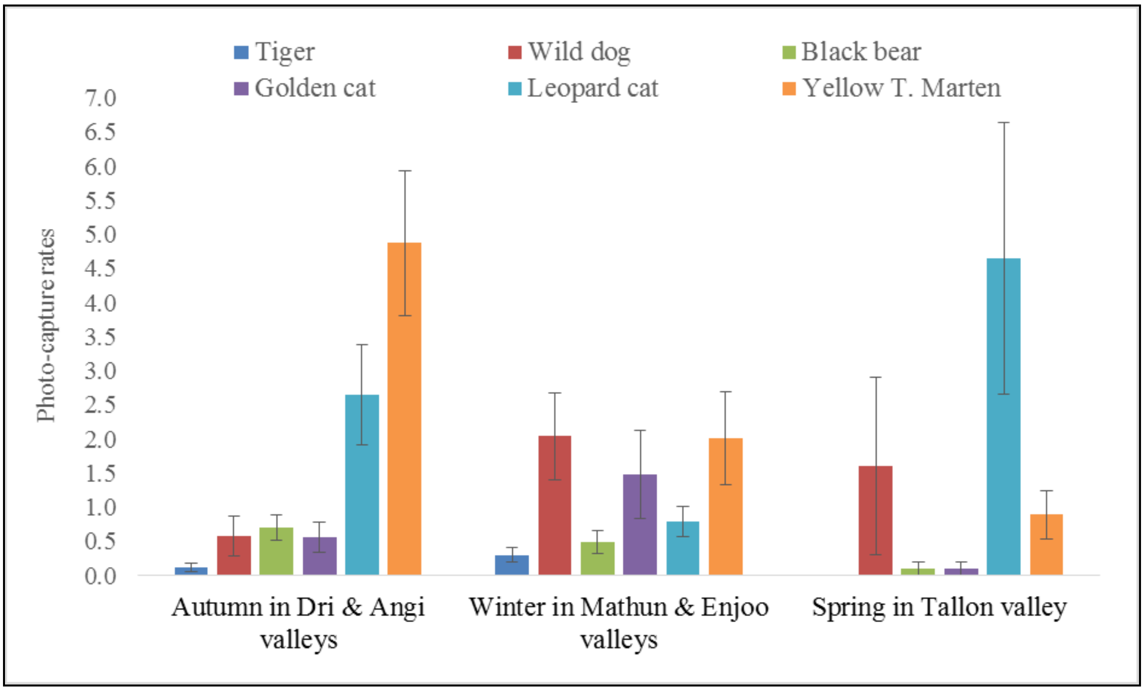


Figure 3.8: Mean photo-capture rates of carnivores at different temporal scale during first-year observation inside DWLS, 2015-16

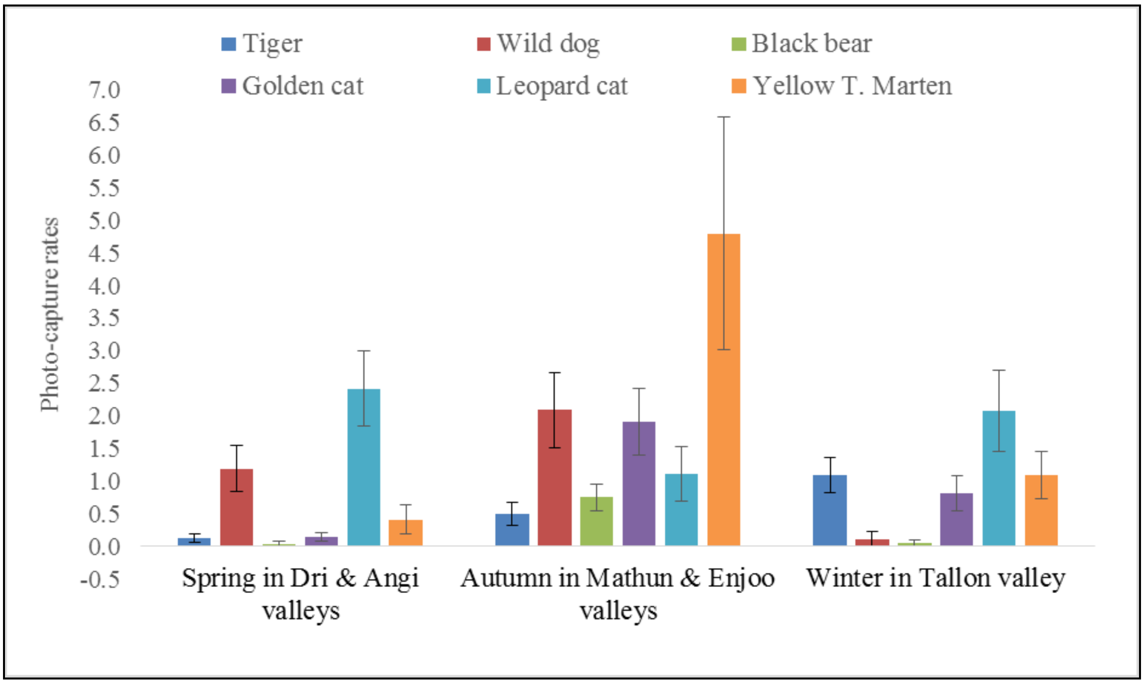


Figure 3.9: Mean photo-capture rates of carnivores at different temporal scales during second-year observation inside DWLS, 2016-17

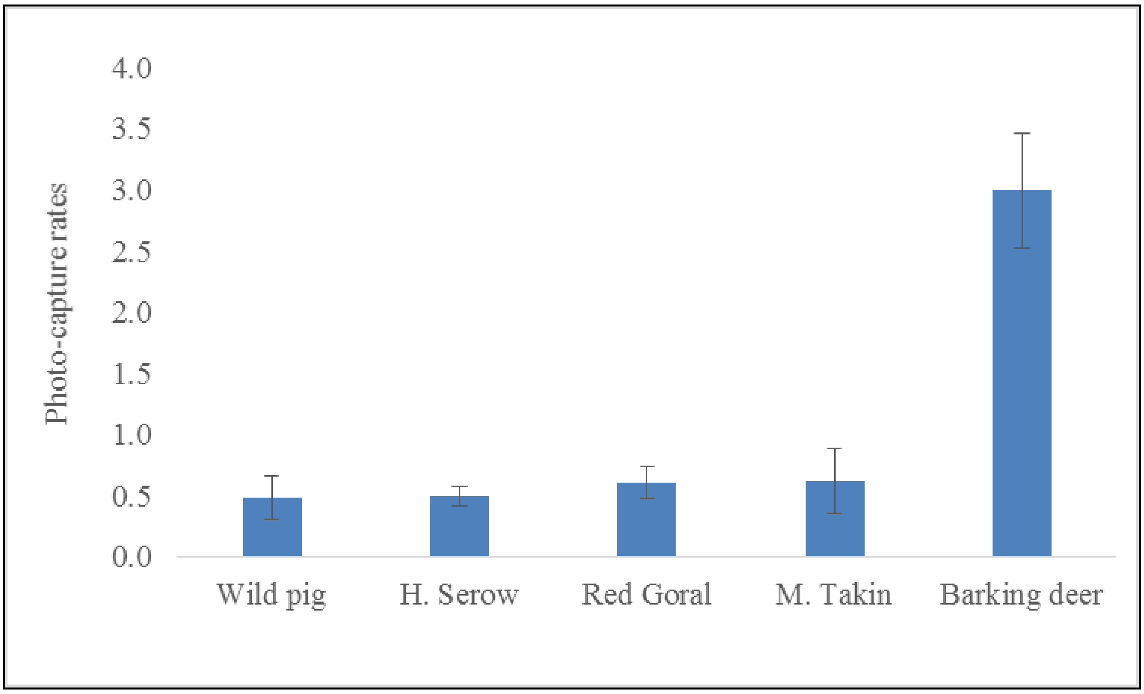


Figure 3. 10: Overall photo-capture rates of ungulate species inside DWLS

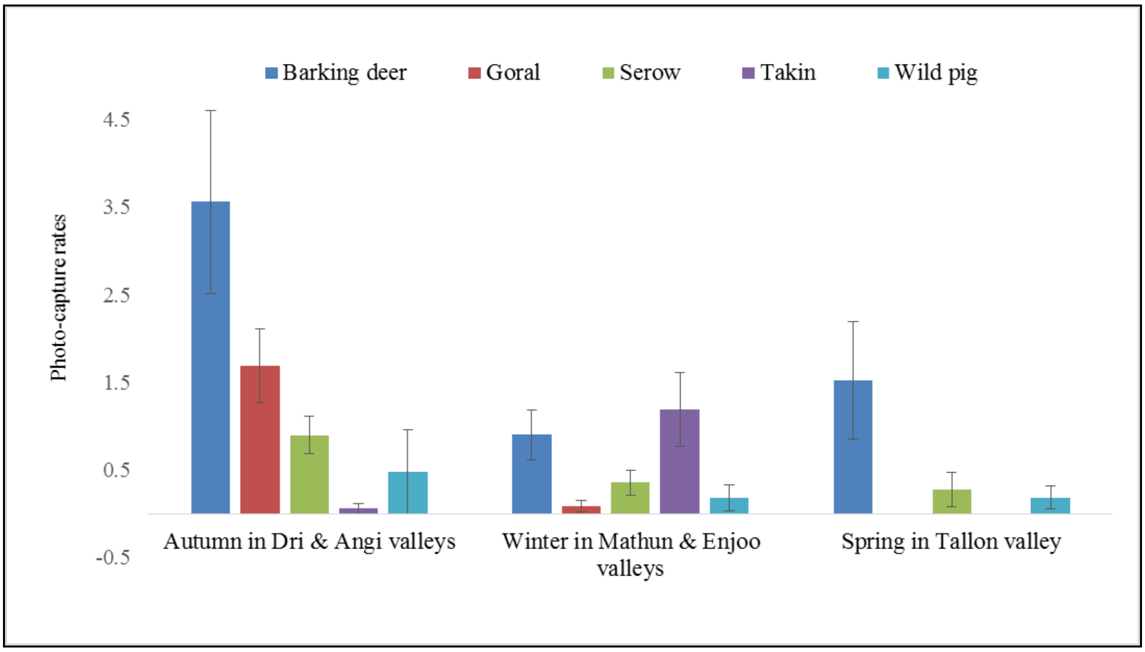


Figure 3.11: Mean photo-capture rates of ungulate species at different temporal scale during first-year observation inside DWLS, 2015-16

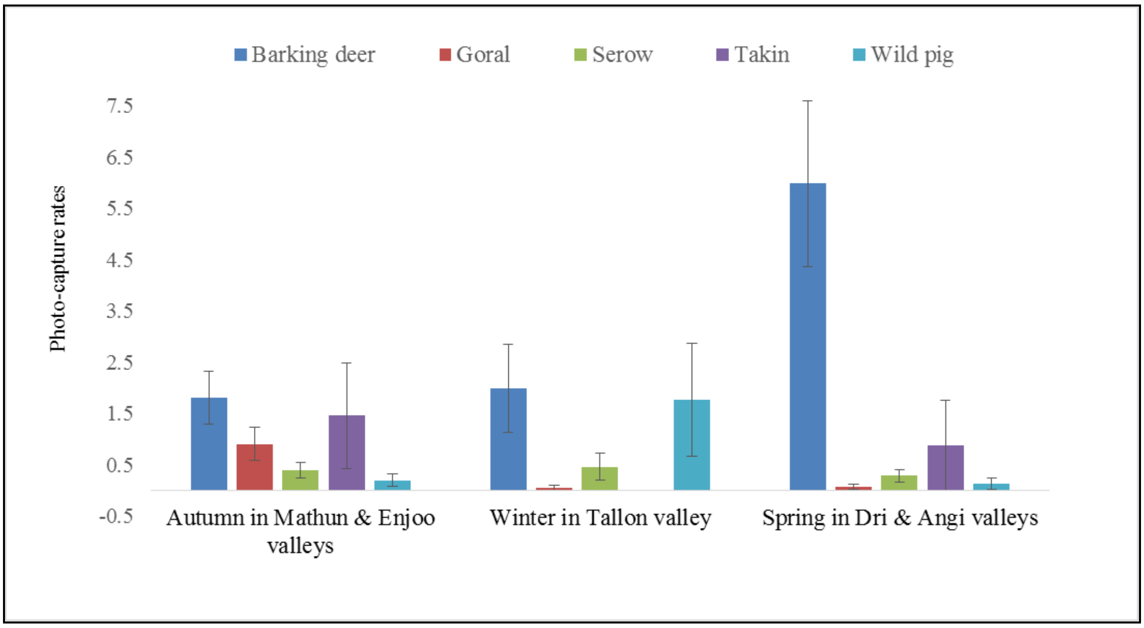


Figure 3.12: Mean photo-capture rates of ungulate species at different temporal scale during second-year observation inside DWLS, 2016-17

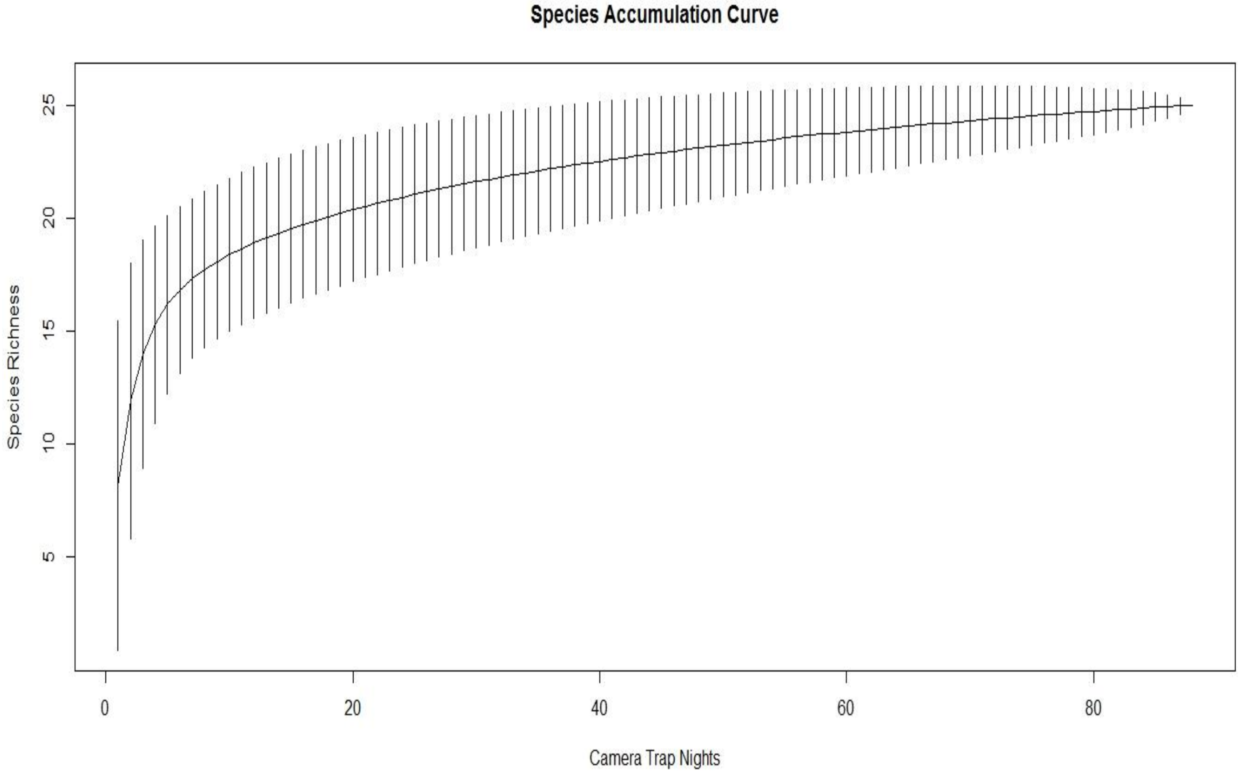


Figure 3.13: Species accumulation curve of mammalian species inside DWLS

3.4.3 Mean group sizes and population structure of the wild dog, Asiatic black bear, tiger, and ungulate species:

A total of 140 wild dog photographs were captured from 42 camera trap locations. From the overall photo-capture images, 72.14% (n=101) were single adult individuals, 17.14% (n=24) contained two individuals, only one photograph comprised of three individuals (2.14%) and 8.58% (n=12) had four individuals in each photo captured including four pups. The mean group size of wild dog was 1.20±0.05. The highest pack size was four and the minimum was one.

Forty camera traps locations captured 46 images of Asiatic black bear form the sanctuary. 93.48% (n=43) were of a single individual and 6.52% (n=3) had three individuals in the photo-captures. The mean group size of the black bear was 1.05 with the SE of ± 0.05.

A total of 83 tiger images were photo-captured from the 36 camera trap locations. Five camera locations were outside the PA in community forests. For the single-sided camera trap locations, the photo-capture images of the flank that was captured a higher number of times were chosen for unique identification. Of these, 42 were of the left flank, 38 were of the right flank, and the remaining three could not be identified due to poor image quality. Hence, 42 left flank photographs (Image 3.1) of the tiger were used and 11 unique individuals of tigers were identified including two cubs. Five unique individual tigers (three adults and two sub-adults) were photo-captured in the community forest adjacent to the sanctuary area whereas the remaining six tigers (4 adults and 2 cubs) were photo-captured inside the sanctuary. Four tigers were identified as male and three as female; the sex of two tigers was unidentifiable. 85.71% (n=36) were of single adult individuals, and 14.29% (n=6) were of two individuals. Amongst these, one had two cubs in the image, one had two sub-adults and one had one adult female and one adult male. The mean group size of the tiger was 1.08 ± 0.04.

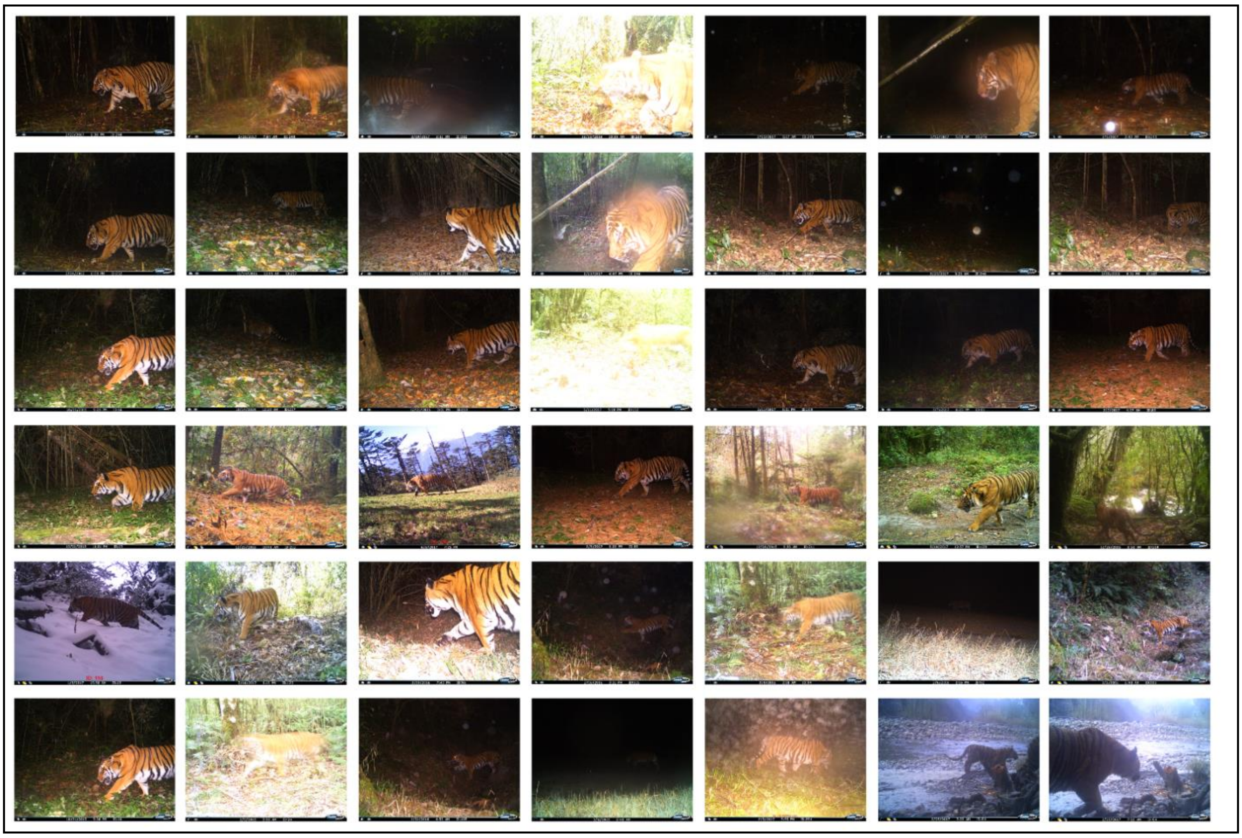


Image 3.1: Since the sampling was to identify the tiger occupied areas, we placed single-sided cameras to cover the maximum area of Dibang Wildlife Sanctuary and its adjoining landscapes. We got 42 photographs of tigers. From these, we have identified 9 adults and 2 cubs.

Within the forest-dwelling ungulates, 349 individuals of barking deer were photo-captured; of which 122 (34.96%) were single male adult individuals, 132 (37.82%) were single adult female individuals, 18 (5.16%) were male-female pairs, 4 (1.15%) were male-male pairs and 10 (2.87%) were of a female with a fawn. 63 photo-captures (18.05%) were not classified due to difficulty in age or sex identification. The mean group size of the barking deer was 1.08 ± 0.01.

55 individuals of serow were photo-captured; of these 2 (7.27%) photo-captures contain four adult individuals of serows and 51 (92.73%) contain a single individual of adult serows. The mean group size of the serow was 1.04 ± 0.03.

The mean group size of goral was calculated as 1.02 ± 0.02 individuals. A total of 67 individuals of goral were photo-captured; 65 (97.01%) photo-captures contain single individuals of adult goral and one (2.99%) photo-capture contained two individuals (2.99%).

The social behavior of Mishmi takin was recorded. 82 individuals of Mishmi takin were photo-captured in total. Eight photo-captures were of multiple individuals. Nine (10.98%) photo-captures contain single individuals, two photo-captures contain two adult individuals (4.88%) each, three photo-captures contain five adult individuals (18.29%) each, another three photo-captures contain multiple individuals — fourteen individuals (17.07%) (Eight adults, four sub-adults and two calves), fifteen individuals (18.29%) (ten adults and five sub-adults), and twenty-five individuals (30.49%) (fifteen adult, eight sub-adult and two calves). The mean group size of Mishmi takin was 4.82 ± 1.65.

58 individuals were photo-captured of wild pig. 51 (87.93%) photo-captures contained single adult individuals, two (6.90%) photo-captures were of two adult individuals each, and one (5.17%) photo-capture contained three adult individuals. The mean group size of the wild pig was 1.07 ± 0.04 individuals (Table 3.11).

Table 3.11: The percentage of individual(s) photo-captures of mammalian species in the PA

Mammal Species	Total # of capture	Single Individual (%)	Two Individuals (%)	Three Individuals (%)	Four Individuals (%)	Five Individuals (%)	> Five indivduals (%)
Tiger	42	85.71	14.29	-	-	-	-
Wild dog	140	72.14	17.14	2.14	8.58	-	-
Asiatic Black bear	40	93.48	-	6.52	-	-	-
Muntjac	349	85.67	14.33	-	-	-	-
H. Serow	55	92.73	-	-	7.27	-	-
Red goral	67	97.01	2.99	-	-	-	-
M. Takin	82	10.98	4.88	-	-	18.29	65.85
Wild pig	58	87.93	6.90	5.17	-	-	-

3.4.4 Spatial distribution patterns of tiger, wild dog, Asiatic black bear and ungulate species:

Intensive camera trapping was carried out both inside and outside the protected area for identifying areas used by tigers, co-predators, and their prey species. (Fig 3.14; 3.15; 3.16).

Camera traps were deployed at different geographical locations. 93.10% of camera traps were installed on slopes between 0°and 30°, and 6.90% between 31°and 87°. The maximum number of camera traps were at aspects of the north (0-22.5 & 337.5-360), northwest (292.5-337.5), south (157.5-202.5), west (247.5-292.5), and southeast (112.5-157.5). Both camera trapping and sign surveys were carried out at an elevation of 1600 to 3783 m amsl, 1600 to 3001 m amsl within the PA, and 3783 m amsl was the highest point outside the PA, with forest types ranging from temperate forest to subalpine forest (Table 3.14). The large mammalian carnivores i.e. tiger, wild dog, Asiatic black bear, and forest-dwelling ungulates, were found through photo capture within the elevation range of 1749 to 3783 m amsl. Among the various aspects and classes, tigers, co-predators, and ungulate species were encountered generally in north, northwest, south, and southeast aspect and within the slope classes of 0°- 30° (Table 3.12 & 3.13).

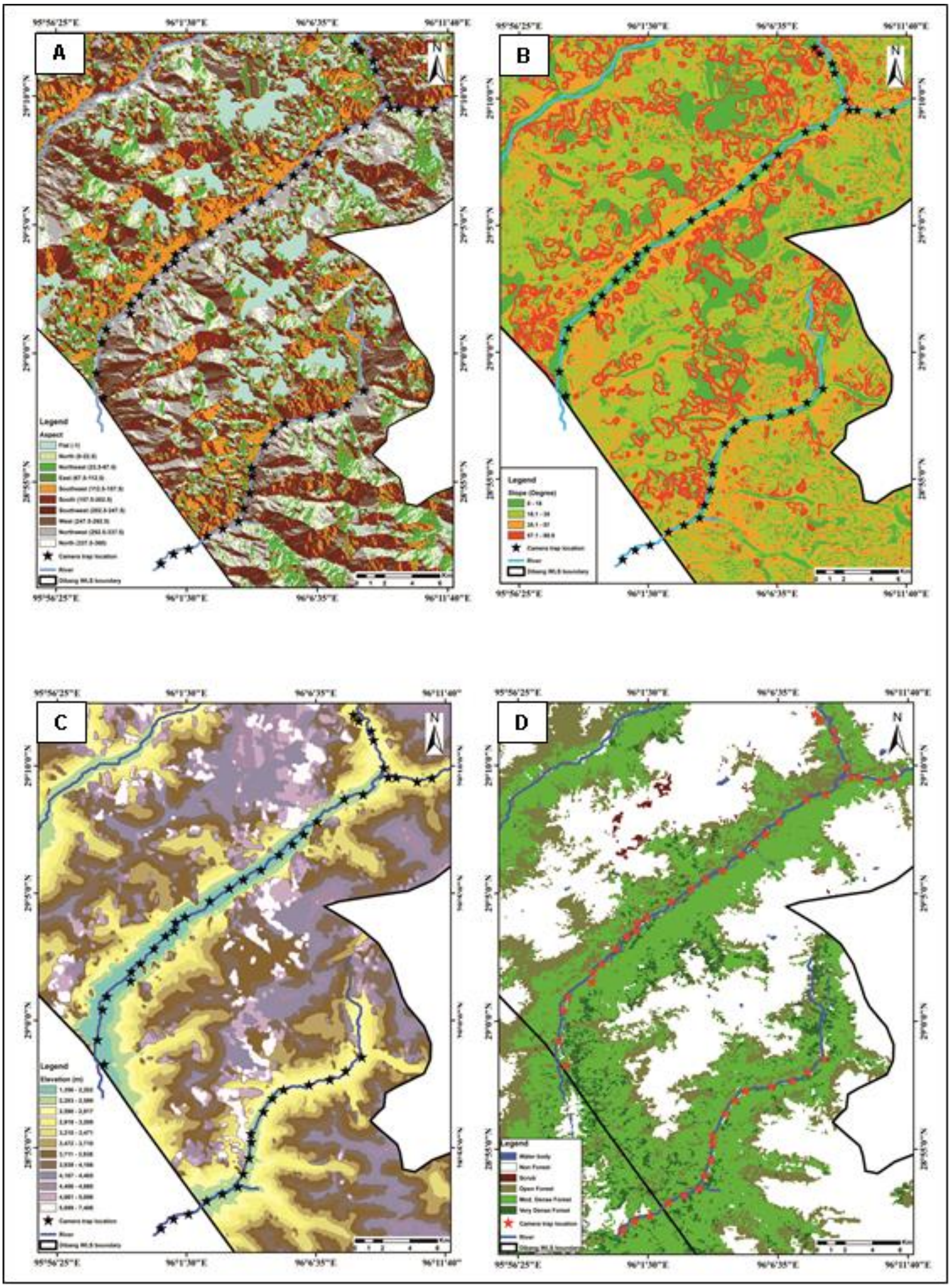


Figure 3.14: Camera trap locations at (A) different aspect classes, (B) different slope categories, (C) different elevation, and (D) different habitat categories in Dri and Angi valleys

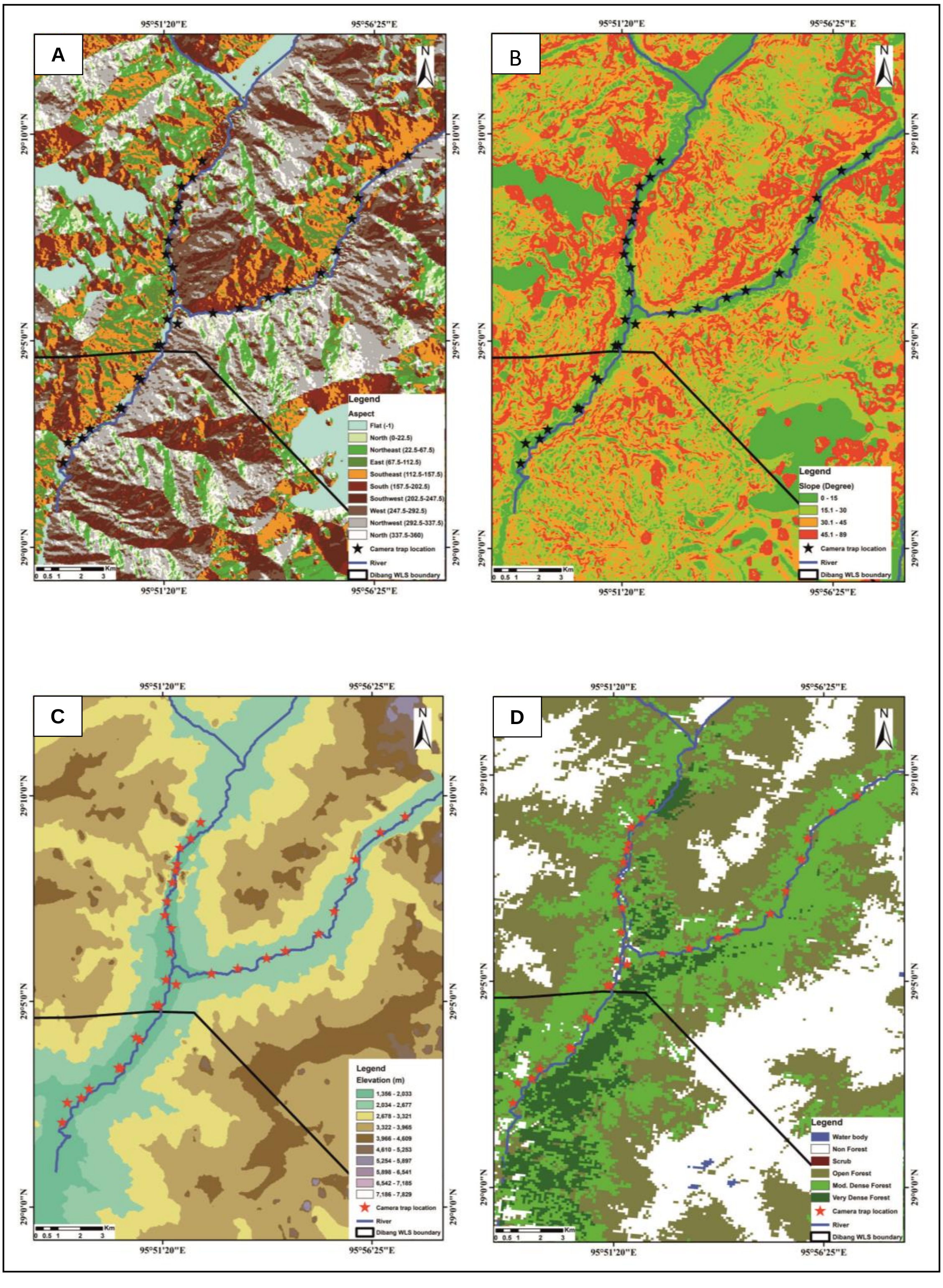


Figure 3.15: Camera trap locations at (A) different aspect classes, (B) different slope categories, (C) different elevation, and (D) different habitat categories in Mathun and Enjoo valleys

