ASPECTS OF ECOLOGY OF LARGE CARNIVORES AND THEIR PREY IN AND AROUND DIBANG WILDLIFE SANCTUARY, ARUNACHAL PRADESH, INDIA

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Summary

Background

The conservation of large mammalian carnivore is prioritized as it acts as keystone species across diverse zones of habitat around the globe. They play an important role in regulating and maintaining the abundance of ungulates, in turn influencing the functioning of the ecosystem. In the last few decades, large carnivore's population have been declining due to anthropogenic activities such as habitat destructions creating forest patch, illegal trade and hunting on wildlife. These threats posed a challenge in the conservation and management of large mammalian carnivores. The co-existence of large carnivores is occurring in many places in the wild due to the availability of less prey base, habitat fragmentation and high human interferences. Thus, the understanding of ecology of large carnivore and their prey species particularly on habitat selection, prey-predators' relations in aspects of distribution and abundance, such ecological data can be useful to evaluate not only their habitat requirement but will also aid in long term management of wildlife and conservation of their habitats. So, efficient conservation and monitoring of large carnivores such as tiger and wild dog (dhole) is required for the assessment of complex mix of ecological, ethical and symbolic inter-relationships.

Study Area

The study was conducted at Dibang Wildlife Sanctuary; it covers an area of 4149 km^2 and situated in Dibang Valley district of Arunachal Pradesh. The sanctuary is located at the northern part of Mishmi hills range in between 28° 38′ and 29° 27′ N latitudes and 95° 17′ and 96° 38′ E longitudes with altitude varying from 1800 to 5500 m amsl. The northern and eastern parts of Wildlife Sanctuary share an international boundary with the Tibet Autonomous Region. The Mishmi hills have a mountain type climatic condition. During summers, the average maximum temperature goes up to 24°C, and the average minimum temperature drops to 0°C. Dibang valley comes under the wet temperate forest type of vegetation classification of India. The sanctuary 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. The dominated tree species are *Michelia* spp., *Quercus lamellosa*, *Quercus* spp., *Magnolia* spp., *Castanopsis indica*, *Castanopsis* spp., *Acer hookeri*, *Alnus nepalensis*, *Populus ciliata*, *Abies* spp., *Tsuga dumosa*, *Rhododendron arboretum*, *Taxus baccata*,

and Pinus wallichiana, *Rhododendron* spp., *Saussurea* spp., *Sedum* spp. *Primula*, *Saxifraga* spp. Apart from this diverse vegetation, many endemic and rare medicinal plants, bamboo, wild banana, cane, and varieties of ferns are also reported. With the diverse vegetation, sanctuary and adjoining landscapes also harbor a high diversity of faunal species, including endangered, rare, endemic, and threatened faunal species like the Bengal tiger (*Panthera t. 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*).

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. Afterward, in the year of 2013-14 a preliminary rapid survey was carried out by the Wildlife Institute of India in collaboration with the National Tiger Conservation Authority, 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 sanctuary.

The primary objectives for the aspects of ecology of large carnivores and their prey in and around Dibang Wildlife Sanctuary are:

a) To estimate the abundance of large carnivores in and around the Dibang Wildlife Sanctuary,
b) Assess the abundance of wild prey in and around the Dibang Wildlife Sanctuary,
c) Assess the food habits and prey selectivity of large carnivores in and around the Dibang Wildlife Sanctuary, and
d) To quantify the extent of human-wildlife interaction in and around the protected area.

Methods

An intensive camera trapping exercise was carried out during October 2015 to June 2017 in the Dibang Wildlife Sanctuary and adjoining landscapes to monitor large carnivores and their prey species. Field work was conducted for six successive sessions during these years in different sampling river valley(s) of protected area and its adjoining landscapes. Prior to camera trapping, carnivore and ungulate sign surveys were conducted to estimate the encounter rate of tiger, wild dog and ungulate species. Afterward camera traps were deployed corresponding to the accessibility of the area. The 3 km^2 grid cell was overlaid, 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 to estimate the relative abundance indices of tiger, wild dog and prey species. Large carnivore scats were collected to obtained the food habits of both carnivore species. Questionnaire survey was administered to collect the data about human-carnivore interaction and the dependency of local communities on forest resources.

Results

A total of 112 camera trap were deployed in the two-year intensive camera trapping exercise which covered an area of 336 km^2 both inside and outside the protected area with total trap nights of 13,761. Within the protected area, 90 camera traps were deployed at area over of about 270 km^2 and 22 camera trap had monitored at outside sanctuary over an area of 66 km^2. 28 number of sign surveys were carried out with total efforts length of 231.85 km during 2015 to 2017. In the analysis, the photo-capture rates (photographs/100 days) were estimated for tigers, dhole and their prey species present only inside the protected area. The photo-capture rates of these sympatric mammalian carnivore and their prey 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 protected area.

The signs encountered rate of tiger (0.099 km^{-1}) was higher than wild dog (0.069 km^{-1}). Mean sign encounter rates of the tiger (p = 0.09) had no significance while wild dog (p = 0.00) were significant along these river valleys. Camera trap revealed that, the mean photo-capture rates of wild dog (1.19 ± 0.20) were higher than the mean photo-capture rates of tiger (0.34 ± 0.06). The mean photo-capture rates of the tiger (p = 0.02) were significance while wild dog (p = 0.22) were not significant.

For ungulate sign encounter rate, the barking deer (0.125 km^{-1}) was highest followed by wild pig (0.06 km^{-1}), Himalayan serow (0.06 km^{-1}), Mishmi takin (0.022 km^{-1}), and goral (0.009 km^{-1}). Among these ungulate species, only barking deer (p = 0.04) sign encounter rates were significant. The mean photo-capture rates of barking deer (2.99 ± 0.47) were highest 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). While barking deer, red goral and Mishmi takin were significant along the different valleys in different temporal scale, while the photo-capture rates of Himalayan serow and wild pig were not significant.

47 scats of tigers, and 38 of wild dog were used to estimate the food habits and prey selection. Six prey remains such as Mishmi takin, serow, goral, wild pig, barking deer and rodent were identified and 82.98% (n=39) were found only single prey items and 17.02% (n=8) had two prey items of prey species composition from tiger scats. While Mishmi takin, serow, goral, barking deer, mithun, and rodent were identified and 86.84% (n=33) were single prey items, 10.53% (n=4) had two prey items and 2.63% (n=1) were found more than two prey items from wild dog scats.

Goral, serow and Mishmi takin remain as the highest in frequency of occurrence (%) and biomass contribution in the diet composition of tiger and wild dog. According to generalized model (Chakrabarti *et al.,* 2016), goral contributes highest both in frequency of occurrence (46.81%) and relative proportion of diet (37.74%) to the tiger diet. In contrast, the linear model (Ackerman *et al.*, 1984), frequency of occurrence was highest for goral (46.81%) followed by serow (24.47%) and takin (19.15%) but in relative proportion of tiger diet, Mishmi takin (44.87%) was highest, followed by goral (25.82%) and serow (23.09%). For wild dogs, according to Floyd *et al.*, 1978 equation, rodent spp. (46.97%) had the highest frequency of occurrence (in percentage) 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%).

Likelihood ratio test reveals that significant prey selection for tiger i.e., χ^2=43.31, df=5, p<0.01 and wild dog i.e., χ^2=43.31, df=5, p<0.01. Generalized model revealed that serow and gorals were consumed more than their availability while Mishmi takin, wild pig and barking deer was less consumed than its availability. Linear model showed 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. Both tiger (B_{sta} = 0.4258) and wild dog (B_{sta} = 0.4205) had medium diverse dietary niche breadth *i.e.*, neither generalist nor specialist. In case of dietary overlaps, 50 % overlaps among the diets of tiger and wild dog. However, no significance overlap was observed in prey item of tiger and wild dog in the scats

The temporal activity profile of tiger and wild dog was nocturnal and diurnal respectively. The mean activity time of tiger was at 23:29 ± 01:34 hrs. with 95% confidence interval (CI) of 20:25-02:34 hrs. The activity pattern of tiger was distributed un-uniformly (Rayleigh Z = 2.91, *p* = 0.054) and the intensity of activity throughout different times of the day was significant difference (Watson's U^2 = 0.191, *p* <0.05). On the contrary, wild dog's mean activity time was at 10:52 ± 00:26 hrs with a 95% confidence interval (CI) of 10:00-11:43 hrs. Wild dog activity was not uniformly distributed (Rayleigh Z = 33.208, *p* <1E-12) and the intensity of activity during different times of the day was significant difference (Watson's U^2 = 1.807, *p* <0.005). For temporal activity profile of ungulate species, barking deer and red goral were crepuscular. Barking deer and red goral shown the mean activity time from 17:58 ± 00:16 hrs. and 06:38 ± 02:42 with 95 % confidence interval (CI) of 17:26-18:31 hrs. and 01:20-11:56 hrs. respectively. Barking deer was un-uniformly distributed throughout the activity day (Z= 82.84, *p* <1E-12) whereas red goral had distributed uniformly in their activity pattern (Z= 0.993, *p* = 0.37) and both the ungulate species had significant difference in their activities. While 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. The distribution patterns of both species were not uniformly distributed all throughout the day and significant difference in the activities patterns. Wild pig showed a typical diurnal and its mean time activity range from

07:05 ± 00:28 hrs. with 95 % confidence interval (CI) of 06:09-08:01 hrs. The wild pig was distributed un-uniformly and significant difference during the activity.

Information on human wildlife interaction were collected from 104 households in the 28 villages of Mipi and Anini circle through semi-structure questionnaire surveyed. Interview covered on average 50-100% of the households from each village in those two circles of the district which situated around the protected area.

Among the indigenous Idu Mishmi community, most of them follow animism and believe in the presence of spirits in their natural surroundings. Among the respondents, 29.81% were government employees, 19.23% were unemployed, 11.54% farmer, 9.62% contractor, 7.69% gaon bura, 4.81% social worker, 4.81% retired government employee, 2.88% business, 2.88% housewife, 2.88% professional hunter, 1.92% craftsman, 0.96% carpenter and 0.96% priest.

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%). Rice (26.02%), Mishmi dal (23.98%), maize (18.88%), millet (18.88%), vegetables (10.20%), soybean (1.02%) and potatoes (1.02%) are cultivated crops in agriculture. 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%). Horticulture is also practiced and the horticultural plants cultivated are apple (39.13%), kiwi (26.09%) orange (26.09%) and cardamom (8.70%).

Mithun is the main livestock reared by Idu Mishmi and is an integral part of the social and cultural activities of the Idu community. Pig is the second most important animal reared, and meat is served especially in the traditional or cultural ceremonial feast of the Idu community.

Though 81.71% of inhabitants were using liquefied petroleum gas (LPG) for cooking, more people were into collecting firewood (96%). 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%).

Crop damage, predation of Mithun and wild animals hunting were frequent in and around the Dibang Wildlife Sanctuary. On average, 65.7% of households were affected due to crop damage mainly by wild animals. 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. 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%). 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.

Predation of Mithun by wild animal 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. 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. 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. No species of livestock, other than Mithun, have reportedly been predated upon.