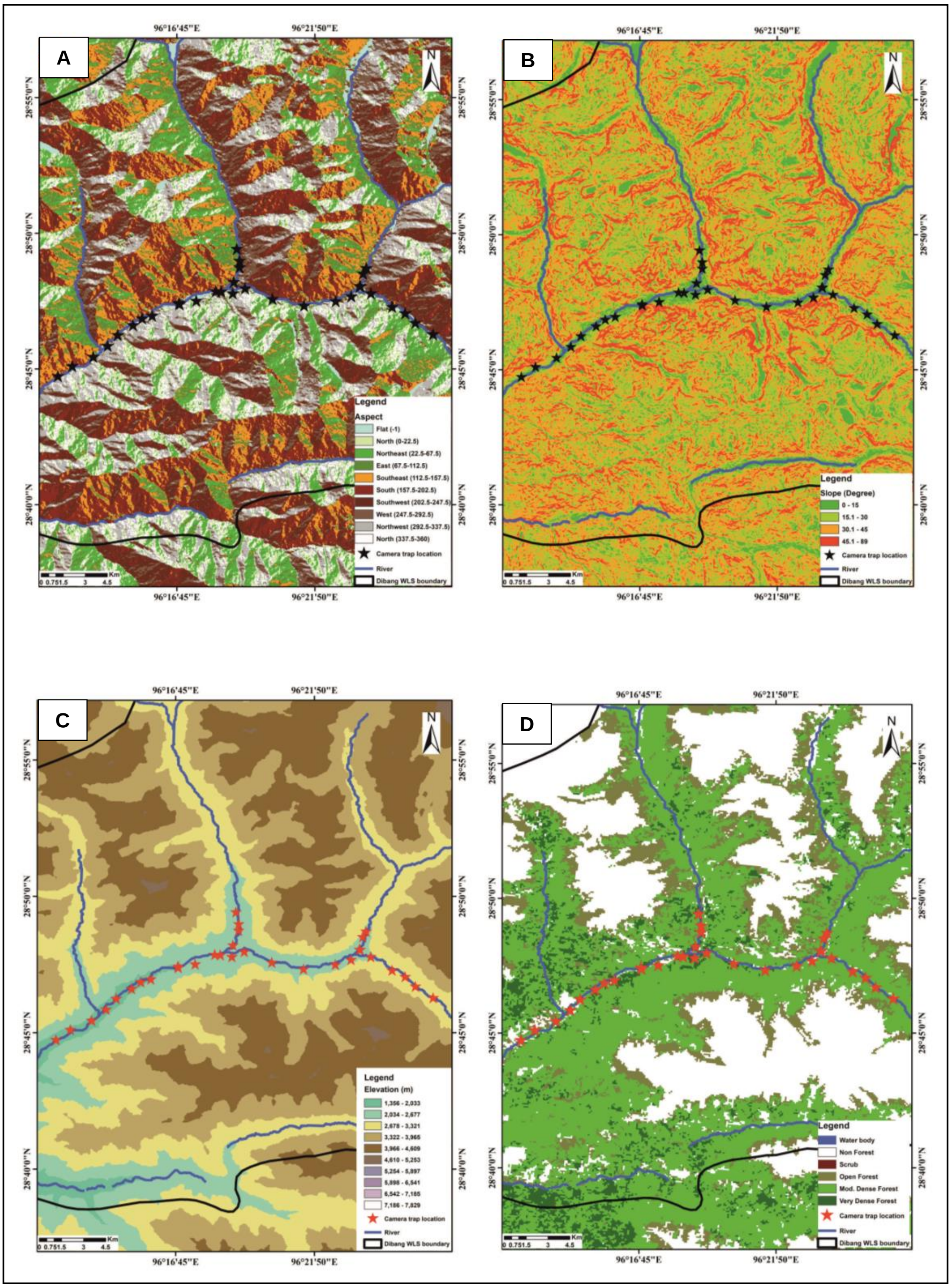


Figure 3.16: Camera trap locations at (A) different aspect classes, (B) different slope categories, (C) different elevation, and (D) different habitat categories in Tallon valley

The photo-capture rate of tiger, wild dogs, and ungulates species was represented with a high, medium, and low frequency of presence. During winter, most camera traps were deployed in lowland temperate forest area, which included few camera traps that were active during snowfall, whereas in the post-winter session, camera traps were deployed in high elevation areas along with lowland temperate forest.

Elevation ranges of tigers captured vary from 1774 m amsl, in temperate broadleaf forest dominated by miscellaneous forest, *Quercus* spp. forest, bamboo forest, and riverine forest, up to 3630 m amsl, in elevated *Abies* spp*. (Abies densa)* and *Tsuga dumosa* dominated forest, Rhododendron forest, bamboo forest, and alpine forest. In the lower temperate vegetation zone, tigers were photo-captured along the river valley, human trekking routes, animal trails, near riverbanks, and on dry riverbeds.

Two male tigers were captured at 3,246 m amsl on 14th January 2017 (Image A) and 29th May 2017 (Image B), during peak winter snowfall in the community forest land that is outside the PA. One of the male tiger (Image A) was recaptured at 3,630 m amsl on 07th June 2017 (Image C) in an area with different vegetation types. The higher elevation of 3,630 m amsl has a sub-alpine forest comprising mainly of *Abies densa* and dwarf *Rhododendron* spp*,* while the lower elevation of 3246 m amsl has mixed vegetation dominated by *Rhododendron arboreum*, bamboo, and pine.

Image 3.2: Tigers were photo-captured at high altitude; (A & B) Two different individual tiger captured at an elevation 3246 m; (C) Same tiger (B) recaptured at 3630 m elevation.

Overall, tiger presence was encountered mainly in north, south, southeast, northwest, and southwest aspect classes, and the highest slope encountered evidence was in 0°-10° and 10°-20°.

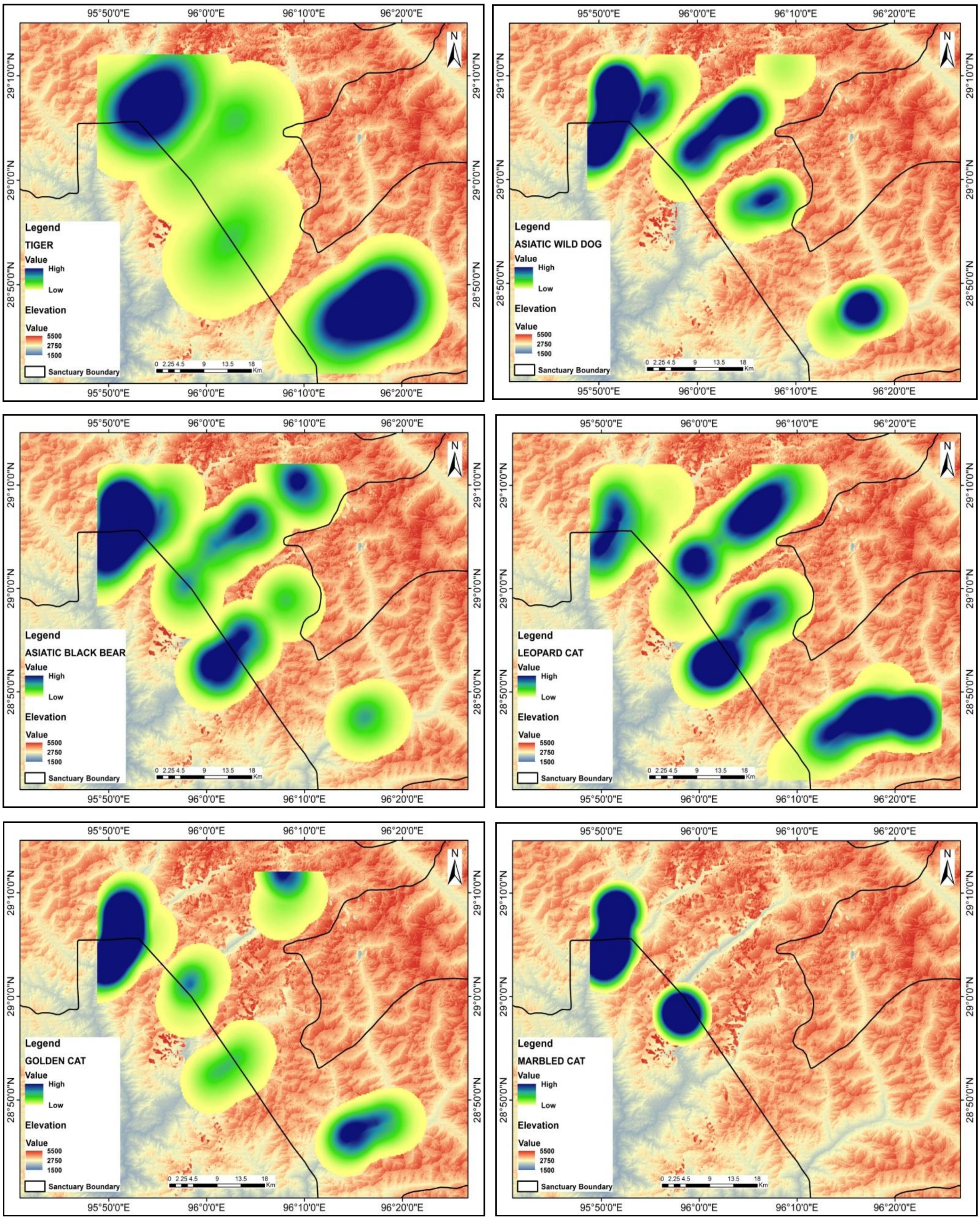
While the presence of wild dog locations was restricted within the temperate forest at the altitudinal range of 1749 to 2142 m amsl. Dominant tree species were oak (*Quercus* spp.), rhododendron, bamboo forest, pine-dominated forest. At higher altitudes, the vegetation composition was dominated by rhododendron and oak forest. The aspect classes of the encountered location of wild dogs were highest in north, northwest, southeast, and south, and the highest slope evidence of wild dogs was encountered in 0°-10°, 10°-20°, and 20°-30°. Similarly, the spatial distributions of Asiatic black bear were confined to the temperate forest at the altitudinal range of 1686 to 2954 m amsl. Dominant tree species were oak (*Quercus* spp.), rhododendron, bamboo forest, pine-dominated forest. The encountered locations of black bear were highest at north, northwest, southeast, west, and east aspect classes. The highest slope evidence of Asiatic black bear was encountered in 0°-10°, 10°-20°, and 20°-30° (Fig 3.17 & Table 3.13).

The photo-capture evidence of Mishmi takins was encountered both in the river valley and the high altitude alpine and sub-alpine areas. The elevation ranges from 1886 m amsl onwards in temperate broadleaf forest dominated by miscellaneous forest, *Quercus* spp*.* forest, bamboo forest, and riverine forest, up to in elevated *abies spp. (A. densa)* and *Tsuga dumosa* dominated forest, high elevated rhododendron forest, and alpine forest. In the lower temperate forest area, Mishmi takins were photo-captured along the river ridge, near the river bank and mountain ridge with a group size of 3 to 25 individuals. Mishmi takin was photo captured at an elevation of 3783 m amsl, on the top of a mountain, during the peak winter season. Overall, Mishmi takin evidence was encountered mainly in north, south, southeast, and southwest aspect classes, and the highest slope encountered evidence was in 0°-10° and 10°-20° (Fig 3.18).

Similarly, the spatial distribution of goral and serow evidence locations were also confined to the sub-alpine and temperate forests at an altitudinal range of 1679 to 2954 m amsl. Oak (*Quercus* spp.), rhododendron, bamboo, and pine were the dominant tree species at the lower altitude, and at a higher altitude, the vegetation compositions were dominated by rhododendron and oak spp. Goral and serow were mainly encountered at west, north, south, northwest, southeast, and east aspect classes, whereas, in the slope category, the highest slope evidence of goral and serow was encountered in 0°-10°, 10°-20°, and 20°-30°.

Barking deer was photo-captured between the altitudinal ranges of 1683 to 2921 m amsl. At higher altitude, Gonshang muntjacs (locally known as black barking deer) were also photo-captured, however this species needs to be validated and verified through genetic analysis in the future. They are confined to the temperate forest and were mainly encountered at northwest, west, north, southeast, and south aspect classes, whereas in the slope category, encountered locations were in 0°-10°, 10°-20°, and 20°-30°.

Wild pig evidence locations were also confined to the temperate forests within the elevation range of 1683 to 3001 m amsl. The encountered locations of wild pig were particularly in north, southeast, south, and northwest aspect classes, whereas in the slope classes, wild pig encountered locations were in 0°-10°, 10°-20°, and 20°-30° (Fig 3.18 & Table 3.12).


95°50'0"E
96°0'0"E
96°10'0"E
96°20'0"E
29°10'0"N
29°0'0"N
28°50'0"N
N
Legend
TIGER
Value
High
Low
Elevation
Value
5500
2750
1500
Sanctuary Boundary
0 2.25 4.5 9 13.5 18 Km
Legend
ASIATIC WILD DOG
Value
High
Low
Elevation
Value
5500
2750
1500
Sanctuary Boundary
Legend
ASIATIC BLACK BEAR
Value
High
Low
Elevation
Value
5500
2750
1500
Sanctuary Boundary
Legend
LEOPARD CAT
Value
High
Low
Elevation
Value
5500
2750
1500
Sanctuary Boundary
Legend
GOLDEN CAT
Value
High
Low
Elevation
Value
5500
2750
1500
Sanctuary Boundary
Legend
MARBLED CAT
Value
High
Low
Elevation
Value
5500
2750
1500
Sanctuary Boundary

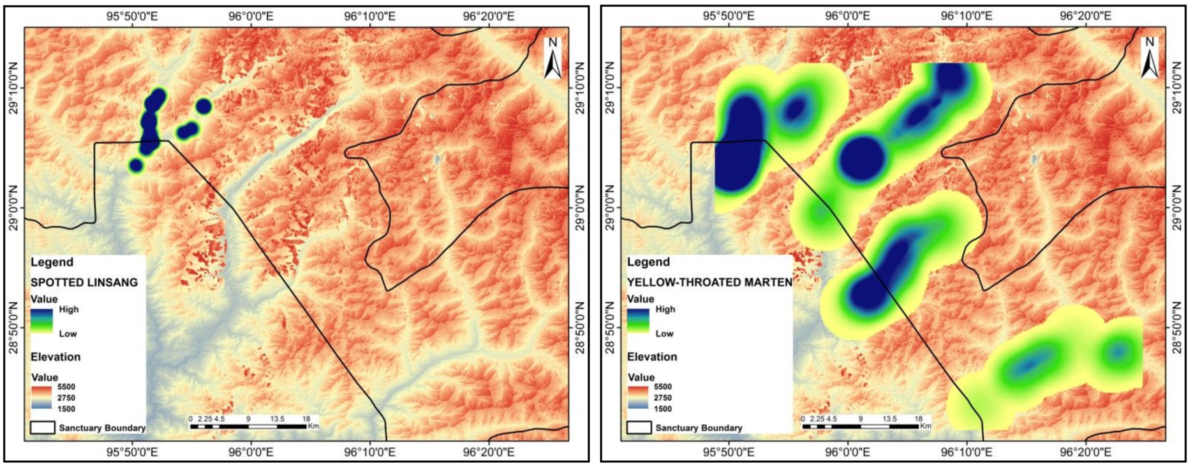


Figure 3.17: Distribution map of mammalian carnivore species in DWLS

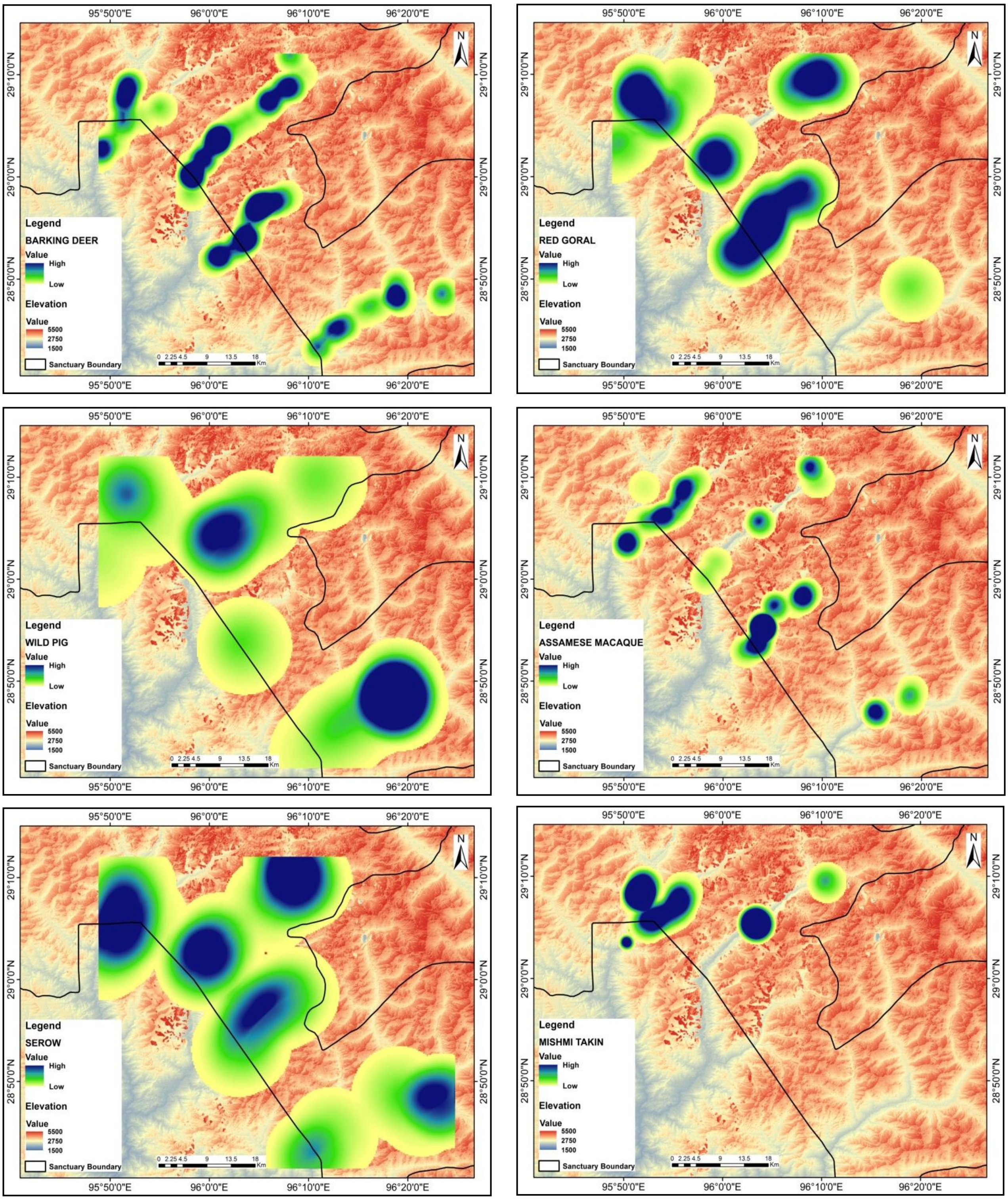


Figure 3. 18: Distribution map of mammalian prey species in DWLS

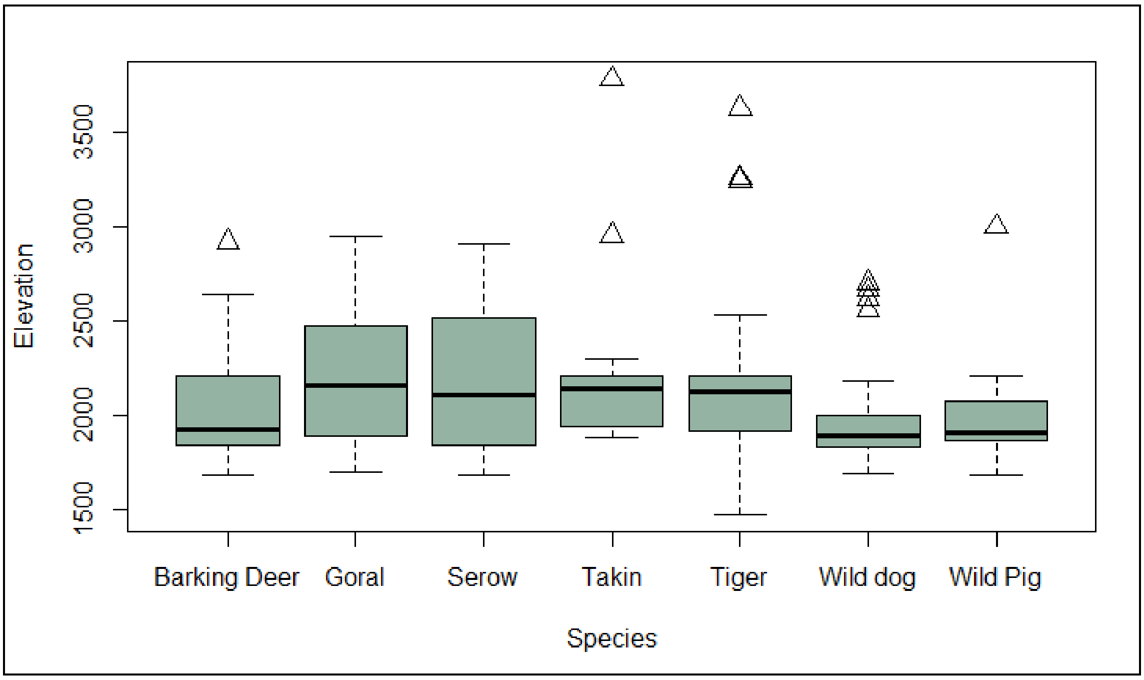


Figure 3.19: Use of elevation (m amsl) by tiger, wild dog and their prey species in DWLS

Table 3.12: Percentage of camera trap locations at different variables and percentage of use of different habitat variables by prey species and pheasants inside DWLS

Variable	Categories	Assamese Macaque		Barking deer		Red Goral		Himalayan Serow		Mishmi Takin		Wild pig		Kalij	
		Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image
Slope	0-10	56.1	77.16	59.76	56.16	53.33	49.25	53.49	52.73	53.33	53.7	50	29.3	54	65
	10-20	26.83	11.42	20.73	26.36	16.67	11.94	25.58	23.64	26.67	37.8	36.36	56.9	31	20
	20-30	4.88	3.05	13.41	11.17	16.67	16.42	9.3	7.27	13.33	2.44	9.09	12.1	15	15
	30-40	4.88	1.52	2.44	3.72	3.33	10.45	9.3	12.73	6.67	6.1	4.55	1.72	0	0
	40-50	2.44	0.25	0	0	0	0	2.33	3.64	0	0	0	0	0	0
	70-80	0	0	1.22	0.86	3.33	2.99	0	0	0	0	0	0	0	0
	80-90	4.88	6.6	2.44	1.72	6.67	8.96	0	0	0	0	0	0	0	0
Aspect	East	2.44	33.5	6.1	4.58	10	14.93	11.63	9.09	0	0	4.55	1.72	12	8.9
	North	19.51	18.53	15.85	11.75	16.67	11.94	16.28	18.18	40	23.2	27.27	19	12	27
	West	19.51	12.18	17.07	24.93	20	13.43	18.6	16.36	0	0	9.09	5.17	19	23
	South	17.07	8.88	14.63	10.89	6.67	4.48	16.28	18.18	20	8.54	18.18	41.4	15	7.6
	NE	4.88	1.78	0	0	6.67	10.45	2.33	1.82	0	0	0	0	3.9	2.5
	NW	14.63	9.9	24.39	23.5	16.67	22.39	16.28	20	6.67	30.5	13.64	8.62	27	25
	SW	9.76	5.58	6.1	3.44	6.67	7.46	4.65	5.45	13.33	7.32	4.55	1.72	3.9	1.3
	SE	12.2	9.64	15.85	20.92	16.67	14.93	13.95	10.91	20	30.5	22.73	22.4	7.7	5.1
Elevation (m)	1600-2100	31.71	22.08	67.07	62.18	40	43.28	48.84	52.73	40	72	77.27	81	85	84
	2100-2600	48.78	69.04	25.61	31.23	46.67	43.28	37.21	34.55	53.33	26.8	18.18	17.2	15	16
	2600-3001	19.51	8.88	7.32	6.59	13.33	13.43	13.95	12.73	6.67	1.22	4.55	1.72	0	0
Canopy (%)	0-25	23.08	18.77	7.89	7.49	16.67	30.91	18.42	23.4	23.08	12.1	14.29	8.93	0	0
	26-50	30.77	23.32	32.89	35.63	37.5	34.55	34.21	34.04	23.08	56.9	28.57	16.1	20	26
	51-75	33.33	51.47	38.16	37.43	37.5	30.91	31.58	29.79	53.85	31	28.57	28.6	44	35
	76-100	12.82	6.43	21.05	19.46	8.33	3.64	15.79	12.77	0	0	28.57	46.4	36	40

Variable	Categories	Assamese Macaque		Barking deer		Red Goral		Himalayan Serow		Mishmi Takin		Wild pig		Kalij	
		Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image
Habitat	Misc.	29.27	50	45.12	54.73	36.67	31.34	39.53	36.36	46.67	42.7	45.45	56.9	46	35
	Riverine	14.63	13.96	13.41	6.88	13.33	14.93	13.95	14.55	6.67	4.88	9.09	8.62	12	18
	Bamboo	7.32	1.02	10.98	12.03	6.67	2.99	13.95	14.55	13.33	36.6	18.18	17.2	31	42
	Alnus nepalensis	7.32	3.81	10.98	12.32	13.33	16.42	6.98	5.45	0	0	4.55	1.72	3.9	2.5
	Oak spp.	19.51	15.23	7.32	4.3	10	13.43	6.98	7.27	13.33	8.54	9.09	3.45	7.7	2.5
	Pine	4.88	6.85	9.76	6.59	3.33	1.49	4.65	3.64	0	0	4.55	5.17	0	0
	Rhododendron	9.76	7.61	0	0	6.67	2.99	4.65	3.64	6.67	1.22	4.55	3.45	0	0
	Grassland	7.32	1.52	2.44	3.15	10	16.42	9.3	14.55	13.33	6.1	4.55	3.45	0	0
Shrub (%)	0-25	36	**62.5**	10.2	7.86	9.09	26.32	11.11	14.29	40	21.2	0	0	23	24
	26-50	4	5	2.04	3.49	9.09	5.26	0	0	20	3.03	0	0	0	0
	51-75	8	3.75	0	0	9.09	15.79	0	0	0	0	7.14	2.38	0	0
	76-100	**52**	28.75	**87.76**	**88.65**	**72.73**	**52.63**	**88.89**	**85.71**	40	75.8	92.86	97.6	77	76

Low **High**

Table 3.13: Percentage of camera trap locations at different variables and percentage of use of different habitat variables by mammalian carnivores inside DWLS

Variable	Categories	Wild dog		Tiger		Asiatic Black bear		Golden cat		Leopard cat		Yellow-t Marten	
		Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image
Slope	0-10	72.92	67.14	57.58	57.14	66.67	60.87	61.22	57.69	59.74	57.94	67.09	74.07
	10-20	20.83	22.14	27.27	30.95	13.89	17.39	24.49	33.65	20.78	19.63	20.25	13.80
	20-30	4.17	5.00	12.12	9.52	8.33	10.87	6.12	2.88	11.69	18.22	8.86	9.76
	30-40	0.00	0.00	3.03	2.38	2.78	2.17	2.04	0.96	3.90	2.80	0.00	0.00
	40-50	0.00	0.00	0.00	0.00	2.78	2.17	0.00	0.00	1.30	0.47	0.00	0.00
	50-60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	60-70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	70-80	0.00	0.00	0.00	0.00	0.00	0.00	2.04	1.92	1.30	0.47	1.27	0.67
	80-90	2.08	5.71	0.00	0.00	5.56	6.52	4.08	2.88	1.30	0.47	2.53	1.68
Aspect	East	6.25	0.07	3.03	2.38	11.11	13.04	14.29	12.50	6.49	4.21	8.86	9.09
	North	25.00	0.26	27.27	26.19	27.78	26.09	30.61	27.88	27.27	29.91	20.25	24.92
	West	8.33	0.04	6.06	7.14	13.89	10.87	14.29	13.46	9.09	8.41	13.92	7.07
	South	12.50	0.13	18.18	16.67	2.78	2.17	10.20	6.73	12.99	10.28	12.66	14.48
	NE	4.17	0.04	3.03	2.38	2.78	2.17	4.08	4.81	2.60	2.34	5.06	4.71
	NW	18.75	0.16	12.12	14.29	19.44	19.57	16.33	24.04	23.38	31.78	20.25	17.51
	SW	8.33	0.10	12.12	11.90	2.78	2.17	2.04	1.92	5.19	5.61	8.86	10.77
	SE	16.67	0.19	18.18	19.05	19.44	23.91	8.16	8.65	12.99	7.48	10.13	11.45
Elevation (m)	1600-2100	81.25	0.84	45.45	47.62	72.22	73.91	77.55	87.50	59.74	66.36	62.03	68.35
	2100-2600	12.50	0.14	54.55	52.38	16.67	17.39	16.33	7.69	29.87	26.17	31.65	25.25
	2600-3001	6.25	0.03	0.00	0.00	11.11	8.70	6.12	4.81	10.39	7.48	6.33	6.40
Canopy (%)	0-25	11.36	9.68	18.75	15.00	13.33	10.81	9.30	6.98	10.81	7.73	6.94	3.10
	26-50	31.82	36.29	34.38	32.50	30.00	32.43	25.58	22.09	35.14	42.51	31.94	26.74
	51-75	31.82	36.29	34.38	40.00	40.00	43.24	37.21	43.02	41.89	37.20	37.50	43.41
	76-100	25.00	17.74	12.50	12.50	16.67	13.51	27.91	27.91	12.16	12.56	23.61	26.74