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. 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 pig (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%).

The household surveys revealed positive perceptions and attitudes towards wildlife conservation, 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. 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. In the surveyed villages, 59.6% of respondents believed in tiger conserved by traditional taboos, 18.3% were negative responded and 22.1% were unaware but comparatively conservation through taboos have higher percent than overall positive responded values.

Conclusion: Dibang Wildlife Sanctuary and its adjoining landscape harbors sizable population of large carnivores such as tiger and wild dogs. The study has reported the first photographic evidence of tiger presence from the community forest of Mishmi hills range 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. Good number of wild dogs' population were also recorded with maximum of 4 numbers of individuals in a pack. The sanctuary has also recorded five prey species of tiger and wild dog with unique prey base i.e., Mishmi takin. 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, wild dog and prey species 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. 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.

The study has confirmed the presence of five ungulates species from the temperate forest of Dibang Wildlife Sanctuary, which proves that the sanctuary has a diverse prey base for large carnivores. The presence of endangered Mishmi takin (*B. t. taxicolor*), near threatened red goral (*N. baileyi*), Himalayan serow (*C. s. thar*), wild pig (*S. scrofa*) and barking deer (*M. muntjak*) makes this area an important region for the long-term conservation. Two species of muntjak were found, one is Indian or Red muntjac (*M. muntjak)* and another is Gongshan or Black muntjak (*M. gongshanensis crinifrons*). 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, Pakke Tiger Reserve with ten ungulates species, Khangchendzonga Biosphere Reserve with seven mountain ungulates, and Dhorpatan Hunting Reserve of Nepal with seven species of ungulates. Such diversity of ungulate species promotes coexistence of tiger and Asiatic wild dog (dhole) in Dibang Wildlife Sanctuary.

Idu Mishmi community has a strong cultural bond with the tigers as a brother, the hunting pressure on tigers is not anticipated. Hunting of other felids species are also 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. However, strict taboos are observed by the hunter, their family members, and anyone who consumes wild meat. Women do not consume wild meat; they can only consume birds, pheasants, rodents, and observe the same set of taboos. Such primeval traditions observing taboos of hunting and consuming aren't allowed to hunt in excess. They need to follow specific rules and regulations before hunting expedition as well as after hunting practices. Thus, the wild animal populations in this valley are protected directly or indirectly by traditional taboos. Hence, the people are claiming that the wild animal populations are fully protected by such practices since ancient time. The Idus are proud of such status and without such taboos, traditional protection, restriction by their community, without having a kinship with tiger, the survival of tiger in Dibang Valley district is questionable.

Aberration

AMSL = Above mean sea level

CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora

cm = centimetre

DWLS = Dibang Wildlife Sanctuary

FAP = Fast as possible

GPS = Global Positioning System

Hrs = Hours

ITBP = Indo-Tibetan Border Police

IUCN = International Union for Conservation of Nature

kg = kilogram

km^2 = Square kilometre

LRPs = Long-range patrolling route

m = Meter

mm = millimetre

NTCA = National Tiger Conservation Authority

NTFP = Non-timber forest products

PA = Protected Area

SE = Standard error

ST = Schedule Tribes

TCLs = Tiger Conservation Landscapes

WII = Wildlife Institute of India

DEM = Digital elevation model

TR = Tiger Reserve

WLS = Wildlife Sanctuary

RAI = Relative Abundance Index

GIS = Geographic Information System

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CHAPTER I

INTRODUCTION

1.1 Background

Around the globe, the conservation of large mammalian carnivore has been on top priority as they act as keystone species across diverse zones of habitats (Wang and Macdonald, 2009). The mammalian carnivores play an important role in regulating and maintaining the abundance of ungulates, in turn influencing the functioning of the ecosystem (Ripple *et al.,* 2014). However, large carnivore populations have been declining since the last two hundred years largely as a result of accelerated habitat destruction (Linnell *et al.,* 2001; Woodroffe, 2000). This decline has exacerbated in the last few decades due to human induced anthropogenic activities such as habitat destruction, creates forest fragmentation, illegal trade and hunting on wildlife (Harrison and Bruna, 1999; Saunders *et al.,* 1991). Continued decline in prey population and habitat degradation may lead to high migration and mortality rate. Habitat fragmentation threatens the existing wildlife population by deceasing the connectivity between the habitats, and thus severely affect population dynamics, increases inbreeding depression, impresses the local extinctions and decreases community resilience (Moilanen and Hanski, 1998; Sankar *et al.,* 2013). Illegal trade and poaching is another major driver of species extinction (Karanth and Sunqusit 1995). Around US$ 8 – 10 billion per year are approximated from the illegal trade of wildlife species through poaching in the international market (Lawson and Vines, 2014). These threats pose a challenge in the conservation and management of large mammalian carnivores.