Variable	Categories	Wild dog		Tiger		Asiatic Black bear		Golden cat		Leopard cat		Yellow-t Marten	
		Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image	Camera trap location	Individual image
Habitat	Misc.	43.75	46.43	60.61	60.98	44.44	45.65	40.82	35.58	50.65	51.87	41.77	33.33
	Riverine	8.33	9.29	6.06	7.32	11.11	13.04	14.29	15.38	7.79	13.08	13.92	20.88
	Bamboo	25.00	24.29	9.09	7.32	11.11	13.04	16.33	25.96	6.49	5.14	13.92	11.45
	Alnus nepalensis	4.17	3.57	0.00	0.00	5.56	6.52	6.12	4.81	5.19	1.87	5.06	2.36
	Oak spp.	4.17	2.14	3.03	2.44	13.89	10.87	4.08	1.92	10.39	4.67	10.13	9.43
	Pine	8.33	9.29	12.12	14.63	5.56	4.35	8.16	8.65	14.29	16.36	8.86	7.41
	Rhododendron	4.17	1.43	3.03	2.44	0.00	0.00	6.12	2.88	2.60	4.21	2.53	3.37
	Grassland	2.08	3.57	6.06	4.88	8.33	6.52	4.08	4.81	2.60	2.80	3.80	11.78
Shrub (%)	0-25	6.90	12.00	21.43	16.67	45.45	46.15	19.35	35.38	13.33	12.40	21.43	15.45
	26-50	3.45	2.67	3.57	2.78	0.00	0.00	0.00	0.00	2.22	1.55	2.38	2.73
	51-75	6.90	4.00	3.57	2.78	0.00	0.00	0.00	0.00	6.67	8.53	0.00	0.00
	76-100	82.76	81.33	71.43	77.78	54.55	53.85	80.65	64.62	77.78	77.52	76.19	81.82

Low **High**

Table 3.14: Observed habitat and topographic types along the five major valleys of DWLS

Sl. No.	Name of valley	Sampling elevation (m)	Observed forest type	Canopy cover (average)	Terrain type	Forest type in the literature with elevation (m) (As per Champion & Seth) & Important species
1	Dri Valley	1736 to 2000	Miscellaneous forest, Bamboo breaks, Riverine forest, *Alnus nepalensis* , Pine forest, etc.	57.14 %	Riverine plain, moderate slope and undulating	1000-1800 m *Pinus roxburghii, Pinus wallichiana and Pinus merkusii*
		2000 to 2500	Pine dominated forest, *Alnus nepalensis*, Miscellaneous forest, etc.	40 %	Moderate slope and undulating	
		2500 to 3001	Dominated the species of *Pinacea* family, Scrubland, Rhododendron forest, Miscellaneous forest, etc.	45 %	High elevated plain, moderate slope, and steep incline	
2	Angi pani Valley	1678 to 2000	Maximum Riverine forest and Miscellaneous forest followed by Rhododendron forest	63.33 %	Undulating	
		2000 to 2500	Dominated by Miscellaneous forest, *Alnus nepalensis* and Pine forest. Less Rhododendron forest and species of *Pinacea* family were found	52.86 %	Undulating and moderate slope	1800-2750 m *Quercus lamellosa, Quercus* spp., *Castanopsis indica, Acer hookeri*
		2500 to 2700	Dominated by the species of *Pinacea* family, Rhododendron forest, etc.	42.5 %	Undulating and moderate slope	
3	Mathun Valley	1697 to 2017	Miscellaneous forest, Bamboo breaks, Riverine forest, *Alnus nepalensis* and Pine and Rhododendron forest were found.	81.36 %	Riverine plain, moderate slope and undulating	

Sl. No.	Name of valley	Sampling elevation (m)	Observed forest type	Canopy cover (average)	Terrain type	Forest type in the literature with elevation (m) (As per Champion & Seth) & Important species
4	Enjoo Valley	1691 to 2000	Miscellaneous forest, Riverine forest, Bamboo breaks, and *Akambo* (local name) forest, etc.	80.83 %	Riverine plain, moderate slope, and rugged terrain	2300-3350 m *Abies* spp., *Tsuga dumosa.*
		2000 to 2336	Dominated by Pine forest, Rhododendron forest, Oak (*Quercus* spp.) and Miscellaneous forest	56.25 %	Moderate slope, undulating, steep incline, and rugged terrain	
5	Tallon Valley	1633 to 2000	Miscellaneous forest, Pine forest, *Akambo* (local name) forest, Grassland, etc.	46.79 %	Plain and moderate slope	
		2000 to 2500	Miscellaneous forest, Pine forest, Rhododendron forest, Riverine, etc.	44.71 %	Moderate slope, undulating and steep incline	3000-5500 m *Rhododendron, Primula, Saussaurea, Saxifraga.*
		2500 to 2934	Oak (*Quercus* spp.) Pine forest, Rhododendron forest, Riverine forest, etc.	34.17 %	High elevated plain, moderate slope, undulating and steep incline	

Table 3.15: Camera traps locations and habitat characteristic for sampling in the targeted valleys of DWLS

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
1	Dri Valley	G 522	127	1753	5	NW	Oak spp., forest
2		G 566	127	1755	4	S	Miscellaneous and Riverine forests
3		G 607	126	1785	12	W	Miscellaneous forest
4		G 646	125	1784	8	W	Riverine forest
5		G 647	55	1847	32	NW	Miscellaneous forest and Grassland
6		G 686	118	1804	5	N	Miscellaneous forest
7		G 724	125	1815	22	NW	Miscellaneous forest
8		G 725	118	1835	12	NW	Miscellaneous forest
9		G 764	118	1854	10	NW	Miscellaneous forest
10		G 765	122	1857	9	SE	Bamboo barrack forest
11		G 764 (b)	52	1875	7	SE	Pine dominated forest
12		G 805	122	1844	5	S	*Alnus nepalansis*
13		G 806	122	1911	3	SE	Pine forest
14		G 838	122	1901	7	NW	Riverine and Bamboo barrack forests
15		G 839	122	1927	4	W	Miscellaneous forest
16		G 872	122	1943	18	N	Miscellaneous forest
17		G 873	120	2036	5	S	Pine forest
18		G 909	120	2074	7	N	Pine forest
19		G 910	120	2128	7	W	Miscellaneous forest
20		G 947	119	2148	1	SW	*Alnus nepalansis* forest
21		G 986	120	2263	10	W	*Alnus nepalansis* forest
22		G 987	119	2352	23	N	*Alnus nepalansis* forest
23		G 1022	115	2521	16	S	Oak spp. forest (Atombo in the local name)
24		G 1058	115	2702	0	N	Oak spp. and Rhododendron forests
25		G1096	115	2782	0	N	Oak spp. forest (Atombo in local name)

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
26		G 1095	48	2921	84	S	Oak spp. dominated forest
27		G 1134	48	2906	0	N	Grassland, Scrubland
28		G 1023	113	2681	15	N	Rhododendron forest
29		G 1023 (Extra)	113	2527	48	NW	Rhododendron forest
30		G 1024	33	2954	4	N	Scrubland
31		G 1025	33	3001	15	NW	Oak dominated
32	**Angi pani Valley**	Outer 1	121	1678	0	NW	Miscellaneous forest
33		Outer 2	124	1774	0	NW	Miscellaneous forest
34		Outer 3	121	1855	0	NW	Miscellaneous forest
35		G 296	118	2073	29	NW	Miscellaneous forest
36		G 296 (b)	59	2110	8	W	*Alnus nepalensis* forest
37		G 337 (a)	118	2149	8	S	Miscellaneous forest
38		G 337 (b)	70	2214	12	W	*Alnus nepalansis* forest
39		G 376	119	2274	10	W	Miscellaneous forest
40		G 422	111	2351	9	SW	Miscellaneous forest
41		G 422 (Extra)	118	2430	15	W	Oak spp. forest
42		G 473	113	2481	22	NW	Miscellaneous forest
43		G 474	118	2506	7	NW	Oak spp. and Pine forests
44		G 528	95	2556	5	SE	Miscellaneous forest
45		G 529	114	2642	4	W	Pine forest
46		G 530	116	2621	4	NE	Oak spp. and Rhododendron forests
47		G 575	76	2666	6	W	Miscellaneous forest
48		G 576	111	2678	3	S	Pine forest
49		Outer 1	141	1697	0	N	Bamboo barrack forest
50		Outer 2	113	1704	0	SE	Miscellaneous forest
51		Outer 3	141	1723	0	N	Riverine forest and Grassland
52		Outer 4	139	1822	0	E	Miscellaneous forest
53		G 795	139	1830	5	S	Riverine forest

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
54	Mathun Valley	G 796 (a)	138	1842	7	E	Bamboo barrack forest
55		G 827 A& B	138	1861	22	NW	Miscellaneous forest
56		G 828 A & B	138	1882	0	N	Miscellaneous forest
57		G 861	137	1876	14	E	Bamboo barrack forest
58		G 860	138	1894	0	E	Riverine and *Alnus nepalensis* forests
59		G 896	138	1884	5	N	Miscellaneous and Riverine forests
60		G 896 Extra	135	1886	11	SE	Miscellaneous forest
61		G 933 Extra	135	1918	9	E	Miscellaneous forest
62		G 933	136	1957	74	E	*Alnus nepalensis* forest
63		934 Extra	134	1940	11	SE	Miscellaneous forest
64		G 934 A & B	136	1996	7	S	Miscellaneous forest
65	Enjoo Valley	N1	148	1691	0	NW	Akambo forest
66		N2	146	1707	0	N	Bamboo barrack forest
67		N3	143	1726	0	N	Riverine forest
68		N4	144	1816	0	W	Miscellaneous and Bamboo forests
69		N5	64	1857	11	NE	Miscellaneous forest
70		G 796 (b)	147	1866	19	NW	Miscellaneous forest
71		G 796 (b) Extra	65	1969	12	W	Miscellaneous and Riverine forests
72		G 829	143	2095	8	SW	Pine forest and Grassland
73		G 830 (a)	143	2113	0	N	Miscellaneous forest
74		G 830 (b)	145	2147	28	S	Miscellaneous forest
75		G 864	145	2186	2	SE	Miscellaneous forest
76		G 900 (A)	144	2209	3	NE	Miscellaneous forest
77		G 900 (B)	145	2197	0	NE	Miscellaneous forest
78		G 937A & B	142	2288	8	SE	Miscellaneous forest.
79		G 938	139	2298	9	S	Tapambo forest (local name)
80		G 976 A & B	64	2336	12	SE	Others
81		G 15	72	1744	35	E	NA

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
82	Tallon Valley	G 25 (Extra)	72	1679	30	S	NA
83		G 26	72	1683	33	SE	NA
84		G 43	72	1719	21	S	NA
85		G 68	71	1790	27	SE	NA
86		G 69	62	1835	18	S	Miscellaneous forest
87		G 95	74	1869	24	S	Miscellaneous forest
88		G 96	63	1898	19	SE	Miscellaneous forest
89		G 123	63	1888	1	SW	Pine forest
90		G 123 (Extra)	69	1902	0	N	NA
91		G 124	66	1902	14	NW	Pine forest
92		G 152	66	1923	0	E	Masumbo forest (local name)
93		G 153	125	1990	9	NW	Miscellaneous forest
94		G 182	112	1997	10	NW	Miscellaneous forest
95		G 183	134	1990	1	N	Riverine forest
96		G 184	102	2043	13	NW	Miscellaneous forest
97		G 185	91	2118	4	S	Miscellaneous forest
98		G 186	134	2217	13	NE	Miscellaneous forest
99		G 186 (Extra)	65	2316	33	N	Pine and Rhododendron forests
100		G 187	133	2424	12	N	Pine and Rhododendron forests
101		G 188	90	2469	10	NE	Miscellaneous forest
102		G 189	64	2520	9	NW	Miscellaneous forest
103		G 218	62	2561	1	S	Oak spp. (Atomboo in the local name) forest
104		G MAL 6	62	2745	13	N	Pine forest
108		G M1	62	2521	3	S	Pine and Riverine forest
109		G M3	62	2521	1	SW	Riverine
110		G M4	62	2629	10	S	Pine forest
111		G M2	62	2637	0	N	Pine forest

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
112		G 214	62	2080	19	SE	Pine and *Alnus nepalensis* forest
113		G 214 (Extra)	62	2137	8	W	Riverine and Bamboo barrack forest
114		G 244 A & B	62	2209	29	SE	Miscellaneous forest
115		G MAL 10	62	2070	12	S	Miscellaneous forest
116		G MAL 11	62	2034	0	N	Pine forest
117		G MAL 12 A & B	62	1975	0	N	Miscellaneous forest
118		G MAL 13	62	1945	6	NW	Pine forest

Table 3.16: Conservation status of fauna photo captured in camera traps in DWLS

Sl.No.	Common name	Local name	Scientific name	Family	IUCN	WPA	Indian Status
1	Tiger	*Amra*	*Panthera tigris tigris*	Felidae	EN	I	Uncommon
2	Clouded Leopard	*Kichi-aruyi*	*Neofelis nebulosa*	Felidae	VU	II	Rare
3	Asiatic Golden Cat	*Amrama* (Melanistic)	*Catopuma temminckii*	Felidae	NT	I	Uncommon
4	Leopard Cat	*Achango*	*Prionailurus bengalensis*	Felidae	LC	I	Uncommon
5	Marbled Cat	*ngurrambo*	*Pardofelis marmorata*	Felidae	NT	I	Rare
6	Asiatic Wild Dog	*Aprupu*	*Cuon alpinus*	Canidae	EN	II	Locally common
7	Asiatic Black Bear	*Ahu*	*Ursus thibetanus*	Ursidae	VU	II	Uncommon
8	Spotted Linsang	*Katoh*	*Prionodon pardicolor*	Prionodontidae	LC	III	Rare
9	Yellow-throated Marten	*Akoko*	*Martes flavigula*	Mustelidae	LC	II	Locally common
10	Stone Marten	NA	*Martes foina*	Mustelidae	LC	I	Uncommon
11	Masked Palm Civet	*Api*	*Paguma larvata*	Viverridae	LC	II	Locally common
12	Red Panda	*Aiminjini*	*Ailurus fulgens*	Ursidae	EN	I	Rare
13	Otter spp.	*Awro*	*Lutra spp.*	Mustelidae	NA	NA	NA
14	Yellow-bellied Weasel	*Eaanoh*	*Mustela kathiah*	Mustelidae	LC	II	Rare
15	Siberian Weasel	NA	*Mustela sibirica*	Mustelidae	LC	II	Uncommon

Sl.No.	Common name	Local name	Scientific name	Family	IUCN	WPA	Indian Status
16	Barking deer	*Manjo*	*Muntiacus muntjak*	Cervidae	LC	III	Locally common
17	Himalayan Serow	*Ma(r)y*	*Capricornis s. thar*	Bovidae	VU	I	Occasional
18	Red goral	*Ami*	*Nemorhaedus baileyi*	Bovidae	VU	III	Rare
19	Mishmi takin	*Awkru*	*Budorcas t. taxicolor*	Bovidae	VU	I	Rare
20	Wild pig	*Amme*	*Sus scrofa*	Suidae	LC	III	Abundant
21	Assamese macaque	*Ameh*	*Macaca assamensis*	Cercopithecidae	NT	II	Locally common
22	Pallas's squirrel	*Adash*	*Callosciurus erythraeus*	Sciuridae	LC	II	Locally common
23	Rat spp.	*Asha(n), Kahoh*	NA	Rodentia	NA	NA	NA
24	Sclater's Monal	*Peba eche*	*Lophophorus sclateri*	Phasianidae	VU	I	NA
25	Temminck's Tragopan	*Peba ala*	*Tragopan temminckii*	Phasianidae	LC	I	NA
26	Kalij Pheasant	*Aro*	*Lophura leucomelanos*	Phasianidae	LC	I	NA
27	Hill Partridge	*Perah*	*Arborophila torqueola*	Phasianidae	LC	IV	NA

3.5 Discussion

3.5.1 Status of mammalian carnivores and forest-dwelling ungulates in and around the protected area:

The three-year (2015-2017) study was conducted in the select river valleys of Dibang Wildlife Sanctuary and its adjoining landscapes for establishing the ecological baselines of tiger, co-predator, and their prey species. Many carnivores and their prey species are categorized differently under International Union for Conservation of Nature and Natural Resources (IUCN), Convention on International Trade in Endangered Species (CITES), and the Indian Wildlife Protection Act 1972 (WPA) (Table 3.16). This ecological baseline information study focused mainly on covering maximum areas in the DWLS and assessing for tiger occurrence. Hence, we chose the five major river valleys in the central, northeastern, and southern portion of the protected area to enrich baseline information and find out effective tiger used areas. Meanwhile, the study was also extended to outside the protected area in the adjacent community forests to know more about the occurrence patterns of the tigers and co-existing carnivores and ungulates. A major portion of temperate forest within the elevation range of around 1600 to 3783 m amsl was covered. More observations at a higher elevation are required to infer the altitudinal movement patterns of carnivores and their prey, especially tiger and Mishmi takin.

The study recorded 11 individual tigers including 2 cubs from DWLS and adjacent community forests within a sampled area of 336 km^2. Tiger in other parts of the country have a sympatric association with multiple large carnivores, however, in DWLS Asiatic wild dog is the only sympatric large carnivores with tiger, and they are sparsely inhabited in and around the protected area. So far neither photographic record nor signs of the common leopard have been encountered from the sanctuary and its adjoining landscape.

Generally, in the Northeastern states including Arunachal Pradesh, the diversity and number of large carnivore coexistence are low. In Pakke Tiger Reserve, the sympatric carnivores i.e. tiger, leopard, and wild dog have been reported (Selvan et al. 2013), leopard and wild dog have been reported in Khangchendzonga Biosphere Reserve (Bashir et al. 2013).

The pack size of wild dogs' ranges from 50 individuals to one individual in the Indian subcontinent (Johnsingh & Manjrekar 2013). However, the ecological study on wild dogs in Northeast India is limited. The maximum number of individuals recorded in a pack is 3, as per the study carried out in Pakke TR (Selvan et al 2013). In this study, 4 individuals were recorded in a pack. Apart from tiger and wild dog, meso-carnivores such as clouded leopard, different morphs of Asiatic golden cats and small cats such as marbled cat and leopard cat have been recorded. Overall, five felids and one canid carnivore species were documented in and around DWLS.

The sanctuary has confirmed the presence of five ungulate species from the temperate forest, which proves that the protected area has a diverse prey base for large carnivores. The presence of endangered Mishmi takin (*Budocas taxicolor taxicolor*), near threatened red goral (*Naemrhedus baileyi*), Himalayan serow (*Capricornis s. thar*), wild pig (*Sus scrofa*), and barking deer (*Muntiacus muntjak*) makes this area an important region for long-term conservation. Two species of barking deer were found, one is Indian or Red muntjac and another is Gongshan or Black muntjac (*M. gongshanensis crinifrons*) (further species identification needs to be confirmed through genetic analysis). Mishmi takin (*B. t. taxicolor*), endemic to Arunachal Pradesh, is a seasonal migratory bovid moving from high elevation to low elevation, and vice versa (Anwaruddin 2006).

In other regions of the country, the major potential prey species for the tiger is usually large ungulates such as gaur *Bos gaurus*, sambar *Cervus unicolor*, nilgai *Bosephalus tragocamelus,* etc. (Biswas & Sankar 2002). However, sambar deer is not distributed in DWLS and its surrounding landscape, as a result, Mishmi takin, Himalayan serow, red goral, wild pig, and barking deer form the major prey base. Mishmi takin is a potential prey species for tigers in this region.

Secondary information during the questionnaire survey and evidence from local hunters confirmed the presence of musk deer and snow leopard in the high elevation areas of the valley; however, there was no photographic and indirect evidence obtained for the presence of musk deer and snow leopard during the study period. This may be due to the deployment of camera traps at a lower elevation and carrying out the sign surveys in river valleys. More surveys at high altitudes may enrich the information on snow leopard, musk deer, and other high elevation-dependent ungulate species.

So far, the diversity of ungulates in this protected area is good and comparable to nearby protected areas such as Namdapha Tiger Reserve that has five ungulates species (Datta et al. 2008), Pakke Tiger Reserve with ten ungulates species (Selvan 2013), Khangchendzonga Biosphere Reserve with seven mountain ungulates (Bashir 2013), and Dhorpatan Hunting Reserve of Nepal with seven species of ungulates (Aryal et al. 2010).

3.5.2 Indices of relative abundance of mammalian carnivore and ungulate species

Estimation of mammalian carnivores and ungulate density in rough terrain brings challenges for the application of robust techniques to derive the desirable outputs. In such conditions, the relative abundance indices based on camera traps have been used (Kawanishi & Sunquist, 2004, Johnson et al. 2006, Datta et al. 2008, Ramesh et al. 2012, Sankar et al. 2012). Before intensive camera trapping, a sign survey was conducted to ensure the capture of target species. Camera traps were placed to overcome the limitation of sign survey and revealed the photographic encounter rates of mammalian carnivore and ungulate species.

During the sign survey and trekking inside the forest, there was no direct encounter with tigers and co-predators. Concerning ungulate species, only Mishmi takin was directly encountered twice. The overall sign encounter rates of large carnivores, co-predators, and ungulates species were highest for the tiger followed by wild dog and Asiatic black bear, while in the case of meso/small carnivores, small carnivore's sign encountered rates were highest followed by yellow-throated marten. In ungulates, sign encounter rates of barking deer were highest followed by wild pig, Himalayan serow and Mishmi takin, and lowest for Red goral.

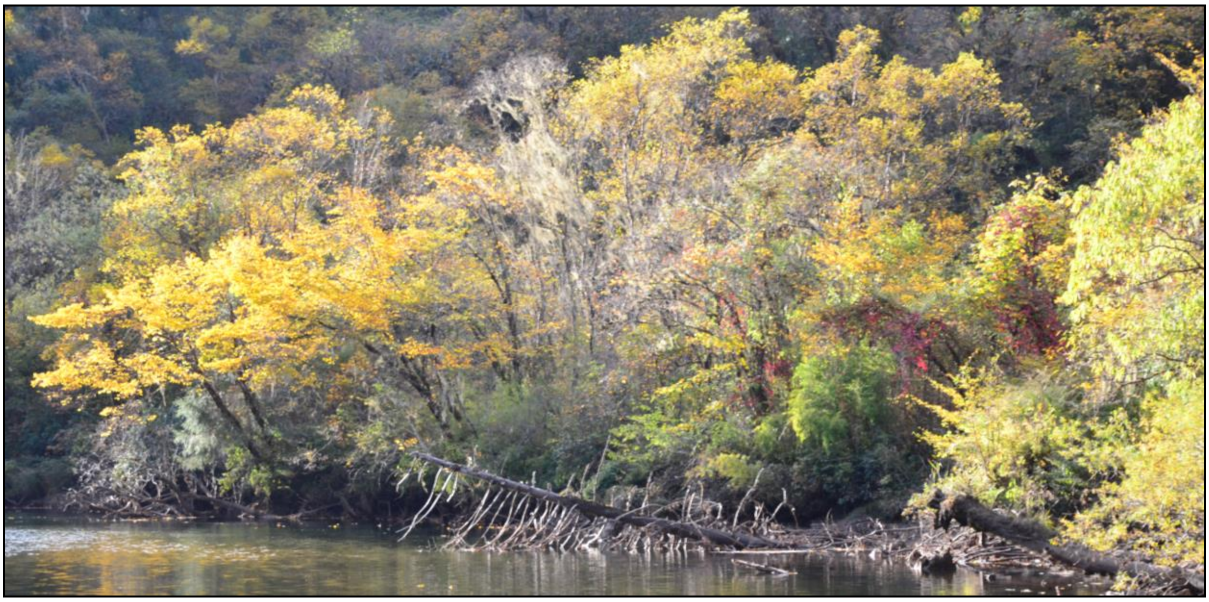
Different valleys have different encounter rates due to the possession of different biological significance and anthropogenic disturbance in each valley. Angi pani and Enjoo valleys have a narrow path, dense vegetation, and steep terrain, however, Dri, Tallon, and Mathun valleys are wider with vast sandy areas compared to other valleys. Frequent rainfall, less open ground cover, and human footprint affects the sign encounter rate of carnivores and ungulates as they are easily washed out, altered, and erased. Overall, 90% of the valleys are covered with moderate to dense vegetation, and high disturbance due to anthropogenic activities are visible in certain river valleys. Among the surveyed five valleys, Dri valley, Mathun valley, and Tallon valley have higher human disturbances as compared to Angi pani and Enjoo valleys. Dri, Mathun, and Tallon valleys are also used by the defense forces to assess and patrol our international borders from time to time. These valleys are also used by local hunters and NTFP collectors. The remaining two valleys i.e., Angi pani and Enjoo are not actively used by defense forces, and only local people, mainly hunters and NTFP collectors, use these two valleys.

The photographic encounter rates (photographs/100 days) of 15 mammalian carnivores, five ungulate species, one primate, four pheasant species, and two rodent species were obtained. Abiotic and biotic factors such as microclimatic factors, diverse vegetation composition, aspect, and slope of the topography, and human disturbances affect the photo-capture rates. Photo capture rates of wild dog were highest (1.19 ± 0.20) followed by Asiatic black bear (0.39 ± 0.06) and tiger (0.34 ± 0.06) in DWLS. According to Selvan et al. 2013, the photographic encounter rate of the tiger was 2.7 ± 0.49 / 100 trap nights and for the Asiatic wild dog was 1.3 ± 0.54/ 100 traps night days in Pakke Tiger Reserve, Arunachal Pradesh. In Kalakadu-Mundanthurai Tiger Reserve (KMTR), Asiatic wild dog photographic encounter was 1.9 in 2006 and 0.6 in 2010 / 100 trap-nights (Ramesh et al. 2012).

For ungulate species, the photo-capture rates of barking deer were the highest followed by Mishmi takin, red goral, Himalayan serow, and wild boar. Generally, barking deer uses the nearby forest cover and riverside for occasional grazing on young, actively growing grass blades, bamboo seedlings, or bamboo shoot (Barrette 1977, Chapman et al. 1993), and drinking water. They have a small home range of around 0.28 km^2 (Chapman et al. 1993). In the case of wild pig, they inhabit the lowland temperate forest and nearby riverside for digging, feeding on new grasses, bamboo shoots, etc. Mostly, barking deer and wild pig signs are frequently encountered along the riverside and nearby forest areas. In contrast, Mishmi takin, Himalayan serow, and red goral encountered signs were very less due to the preference of different habitat types, as they prefer different elevation gradients, diverse forest types, hilly terrain, and mountain area. Different ungulates have different ecological characteristics, home range size, and habitat selectivity. The Mishmi takin is restricted to specific habitat by seasonal factors and seasonal altitudinal movements throughout its distribution range (Schaller 1985). During the summer, takins gather together and they migrate to the subalpine and alpine scrub zone (West 1926) to reach an open high elevated area for salt licks and foraging ground, whereas in winter they move down to mixed bamboo-rhododendron thickets at lower elevation due to less availability of food at higher altitude. During the altitudinal seasonal migration, direct observation was recorded in Angi pani valley as they prefer steep terrain, thicket vegetation, and mountain edge, and follow the traditional fixed-route along the river valley. In the case of Himalayan serow and red goral, they are sympatric species in their distribution range but their habitat preference is different. Himalayan serow prefers moist densely wooded gorges and adjoining grassy slope (Prater 1971, Mishra et al. 1994, Sathyakumar 1994) and red goral avoids forested vegetation types owing to the presence of extensive understory and absence of grass. However, goral chooses the forest cover along the cliffs to escape from predation (Mishra 1993, Mishra & Johnsingh 1996).

Maximum photo-captures were obtained in the slope classes of 0°-30° along the north and northwestern areas. Comparatively, other ungulates such as Mishmi takin, red goral, and Himalayan serow had less photo-capture rates due to fewer placements of camera traps in higher slope classes i.e. 30° to 86°. Fewer camera traps were deployed at a higher slope degree i.e. 30° to 86°, therefore certain ungulates were photo-captured less. Ungulates prefer dense forest, good ground cover for escaping and hiding from predators, grazing or browsing, and hiding their fawn. Photo capture rates of ungulates were more at north and northwestern aspect classes as the north-facing forests harbored more tree density, along with seedling and sapling densities, less radiation, and receive high precipitation whereas as south-facing forest harbored old mature trees with less density, more radiation and low precipitation (Maren et al. 2015). Interestingly, tiger, co-predators, and ungulates species signs and photo-captures have been found from all the surveyed valleys. However, during the replicate sampling, some mammalian carnivores and ungulate signs and photo captures were not found due to conducting surveys in a season different than the previous year.

The present assessment for establishing the ecological baselines for tiger, co-predators, and their prey species through indices of relative abundance, both camera traps and sign survey methods, is a first for DWLS situated in the Mishmi Hills range of the Indian part of the Eastern Himalayan Biodiversity hotspot. Field and analytical methods to enhance the robustness of the finding depends on financial and manpower resource availability. With limited resources, estimates through RAI can yield crucial information required for management, as demonstrated in this study. However, attempts can be made to enhance the robustness with statistical validation by using advanced methods like occupancy surveys, SECR, REM based population estimates, etc., that are resource-intensive. Long-term monitoring of migratory ungulates such as Mishmi takin, as well as movement patterns of the tiger must be carried out for better understanding and to develop corridors for sustaining the viable population of the species.



CHAPTER 4

FOOD HABITS AND PREDATION PATTERNS

4.1 Background

Diet preference of tiger and co-predators are determined using scat analysis since remains of prey species are very much evident in carnivore feces or scat (Reynolds & Aebischer 1991, Biswas & Sankar 2002, Sankar & Johnsingh 2002, Bagchi et al. 2003, Andheria et al. 2007). Scat analysis is a non-invasive tool that aids in examining the diet profile of carnivores and draws the outlines of the food habits (Johnsingh 1992, Mukherjee et al. 1994, Karanth & Sunquist 1995, Sankar & Johnsingh 2002, Selvan et al. 2013). Besides, determining the relative frequency of occurrence of prey remains in the carnivore food profile, this technique provides evidence on various species of prey consumed by tiger and co-predators. In the earlier food habit studies of carnivores, the methodology of scat analysis has been reviewed and applied (Reynolds & Aebischer 1991, Karanth & Sunquist 1995, Ramesh et al. 2010). Scats of targeted carnivores i.e. tiger and co-predators were collected from the study area from 2015 to 2017.

4.2 Methodology and analytical methods

4.2 (a) Scat processing and laboratory procedure

The collected scats were washed with water in a 1-millimeter sieve and oven-dried at 56°C for at least 24 hours (Jethva & Jhala 2004). The undigested prey remains such as hair, hooves, bone, quill, feathers, teeth, etc., which were used to determine the dietary profile and prey selection of target carnivores (Mukherjee et al. 1994). Minimum 20 hairs were selected randomly from each scat for preparation of slides and then examined for prey species identification under an electronic microscope. Micro-histological features like medullary pattern, length, width, color, thickness, texture, basal configuration, and cortex pigmentation was observed and compared with the reference slides available in the research laboratory of Wildlife Institute of India, Dehradun (Schaller 1967, Sunquist 1981, Johnsingh 1983, Karanth & Sunquist 1992, Mukherjee et al. 1994, Biswas & Sankar 2002, Sankar & Johnsingh 2002, Bagchi et al. 2003, Selvan et al. 2013).

4.2 (b) Biomass estimation

Different techniques were used for estimating the carnivore's diet profile; however, techniques are subjected to different biases (Nielsen et al. 2018). Most often, the carnivore's diets were quantified by undigested prey remains in scats. However, the relative frequencies of prey remain in scats do not represent their consumed biomass (Floyd et al. 1978), leading to a biased estimation of the predator's diet. The reason is due to the differential digestibility of small and large prey. When a carnivore consumes a small prey, the prey remains are more frequent in scats than in the case of consumption of large prey. Therefore, the relative frequencies of prey remain in scats overestimate small prey in a carnivore's diet (Mech 1970). The differential digestive ability of a predator for different sized prey can be used for accurate estimation of diet (Jethva & Jhala 2004). Biomass models can be used to convert the relative occurrence of prey remains in scats to actual biomass consumed (Jethva & Jhala 2004). The problems of computing biomass consumption from prey occurrences in carnivore scats took a new turn with Mech's hypothesis (1970). Estimating the relative contribution of prey biomass to the tiger and wild dog diet, the biomass model (Chakrabarti et al. 2016) and the correction factor (Ackerman et al. 1984) was used for tiger and wild dog (Floyd et al. 1978). Assuming that these carnivores have a diet similar to that of cougar (tiger and leopard), wolves (wild dog).