These mega-carnivores exhibit niche differentiation and resource partitioning (Selvan *et al.,* 2013a), which allows them to survive in a resource restricted environment and increase the chances of survival (Bekoff *et al.,* 1984; Caro and Stoner, 2003). The co-existence of large carnivores is occurring in many places in the wild due to the availability of less prey base, habitat fragmentation and high human interferences (Gittleman and Harvey, 1982; McCarthy and Chapron, 2003). Large mammalian carnivores mainly prey on large ungulate species (Karanth and Sunquist, 1995), however few studies have suggested prey selection according to different size class to nurture coexistence of mega-carnivores in same area. Differential activity pattern also aids in co-existence (Hayward and Slotow, 2009). Large carnivores follow different patterns of predation as per the availability of prey, prey behaviour, morphology, habitat selection and other major factors like presence of sympatric carnivores (Bakker, 1983; Kruuk, 1986). Co-existence of large carnivores are facilitated due to differential use at different tropic level, different activity pattern in space and time and resource partitioning (Karanth and Sunquist, 1995; 2000). Such co-existence is cause and effect of inter or intra specific interaction between the species owing to stochastic effects has, however, been the subject of debate (Schoener, 1982). Many theory was adopted to explain the predations pattern and prey selectivity. Such theories concern cost and energetic benefits and proximate mechanism of prey selection (Griffiths, 1975; Curio, 1976; Taylor, 1976; Stephans and Krebs, 1987; Temple, 1987; Karanth and Sunquist, 1995). Large mammalian carnivore prey selection is a complex phenomenon (Sunquist and Sunquist, 1989), recent studies have examined large carnivore predation in animal communities of temperate zone forests (Huggard, 1993; Ripple *et al.*, 2010) and of tropical savannas (Stander and Albon, 1993; Nordberg and Schwarzkopf, 2019) has indicated that the prey population may be maintaining by the large mammalian carnivores in this stable environment. However, ecological studies on prey predators' relationship have been minimal in these habitats as well as tropical forests (Schaller, 1967; Johnsingh, 1983; Karanth and Sunquist, 1995). In the tropical forest prey selection pattern by large carnivore are poorly understood (Karanth and Sunquist, 1995).

Thus, the understanding of ecology of wild animal species particularly on habitat selection, prey-predators' relations in aspects of distribution and abundance (Tejeda-Cruz *et al.,* 2009) is important. Such ecological data can be useful to evaluate not only their habitat requirement but also will aid in long term management of wildlife and their habitats (Sankar *et al.,* 2013). Taking the foregoing discussion into consideration, efficient conservation and monitoring of large carnivores such as tiger and dhole have required the assessment of complex mix of ecological, ethical and symbolic inter-relationships (Kellert *et al.,* 1996).

1.2 Tiger

The tiger is a large and wide ranging cat that occupies a broad range of habitats in Asia. It is a top predator and charismatic animal in the world, consistently drawing global attention and conservation efforts. In the ecosystem pyramid, tigers are regulating and perpetuating ecological processes and system. Nine tiger subspecies have been identified globally, based on morphometrics, characteristics of the pelage and stripe patterns (Hemmar, 1987; Herrington, 1987), *viz*., 1. Bengal tiger (*Panthera tigris tigris)*, 2. Amur tiger (*Panthera tigris altaica)*, 3. South China tiger (*Panthera tigris amoyensis)*, 4. Indochinese tiger (*Panthera tigris corbetti)*, 5. Malayan tiger (*Panthera tigris jacksoni)*, 6. Sumatran tiger (*Panthera tigris sumatrae*, 7. Balinese tiger (*Panthera tigris balica)*, 8. Javan tiger (*Panthera tigris sontaica)* and 9. Caspian tiger (*Panthera tigris virgate).* Among these nine subspecies, the Balinese tiger, Javan tiger and the Caspian tiger went extinct in the 1940s, 1980s and 1990s respectively (Seidenticker, 1997, Sunquist and Sunquist, 2002, Tilson *et al.,* 2004). Perhaps, the variability among the subspecies is due to environmental, physiological and ecological factors.

1.2.1 General description

Panthera t. tigris is the second largest of all extant subspecies. It has pelage of light tawny to deep ochre or orange, with white patches in the underparts of the abdomen, around the eyes, cheek and inner limbs. Distinct black stripes with patterns showing considerable variation are unique to each individual. The tiger has a strong skeletal structure but light, and designed for high speed and alertness. They possess the excellent ability to detect the movements of prey and judge the distance, particularly at low light levels. This is due to the morphological structure of large, round, forward facing eyes and acute sense of hearing. However, the sense of smelling is used for the detecting scent from the ground or vegetation which attracts or repels other tigers and helps maintain their respective territory. Tiger, like other felids, possess several glands which secretes scent from their anal region, tail, toes and around their cheeks (Ewer, 1985). Body length is of 270-310 centimeter (cm) and weighs about 175-200 kilogram (kg) for the male tiger, whereas a female tiger has 240-265 cm body length and weighs around 100-160 kg, thus, showing substantial sexual dimorphism. Height at the shoulder is 90-110 cm. Male tiger matures at 4.8 years for the first reproduction and female tiger matures at 3.8 years.

The gestation period is 106-112 days. Generally, litter size is 1-7 cubs but most of the time 1-2 is common. The lifespan of a tiger is around 12 to 15 year in the wild.

1.2.2 Geographical distribution

Tigers were widely distributed throughout Asia, in the western up to Turkey and the eastern coast of Russia (Nowell and Jackson, 1996). They are native to India, Bangladesh, Nepal, Bhutan, China, Russia, Indonesia, Lao, Malaysia and Thailand. Tigers inhabits varied geographical areas of different vegetation types. They thrive in the dry forests of India and Indochina to the tropical rainforests of Sumatra and Malaysia and mangroves forest of Sundarbans in India and Bangladesh to the taiga forests of China and Russia Far East (Chundawat *et al.,* 2012).

In India it extends up to the Indus river valley of Pakistan (Seidensticker, 1997). Presently, 2967 tigers are distributed across 50 Tiger Reserves over 20 Indian states, which translate >80% of global population of tigers (Jhala *et al.,* 2020). In the few pockets of forest of Goa, Manipur, Nagaland, Meghalaya, and Haryana, occasional tiger sightings have been reported (Chundawat *et al.,* 2012). Although in global scenario, the tiger populations are still declining (Rao *et al.,* 2005) and they now occupy only less than 7% of their global historical range (Dinerstein *et al.,* 2007).

1.2.3 Conservation status and threats

Tiger is listed as an endangered species in the Red List of Threatened Species, International Union for Conservation of Nature (IUCN) (2015). It is also listed in Appendix I given by Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and Schedule I by Indian Wildlife (Protection) Act, 1972. It shows that tiger conservation has always been a priority in wildlife conservation. "Global Tiger Recovery Plan" was initiated by the 13 tiger range countries in 2010 to increase the number of present wild tiger population to double in 2022, popularly known as "TX2". Nevertheless, despite of these global efforts, breeding tiger populations occur only in eight countries *viz*., India, Bangladesh, Nepal, Russia, Indonesia, Lao People's Democratic Republic, Malaysia and Thailand (Walston *et al*., 2010). In fact, 41% of tiger's habitats have declined since 2006 and vanished tigers from central and southwest Asia in the past 100 years (Goodrich *et al.,* 2015). Habitat loss, poaching of tigers and their prey are menace to its survival (Nowell and Jackson, 1996; Chapron et al., 2008).

Anthropogenic pressure resulting from development often lead to conversion of forest land into commercial logging, agriculture land, and human settlements, these contribute to habitat loss of tiger and its prey (Hanski, 2011). Tiger poaching for trade in the pressure of demand of their body parts including skins, bones, meat and tonic for uses in Traditional Chinese Medicine (TCM), which led to blink wild population (Ellis, 2013). 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.

1.3 Dhole (Asiatic wild dog)

Dhole is native to the Asian continent. Primarily pack living large canid, a major predator and one of the least studied social carnivore in the wild (Johnsingh, 1982). They are found in wide range of forest types even in disturbed forest area. Based on the dentition and body size, dholes were distinguished into two species *viz., Cuon alipinus* (the northern dhole) and *Cuon javanicus* (the southern dhole) (Mivart, 1890). However, Ellerman and Morrison-Scott (1951) recognized 10 sub-species of dhole in the world, later revised to nine (*Ibid.* 1966), and in 1990 Ginsberg and MacDonald identified 11 sub species across the world. Dholes have lost more than 75% of its historical distribution range due to habitat loss, declining prey base, retaliation killing due to livestock depredation and disease transmission from domestic dog (Kamler *et al.,* 2015).

1.3.1 General descriptions

The morphology of wild dogs varies in size and colour regionally (Sheldon, 1992; Mennon, 2003). In India, the northern wild dogs are slightly larger than the southern ones (Johnsingh, 1982) and the recognition of individuals is very difficult due to uniform coloration (Kotwal, 1981). Seasonally, wild dogs have distinct colour coats with long and furry coats with a dense under coat during winters (Novikov, 1962; Clutton-Brock *et al.,* 1976). Wild dogs have some resemblance to red, village pariah dogs except for the black bushy tail, slightly more rounded and furry, ears and more convex face profile (Johnsingh and Manjrekar, 2013). Occasionally, some wild dogs have tuft of white or grey at the end of the tails (Brander, 1923; Cohen, 1977; Prater, 1980; Fox, 1984). On an average, females are slightly lighter than males (Cohen, 1977; Prater, 1980; Johnsingh, 1982; Fox, 1984). The average weight of the males is 15-20 kg whereas the females weigh 10-13 kg (Sosnovskii, 1967; Cohen *et al.,* 1978). Body length is 80-113cm and tail length 40 to 50 cm. The legs are long and slender (Novikov, 1956; Stroganov, 1962; Mennon, 2009). Sexual dimorphism is not very distinct (Novikov, 1962; Prater, 1980; Johnsingh, 1982). Dholes mature in about one year; the gestation period is 60-62 days (Burton, 1940; Sosnovskii, 1967). Litter size vary: 2-6 (Burton, 1940), 4-6 (Sosnovskii, 1967), 5 (Inverarity, 1901), 6 (Hood, 1895), 7-9 (Adams, 1949), 11 (Middleton, 1951), 7.3 ± 1.9 (Venkataraman *et al.*, 1995). Female has 14 to 16 mammae instead of usual 10 found in *canids* (Pocock, 1936; Krishnan, 1972; Cohen *et al.,* 1978). The life span of dholes in captivity have been reported at 15-16 years (Sosnovskii, 1967).

1.3.2 Geographical distribution

Historically, the distribution of dholes extended throughout eastern and central Asia (Sheldon, 1992), predominantly south, east and Southeast Asia (Durbin *et al.*, 2008). From the far north, where they occurred up to the southern parts of the Russian and to the far west, to the mountain ranges in eastern Kazakhstan to northern Pakistan including the western Himalayan mountains (Heptner and Naumov, 1967). They inhabited a wide variety of habitat types such as tropical dry forest to moist deciduous forest; evergreen to semi evergreen forests; temperate forests; boreal forests; dry thorn forests; grassland–scrub–forest and alpine region (Kamler *et al.*, 2015). Asiatic wild dogs are native to India, Nepal, Bhutan, Bangladesh, Myanmar, China, Indonesia, Lao PDR, Malaysia, Cambodia, and Thailand. Dholes are possibly extinct from Vietnam (Kamler *et al.*, 2015).