The regression equations for tiger and wild dog are given below:

$\mathbf{Y = 0.033 - 0.025exp^{-4.284X}}$ [(Chakrabarti et al. 2016); used for tigers]

$\mathbf{Y = 1.980 + 0.035X}$ [(Ackerman et al. 1984); used for tigers]

$\mathbf{Y = 0.035 + 0.020X}$ [(Floyd et al. 1978); used for wild dogs]

Where Y = weight of prey species consumed per field collectible scat and X = average weight of an individual of species.

4.2 (c) Estimation of prey selectivity

Prey selectivity by tiger and wild dogs was measured using Jacobs' selectivity index (Jacobs 1974). This index standardizes the relationship between the relative proportion that each species makes up in the carnivores diet *r* and prey relative abundance *p* (i.e., the proportion that each species makes up of the total abundance of all censused prey species at a site) concerning prey preferences of large predators (Hayward et al. 2006, 2011, 2012). The formula for Jacobs' index is:

$$D = \frac{(r_i - p_i)}{(r_i + p_i - 2r_i p_i)}$$

where r_i is the relative biomass proportion of prey species *i* in the carnivore scats and p_i is the proportion of biomass of the prey species *i* in the available prey community. The values range from +1 to -1, where +1 and -1 indicate maximum preference and maximum avoidance, respectively.

A Chi-square ratio test was used to evaluate prey selectivity between the observed biomass consumed and expected biomass available concerning prey species. Estimation of proportion of expected prey availability biomass from camera trap data as relative abundance index (number of individuals captured/100 trap days) can be considered independent captures at 0.5-hour duration (Carbon et al. 2002). Through this index, the available biomass was expressed by multiplying the individual body weights of prey species, i.e., 3/4 × mean adult female body mass of prey species was used to take account of calves and sub-adults eaten (Hayward & Kerley 2005).

4.2 (d) Estimation of niche breadth and dietary overlap

The frequency of occurrence (in percentage) and relative proportion of diet categories in the food profile of tiger and wild dogs were used to determine their niche breadths and dietary overlaps. The standardized Levins' index (B_{sta}) (Levins 1968, Colwell & Futuyama 1971) was used to calculate the trophic niche breadth of tiger and wild dogs. The Levins' index formula is:

$$B = \frac{1}{\sum_{i=1}^{n} p_i^2}$$

Where *n* is the number of food categories and *p* is the proportion of records in each food category (*i*) set at 100%.

The standardized Levins' index is calculated as:

$$\mathbf{B_{sta} = (B - 1) / (B_{max} - 1)}$$

Where *B* is the Levins' index (Levins 1968, Krebs 1989) and B_{max} is the total number of food categories recognized. The index values range from 0 to 1.

Pianka index (Pianka 1973) was used to determine the dietary overlap between sympatric carnivores. The values range from 0 (no overlap) to 1 (complete overlap).

$$Pianka\ Index = \frac{\sum pij \times pik}{\sqrt{(\sum i\ (pij)^2 \times \sum i(pik)^2)}}$$

Where pij = percentage of prey items "i" of predator "j" and pik = percentage of prey items "i" of predator "k".

4.3 Temporal activity patterns of carnivores and their prey

The temporal activity pattern of tiger, co-predators, and their prey species were calculated from the camera trap data. The activity time and date of each species were obtained from the camera trap photographs. Assuming that the numbers of photographs taken were related to the activity of carnivores (Kawanishi 2002). At a site, an independent record is regarded when the capture events of species are of a 0.5-hour duration (Bowkett et al. 2007). The independent time records of species for every 0.5-hours were taken into account every 24 hours and the mean activity period was determined using the program Oriana (Kovach 2011). The carnivore can be determined as nocturnal or diurnal based on the time-activity pattern.

Analytical method

To analyze the uniformity in the activity pattern of each carnivore, Rayleigh Test was applied. The differences within the activity pattern of tiger, wild dog, and their prey were also tested through Watson's U^2 Test (for single species and pairwise) in program Oriana 4.0 (Kovach 2011). Date and time information on the camera trap photographs was used to analyze assuming that the numbers of photographs taken were associated with the carnivore activity levels (Kawanishi 2002).

4.4 Results

4.4 (a) Prey species composition

A total of 222 scats were collected from the study area from 2015 to 2017. Among these, 47 scats were of tigers, 38 were of Asiatic wild dog, 54 were of meso or small-carnivores, 33 scats were unidentified and 50 scats had no undigested prey remains. Six prey species were identified in 47 tiger scats *viz.* Mishmi takin, serow, goral, wild pig, barking deer, and rodent. In the analyzed tiger scats, 82.98% (n=39) had single prey items and 17.02% (n=8) had two prey items of prey species composition. The wild dog had six prey items *viz*. Mishmi takin, serow, goral, barking deer, mithun, and rodent. In 38 scats of wild dog analyzed, 86.84% (n=33) of scats had single prey items, 10.53% (n=4) had two prey items and 2.63% (n=1) had multiple prey items. Other felids species had six prey items *viz*. Mishmi takin, serow, goral, wild pig, barking deer, and rodents spp. The analysis revealed that 87.27% (n=47) had a single prey item and 12.96% (n=7) had two prey items of prey species composition. However, collected meso or small carnivore scats were unable to be segregated properly due to the scat's conditions, as they were very old as well as deformed in structure. Therefore, the biomass model was not applied in the other felids' scats.

In the diet composition of tiger and wild dog, goral, serow, and Mishmi takin remains had the highest frequency of occurrence (%) and biomass contribution (Tables 4.1, 4.2, 4.3 & 4.4). According to the biomass model (Chakrabarti et al. 2016), goral contributed highest in terms of both frequency of occurrence (46.81%) and relative proportion (37.74%) of the tiger diet (Fig 4.1 & 4.4). In contrast, the correction factor equation (Ackerman et al. 1984), frequency of occurrence was highest for goral (46.81%) followed by serow (24.47%) and takin (19.15%) but in the relative proportion of tiger diet, Mishmi takin (44.87%) was highest, followed by goral (25.82%) and serow (23.09%) (Fig 4.2 & 4.5).

For wild dog, according to Floyd et al. 1978 equation, rodent spp. (46.97%) had the highest frequency of occurrence in the diet composition followed by serow (24.54%), goral (19.26%), and mithun (5.28%) whereas in the relative proportion of the diet, mithun (40.66%) was highest followed by serow (35.47%), Mishmi takin (13.13%) and goral (8.79%) (Fig 4.3 & 4.6).

Table 4.1: The percentage of prey species occurrence in tiger and wild dog scats

Mammalian Species	Tiger		Wild dog	
	Frequency (F)	**Frequency (%)**	**Frequency (F)**	**Frequency (%)**
Mishmi Takin	9	19.15	1	2.64
Serow	11.5	24.47	9.3	24.54
Goral	22	46.81	7.3	19.26
Wild pig	2.5	5.32	0	-
Barking deer	1.5	3.19	0.5	1.32
Mithun	0	0	2	5.28
Rodent spp.	0.5	1.06	17.8	46.97

Table 4.2: Biomass model of prey species composition in tiger, relative biomass proportion of diet and production of scats in each prey species

Mammalian Species	Average prey mass (kg) (X)	Biomass consumed per scat (Y)	Frequency Occurrence (FO)	Biomass consumed (kg)	Relative biomass proportion of the diet
Mishmi Takin	290	4.95	9	44.54	24.54
Serow	83	4.60	11.5	52.90	29.14
Goral	25	3.11	22	**68.50**	37.74
Wild pig	58.33	4.24	2.5	10.60	5.84
Barking deer	21.33	2.91	1.5	4.37	2.41
Mithun	450	4.95	0	0.00	0.00
Rodent spp.	0.05	1.21	0.5	0.60	0.33

Table 4.3: Correction factor of prey species composition in tiger, relative biomass proportion of diet and production of scats in each prey species

Mammalian Species	Average prey mass (kg) (X)	Biomass consumed per scat (Y)	Frequency Occurrence (FO)	Biomass consumed (kg)	Relative biomass proportion of the diet
Mishmi Takin	290	12.13	9	**109.17**	44.87
Serow	83	4.89	11.5	56.18	23.09
Goral	25	2.86	22	62.81	25.82
Wild pig	58.33	4.02	2.5	10.05	4.13
Barking deer	21.33	2.73	1.5	4.09	1.68
Mithun	450	17.73	0	0.00	0.00
Rodent spp.	0.05	1.98	0.5	0.99	0.41

Table 4.4: Regression equation of prey species composition in wild dog, relative biomass proportion of diet and production of scats in each prey species

Mammalian Species	Average prey mass (kg) (X)	Biomass consumed per scat (Y)	Frequency Occurrence (FO)	Biomass consumed (kg)	Relative biomass proportion of the diet
Mishmi Takin	290	5.84	1	5.84	13.13
Serow	83	1.70	9.3	**15.76**	35.47
Goral	25	0.54	7.3	3.91	8.79
Wild pig	58.33	1.20	0	0.00	0.00
Barking deer	21.33	0.46	0.5	0.23	0.52
Mithun	450	9.04	2	**18.07**	40.66
Rodent spp.	0.05	0.04	17.8	0.64	1.44

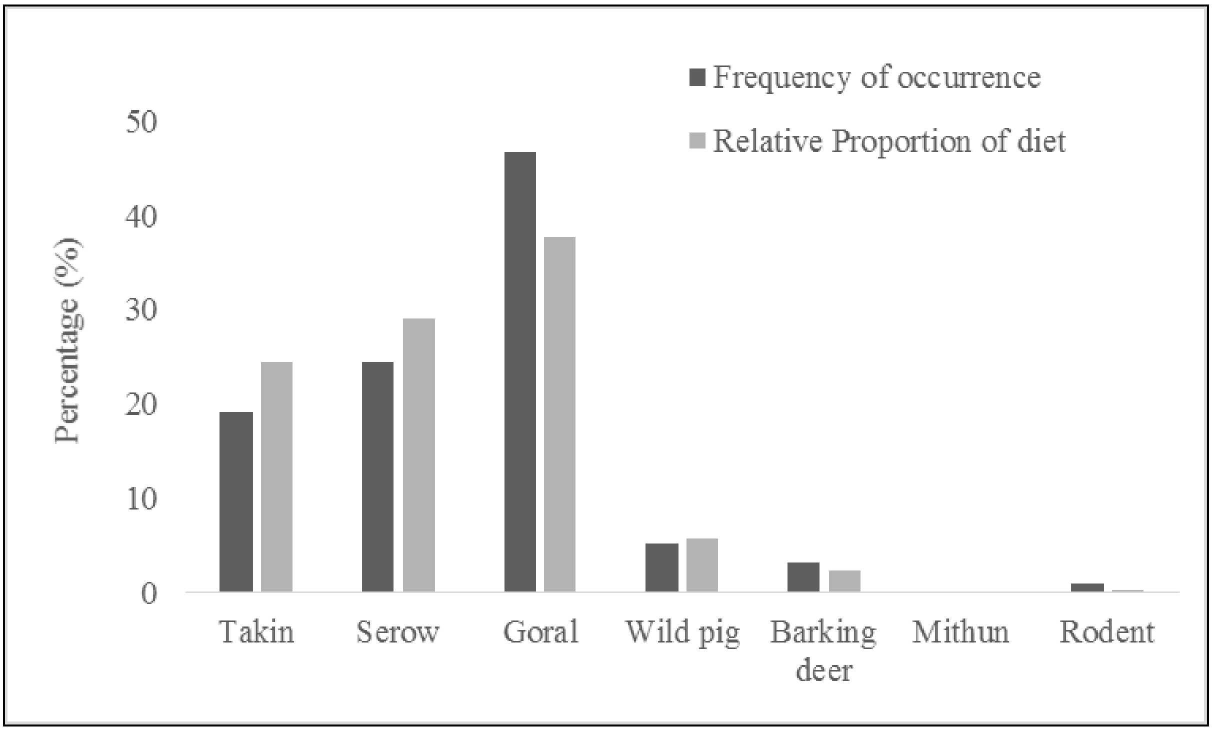


Figure 4.1: Comparison of frequency of occurrence for prey species and prey relative proportion of diet through Biomass model for tigers' diet

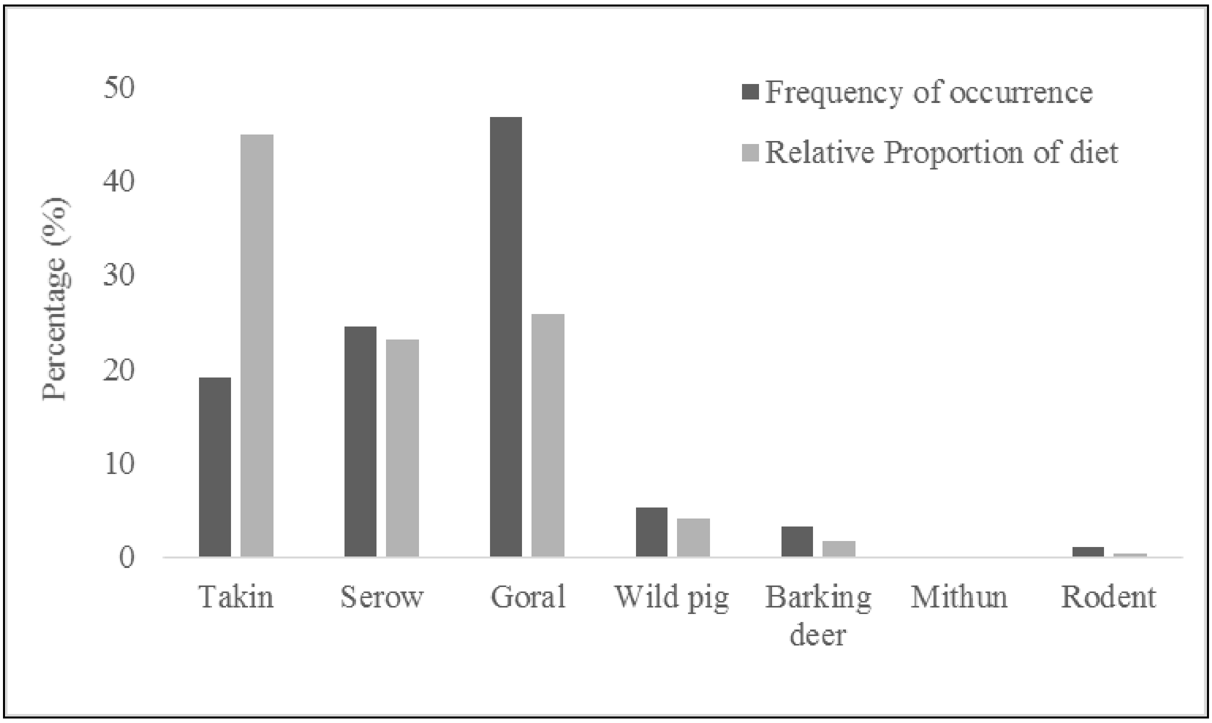


Figure 4.2: Comparison of frequency of occurrence of prey species and prey relative proportion of diet through correction factors model for tigers' diet

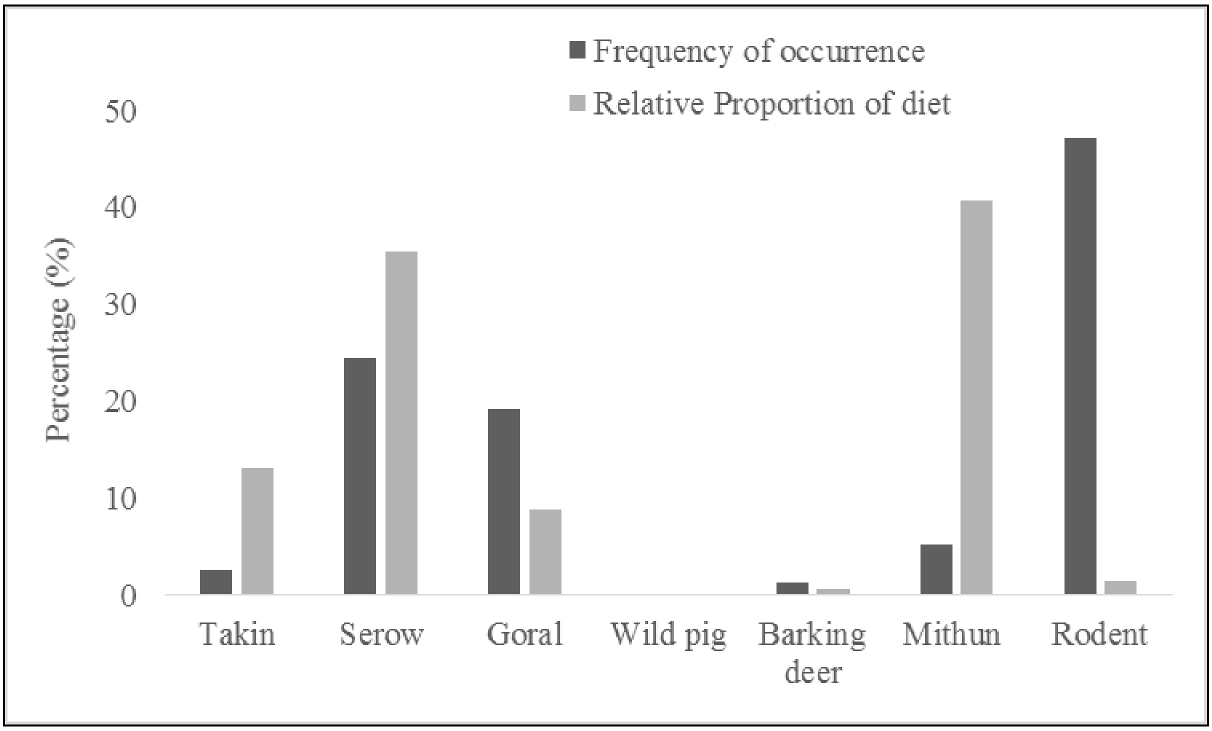


Figure 4.3: Comparison of frequency of occurrence of prey species and prey relative proportion of diet through correction factor model for wild dogs' diet

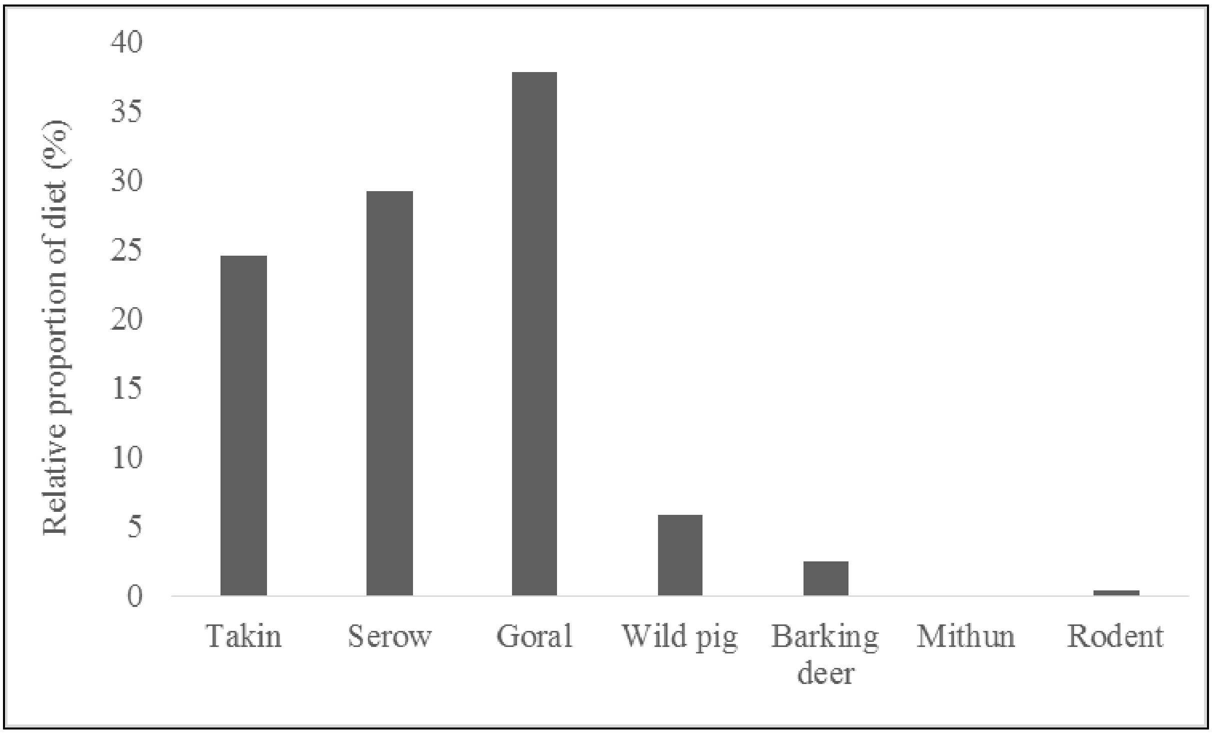


Figure 4.4: Biomass model (Chakrabarti et al. 2016) showing the relative proportion of diet (%) of tiger

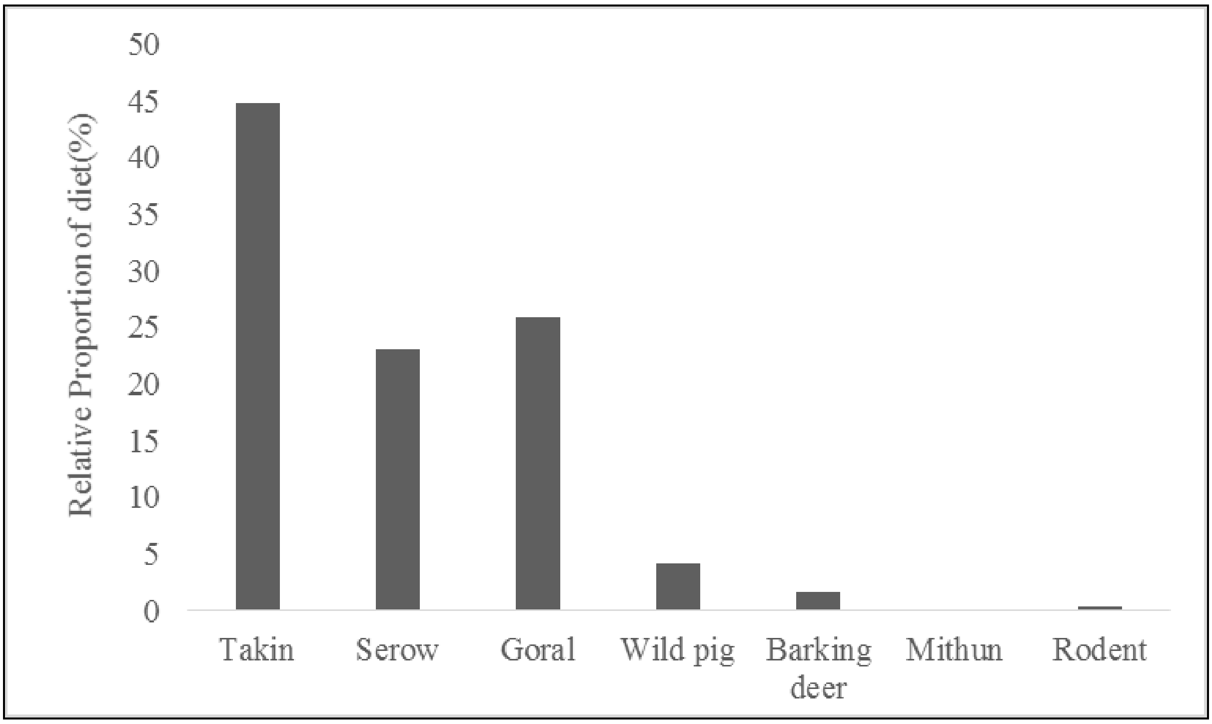


Figure 4.5: The correction factor (Ackerman et al. 1984) showing the relative proportion of diet (%) of tiger

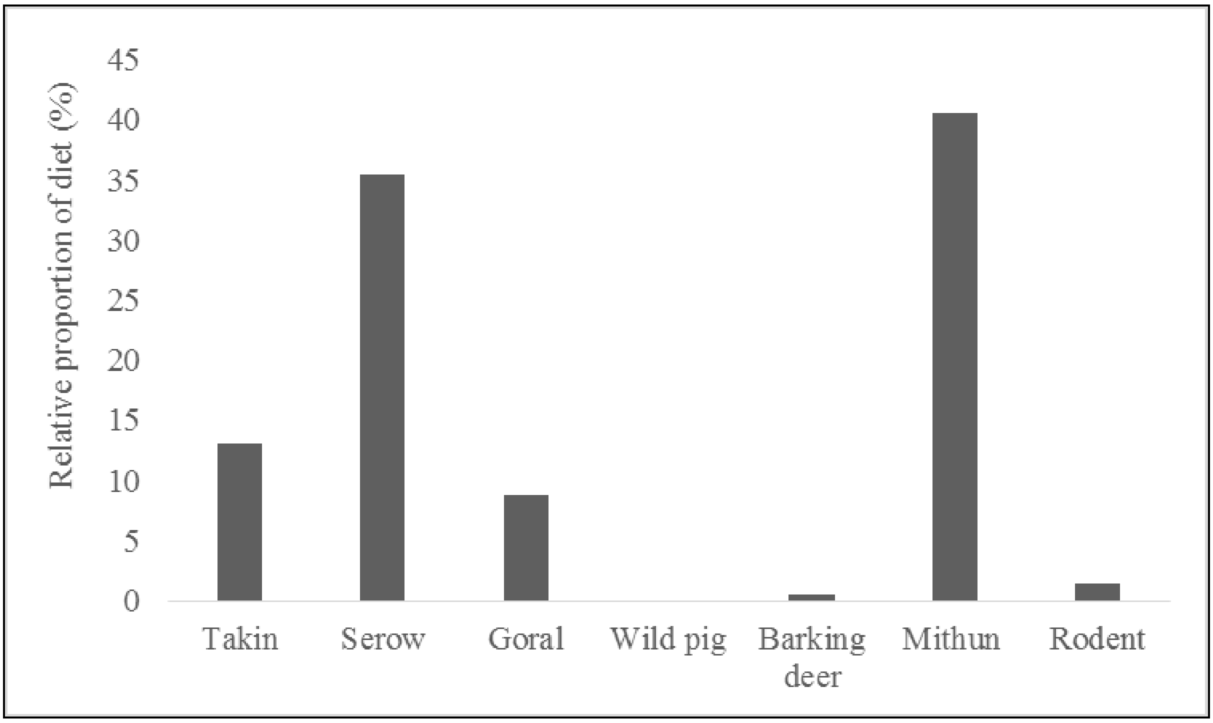


Figure 4.6: The Regression equation showing the relative proportion of diet (%) of Wild dog

4.4 (b) Prey selectivity

Prey selectivity by tiger and wild dogs was assessed through Jacob's index. Serow and gorals were utilized more than their availability while barking deer, Mishmi takin, and wild pig was utilized less than its availability, according to the biomass model. Ackerman model predicted that barking deer, wild pig, and Mishmi takin were utilized less than its availability. Wild dog preferred goral and serow more than their availability in the area while wild pig, barking deer, and Mishmi takin were utilized less than their availability (Table 4.5).

Table 4.5: Prey selection by the tiger and wild dog based on available and consumed biomass

Prey species	**Tiger (Biomass model)**	***P***	**Wild dog**	***p***
Mishmi Takin	-0.5752	0.25	-0.7773	0.99
Serow	0.4803	0.99	0.5839	0.99
Goral	0.8515	0.001	0.3292	0.18
Wild boar	-0.2107	0.99	-1.0000	0.99
Barking deer	-0.8141	0.99	-0.9575	1.00

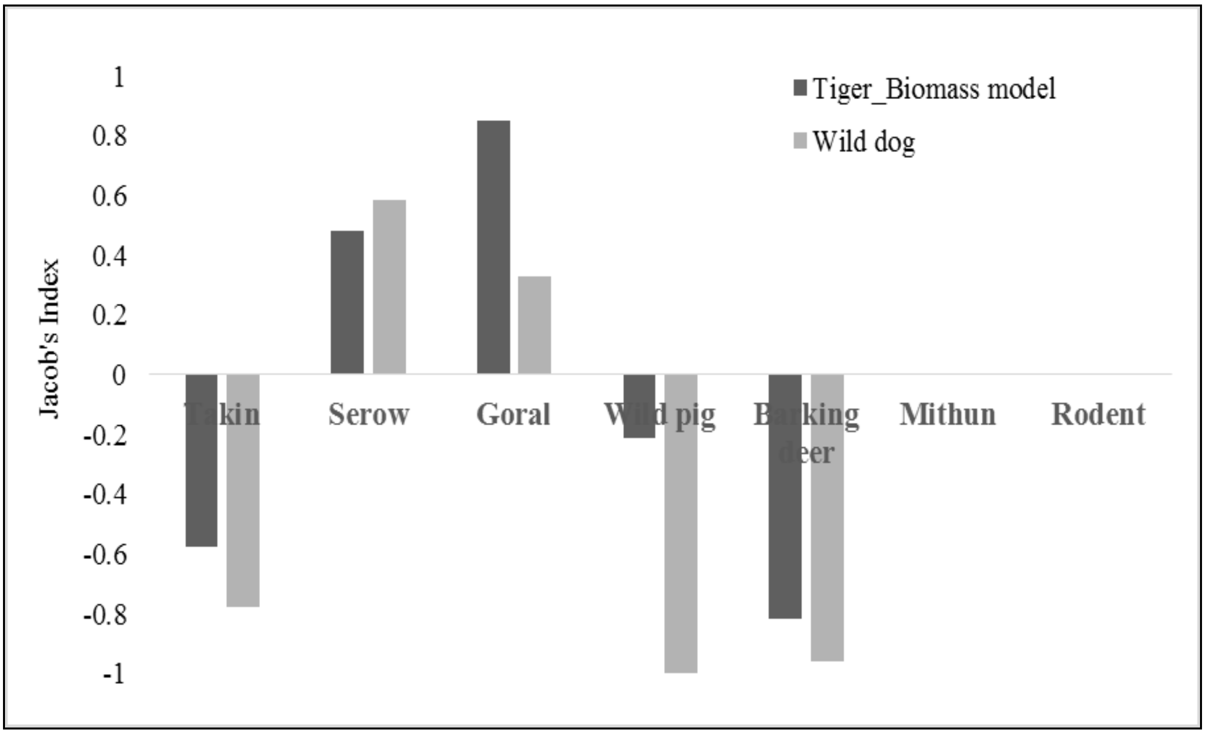


Figure 4.7: Jacob's index for prey selection tiger and wild dog based on the biomass and Floyd models respectively

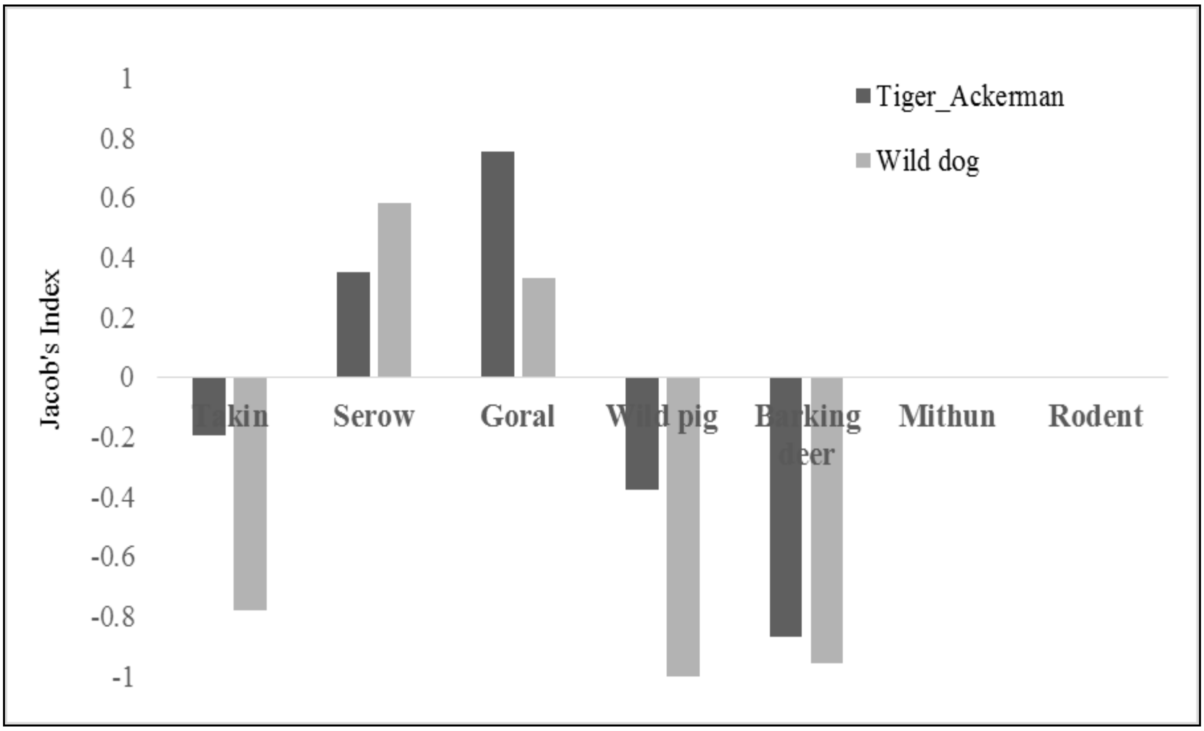


Figure 4.8: Jacob's index for prey selection by the tiger and wild dog based on the Ackerman model and Floyd models respectively

4.4 (c) Niche breadth and dietary overlap of tiger and wild dogs

Levin's standardized index measures the dietary niche breadth of tiger and wild dog. The standardized Levins' index (B_{sta}) of tiger and wild dog were 0.4258 and 0.4205, respectively

(Table 4.6). Both tiger and wild dog had medium diverse dietary niche breadth i.e. neither generalist nor specialist. Pianka niche overlap index shows 50% dietary overlaps among the diets of tiger and wild dog based on the relative occurrence of prey items. However, no significant overlaps were observed in prey items of tiger and wild dog in the scats (Table 4.7).

Table 4.6: Niche Breadth Index of tiger and wild dog based on relative frequencies of occurrence (RO) and relative proportion of biomass (RB) of prey species

Carnivore Species	**Bsta** (RO)	**Bsta (RB)** (Biomass model)	**Bsta (RB)** (Ackerman equation for tiger & Floyd for wild dog)
Tiger	0.4258	0.4859	0.4186
Wild dog	0.4205	-	0.4324

Table 4.7: Dietary overlap between the tiger and wild dog based on relative occurrence (RO) and relative biomass (RB) of prey species

Carnivore Species	**Relative Occurrence** (RO)		**Relative Biomass (RB)** (Biomass model)		**Relative Biomass (RB)** (Ackerman equation)	
	Pianka index	***P***	**Pianka index**	***P***	**Pianka index**	***P***
Tiger-Wild dog	0.4993	0.18	0.5563	0.29	0.5117	0.19

4.4 (d) Temporal activity profile of mammalian carnivores and its prey species

The temporal activity profile of mammalian carnivores *viz.* tiger, wild dog, Asiatic black bear, Asiatic golden cat, leopard cat, and yellow-throated marten, and its prey species such as barking deer, red goral, Himalayan serow, Mishmi takin, wild pig, and kalij pheasant were documented. The remaining mammalian species were less photo-captured and, hence, they were excluded from the activity pattern analysis.

The temporal activity profile of the tiger, wild dog, and Asiatic black bear was nocturnal, diurnal, and arrhythmic, respectively (Fig 4.9). The mean activity time of the tiger was at 23:29 ± 01:34 hrs with a 95% confidence interval (CI) of 20:25-02:34 hrs (Table 4.8). Its activity was not uniformly distributed (Rayleigh Z = 2.91, p = 0.054) having a significant difference in the intensity of activity during different times of the day (Watson's U^2 = 0.191, p <0.05) (Table 4.9). On the contrary, wild dog mean activity time was at 10:52 ± 00:26 hrs with a 95% confidence interval (CI) of 10:00-11:43 hrs (Table 4.8). Wild dog activity was not uniformly distributed (Rayleigh Z = 33.208, p <1E-12) with a significant difference in the intensity of activity during different times of the day (Watson's U^2 = 1.807, p <0.005) (Table 4.9). However, the mean activity time of the Himalayan black bear was at 16:32 ± 01:12 hrs with a 95 % confidence interval (CI) of 14:09-18:54 (Table 4.8). The activity pattern of the Himalayan black bear was not uniformly distributed (Rayleigh Z = 4.77, p = 0.01) with a significant difference in the intensity of activity during a different time of the day (Watson's U^2 = 0.02, *p* <0.01) (Table 4.9**)**.

For the meso carnivores, the activity pattern of the golden cat was arrhythmic and was most active during nighttime. The activity profile was not uniformly distributed throughout the day (Z = 4.35, p = 0.01), there was a significant difference in the intensity of activity patterns (Table 6.9) with its mean activity time at 23:07 ± 01:17. In contrast, the leopard cat showed a typical nocturnal activity pattern (Fig 10.9), with mean activity time at 23:27 ± 00:13 hrs. Its activity profile was not uniformly distributed throughout the day and a significant difference in the activity profile at different times of the day (U^2 = 6.315, p < 0.005). Yellow-throated marten showed a diurnal activity pattern (Fig 10.9), with a mean activity time at 10:47 ± 00:13. The activity profile of yellow-throated marten was not uniformly distributed with significant differences in the activities at different times of the day.

Table 4.8: Circular statistic of temporal activity patterns of tiger, wild dog, and ungulate species

Species	N	Mean vector (μ)	S.E.	95% CI	Circular variance
Tiger	83	23:29	01:34	20:25-02:34	0.813
Wild dog	140	10:52	00:26	10:00-11:43	0.497
Black bear	60	16:32	01:12	14:09-18:54	0.718
Golden cat	182	23:07	01:17	20:35-01:38	0.845
Leopard cat	364	23:27	00:13	23:01-23:53	0.422
Yellow t. Marten	349	10:47	00:13	10:21-11:14	0.429
Barking deer	349	17:58	00:16	17:26-18:31	0.526
Red Goral	67	06:38	02:42	01:20-11:56	0.891
Serow	55	22:22	00:58	20:28-00:16	0.666
Mishmi takin	82	09:24	00:40	08:05-10:43	0.601
Wild pig	58	07:05	00:28	06:09-08:01	0.382

In the case of ungulates temporal activity profile, barking deer and goral were crepuscular in their activity (Fig 4.10). The mean activity time of barking deer and goral range from 17:58 ± 00:16 hrs to 06:38 ± 02:42 with 95 % confidence interval (CI) of 17:26-18:31 hrs and 01:20-11:56 hrs respectively (Table 4.8). Also, the activity pattern of barking deer was not uniformly distributed throughout the day (Z= 82.84, *p* <1E-12) but goral was almost uniformly distributed throughout the day (Z= 0.993, *p* = 0.37) (Table 4.9). Their activities were significantly different across different times of the day. Both the species of the Bovidae family showed the opposite temporal activity pattern. Serow and Mishmi takin were both nocturnal and diurnal with mean activity times at 22:22 ± 00:58 hrs and 09:24 ± 00:40 with 95 % confidence interval (CI) of 20:28-00:16 hrs and 08:05-10:43 hrs, respectively (Table 4.8). The distribution patterns of both species were not uniformly distributed throughout the day and were significantly different across different times of the day (Table 4.9). Wild pig showed a typical diurnal activity pattern (Fig 10), with mean activity time at 07:05 ± 00:28 hrs with a 95 % confidence interval (CI) of 06:09-08:01 hrs. The wild pig was not uniformly distributed with a significant difference across different times of the day.

Table 4. 9: The activity pattern of tigers, wild dogs, and their prey, p is the probability of significance

Species	Rayleigh test (Z)	*P*	Watson's test (U^2)	*P*
Tiger	2.91	0.054	0.191	<0.05
Wild dog	33.208	<1E-12	1.807	<0.005
Black bear	4.77	0.01	0.27	<0.01
Golden cat	4.35	0.01	0.27	<0.03
Leopard cat	121.48	<1E-12	6.314	<0.005
Yellow t. Marten	113.678	<1E-12	5.878	<0.005
Barking deer	82.84	<1E-12	5.294	<0.005
Red Goral	0.993	0.37	0.079	>0.25
Serow	7.346	0.000645	0.417	<0.005
Mishmi takin	14.937	0.000000326	0.908	<0.005
Wild pig	25.208	1.13E-11	1.345	<0.005

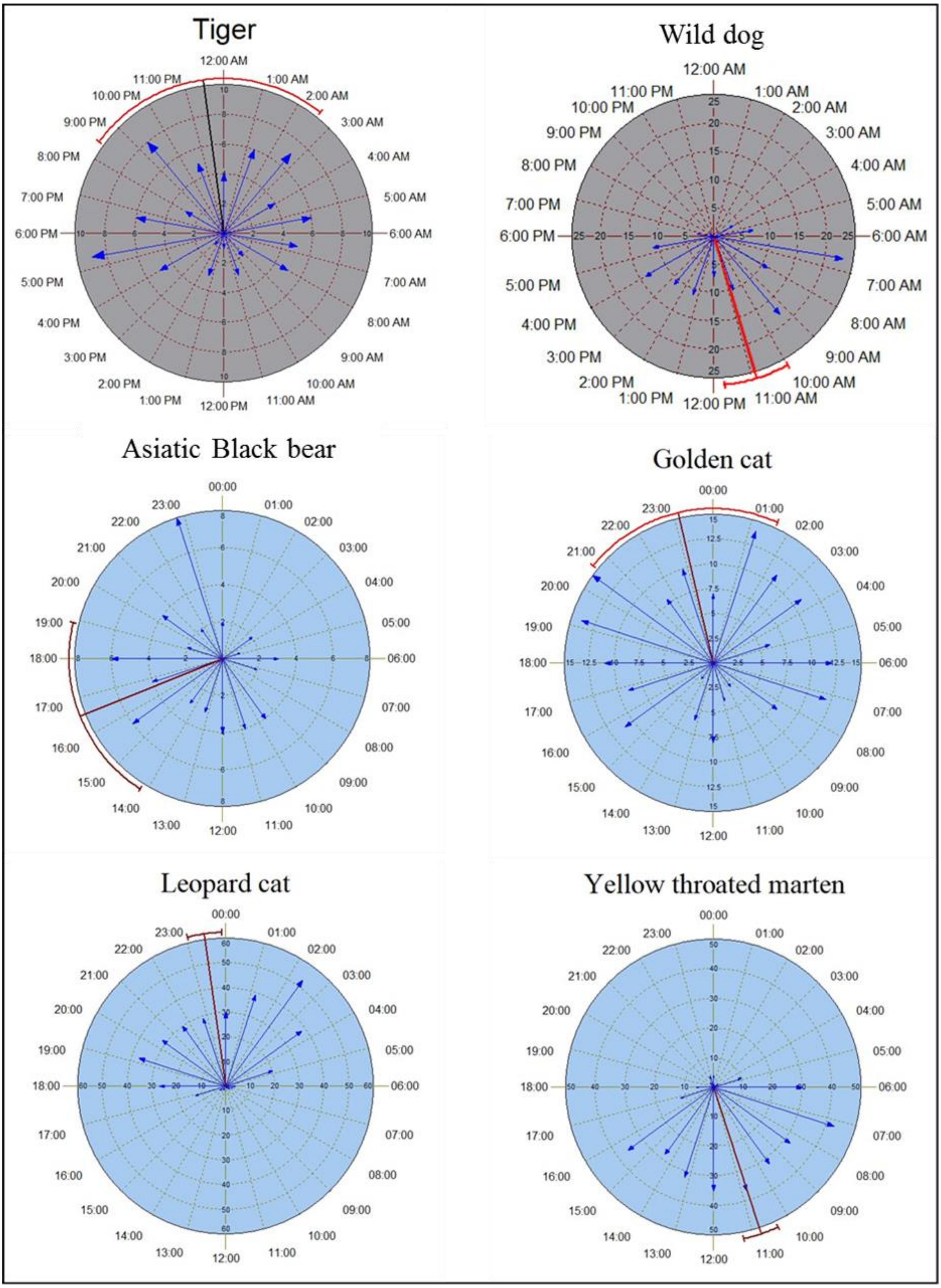


Figure 4.9: Diel activity patterns of mammalian carnivores in Dibang Wildlife Sanctuary during 2015-2017.

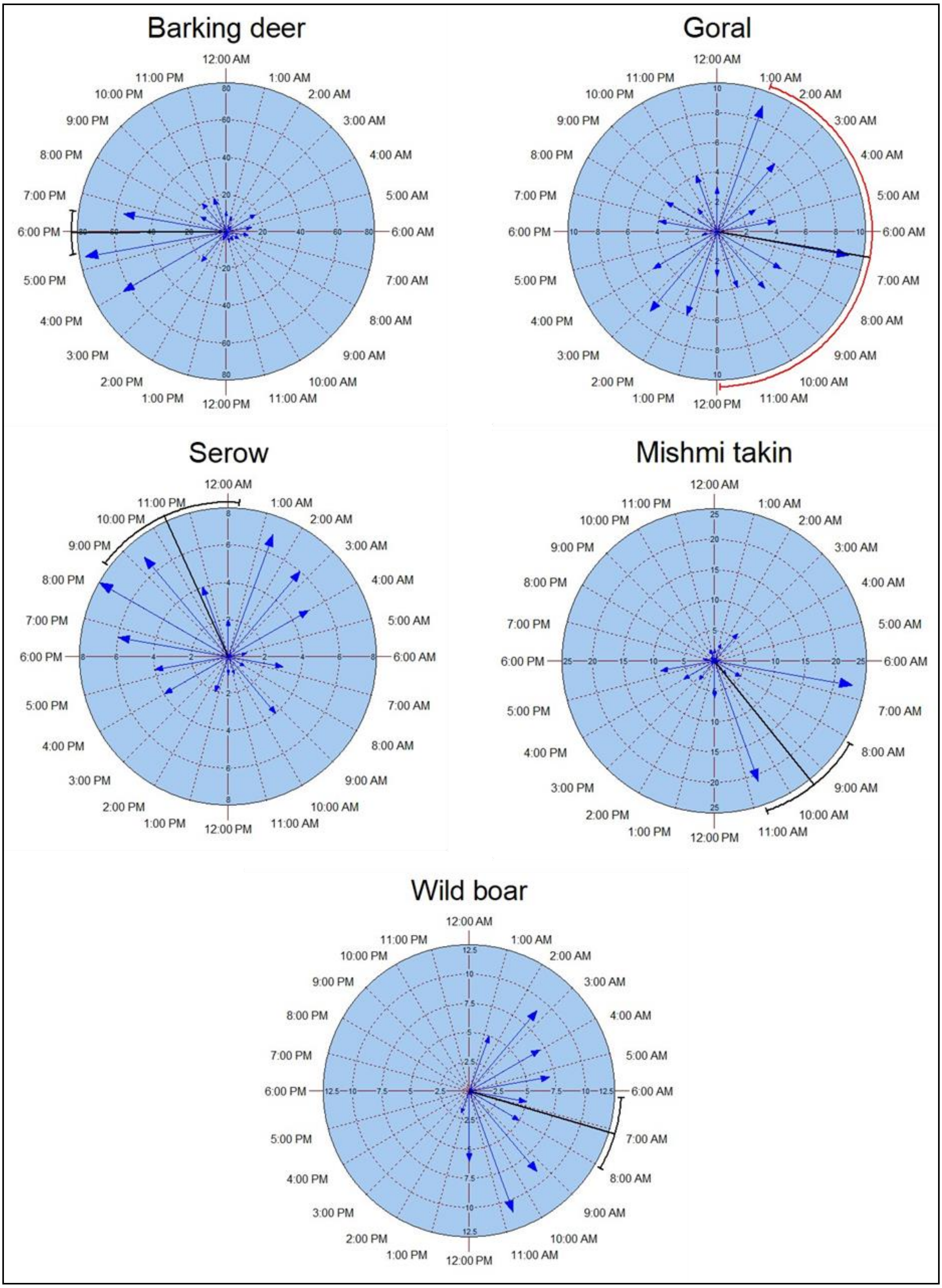


Figure 4.10: Diel activity patterns of forest-dwelling ungulates in Dibang Wildlife Sanctuary

4.4 (e) Temporal overlap of tiger and wild dogs and its prey species

The activity profiles of tiger, wild dog, and prey species were different from each other in most of the cases as exhibited by Watson's U^2 test (Table 4.10). The activity pattern of tiger and wild dogs was significantly different as revealed by Watson's U^2 test ($U^2 = 1.471$, $p < 0.001$). In carnivores and ungulates activity pattern, the most significant differences were observed between tiger and wild boar ($U^2 = 0.854$, $p < 0.001$), and tiger and Mishmi takin ($U^2 = 0.812$, $p < 0.001$). Whereas in wild dog, the most significant differences were observed with serow ($U^2 = 1.782$, $p < 0.001$) and barking deer ($U^2 = 3.071$, $p < 0.001$).

On the other hand, the activity profiles between the ungulates were tested by Watson's U^2 test (Table 4.11). The most significant differences in the ungulate's activity pattern were observed between serow and Mishmi takin ($U^2 = 1.025$, $p < 0.001$), and serow and wild boar ($U^2 = 0.096$, $p < 0.001$). Additionally, significant differences were observed in between barking deer and goral ($U^2 = 1.406$, $p < 0.001$).

Table 4.10: The activity patterns between the carnivore and ungulates species

Species	Watson's test (U^2)	*p*
Tiger-Wild dog	1.471	< 0.001
Tiger-Barking deer	0.69	< 0.001
Tiger-Goral	0.166	0.1 > p > 0.05
Tiger-Serow	0.091	0.5 > p > 0.2
Tiger-Mishmi takin	0.812	< 0.001
Tiger-Wild pig	0.854	< 0.001
Wild dog-Barking deer	3.071	< 0.001
Wild dog-Goral	0.591	< 0.001
Wild dog-Serow	1.782	< 0.001
Wild dog-Mishmi takin	0.176	0.1 > p > 0.05
Wild dog-Wild pig	0.327	< 0.005

Table 4.11: The activity patterns among the forest-dwelling ungulates species

Species	Watson's test (U^2)	*p*
Barking deer-Goral	1.406	< 0.001
Barking deer-Serow	0.745	< 0.001
Barking deer-Mishmi takin	2.051	< 0.001
Barking deer-Wild pig	2.69	< 0.001
Goral-Serow	0.359	< 0.002
Goral-Mishmi takin	0.344	< 0.005
Goral-Wild pig	0.575	< 0.001
Serow-Mishmi takin	1.025	< 0.001
Serow-Wild pig	1.096	< 0.001
Mishmi takin-Wild pig	0.234	< 0.02

4.5 Discussion

4.5 (a) Diet profile of tiger and wild dogs:

Tiger and wild dogs mainly depend on large to small-sized ungulates such as Mishmi takin (*Budorcas taxicolor taxicolor*), Himalayan serow (*Capricornis sumatraensis thar*), red goral (*Naemrhedus bailey*), wild pig (*Sus scrofa*) and barking deer (*Muntiacus muntjac*), and livestock i.e. Mithun (*Bos frontalis*). Even the presence of rodents was found in tiger and wild dog diet composition, which may be due to low prey densities or some other factors in the study area (Selvan et al. 2013, Johnsingh & Manjrekar 2013). Among sympatric carnivores', supplementary prey such as livestock, act as a buffer and potentially enhance coexistence (Kok & Nel 2004, Wang & Macdonald 2006). Based on the biomass model, the relative proportion of the tiger diet has 97.26 % of prey remains of goral, serow, Mishmi takin, and wild pig, and 2.74 % of barking deer and rodent (Chakrabarti et al. 2016).

Also, as per the correction factors model by Ackerman et al. 1984, 97.91 % of prey remains are Mishmi takin, goral, serow, and wild pig, and 2.08% are barking deer and rodent, in the relative proportion of the diet.

Both the biomass estimation models reveal that tigers have specifically selected more of Mishmi takin, serow, goral but less towards the wild pig, barking deer, small prey, and livestock i.e. Mithun. The resident tigers of the Indian subcontinent *(P. t. tigris*) are specifically selective of large prey to medium size prey as revealed from the study of diet composition throughout India. The main prey items are sambar, gaur, wild pig (Sunquist 1981, Karanth & Sunsquit 1995, Stoen & Wegg 1996, Bagchi et al. 2003, Reddy et al. 2004, Andheria et al. 2007, Ramesh 2011), and small to very smaller prey such as mouse deer, porcupine, hare, rodent (Reddy et al. 2004, Ramesh 2011, Selvan 2014). However, along the high-elevated Mishmi Hills range, there is no report of the presence of sambar, particularly in the Dibang Valley district. Hence, Mishmi takin is the only selective large prey for tigers in the study area. Apart from this large size prey base to medium size one, remains of barking deer and rodents in the tiger's diet show preference for a wide range of small to very smaller prey.

In the wild dog diet profile, 57.38 % of the relative proportion of diet is contributed by medium to large prey sizes such as serow, goral, and Mishmi takin, and 1.96 % by small and very small prey such as barking deer and rodents.

Rodent remains have the highest frequency of occurrence in the wild dog scats due to their ability to flush out and hunt the smaller and cryptic prey species in the bushes (Venkataraman 1995, Kumaraguru et al. 2011). Additionally, the presence of a high occurrence of rodents is supported by the studies from Kanchendzonga Biosphere Reserve (Bashir 2015) and Pakke Tiger Reserve (Selvan 2014). As mithun is easily accessible in a large number from the adjacent villages in the study area, they are preyed upon by wild dog and contributed in the highest relative proportion (40.68%) in their diet. Generally, the probability of livestock depredation is minimal when wild ungulate prey populations are found in abundance (Biswas & Sankar 2002, Reddy et al. 2004).

In the diet composition, 55.63% of diet overlap exists between the tiger and wild dog with almost similar dietary niche breadth contrasting in Pakke Tiger Reserve (Selvan 2014) where a high overlap between wild dog and tiger (77.5%) was found. Many studies have shown that tiger specialized on large-sized prey *viz.* gaur and adult sambar (Selvan et al. 2013, Johnsingh & Manjrekar 2013) while wild dog preferred medium-sized prey (Karanth & Sunsquit 1995).

Mishmi takin, goral, and serow were found to be the preferred prey for tiger and wild dog whereas Mithun, which is semi-domesticated livestock in the study area, was also found to be subjected to predation by wild dog. The present study found tiger and wild dogs prefer large to medium prey size, and the reason might be due to low prey base availability inside the protected area of Dibang valley. However, both tiger and wild dogs are sympatric in the study area due to differential prey selection, hunting habits, and their temporal activity patterns (Husseman et al. 2003, Scognamillo et al. 2003). Tiger is large predators, solitary hunters, and select large prey (Karanth & Sunquist 1995) whereas small body size predators such as wild dog largely dependent on the pack size to hunt the large prey base (Hayward et al. 2006). Low prey base creates high feeding competitions that turn into supplementary predations near the protected area. Carnivores preferred prey with different age and size classes, and which are ample in the habitat (Bekoff 1984). Large predators *viz.* lion, spotted hyena and African wild dogs compete for food (Breuer 2005). Wild dogs are social and pack hunters; therefore, they can easily hunt large ungulates like Mishmi takin. However, in the diet composition of tiger and wild dogs, there is the presence of small prey. This is possible only if the availability of appropriate size classes of prey is not a limiting resource (Karanth & Sunquist, 1995).

Prey selection influences the coexistence of tiger and Asiatic wild dog, which is a behavioral mechanism (Seidensticker 1976, Johnsingh 1983, 1992). The sympatric association of large carnivores is affected by prey selection, availability of appropriate prey size classes not being a limiting factor (Karanth & Sunquist 1995). The findings of our study inferred that the coexistence of tiger and Asiatic wild dog in Dibang Wildlife Sanctuary is due to the availability of different prey size classes *viz.* large-sized prey (Mishmi takin), medium-sized (Serow), and small (Goral and Barking deer).

In Arunachal Pradesh, hunting, particularly the traditional hunting practices by the indigenous communities, is one of the major threats to the wildlife population (Aiyadurai, 2007). The presence of smaller prey and livestock such as rodents and Mithun in wild dog diet is indicative of the low densities of wild ungulate population in the study area and makes it evident that wild dog has tried to sustain on smaller prey species and livestock i.e., Mithun (Biswas & Sankar 2002, Reddy et al. 2004). The hunting issue needs to be addressed by engaging with local people; else, the fate of large carnivores will be bleak. Consequently, a time will arise where there will be negative human-wildlife interaction in the region due to lack of wild prey for the carnivores leading to increased attacks on domesticated animals.

CHAPTER 5
SOCIO-ECONOMIC ASSESSMENT

5.1 Background

Human and wildlife are integral components of forest ecosystems, which share the same resources in diverse magnitudes for their survival (Philip J. Nyhus 2016). Consequently, they interact with each other due to their existence in the same habitat and use of the same natural resources. These interactions can be in the continuum from positive to negative, in intensity from minor to severe, and in frequency from rare to common (Soulsbury and White 2015). When the interaction impacts negatively on either humans or wildlife, it results in conflict (Rodgers 1989; Treves & Karanth 2003, Madden 2004). These conflicts may be any action by humans or wildlife that have an adverse effect on the other, such as threats posed by wildlife to human life, economic security, or recreation and retaliation by humans (Conover 2002, Treves & Karanth 2003). Human-wildlife conflict may thus be defined as "any interaction between humans and wildlife that results in negative impacts on human social, economic or cultural life, on the conservation of wildlife populations, or the environment". Globally, human-wildlife conflict is a significant and conservation problem (Sarpo 2005).

The Northeastern states of India are arguably amongst the richest regions of the country in terms of its terrestrial biodiversity. However, the hunting practices are more frequent as compared to the rest of the country. As people living in remote areas are economically backward as compared to mainland areas, they depend on hunting for wild meat and gathering of other forest resources for their sustenance (Hart 1978, Payne 1992, Lahm 1993, Noss 1995).

To get a better understanding of the human-wildlife interactions, and the dimensions of negative and positive interfaces between the Idu Mishmi community and wild animals in and around DWLS, a questionnaire survey was conducted. The main objectives of the survey were (i) to quantify the extent of human-wildlife interaction, (ii) to determine the livestock depredation instances by wild carnivores and reason, (iii) to quantify the attitude of the local people towards the wild animals in and around the protected area, and (iv) to study the social norms and taboos about wildlife.

5.2 Methodology

5.2 (a) Questionnaire survey

Before carrying out the survey, the respondents were briefed in detail about the research work, and the field assistant usually introduced us to the household head, they also acted as a bridge for overcoming the language barrier. We followed the protocols of wildlife research ethics and verbal consent was sought before continuing with the survey. A semi-structured questionnaire was used to collect data about human-carnivore interaction and the dependency of local communities on forest resources. The surveys were conducted of randomly selected households from each village and maximum, accessible households were targeted, and designed to collect information on the socio-economic conditions, dependency on forest produce, crop-raiding, Mithun predation, human casualties if any, etc. (Karanth 2007). Information on socio-economic variables like primary occupation, livestock holding (especially Mithun), level of income, land ownership, quality and quantity of forest products, and non-timber forest product collection for each household sampled (Karanth 2007) was collected. Information on religious profile, social norms, and taboos about the wildlife from the village headman, local naturalists, elderly persons, Igus (shaman), women, and local hunters were also collected (Karanth & Nichols 2002).

Both closed and open-ended questionnaire surveys were conducted, to get an overview of the local people's attitudes, their interaction with wild animals, and their views on wildlife protection and conservation in DWLS and its adjoining landscapes. The villages were categorized based on the distance from the protected area (Fig 5.1).

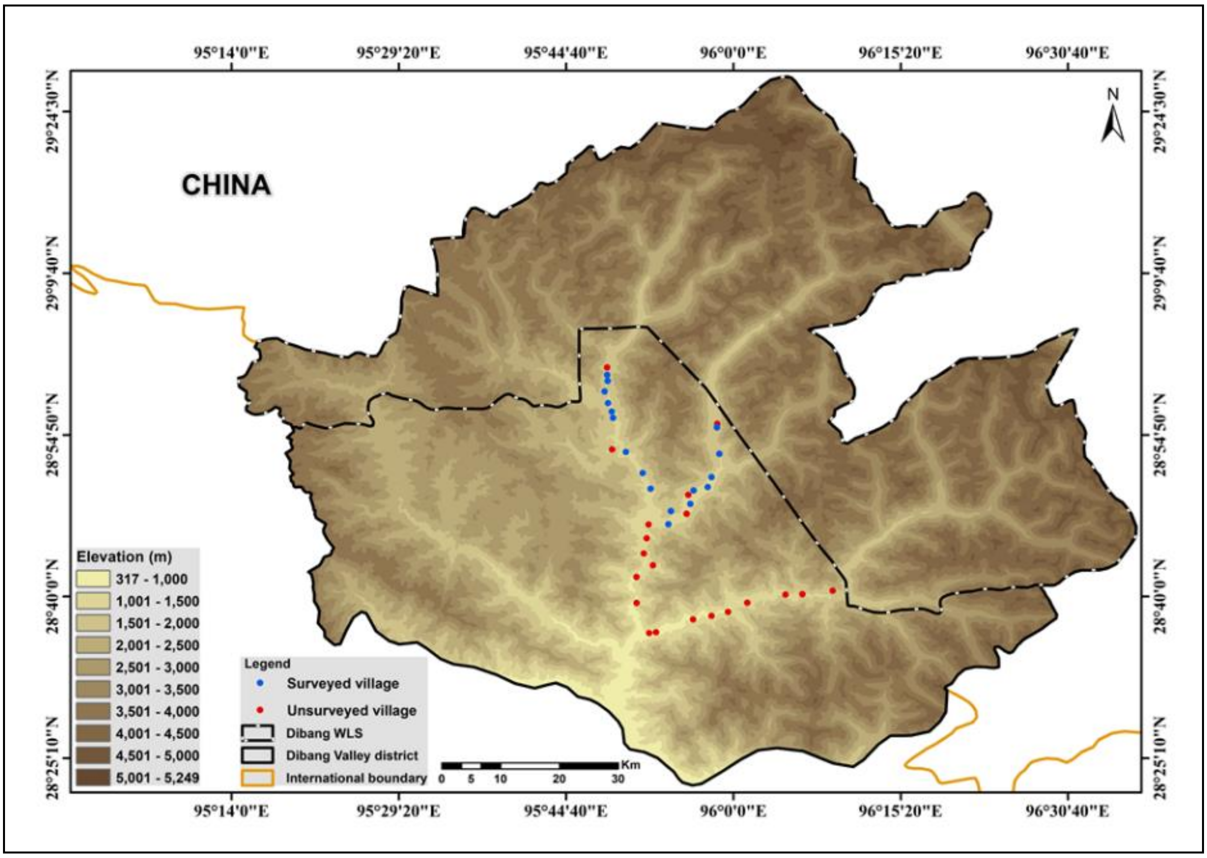


Figure 5.1: The socio-economic surveyed villages in Mipi and Anini circle of Dibang Valley district during 2015-2017

5.3 Results

5.3 (a) Socio-economic and religious profiles of Idu Mishmi

The surveys were conducted in 28 villages of Mipi and Anini circle, out of which 12 villages and 16 settlements/villages were covered from the rural area and Anini town, respectively. Villages in the Etalin Circle could not be covered due to various reasons such as i) time constraint, ii) villagers were not found when the team went for a survey, and iii) only household structures exist with villagers residing elsewhere. 104 households in the selected areas of Dibang valley district were surveyed. Interviews covered 50-100% of the households from each village in those two circles of the district. Among the indigenous Idu Mishmi community, most of them follow animism and believe in the presence of spirits in their natural surroundings. The household survey revealed that most of them follow Animism (96%), while a few of them have converted to Christianity (4%) (Fig 5.2).