Currently, it is distributed in central and eastern Asia, India, Nepal, Bhutan, Bangaladesh, Indochina, Myanmar, Indonesia and Malaysia. *C. a. alpinus*: found in Eastern Russia, including Amur, *C. a. adustus*: found in Northern Myanmar and Indo-China, *C. a. dukhunensis*: found South of the Ganges in India, *C. a. fumosus*: found in Western Szechuan, China and Mongolia, *C.a infuscus*: found in Southern Myanmar, Malaysia, Thailand and Vietnam, *C. a. javanicus*: found in Java, *C. a. laniger*: found in Kashmir and Southern Tibet, *C. a. lepturus*: found South of the Yangze in China, *C. a. primaevus*:

found in Himalayan regions of Nepal, Sikkim (India) and Bhutan, and has long hair on the paws *C. a. sumatrensis*: found in Sumatra, *C. a. hesperius*: found in Eastern Turkestan, Southern Siberia and Western China. In India, wild dogs are widespread *canids* in several regions and the country nurture certainly the largest numbers of dholes globally. Prater 1980 reported the three subspecies of wild dog in India. Based on morphology, Ginsberg and Macdonald, (1990) recognized four subspecies in India. Karanth *et al.,* (2009) study shows that the wild dogs populations are relatively high in the forests of Western Ghats and Central India compared to Eastern Ghats. In the Northern India, wild dogs are reported from the Terai landscape (Karanth *et al.,* 2009) and Ladakh (Kamler *et al.,* 2015). In the northeastern region, wild dogs are reported from Sikkim (Bashir *et al*., 2014) and Arunachal Pradesh (Selvan *et a*l., 2013a) however, populations are low due to low prey species and retaliatory killings from livestock depredation (Gopi *et al.,* 2010). Direct encounters of wild dogs are frequently reported by local villagers in Itanagar Wildlife Sanctuary, Arunachal Pradesh (Aiyadurai and Verma, 2003). While indirect evidences indicate presence of wild dogs in Namdapha (Datta *et al.,* 2008).

1.3.3 Conservation status and threats

Asiatic wild dogs are categorised as Endangered species under the IUCN and Appendix II in CITES. In India, the Wildlife (Protection) Act 1972 lists wild dog as a Schedule II species. The species is protected from hunting, unless prior permission is granted by the Chief Wildlife Warden of the state. In Russia, wild dogs are granted as “Protected Animals”. Similarly, in Vietnam, wild dogs are insured by Decree18/HDBT and the amendment Decree 48/2002/ND-DP under category IIB, which limits extraction and utilization. Population of wild dog is particularly vulnerable to extinction due to the anthropogenic pressure, particularly habitat loss and hunting. Wild dogs have been facing tremendous pressure from humans in the form of poisoning, den digging and killing of pups (Fox, 1984; Johnsingh, 1984), a pack of wild dog died by strychnine in southern India (Durbin, 2004). Prey depletion by humans in terms of poaching one of the major reasons for dhole population decline (Fox, 1984). The major prey of dholes, the barking deer are severely depleted by hunting by the local tribes in Arunachal Pradesh (Aiyadurai, 2007**).** Road mortality due to highways passing through the wildlife habitats is also possible reason for dhole population decline (Durbin, 2004; Woodroffe and Ginsberg, 1998). Tigers and leopards often kill dhole (Venkataraman *et al.,* 1995). In south India, stealing of the prey by Kurumba tribes was a major problem for dholes (Macdonald, 2004). Dholes are also often subjected to diseases such as rabies, trypanosomiasis, canine distemper which causes mortality (Morris, 1942; Davidar, 1975).

1.4 Study justification

The Dibang Wildlife Sanctuary (DWLS) is one of the most biologically diverse regions in the Indian part of the Eastern Himalaya. However, detailed studies on the status, ecology, inter-specific relationships and competition among large carnivores in the area is lacking. This necessitates an in-depth study of large carnivores such as tiger, wild dog and their prey in the area. In 2014, a pilot survey was conducted in DWLS by the Wildlife Institute of India (WII) and National Tiger Conservation Authority (NTCA) to monitor tiger and their prey populations. This preliminary study was carried out after the rescue of tiger cubs from the district in Angrim valley in December 2012. This was a first ever report of a tiger from the Dibang Wildlife Sanctuary (Gopi *et al.,* 2014). According to the report, the district has a unique landscape in having tiger population at high altitude temperate forests in the Eastern Himalaya; which indicates tiger presence in nearby similar areas, calling for further studies in those areas. The outcome of this study will be immensely useful for the sanctuary administration for conservation and management of these species and their habitats.

1.5 Objectives

The primary objectives for the aspects of ecology of large carnivores and their prey in and around Dibang Wildlife Sanctuary are:

a) To estimate the abundance of large carnivores in and around the Dibang Wildlife Sanctuary.

b) Assess the abundance of wild prey in and around the Dibang Wildlife Sanctuary.

c) Assess the food habits and prey selectivity of large carnivores in and around the Dibang Wildlife Sanctuary.

d) To quantify the extent of human-wildlife interaction in and around the protected area.

1.6 Key questions

a) What is the population status and distribution of large carnivores in and around Dibang Wildlife Sanctuary?

b) What is the population status and distribution of prey in and around Dibang Wildlife Sanctuary?

c) How do the different carnivores partition their resources spatially and temporally?

d) What is the status of awareness, attitudes and perceptions among local community about large carnivores' conservation?

1.7 Hypothesis

Objective a): Abundance of carnivores in and around Dibang WLS.

Variable	**Hypothesis**	**Supporting literatures**
H-1: Prey density	Spatio-temporal distributions of large carnivores exhibit a pattern consistent with the distribution of major prey species.	Salek *et al.*, 2010, Ramesh *et al.*, 2011
H-2: Trophic release	Low apex predators' abundance is associated with greater abundance of herbivores.	Brashares *et al.*, 2010, Oksanen *et al.*, 2011 and Brodie *et al.*, 2013.