The employment status as per the survey showed that 29.81% of the respondents were government employees while 19.23% were unemployed; other occupations include farmer (11.54%), contractor (9.62%), gaon bura (7.69%), social worker (4.81%), retired government employees (4.81%), business (2.88%), housewife (2.88%), professional hunter (2.88%), craftsman (1.92%), carpenter (0.96%) and priest (0.96%) (Fig 5.3).

The land is owned as per customary law of the Idus and the land is used for agriculture (67.31%), private plantation (25.0%) and orchard (15.38%) (Fig 5.4). In agriculture, crops cultivated are rice (26.02%), Mishmi dal (23.98%), maize (18.88%), millet (18.88%), vegetables (10.20%), soybean (1.02%) and potatoes (1.02%) (Fig 5.5). Under agroforestry, the plants cultivated are bamboo (32.0%), *Alnus nepenlansis* (locally known as *'kanimbo'*) (30.0%), pine tree (26.0%), *akemboo* (local name) (4.0%), *thuja* (local name) (2.0%), wild nut (2.0%), *ambamboo* (local name) (2.0%) and *masumboo* (local name) (2.0%) (Fig 5.6). Horticulture is also practiced and the horticultural plants cultivated are apple (39.13%), kiwi (26.09%) orange (26.09%) and cardamom (8.70%) (Fig 5.7).

Mithun is the main livestock reared by Idu Mishmi and is an integral part of the social and cultural activities of the Idu community. It is a semi-domesticated animal, which is not stall-fed. Pig is the second most important animal reared, especially in the traditional or cultural ceremonial feast of the Idu community. The approximate cost of an adult Mithun is INR 70000, and an adult pig is INR 25000 (Fig 5.8).

Though 81.71% of inhabitants were using liquefied petroleum gas (LPG) for cooking, more people were into collecting firewood (96%) from nearby forests and their clan owned community forestland (Fig 5.9). 12.5% respondents also collected Non-Timber Forest Produce (NTFP), such as *Paris polyphylla* (84.62%), *Coptis teeta* (7.69%) and cane species (7.69%) (Fig 5.10 & 5.11).

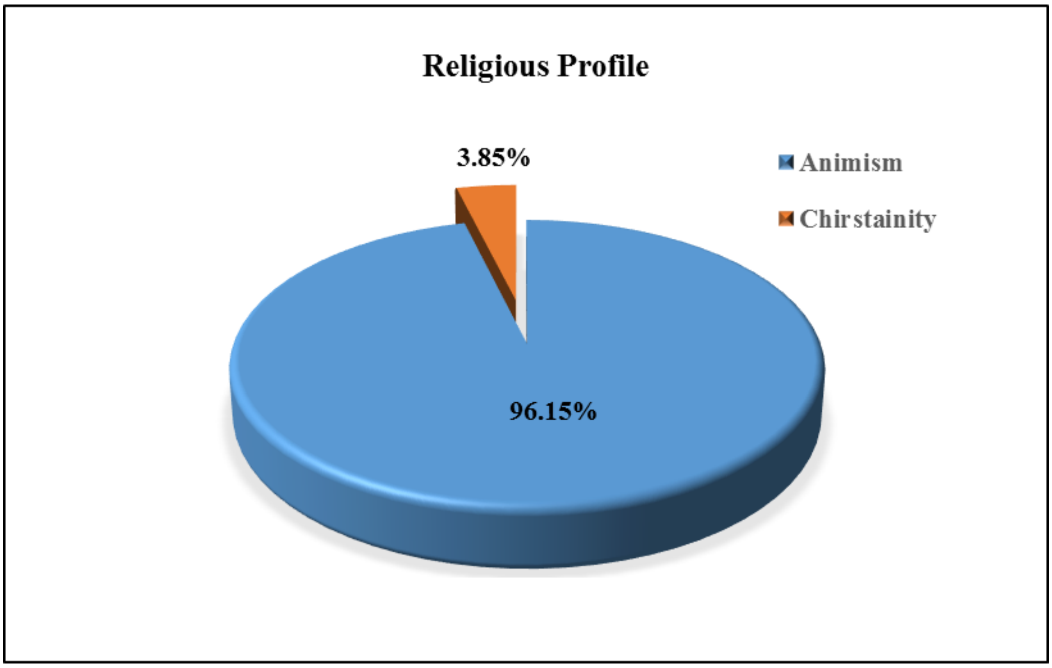


Figure 5.2: The religious profile of the surveyed respondents

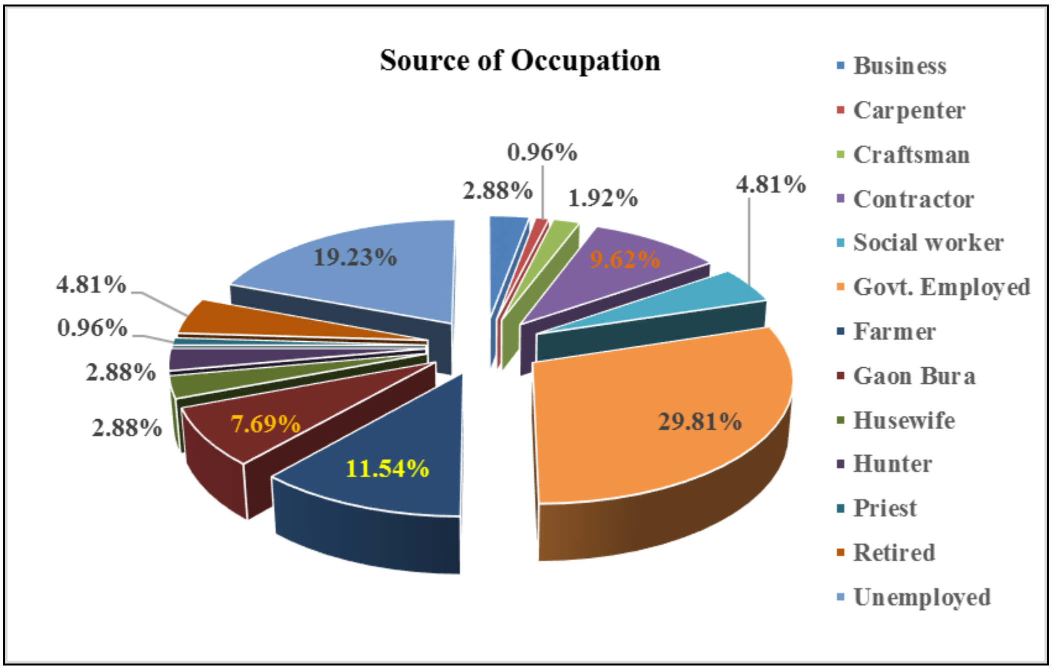


Figure 5.3: The major source of occupation of surveyed villages of Mipi and Anini circles

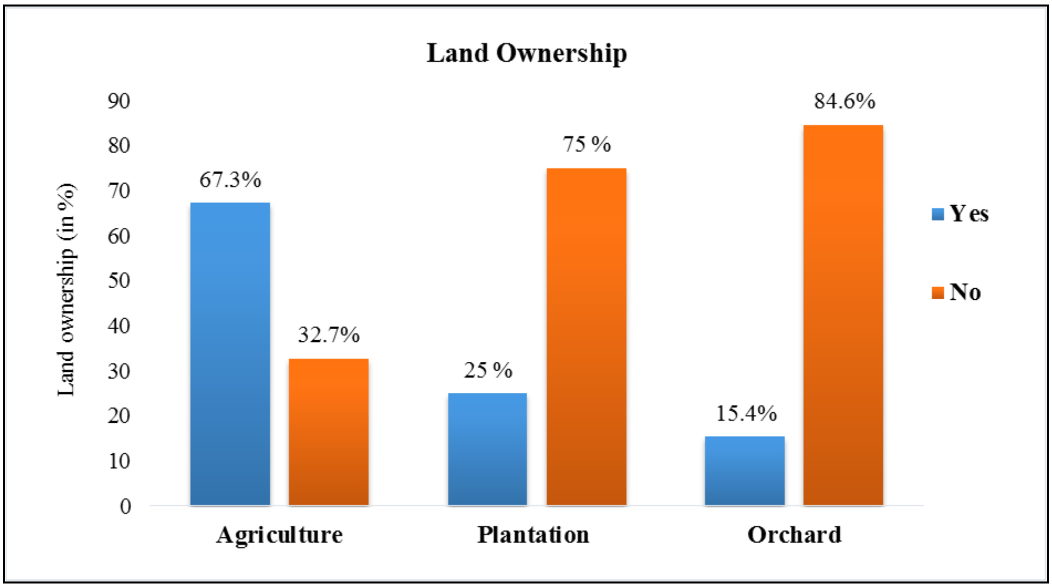


Figure 5.4: Land ownership (%) in surveyed villages of Mipi and Anini circles

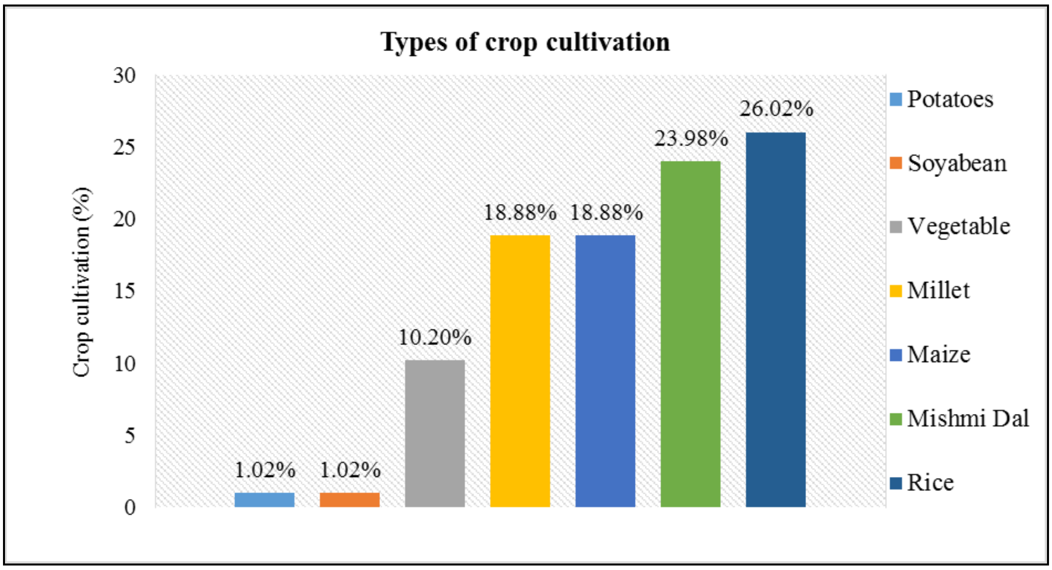


Figure 5.5: Types of crop cultivation in Mipi and Anini circles

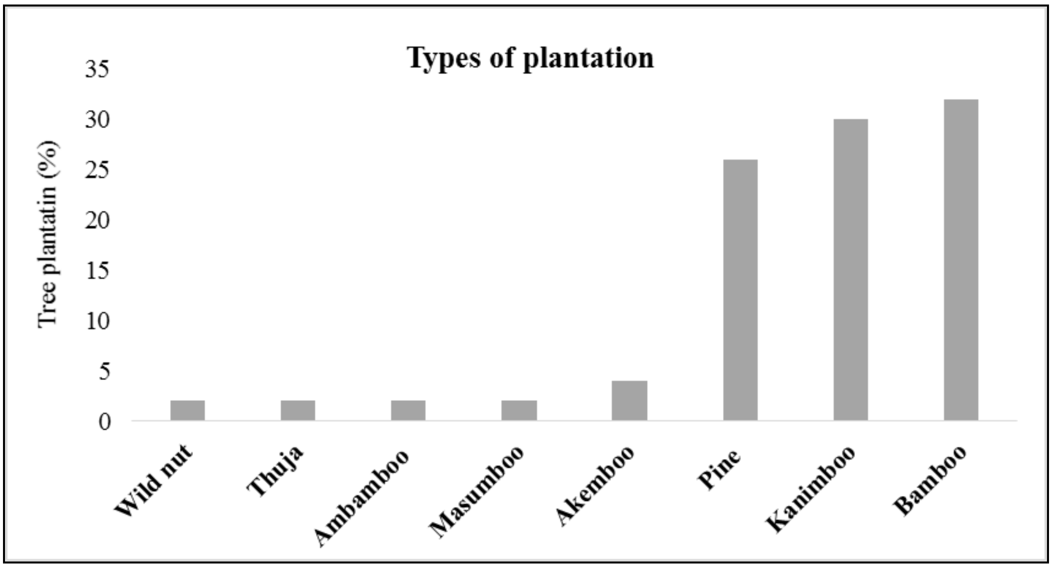


Figure 5.6: Types of plantation in the surveyed villages of Mipi and Anini circles

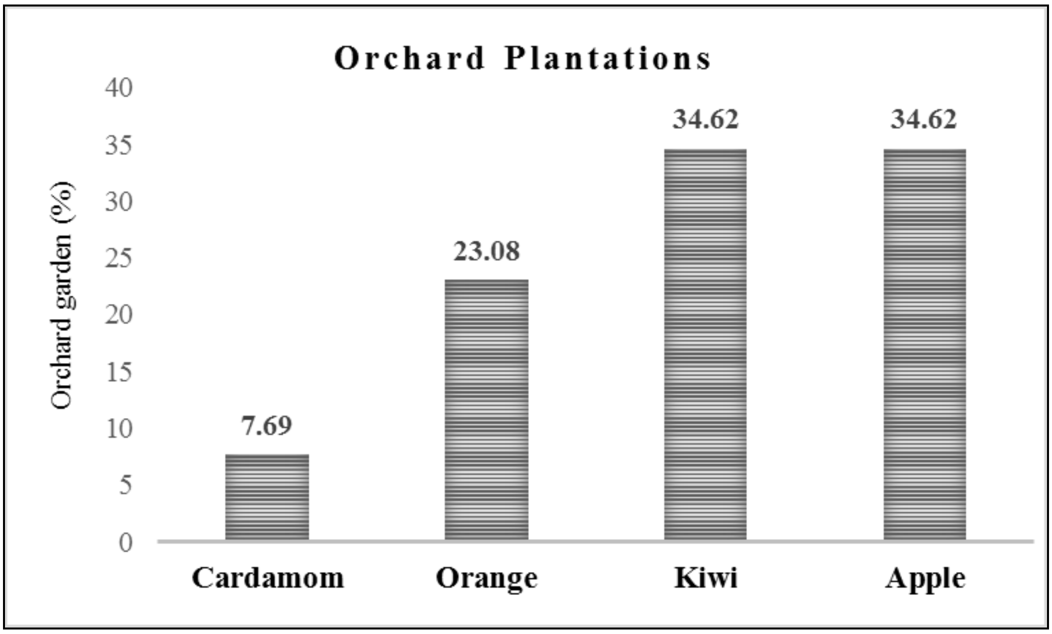


Figure 5.7: Different orchard plantations in the surveyed villages

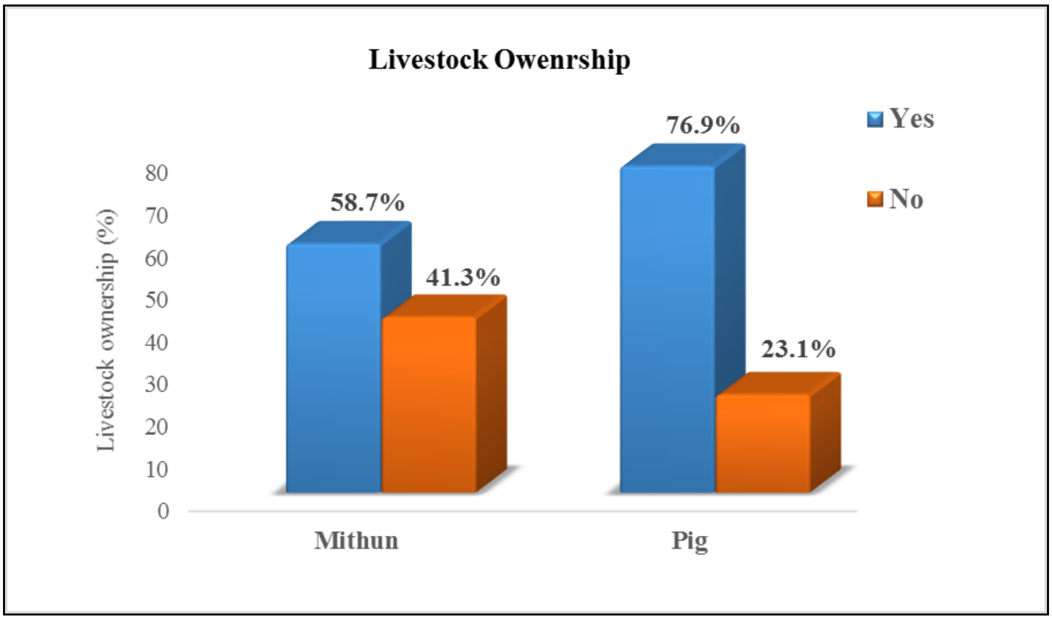


Figure 5.8: Livestock ownership (%) in surveyed villages

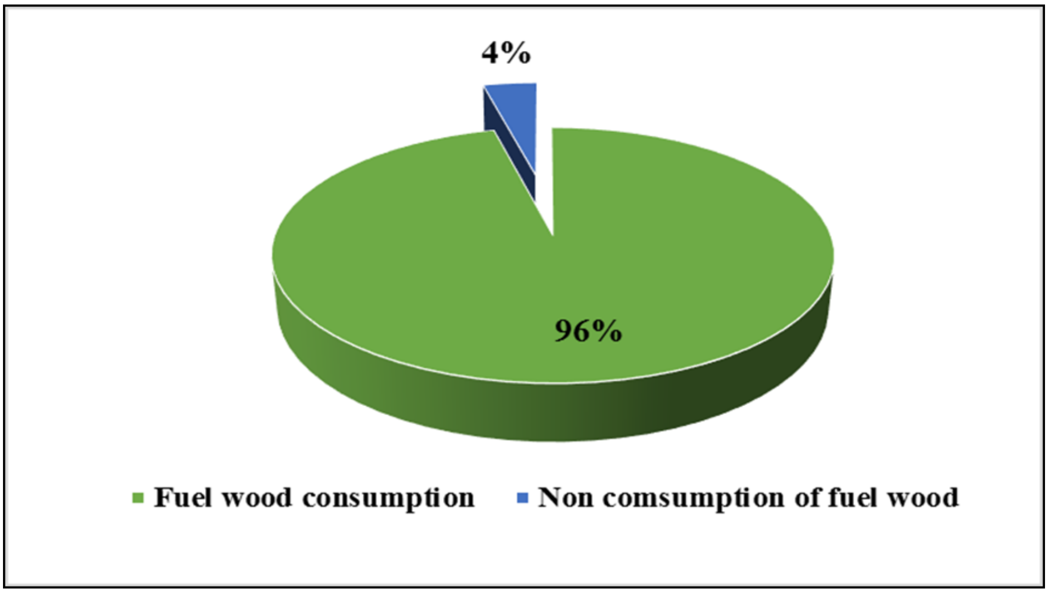


Figure 5.9: The fuelwood consumption and non-consumption percentage of respondents

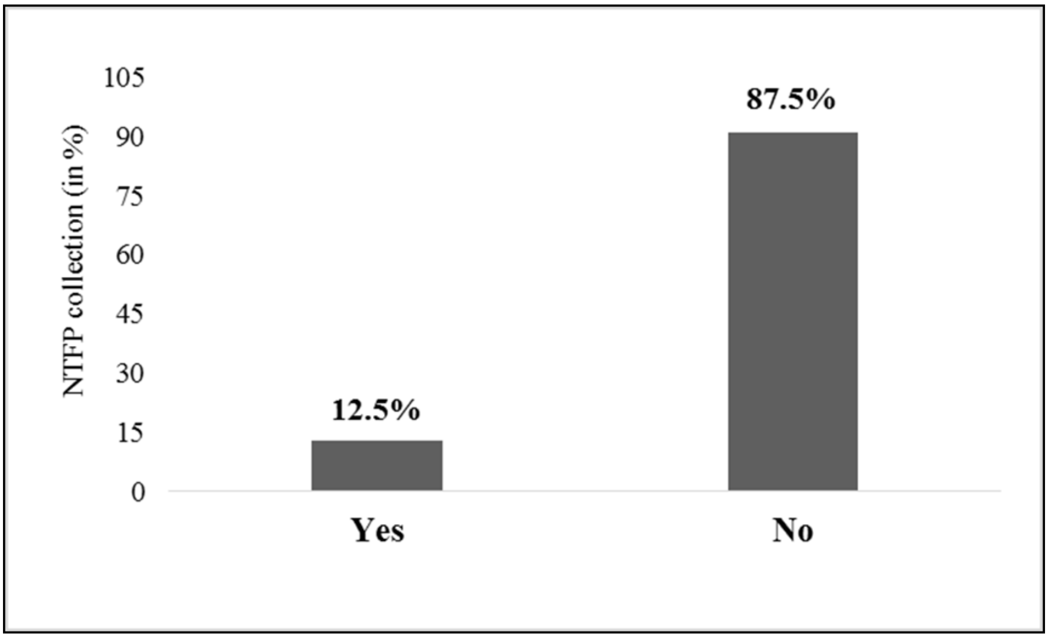


Figure 5.10: Non-Timber Forest Product (NTFP) collection by local people

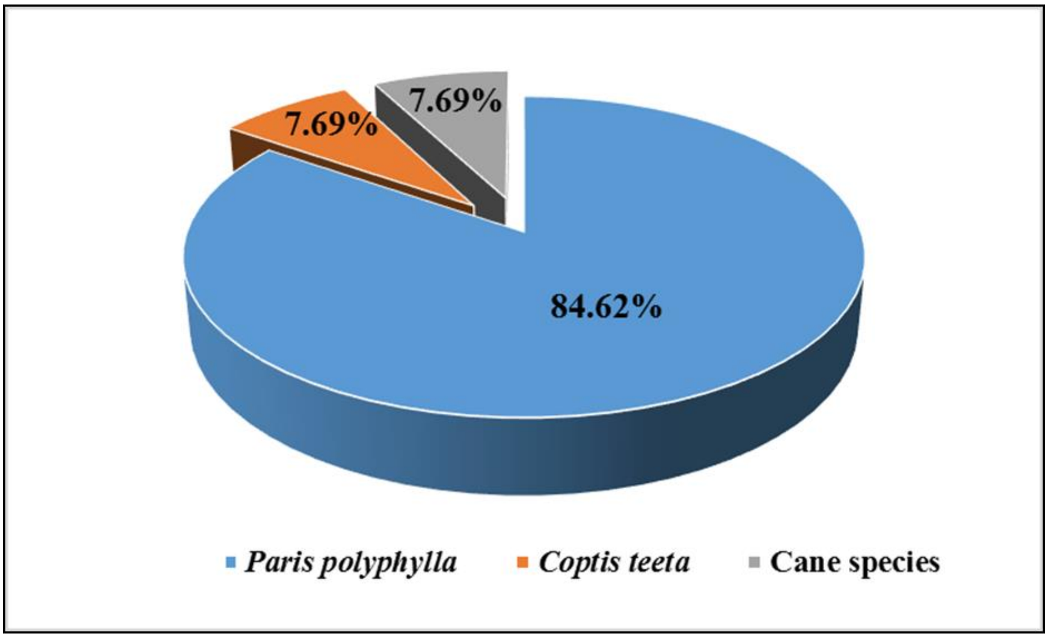


Figure 5.11: Collection of NTFP such as Medicinal plants and cane species

5.3 (b) Crop damage

The highest crop damage was reported in Etabe (15.2%) followed by Kongo I (13%) in the Anini circle and Emuli (13%) in the Mipi circle (Fig 5.12). On average, 65.7% of households were affected due to crop damage mainly by wild animals. Only 34.3% did not report crop damage in their cultivated land (Fig 5.13). Wild pig (32.6%) was the major crop raider followed by Asiatic black bear (31.9%), barking deer (25.2%), and Assamese macaque (8.1%). Few of the inhabitants also reported crop loss from semi-domesticated Mithun (2.2%) (Fig 5.14). Maize (40.8%) and rice (22.5%) were the most raided crops followed by *Mishmi dal* (19.7%), vegetables (11.3%), and millet (5.6%) by wild animals (Fig 5.15).

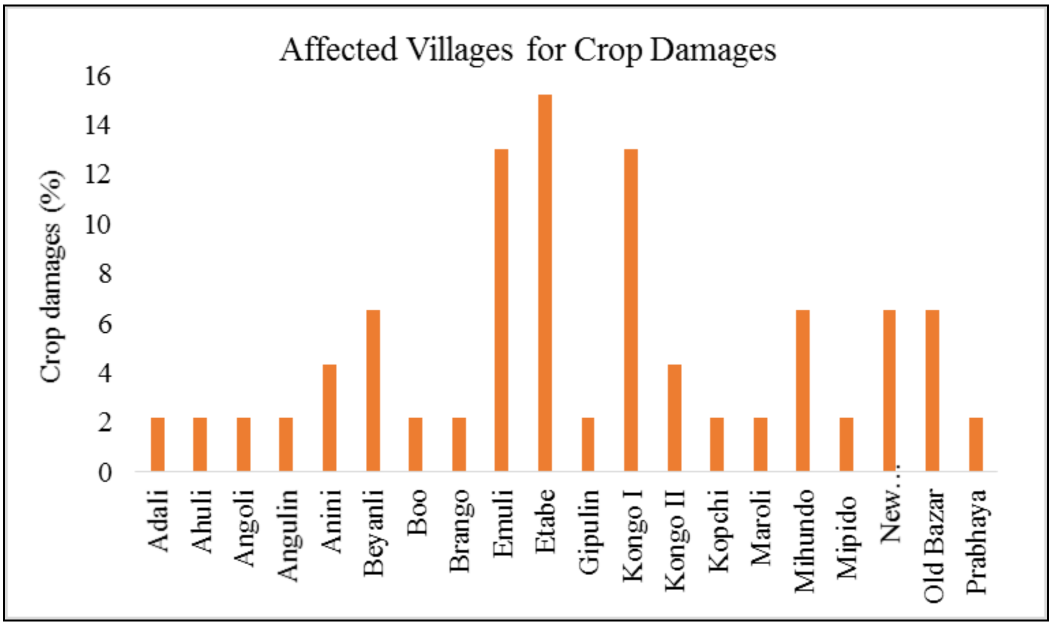


Figure 5.12: Crop damages in surveyed villages

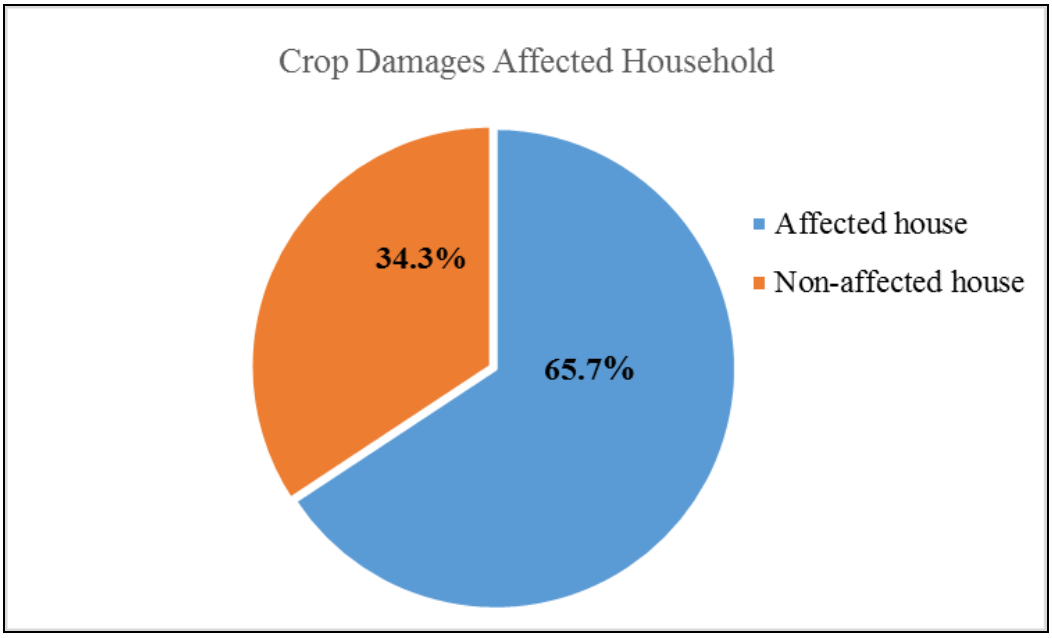


Figure 5. 13: Affected and non-affected households in surveyed villages

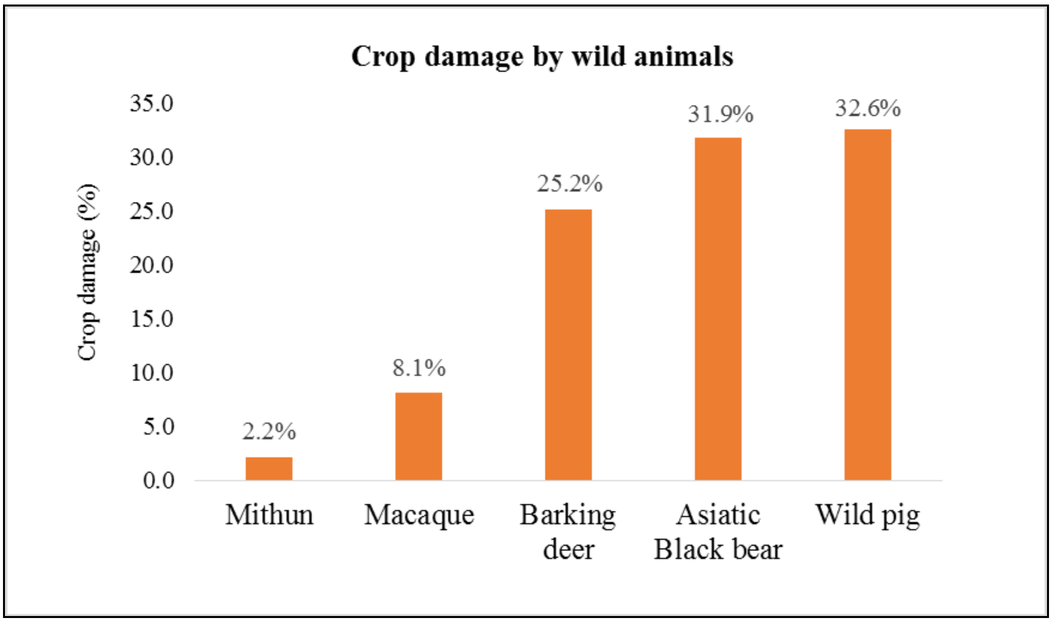


Figure 5.14: Crop damage due to wild animals including semi-domesticated Mithun

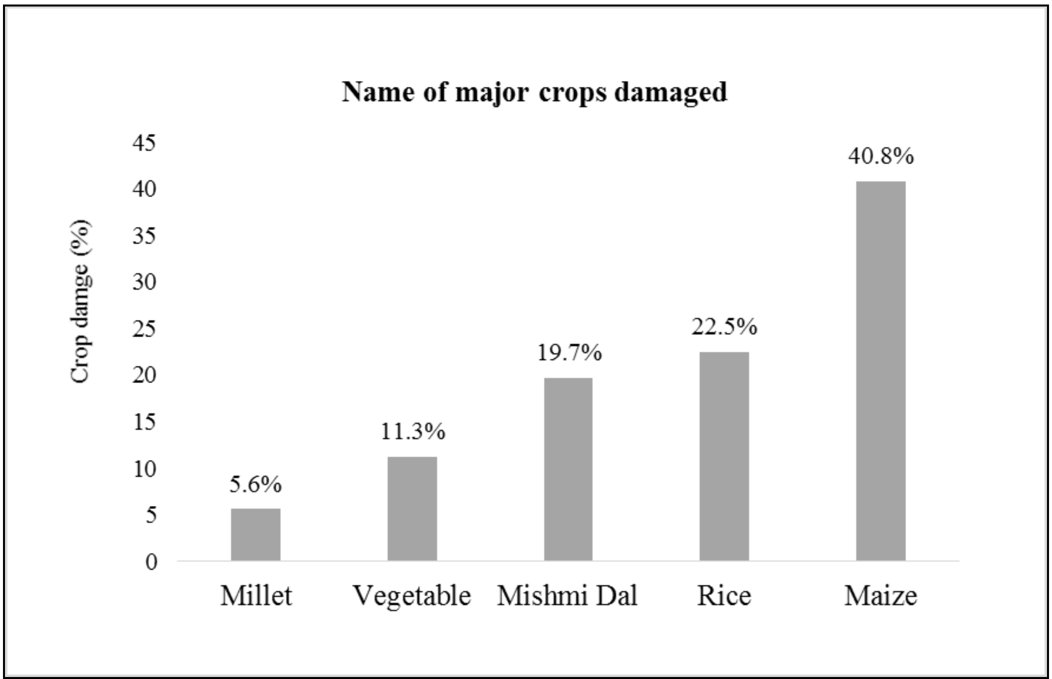


Figure 5.15: Major crops damaged by wild animals in surveyed villages

5.3 (c) Predation

Predation of Mithuns by wild animals was higher in Kongo I (17.6%) followed by Kongo II (11.8%) in the Anini circle and Emuli (11.8%) in the Mipi circle. The lowest predation cases were recorded in Acheso (5.9%), Aguli (5.9%), Kawe (5.9%), Mihundo (5.9%), Old bazaar (5.9%), and Prabhaya (5.9%) in Anini circle, and Beyanli (5.9%) and Brango (5.9%) in Mipi circle (Fig 5.16). In the surveyed villages, 27.9 % of households reported Mithun predation by tigers and dholes whereas 72.1% of households did not report Mithun predation in and around the protected area (Fig 5.17). The percentage of Mithun predation was higher in winter than in summer. The survey reveals that 55.0% of predation was done by the tiger and 45.0% by wild dogs (Fig 5.18). No species of livestock, other than Mithun, have reportedly been predated upon.

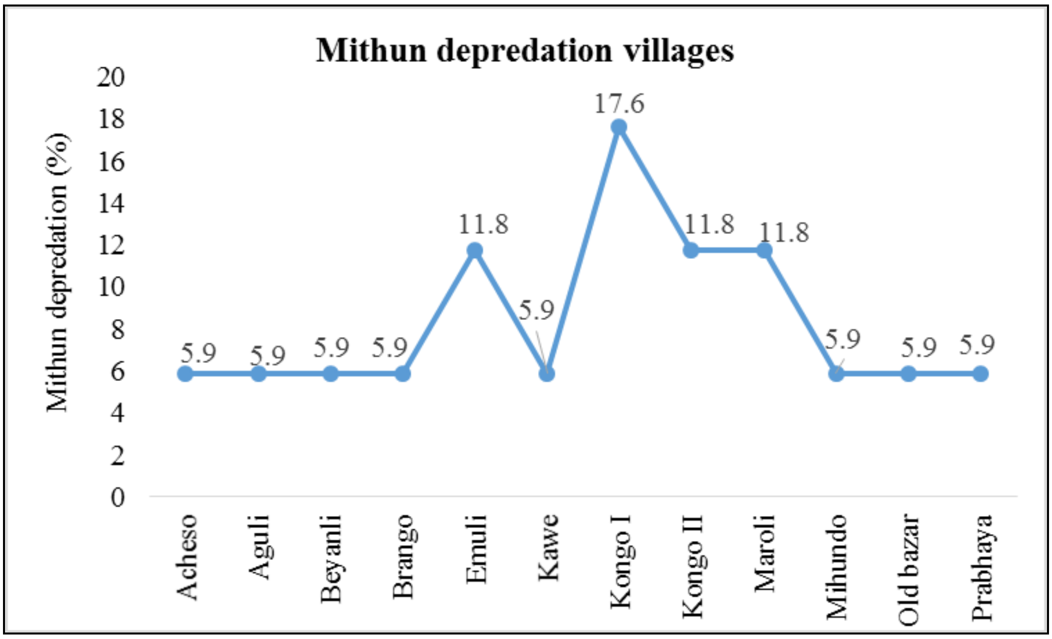


Figure 5.16: Mithun depredation reported across the surveyed villages

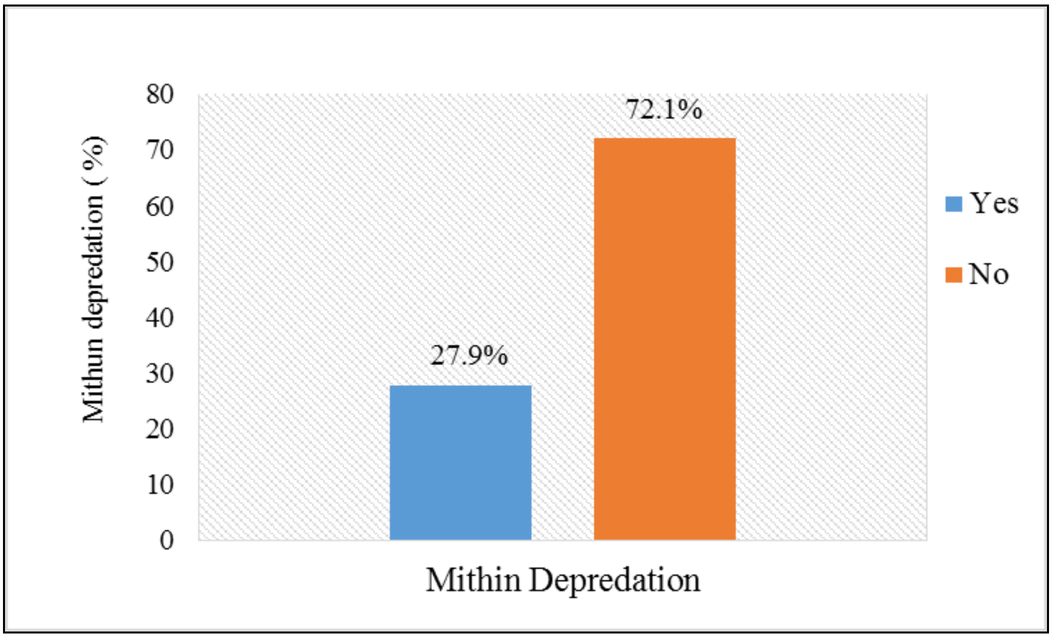


Figure 5.17: Affected household of Mithun depredation by the large carnivores

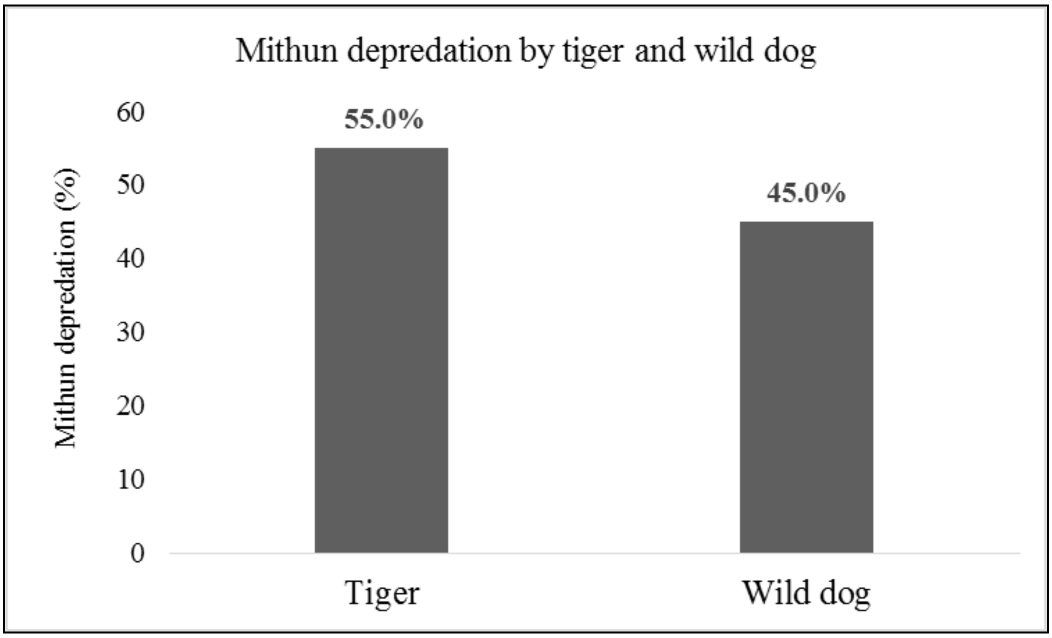


Figure 5.18: Mithun depredation by the tiger and wild dog

5.3 (d) Hunting

The survey reveals that 61.5% of respondents hunted wild animals whereas 38.5% of the respondents were not involved in hunting. Among the 61.5% of respondents, only 2.9% were professional hunters (Fig 5.19). A total of 11 mammalian species was reported to be hunted in the surveyed villages. The frequently hunted species were barking deer (15.0%), goral (13.9%) followed by wild boar (13.1%), serow (12.9%), Asiatic black bear (11.8%), Mishmi takin (11.8%), and musk deer (11.8%), and the lowest was Assamese macaque (9.7%) (Fig 5.20). Hunting frequency and purpose of hunting is dependent on the season and type of ungulates availability. The majority of hunters have low income, and the age of hunting groups was between 35 and 56 years old (Fig 5.21 & 5.22).

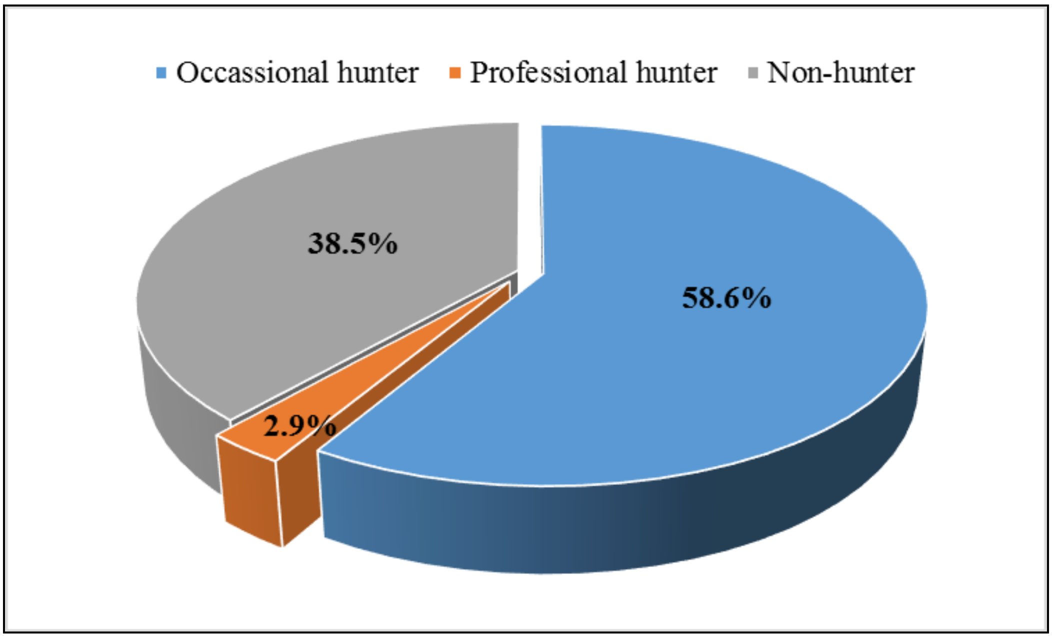


Figure 5.19: Percentage of the hunters, professional hunters, and non-hunters

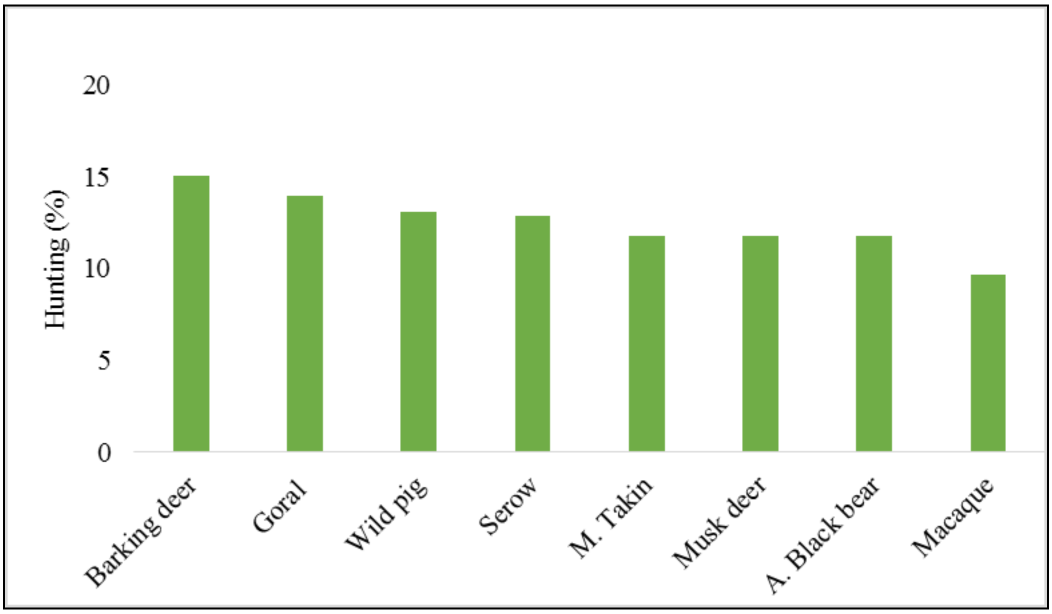


Figure 5.20: Frequency of hunted wildlife

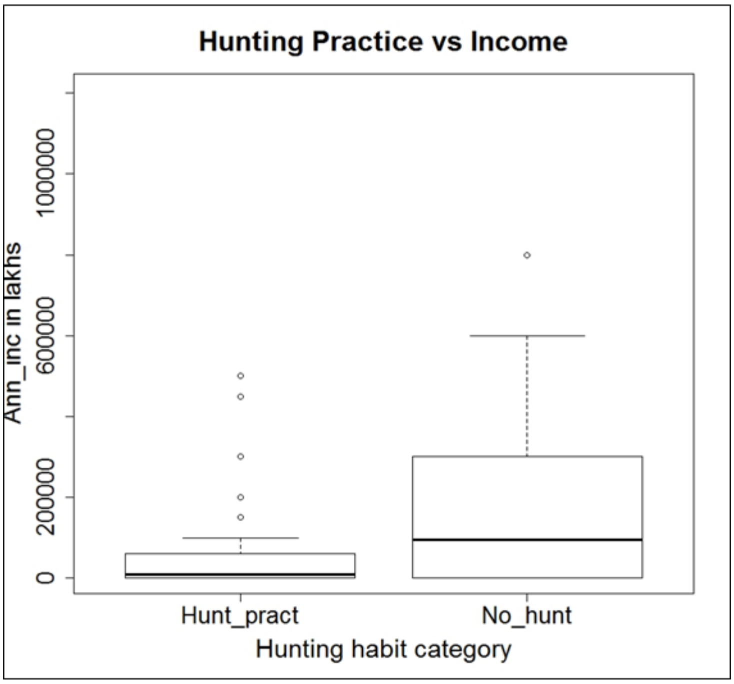


Figure 5.21: Mean box graph showing the income based on hunting

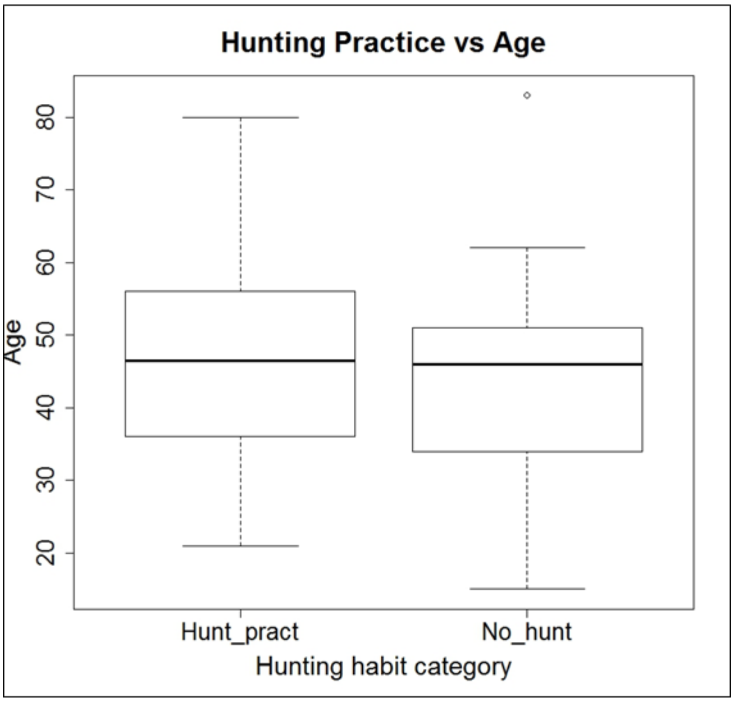


Figure 5.22: Mean box graph showing the age and hunting practiced

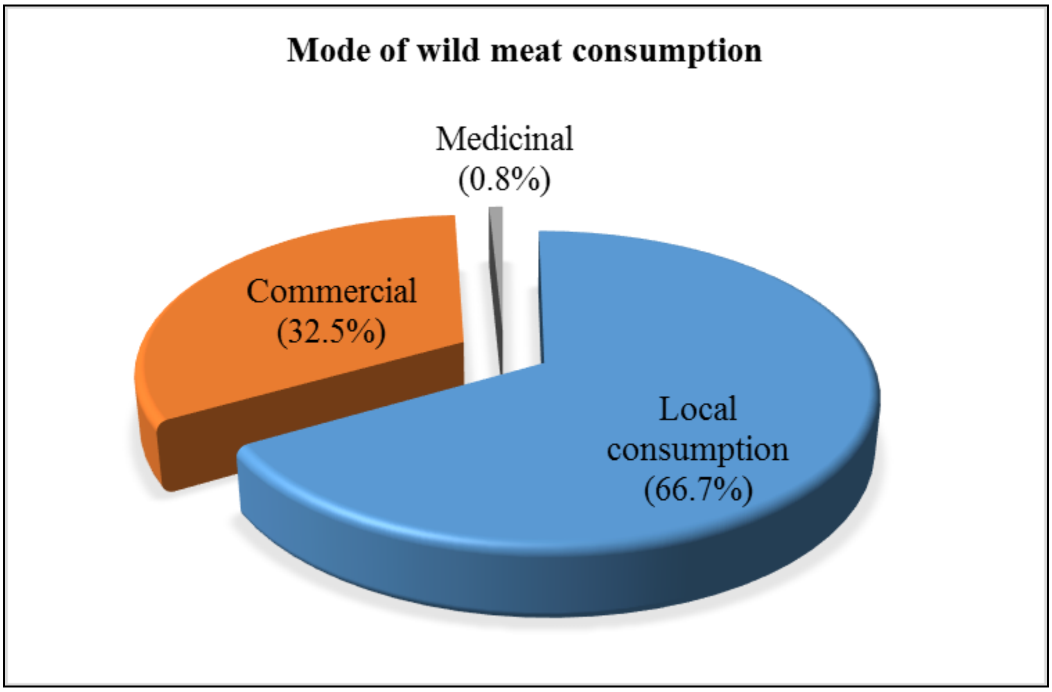


Figure 5.23: Wild meat consumption for a different purpose

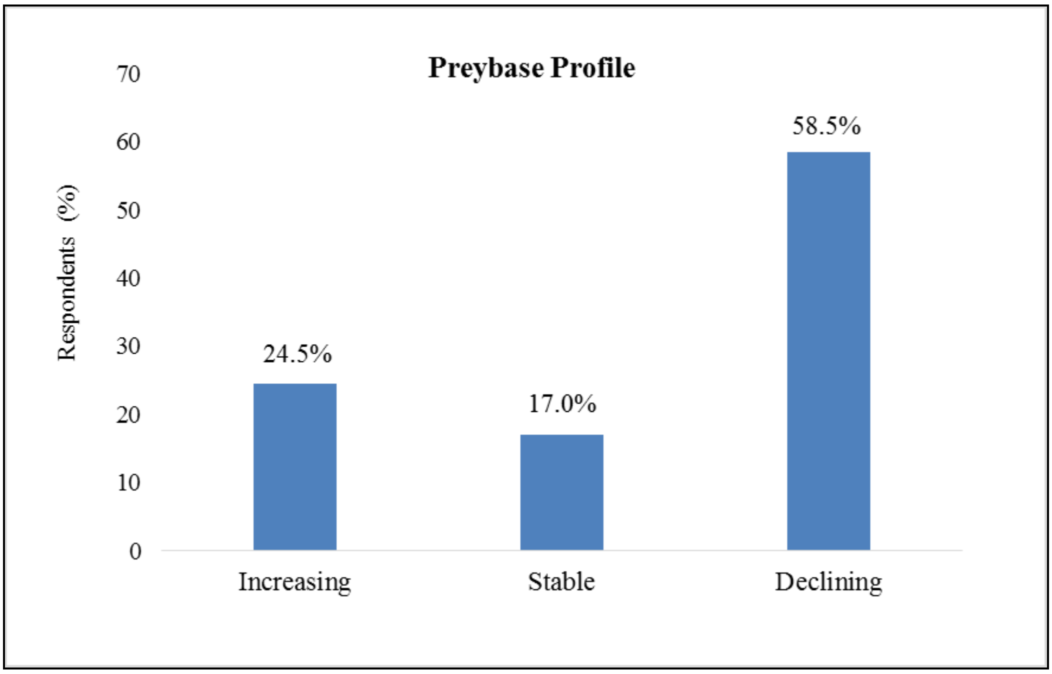


Figure 5.24: The perception of respondents on ungulates population profile

Table 5.1: List of wildlife hunted in the surveyed villages of Dibang Valley

Sl. No.	Common Name	Local Name	Hunting Season	Hunting Techniques	Purpose of Hunting	Taboos	No. of days to observe the taboo	IUCN Status	WPA Schd.
1	Bengal Tiger	*Amra*	Not hunted	Restricted	Restricted, Ritual (Tiger teeth used by Igu as an attire)	Yes	5	EN	I
2	Clouded Leopard	*Kichi-aruyi*	Not hunted	Restricted	Restricted, Ritual (Tiger teeth used by Igu as an attire)	No	NA	VU	II
3	Asiatic Golden Cat	*Amrama* (Melanistic)	Not hunted	Restricted	Restricted, Ritual (Tiger teeth used by Igu as an attire)	Yes	5	NT	I
4	Leopard Cat	*Achango*	Not any specific time	Gun & Twig trap	Meat (Traditional taboo)	No	0	LC	I
5	Marbled Cat	*Ingurrambo*	Not any specific time	Gun & Twig trap	Meat consumption	No	0	VU	I
6	Asiatic Wild dog	*Aprupu*	Not any specific time	Gun	Retaliatory killing	No	0	EN	II
7	Asiatic Black bear	*Ahu*	Throughout the year	Snare, Gun, Laa-da (Idu)	Gall bladders, Skins used in making sitting mats carry bags, Meat for consumption, trophy	Yes	5	VU	II
8	Spotted Linsang	*Katoh*	Not hunted	Accidental	Meat consumption, trophy	No	0	LC	III
9	Yellow-throated Marten	*Akoko*	Not hunted	Accidental	Strict taboo	No	0	LC	II
10	Stone Marten	NA	Not hunted	Accidental	NA	No	0	LC	I
11	Masked Palm civet	*Api*	Not hunted	Gun & Loop trap	Meat consumption, fat for joint pain	No	0	LC	II
12	Red Panda	*Aiminjini*	June-August	Accidental	Skin as trophy	No	0	EN	I
13	Smooth Coated Otter	*Awroga*	Not a specific time	Gun	Meat consumption, Skin as a trophy	No	0	VU	II
14	Eurasian Otter	*Awro*	Not a specific time	Gun	Meat consumption, Skin as a trophy	No	0	NT	I
15	Yellow-bellied Weasel	*Eaanoh*	Not hunted	Accidental	Strict taboo	No	0	LC	II
16	Siberian Weasel	*NA*	June-August	Stone trap	Meat consumption	No	0	LC	II
17	Barking deer	*Manjo*	Throughout the year	Guns & Snare	Meat consumption, Skins used as mat, trophy	Yes	5	LC	III
18	Gongshan Muntjac	*Manjo-imbo*	Throughout	Guns & Snare	Meat consumption, Skins used as	Yes	5	DD	NA

			the year		mat, trophy				
19	Himalayan Serow	*Ma(r)y*	Throughout the year	Guns & Snare	Meat consumption, Skins used as mat, trophy	Yes	5	NT	I
20	Red Goral	*Ami*	June to Sept.	Guns & Snare	Meat consumption, Skins used as mat, trophy	Yes	5	VU	III
21	Wild pig	*Amme*	Throughout the year	Guns & Snare	Meat consumption, trophy	Yes	5	LC	III
22	Musk deer	*Ala*	June to Sept	Gun in summer, snare in winter	Meat consumption, Selling of scent glands, Trophy	Yes	5	EN	I
23	Mishmi Takin	*Awkru*	Summer: June to Aug; Winter: Nov to Feb	Snare, Gun,	Meat consumption, Trophy, used in making sitting mats	Yes	5	VU	I
24	Assamese macaque	*Ameh*	June-July	Gun	Meat consumption, Trophy	No	0	EN	NA
25	Pallas's Squirrel	*Adashumbo*	Throughout the year	Gun, stone Trap	Meat consumption, Trophy	No	0	LC	II
26	Himalayan Striped Squirrel	*Adaka*	June-August	Catapult	Meat consumption	No	0	LC	II
27	Orange-bellied Squirrel	*Anoche*	Throughout the year	Catapult, Gun, Stone Trap	Meat consumption	No	0	LC	II
28	Mishmi Hill Giant Flying Squirrel	*Kamney*	Sept-Oct	Gun	Meat consumption, Trophy &Ornamental use (as Muffler)	No	0	LC	II
29	Himalayan Monal	*Chenda*	June to August	Gun, Loop Trap, Twig trap	Meat consumption	Yes	1	LC	I
30	Sclater'sMonal	*Pidi*	June to August	Gun, Loop Trap, Twig trap	Meat consumption, Ornamental use (as hand fan)	Yes	1	VU	I
31	Temminck'sTragopa n	*Peba*	June to August	Gun, StoneTrap	Meat consumption	Yes	1	LC	I
32	Blood Pheasant	*Chikhhu*	June to August	Gun, Stone Trap	Meat consumption	Yes	1	LC	I
33	Kalij Pheasant	*Aroo*	Throughout the year	Gun, Stone Trap	Meat consumption	No	0	LC	I
34	Hill Partridge	*Perah*	June to Sept	Gun, Stone Trap	Meat consumption	Yes	1	LC	IV
35	Rufous-throated Partridge	*Pokoh*	June to Sept	Gun, Stone Trap	Meat consumption	NA	NA	LC	IV
36	Chestnut Breasted Partridge	*Paiba*	June to Sept	Gun, Stone Trap	Meat consumption	NA	NA	VU	IV

5.3 (e) People’s outlook and role of taboos in wildlife conservation

The household surveys revealed positive perceptions and attitudes towards wildlife conservation (Fig 5.25), especially in the case of tiger conservation. 53.8% of respondents were in favor of tiger protection by the concerned government authorities. While a few of them (32.7%) opposed the idea of the formation of the Tiger Reserve, 13.5% of respondents were not aware of the pros and cons of tiger conservation (Fig 5.26). Idu Mishmi community believes in having kinship with tigers and claim that they do not hunt tigers. Social taboos related to the hunting of wild animals are stringently followed.