Objective b & c: Prey selection among the carnivores

Variable	**Hypothesis**	**Supporting literatures**
H-3: Prey size	Large carnivores differentially select prey size to facilitate resource partitioning.	Karanth and Sunquist 1995; Radloff and Du Toit 2004; Kamler *et al.*, 2012.
H-4: Dietary overlap	Greater dietary breadth and lesser dietary overlap among large carnivores facilitate resource partitioning.	Azevedo *et al.*, 2005; Andheria *et al.*, 2007; Selvan *et al.*, 2013a.

Objective d: Human- Wildlife Interaction

Variable	**Hypothesis**	**Supporting literatures**
H-5: Livestock depredation	Depredation is higher in areas of low prey densities.	Biswas and Sankar, 2002
H-6: People perception	Peoples' perception of a carnivore in conflict is likely to be influence by (and in turn influence) their attitude towards the carnivore species.	Suryawanshi *et al.*, 2013; Lyngdoh *et al.*, 2014.

1.8 Organization of thesis

The thesis is organized into eight chapters. Chapter I deals with the preamble of the study, objectives, study justification, key research questions and hypothesis of the study. Chapter II deals the review of literature of the targeted species. Chapter III describes the study area in detail, providing biogeography and historical background. Chapter IV deals with the estimation of the abundance of large carnivores in and around the Dibang Wildlife Sanctuary. Chapter V discusses the abundance of their prey in and around the Dibang Wildlife Sanctuary. Chapter VI highlights the food habits and prey selectivity of large carnivores in and around the study area. Chapter VII discusses about the human-wildlife interaction in and around the protected area. Chapter VIII reveals the conservation implications of the study and recommendations for future conservation and management.

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CHAPTER II

LITERATURE REVIEW

2.1 Tiger

Tiger is believed to have originated from the East Asia (Herrington, 1987; Mazak *et al.*, 2012); and took two major dispersals about two million years ago. Tigers migrated towards north-west by passing through woodlands and they took the path of river banks towards South-West Asia. To the South and South-West, some tigers took dispersal and moved to continental South-East Asia, crossing to Indonesia Islands and other finally arrived in India (Nowell and Jackson, 1996). Tigers came pretty late in the Indian sub-continent with no evidence of their presence in Sri Lanka; a land totally cut off by rising sea levels at the beginning of Holocene (Kitchener, 1991). Tigers had colonized in India either coming through Northeast Asia via Central Asia, or through north-west India (Heptner and Sludskii, 1992). At present, there are about 160 distinct and fragmented populations of tiger's distribution range, which have been designated as Tiger Conservation Units (TCUs) (Chundawat *et al.,* 2012). Like different features of human beings, each tigers have unique identity and their distinguishing features mainly include four parameters *viz.*, body size, stripe patterns and color of the pelage, and skull characteristics (Kitchener, 1991). Even within the sub-species population of tigers there are wide variation in coat color and markings can be pointed out (Heptner and Sludskii, 1992).

Tigers, leopard and dholes 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 use of the habitat (Johnsingh, 1992; Karanth and Sunquist, 1995).

General ecology of tiger, habitat selection, home range, tiger on human dominated landscape and interaction with human were studied in their distribution range (Seidensticker *et al.,* 1999). In India various aspects of tiger ecology were focused and widely documented on general ecology of tiger (Schaller, 1967; Johnsingh, 1983; Seidensticker and McDougal, 1993), prey selection (Karanth and Sunquist, 1995; Biswas and Sankar, 2002; Bagchi *et al.*, 2003; Majumden *et al.,* 2012), food habits

(Schaller, 1967; Johnsingh, 1983; Stoen, 1994; Sankar and Johnsingh, 2002; Uma Ramakrishnan *et al.,* 1999; Andheria *et al.,* 2007; Selvan *et al.*, 2013a), social organization (Sunquist, 1981), population dynamics and land used system (Panwar, 1979; Smith *et al.,* 1987; Gogate and Chundawat, 1997; Vanak, 1997), dispersal and communication and its effect on prey species (Tamang, 1983; Karanth, 1993), the response of the tiger to the removal of anthropogenic disturbances (Harihar *et al.*, 2009a), tiger-leopard interaction (Seidensticker, 1976), and population estimation (Karanth, 1999; Jhala *et al.*, 2011; 2015; Ramesh *et al.*, 2011). The above mentioned studies give an overview of tiger ecology from only some of the habitats where it occurs.

2.1.1 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). Luo *et al.*, (2004) recognized six sub-species of tigers based on distinctive molecular makers. Recently, the IUCN SSC Cat Specialist Group revised the sub specific 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).

2.1.2 Distribution

In the past, the tiger was widely distributed across Asia (Nowell and Jackson, 1996). However, only in 1994 an assessment was held to define the tiger range based on the its present and past distribution range (Dinerstein *et al.*, 1997). Afterward, every ten years this assessment was carried out to revised and updated in defining TCLs which give the importance to records the actual tiger presence and breeding population (Sanderson *et al.*, 2006). In a shocking surprise, tiger population has lost over 93% of their historic range globally (Sanderson *et al.*, 2006; Walston *et al.*, 2010). However, their resilience character to adaptability and high fecundity, has allowed them to survive the massive onslaught and habitat loss of the past century (Kawanishi, 2002). Currently, tigers are found in 13 Asian countries *viz.,* India, Nepal, Bhutan, Bangladesh, China, Myanmar, Russia, Cambodia, Indonesia, Vietnam, Malaysia, Lao People's Democratic Republic and Thailand. They may persist in North Korea but no record is available in the public domain (Goodrich *et al.*, 2015).