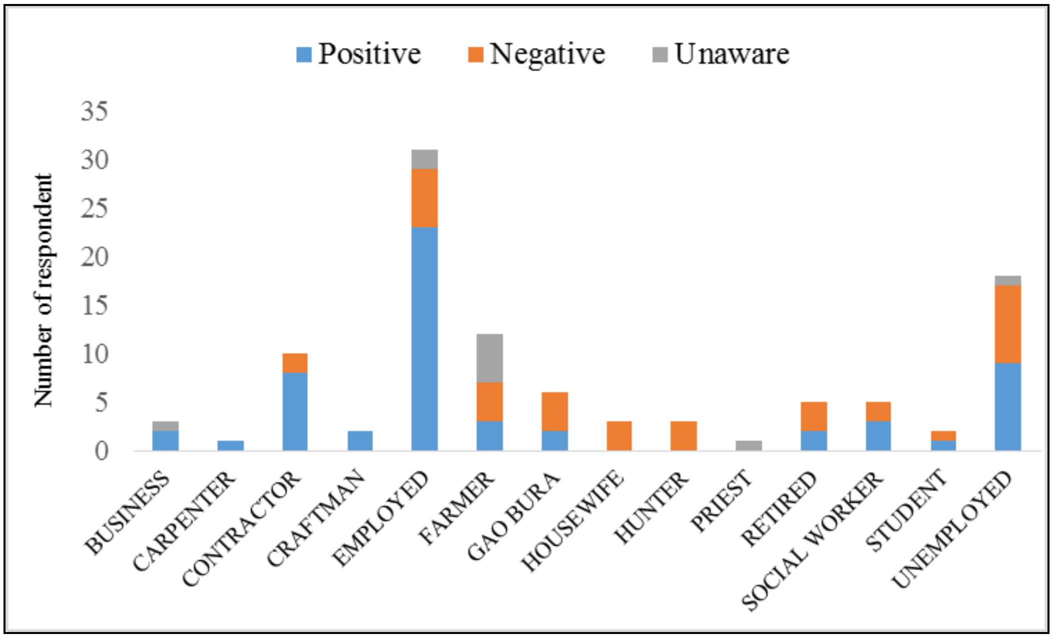


Figure 5.25: The surveyed people's perception towards tiger conservation

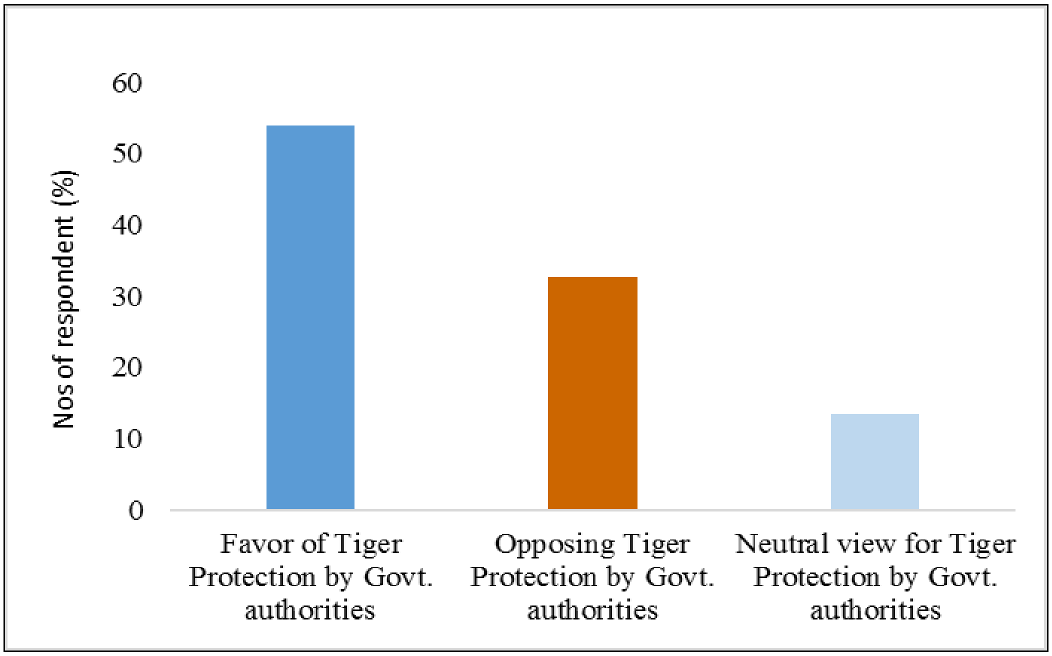


Figure 5.26: The respondent's response to tiger protection

In the villages surveyed, 59.6% of respondents believed that their traditional norms and taboos support tiger conservation, while 18.3 % respondents didn’t believe that taboos play a major role in tiger conservation and 22.1 % respondents are not of any opinion regarding the role of taboos in tiger conservation, they neither believe nor denied the role of taboos. (Fig 5.27).

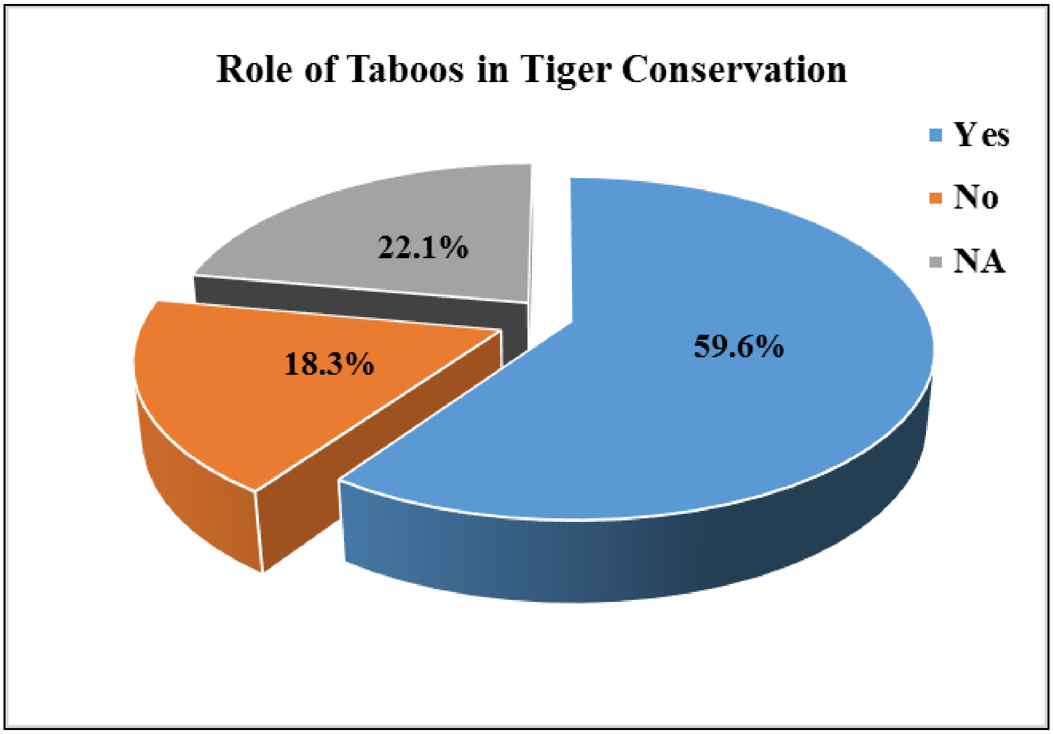


Figure 5.27: Direct role of taboos in tiger conservation by traditional norms

The majority of the respondents hold a strong belief in their mythological story of the tiger and *Idu Mishmi*. Also, they observe certain strict rules and regulations on hunting activities that are governed by their tradition and culture since time immemorial.

Tiger (Idu: *Aam-mra*): According to Idu Mishmi's mythology, the tiger and *Idu* was born to the same mother named *Erayii.* Tiger, the most revered animal, also enjoys higher social status like a human in their society. Idu's do not kill tigers wantonly except if they are accidentally caught in a snare or retaliatory killing that happens due to repeated attacks on their livestock like Mithun. However, they will always take the responsibility of killing *Aam-mra* (tiger) and are expected to perform rigorous rituals similar to human funerals. Only five clans among them, i.e. Meme, Mena, Umpo, Mishiwo and Mishi are exempted to perform this ritual after killing tigers. However, killing a tiger is still a taboo for them, as it is believed that it will bring misfortune to the whole family and their generations. Therefore, the tiger enjoys a special status and regard from society.

Black cat (Idu: *Aam-mra-ma*): Idu's believe that the black cat (melanistic Asiatic golden cat) is more dangerous than the tiger. The mythology narrates the story about the black cat sitting on the tiger's back and riding the tiger. Therefore, they believe that the black cat is more powerful than the tiger itself and they don't kill the black cat as well.

Other felids species: Hunting other felids species such as the leopard cat (*Achango*), marbled cat (*Ingurrambo*), Asiatic golden cat, and clouded leopard (*Kichiaruyi*) are restricted by taboos in the *Idu Mishmi* community. Apart from these felids' family, Idu people hunt other ungulates, pheasant, and many rodent species for their monetary needs, to meet their subsistence requirements and for making household articles as well as accessories.

Ungulate species such as Mishmi takin, Himalayan serow, barking deer, wild pig and red goral, and carnivore species such as Himalayan black bear are hunted for various reasons as stated in Table 5.2. Strict taboos are observed by the hunter, their family members, and anyone who consumes wild meat. However, there are few species such as musk deer for which there is a flexible taboo system as they play an important role in livelihood earnings. Women do not consume wild meat harvested from high altitudes; they can only consume birds, pheasants, rodents, and observe the same set of taboos.

Taboos observed by the hunter

After a successful hunt, hunters follow a ritual called "*Aaphun-anghii"* to show gratitude towards the God of mountains, "*Golo(n)".* They cut a portion of the hunted animal's right ear on a bifurcated bamboo or a bifurcated twig and piece of metal, specifically brass for keeping it on the ground altogether. In the case of Mishmi takin, they offer three times than other animals hunted. A small piece of the right ear, then some from the right shoulder part of the scapula and some skin from the right hindfoot is taken and placed on a leaf, along with a metal piece (especially brass), and then finally offered to God "*Golo(n*)". They do it for triumphant hunting, as well as for the safety of the hunters' family from being cursed by the spirit. The hunters observe five days taboos for all wild animals such as Mishmi takin, serow, red goral, wild pig, Himalayan black bear, barking deer, musk deer, Gongshan muntjac, etc. Those who consume wild meat, also have to follow one-day taboos (*Aena*). The taboos include:

a) Not consuming local spices, such as garlic, onion, and chilli as well as few vegetables, like mushroom, maisena, etc.

b) Cooking wild meat is prohibited inside the house. They cook wild meat in utensils not used by family members to cook food in a day to day life.

c) The hunters as well as anyone who consumes wild meat is prohibited to sleep with their wife or any other woman during the period taboo is followed.

d) No washing of clothes for a month after the hunt. (They follow the lunar cycle in this case).

e) The hunters and family members should not attend a funeral function or any other auspicious ritual function such as marriage ceremony, childbirth ritual, any ritual related to the welfare of family and house.

Taboos observed by family

The female members of the family have their share of taboo observation before and during the hunt by their male members. They cook the food items that are required to be carried on the hunting trip. It is regarded inauspicious for the other individuals who are going for the trip if the woman of any household going for the voyage is having menstruation. Thus, the traditional ritual named "*Am-bu*" is performed for the safety of the individuals involved. Weaving, eating of mushroom, *masena* (a local vegetable), local onion, and wandering around the community are prohibited for the women, particularly the wife of the hunters, when their male members are in their hunting expedition. Thus, the support of the family members of the hunters is necessary for successful hunting. It is believed that if the family members, especially the wife of the hunter doesn't observe the taboos, it can be seen in the dream of the hunter during their hunting expedition, which results in an unsuccessful one.

Effect of disobeying taboos: According to their mythology, *Ani Anjuli* (Goddess) and *Aba´-Abroya* (God) are guardians of wild animals found in forests. If the guardians are satisfied with *Am-bu,* they provide sufficient wild animals during hunting and for the next trip too. However, if hunters will kill wild animals beyond the limit they can carry, the guardians would get angry and their wrath will occur upon them. The level of effect and misfortune depends upon the level of hunting, from the individual level to society level. At an individual level, they are allowed to kill one or two wild animals per trip.

a) According to belief, if more than two animals are killed, it will affect the individual, at the individual level. The possible outcomes will be prolonged illness, major or minor accidents, unnatural death of the hunter.
b) The family will get affected if more than four to five animals are killed by the hunter, far beyond the own carrying capacity. The possible impacts are the illness of any family member, unnatural death, burning of the house, loss of property, etc.
c) If more than seven or eight animals are killed, *Aanteko* or the village will suffer, meaning mass death. The sudden spread of epidemics is such an example.
d) The overhunting of wild animals will not only affect society but will also affect the ecosystem as a whole.

5.4 Discussion

The people of Dibang valley have different opinions on wildlife, especially regarding tiger and wild dogs. Most people responded positively while a few responded negatively. There are reasons for people having varied opinions. To name a few, firstly, the tiger has been given high status, being regarded as an elder brother. Secondly, due to the depredation of mithun, a negative response has been observed. Tiger and wild dogs are regarded equally but they regard the tiger as having a kinship with the Idu people while they don't comment on the relationship with that of wild dog. Therefore, there have been restrictions on the hunting of tigers and the related felids found in the region but the same is not the case for wild dogs. Nevertheless, they don't hunt wild dogs, perhaps due to the belief that it will bring a bad omen to their community. Intentionally, tiger and wild dogs can be hunted down when they attack humans or livestock as self-defense or in retaliation to livestock i.e. Mithun predation. Conversely, a ritual is performed after the hunting of a tiger but the same is not observed in the case of wild dog. Therefore, with such beliefs, the tiger has inhabited and thrived in the region with full respect and in harmony with the local people.

The Idu Mishmis are animists, believing in the presence of spirits around them and follow their customary laws and traditional knowledge system (Baruah 1960). The customary restriction i.e. taboo is one of the ideal principles followed by this community (Aiyadurai 2007, 2016). They are firmly attached by un-manifested force with wild animals and their day to day life. There are (a) animals that cannot be killed and strict taboos are observed even if killed in self-defense or unintentionally, (b) animals that can be hunted down, but after performing certain taboos and rituals, and (c) animals they contemplate and/or regard as a bad omen and don’t kill. With these rules and regulations imposed by customary law, they have co-existed with nature since time immemorial.

The world is changing rapidly; people change their attitudes and thoughts with time. In this modern world, a question arises on how and until what time the traditional taboos and customary laws will survive and/or will be followed. The total population of Dibang Valley is 8004 and Idu Mishmi is the lone indigenous tribe inhabiting the area (Census of India, 2011). For centuries, the tribe has been protecting their natural resources through their strong traditional knowledge systems and practices, which has helped them sustain their natural world. Owing to such strict customary restrictions, Idus have retained their biodiversity and by far DWLS is richest in its biodiversity value (Aiyadurai et al. 2010, Aiyadurai 2018). They take pride in the fact that it is due to their taboos, traditional protection, and/or restriction that wild animals are found abundantly in the region in comparison to other protected/non-protected areas in Arunachal Pradesh, where the tribes do not observe such strict customary restriction. One of the respondents said, *"Nyishi Jungle mein to ek chidiya bhi nahi milega, hamare yahan to bahut chidiya milega. Hum to niyam karta hai wo logo ka to koi niyam nahi"*, meaning that in other tribe’s community forests such rich wildlife cannot be found as they don’t have such strong taboos like the Idu mishmi's and it iterates the fact of following their taboos and respecting them, and how it helps in conservation of wildlife.

Without such taboos, traditional protection, and/or restriction by their community, without having a kinship with tiger, the survival of tiger in Dibang Valley district is questionable (Aiyadurai 2018). While trying to declare it as a tiger reserve, they have a strong argument that with their age-old traditions and taboos, the tigers and other wild animals have been protected and will be protected in the future as well, then why declare it a tiger reserve? The valid points must be kept in our mind; we need to look at cultural aspects of protection, the role of taboos that take a distinct role in the harmonious coexistence of humans and wildlife. This outstanding practice leading to harmonious coexistence with nature needs to be learned by the present generation and ought to motivate them. However, with the change in the present scenario, the status of the Dibang valley gets affected negatively too. Construction of highway, more interaction with outsiders, reaching of modern technologies such as the use of hi-tech technologies, development in telecommunications and media, change in the religious beliefs, poor economic conditions, etc., and pressure to meet the demands of growing modern facilities and technologies, the introduction of sophisticated weapons might also negatively influence the Idu Mishmi age-old traditions, which will be difficult to uphold for a long period in the future. Further, if the Idu communities are carried away by these changes, the future for the conservation of tigers and other wildlife will be uncertain. However, the Indian Wildlife (Protection) Act, 1972 conserves and preserves the wild flora and fauna in India. In regions like the Northeastern part of India, which is predominantly inhabited by tribal communities, the full implementation of such laws is a challenging and sensitive task (Dollo et al. 2010). The lack of development, lack of adequate staff in the forest department, financial problem, economic crisis, etc. are some of the major reasons why implementing such laws in spirit are complicated, and above all the maximum forest cover areas are governed by local tribal right. In such situations, there is a necessity for the conservation of endangered species via a participatory approach with the active involvement of local communities.

CHAPTER 6

CONCLUSION AND SYNTHESIS

6.1 Background

The Mishmi Hills are located in the Indian part of the Eastern Himalayan biodiversity hotspot, which is one of the regions of high biological diversity and is the biogeographically gateway of India (Bailey 1992, Chakravarty et al. 2012). Topographically the area is located in the transition zone between the Indian plate and Indo-Chinese plates; due to this, several flora and fauna are endemic to these regions and have unique characteristics (Rao 1994, Chatterjee et al. 2006). Large carnivores such as tiger and wild dogs, are some of the flagship animals inhabiting this region and are also widely distributed in DWLS and its adjoining landscape. The altitude of the sanctuary varies from 1678 to 5000 m amsl with diverse vegetation from temperate to alpine forests. The study has reported the first photographic evidence of tiger presence from the community forests of Mishmi hills in Dibang valley district at an altitude of 3630 m amsl and it is the highest record from the Indian part of the Eastern Himalaya biodiversity hotspot (Adhikarimayum & Gopi 2018). Thus, further studies are required to know the favorable conditions or insight about the occurrence of the tiger at this elevation and beyond. Meanwhile, there have been reports on the abundance of tigers at a high elevation from neighboring countries like Bhutan (McDougal and Tshering 1998, Sherpa et al. 2004). Even in other parts of the Indian sub-continent, there have been photographic reports of the occurrence of tigers at this elevation in Uttarakhand, Western Himalaya (Bhattacharya & Habib 2016), and Trans Himalaya of Sikkim (Lachungpa & Usha 1998).

The Northeast tiger population, including the Dibang valley, is a unique population due to their distinct genetic composition (Jhala et al. 2015). However, species with small populations are prone to extinction (MacArthur and Wilson, 1967) and especially tigers in rainforests are at risk due to various factors like low densities of prey, hunting pressures, and habitat fragmentation. Population viability analysis on tigers in other landscapes has revealed that 24 breeding females in a population or a population having at least 68 individuals can persist over the next 100 years (Karanth and Stith, 1999, Tilson et al 1984). The Dibang Valley District, if surveyed extensively and fully may have a potentially high number of tiger individuals and will meet the above condition. Also, because the direct hunting pressure is not there on tigers, as the Idu Mishmi community has a strong cultural bond with the tigers. Though the tigers are safe and have existed here in the landscape since time immemorial, efforts to further the understanding of the connectivity between other populations, detailed investigations on demographic parameters, genetic uniqueness of this population, and minimizing the hunting pressure on prey populations needs to be carried out in future.

6.2 Threats to the protected area

Dibang Wildlife Sanctuary is a protected area with a total area of 4149 km^2. The topographical feature of this sanctuary is rough terrain, fragile mountains, and steep slopes, which makes most of the areas inaccessible. Most of the time, the district receives rainfall, which results in the availability of short to minimal duration of accessibility. Further, in addition to the above natural and topographical challenges, the availability of limited forest staff poses another major challenge to monitor and manage the sanctuary. With just a few forest personnel, it is a demanding task to monitor the vast area of the sanctuary all the time, as a result, illegal movement and extraction of forest products are witnessed inside the sanctuary. Implementation of the Indian Wildlife Protection Act, 1972 is difficult and sensitive in the prevailing conditions.

6.3 Over exploitations of forest resources

The people of Dibang valley are directly or indirectly dependent on the forest and its resources. The forest is also the economic backbone of the people to meet their necessities. As the valley is situated at a higher elevation, it receives frequent rain and snowfall in the winter, making the region very cold, so fuelwood is needed for keeping the house warm. Forest products such as timber are used for construction and monetary gains; NTFPs such as bamboo, edible plant parts, etc., and wild meat that constitutes an important part of their diet are extracted from the forest. Idu Mishmis are experts in collecting edible leaves, tubers, mushrooms, fruits, etc. from the forest. Fallow lands are used for Mithun grazing. Their culture has a unique relationship with the forest; they regard it as their lifeline and identify their identity with the forests.

However, with modernization, a change in their way of living is observed. They are trying to generate income from the forest and its products to live a financially sound life. In the past, the hunting of wildlife such as musk deer hunting was done for supplementing dietary requirements and basic income generation. However, in the present scenario, hunting is getting commercialized as an income-generating occupation resulting in the hunting of many wildlife species. Besides wildlife, many endemic medicinal plants, timber, NTFP, etc., are extracted. If this continues, a situation will arise where the endemic flora and fauna will be endangered or might even become extinct in the future.

a) Over extraction of *Paris polyphylla*

Paris polyphylla, locally known as *Inusigatama*, is one of the medicinal plants that is found in abundance in the Dibang valley. This plant is used in limited quantities on special occasions by the *Igu* (priest) as a medicine. The non-imparting of traditional knowledge about the use of this plant by the older generation to the younger generation is the main reason for its minimal use. The fruits are used as lip balms and paste is used as an ointment on the wounds. However, this is not practiced by the present generation.

Paris poyphylla is one of the major medicinal plants that have a high value in the international market, resulting in an over-extraction by the locals. The plants have been extracted locally for commercial reasons from the year 2012-13 onwards. Initially, the plant was extracted by the local people from their villages or their landholdings. The market value of this plant was not known by all locals in the earlier days. In Traditional Chinese Medicine (TCM), *Paris poyphylla* has been reported as one of the important medicinal plants. The species of this plant found in India is probably exported illegally. The illegally extracted plants from Northeast India, particularly from Arunachal Pradesh, are probably transported to the international market of China. In the last two to three years, the people of Dibang valley have realized the market value of *Paris* spp. in the international market. Consequently, the plant is being extracted excessively. The price of this medicinal plant fetches INR 3500- 5500 per kg in the local market, particularly in Anini and Roing. Laborers from other places are employed by the locals for the extraction of this medicinal plant in the vast area of the district. Mainly non-tribal people, who are brought from other districts, extract the medicinal plant inside the sanctuary, with the help of local people. In 2017-18, the continuous extraction of *Paris* spp. has resulted in the non-availability of this plant in the nearby villages. Consequently, people have started extracting *Paris* spp. from inside the wildlife sanctuary. Normally, the accessible areas for extraction of *Paris* species require a minimum of a whole day of trekking; however, in recent times it is not accessible even after three to five days of trekking due to its over-extraction and limited availability.

In the present scenario (2018-19), excessive extraction of *Paris* spp. is undertaken by the locals with the help of employed laborers inside the sanctuary as there is least to minimal forest staff to monitor the entire sanctuary. Therefore, a full-grown *Paris* spp. is hard to encounter in such situations. It can be concluded that the ecological balance of this plant has been disturbed and it is difficult to revive back to its original scenario unless management interventions are made.

b) Modernizing approach for the hunting of wildlife

The Idu Mishmi believe that hunting of wild animals is one of the major occupations of the man folks of their community. This has been practiced from the olden times in the community. Traditional traps, arrow, and bow were the major weapons used for hunting by the older generations. Wild animals were hunted mainly to supplement dietary requirements; however, few species were hunted for commercial gains to support the family. Taboos are observed by the hunters and the person who consumes wild meat.

The use of modern and sophisticated weapons and hunting for commercial purposes by the present generations has tremendously impacted the population of wild animals. Also, there are fewer restrictions in the hunting of animals as compared to the restriction followed by the older generations. The practice of taboos is becoming less with the advancement of the modern era. The open sale of wild meat is not seen in the local market. However, during the survey, there were preliminary findings regarding the selling of wild meat in Anini. Nevertheless, this couldn't be confirmed due to field constraints and limiting factors. There is no rule in buying wild meat by the locals. However, there is a rule in the sharing of the hunted animals with the people of the village by the hunter(s). A detailed study is required to understand how the commercialization of hunting practices has evolved and who is buying the wild meat. There is a high chance of selling wild meat in the local market for monetary gain by the locals, which will result in excessive hunting of wild animals by the hunters. This might have an impact on the ecological balance of the ecosystem.

Generally, hunting is mainly practiced by the locals and non-locals from other districts. They are mainly brought by the local people for the extraction of *Paris* spp. The hunting of wild animals is usually preferred during the winter season and the extraction of *Paris* spp. is performed usually during February to June. However, such taboos are not observed by the non-locals, who come from other districts in the state. Therefore, they are not reluctant in hunting wild animals and hunt them as per their own will. The *Idus* regard tiger as their sibling born to the same mother and restrict themselves from hunting of tigers and other cat family species. Even, wild ungulate hunting is controlled by social taboos. However, mainly non-tribal peoples might poach tigers and engage in uncontrolled hunting as they aren't constrained by taboos. A detailed investigation is required to investigate the hunting of wild animals along with the extraction of *Paris* spp. by the non-locals.

c) The influx into the district

The Dibang Valley is inhabited by the Idu community only. As the valley has a low population, it is reasonable to import cheap labor from outside the district for developmental works. The laborers who are mainly brought in for carrying out the daily labor have resulted in an influx in the local population with the potential to impact the cultural identity of the Idu community and they have also started inhabiting the villages after marrying women in the community. This might lead to cultural conflicts with the locals in the future and have a huge impact on their identity, and the taboos observed by the indigenous tribal community. As the non-locals aren't bounded by taboos, it might lead to poaching of various wild animals from time to time. The Idu community, which has its unique history, identity, cultural norms, and traditional systems, might get affected if an uncontrolled influx of non-locals continues and is not restricted in time.

6.4 Tiger Reserve through community consensus

The abundance of tigers and other wild animals in this region is agreeable to all. In India, there are 50 tiger reserves distributed in 18 states that are directly administered under the project Tiger 1973 by National Tiger Conservation Authority (NTCA). Tiger reserve may be declared inside the protected area after boundary rationalization of the existing protected area with the community consensus. Such an initiative might have a positive impact on other indigenous communities and this must be initiated with the active involvement of the local community.

Undoubtedly, even after 20 years of the present DWLS administration, no proper boundary delineation of the sanctuary has been done to date. The present existing boundary is also an imaginary boundary and is in conflict with local people in many places. The forest department of Dibang valley district doesn't have enough manpower and logistic support. There is a need to settle the prevailing boundary dispute by rationalizing the boundary and recruiting more staff to strengthen the manpower of the forest department. Consultative meetings should be held between concerned government authorities, state forest department, and politicians before any further conservation reserve declarations are taken up.

6.5 Future research perspectives

This ecological baseline study has provided insight into the tigers, co-predators, and their prey species abundance as well as photo captured tigers in the highest elevation for the first time from the Mishmi Hills of the Indian part of Eastern Himalaya (IEH). The study highlights that a 55 % diet overlap exists between tigers and wild dogs. Due to the hunting of prey base of both the species, it is quite evident that this will further increase the incidence of Mithun predation. As mentioned, the predated livestock species, Mithun, is an important asset to the people of Arunachal Pradesh and forms an integral part of the tribes in the state. This study documented that a majority of respondents have a positive towards wildlife conservation. There are several scopes and avenues to carry forward this work in the future, such as:

a) A long-term study is required for the newly discovered high-altitude tiger habitats and to find out the active corridor to sustain the unique population in and around the landscape of DWLS.

b) A detailed long-term study on the wild dog and its ecological baseline are mandatory to enhance the adaptability patterns and its sympatric ecological impacts on the tigers, in and around the landscape of DWLS.

c) A long-term study is required to monitor the habitat types and migratory patterns of Mishmi takin and also study the ecology of forest-dwelling ungulates.

d) To study the human-wildlife interaction and develop management strategies for the negative interactions between humans and wildlife.

e) To document the local indigenous knowledge in detail for formulating any conservation policy.

f) A study of medicinal plants such as *Paris polyphylla*; *Coptis teeta* etc. an overexploited, patchily distributed, and economically important plant species in and around the DWLS.

g) To study the grazing patterns of Mithun and its food habits, and identify sustainable grazing land.

h) A long-term study and quantification of use, availability, and means of extraction of non-timber forest products (NTFP) by local communities to get a better understanding of their use pattern and resource need, to design management and sustainable use regime for long-term availability.

i) A study on the movement ecology of threatened species like tiger and Mishmi takin.

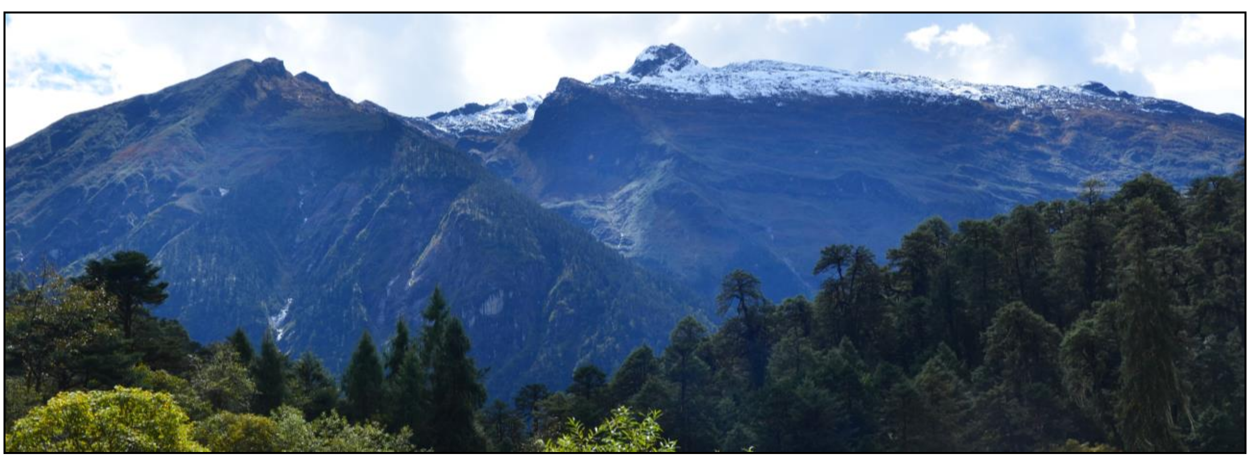


PLATE 1: Camera trap images of mammalian carnivore and forest dwelling ungulates in Dibang WLS

Tiger 1: Photo-captured inside DWLS at Tallon Valley

Tiger 2: Photo-captured inside DWLS at Enjoo Valley

Tiger 3: Photo-captured inside DWLS at Tallon Valley

Tiger 4: Photo-captured inside DWLS at Enjoo Valley

Tiger 5: Photo-captured outside the protected area in community forest at Mipi

Tiger 6: Photo-captured outside the protected area in community forest at Mipi

Tiger 7: Photo-captured outside the protected area in community forest at Mipi

Tiger 8: Photo-captured outside the protected area in community forest at Anini

Tiger 9: Photo-captured inside DWLS at Angi-pani Valley

Tiger 10 and 11: Photo-capture of tiger’s cubs inside DWLS at Tallon Valley

Clouded Leopard (*Neofelis nebulosa*)

Asiatic Golden Cat (*Catopuma temminckii*)

Marbled Cat (*Pardofelis marmorata*)

Leopard Cat (*Prionailurus bengalensis*)

Asiatic Wild dog (*Cuon alpinus*)

Spotted Linsang (*Prionodon pardicolor*)

Asiatic Black Bear (*Ursus thibetanus*)

Masked Palm civet (*Paguma larvata*)

Stone Marten (*Martes foina*)

Yellow-throated Marten (*Martes flavigula*)

Siberian Weasel (*Mustela sibirica*)

Yellow-bellied Weasel (*Mustela kathiah*)

Red Panda (*Ailurus fulgens*)

Otter species

Barking Deer (*Muntiacus muntjak*)

Gongshan Muntjac (*Muntiacus gongshanensis*)

Mishmi Takin (*Budorcas taxicolor taxicolor*)

Red Goral (*Naemorhedus baileyi*)

Himalayan Serow (*Capricornis s. thar*)

Wild Pig (*Sus scrofa*)

Assamese Macaque (*Macaca assamensis*)

Pallas's squirrel (*Callosciurus erythraeus*)

Rat spp

Sclater's Monal (*Lophophorus sclateri*)

Kalij Pheasant (*Lophura leucomelanos*)

Temminck'sTragopan (*Tragopan temminckii*)

Hill Partridge (*Arborophila torqueola*)

PLATES 2: Photos taken during the study period

Aerial view of Anini Town: The District headquarter of Dibang Valley district, Arunachal Pradesh

Traditional house of Idu Mishmi at Dibang Valley, Arunachal Pradesh


Traditional attires of Idu Mishmi during the Reh festival


The attires of Igu (shaman) during the ritual ceremony

Idu Mishmi Family, Dibang Valley

Informal discussion with local people

Semi domesticated Mithun

Traditional handlooms of Idu Mishmi

Camping during camera trapping at Tallon valley, Dibang Wildlife Sanctuary

Celebrating World Environment Day, Anini

Tree plantation in Anini

Nature Drawing Competition in Anini

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