2.1.3 Feeding and breeding ecology

Prey availability drives the carnivore abundance and its ecology therefore, the understanding of feeding ecology and behavioral flexibility of felids in prey selection is essential to ensure their conservation. (Schoener, 1974; Pokheral and Wegge, 2018). Tiger as large carnivore predators, establish the physical features to kill and predations on large prey base along with physical abilities and appropriate patterns of behavior in the evolutionary account (Turner, 1997). Tiger have to hunt large ungulate prey solitarily, as the evident from their evolutionary history of tigers (Seidensticker, 1997; Johnsingh and Manjrekar, 2013). In India since the early 1980's, studies on the feeding ecology of tigers have been conducted in Central India (Schaller, 1967; Biswas and Sankar, 2002; Edgaongar, 2008), Southern India (Johnsingh, 1983), Northern India (Harihar, 2005), Western India (Bagchi *et al.*, 2003; Avinandan *et al.*, 2008) Eastern India (Khan, 2008), and Northeast India (Selvan *et al.,* 2013a). Neighboring countries like Nepal (Sunquist, 1981; Stoen and Wegg, 1996) and Bhutan (Wang, 2008) have also been studied.

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 and 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 and 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.*, 2013a). They mate throughout the year; the peak period of natal time 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 and Manjrekar, 2013).

2.1.4 Population ecology

In India, the estimates of a countrywide tiger population started in 1972 through pugmark methods (Panwar, 1979). However, the pugmark technique of estimating tiger numbers was later discontinued due to the 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 and Nichols, 1998). In a nationwide survey, the tiger population within the North-Eastern Hills and Brahmaputra plains in 2006 was estimated to be 100 (84-118) tigers, 148 (118-178) tigers in 2010, 201 (174-212) tigers in 2014 and 219 (194-244) tigers in 2018 (Jhala *et al.,* 2020). This estimation shows that the tiger population shows an increasing trend in the North-Eastern Hills and Brahmaputra plains from 2006 to 2018. The North-Eastern hills tiger populations were identified under the conservation priority, based on genetic uniqueness, diversity, and vulnerability (Kolipakam *et al.*, 2019).

2.2 Dhole or Asiatic Wild Dog

Dhole are pack living animals and belonging to the genus *Cuon* (Johnsingh, 1983). Based on the fossils remains of dholes, the possible origin of *Cuon* is considered to be post-Pleistocene (Thenius, 1954) which were widely abundant across the range of North America, Europe and Asia (Cohen, 1977). But the fragmented dhole's population are now confined to South, East and Southeast Asia (Kamler *et al.,* 2015). So far, a very limited long-term studies have been conducted on this species (Gopi *et al.,* 2010). To supplement the basic information given by earlier studies on dhole's ecology (Johnsingh, 1982; 1983; Karanth and Sunquist, 1995; Venkataraman *et al.*, 1995; Acharya., 2006; Gopi *et al.*, 2010), more information on inter-specific relationships *viz.*, competition and niche separation between dhole and other large carnivores, such as tiger and leopard, would be of relevant conservation value.

2.2.1 Taxonomy

Dhole (*Cuon alpinus*) belong to the genus *Cuon* (Hodson, 1838) in the family *Canidae* (Simpson, 1945). The genus *Cuon* is closely allied to extant jackals and then to wolves (Thenius, 1954) often misplaced with domestic dogs (*Canis familiaris*). However, they are easily discerned from the genus *Canis* by the more rounded ears and proportionately shorter muzzle (Burton, 2003) with two molars on each side of the lower jaw, instead of three (Johnsingh, 1984; Burton, 2003). *Cuon* have differentiated into two species of *viz.*, *Cuon alpinus* and *Cuon javanicus* based on their body size and dentition (Mivart, 1890).

Ellerman and Morrison-Scott, (1966) and Stains (1975), however, recognized 10 subspecies; later Ginsberg and Mac Donald revised to 11 subspecies across the world.

2.2.2 Distribution

Dholes are extant in Eastern and Central Asia (Sheldon, 1992), generally in South, East and Southeast Asia (Durbin *et al.,* 2008). More than 75 % of their historical range have been disappeared and remaining populations are fragmented. Presently, dholes are distributed in India, Nepal, Bhutan, Bangladesh, China, Myanmar, Indonesia; Lao People's Democratic Republic, Malaysia; Thailand and Cambodia (Kamler *et al.*, 2015). In Indian subcontinent and its Himalayan range *Cuon a. dukhunensis* are found in South of the Ganges, *Cuon a. laniger*: found in Kashmir and Southern Tibet; *Cuon a. primaevus*: found in Himalayan regions of Nepal, India (Sikkim), and Bhutan.

Jerdon 1867, conducted the first assessment on dhole distribution and which identified that dholes were common in India and Sri Lanka. After almost a century, Stains 1975 mapped the dhole distribution, which indicated their absence from the southern tip of the Indian sub-continent. Dholes were absent in Sri Lanka. (Pocock, 1936; Burton, 1940; Stains, 1975; Prater, 1980; Johnsingh, 1982; 1985; Fox, 1984). Among the south Asian sub population *C.a. dhukenensis* is found in south of the river Ganga, Central Indian high land and Southern India (Johnsingh, 1985). *C.a. primaevus* sighted by Israel and Sinclair (1987) in Corbett Tiger Reserve and Chitwan (Israel and Sinclair, 1987; Stewart, 1993). *C.a. laniger* also rare in Ladakh and *C. a. adjustus* found in north east India. In Arunachal Pradesh, it shows decline in numbers (Datta *et al.,* 2008). *C.a. infuscus* is found in Myanmar and Bangladesh.

2.2.3 Feeding and breeding ecology

Dholes hunt in packs during hunting times, lone individuals or a pair may also be seen hunting. The hunting methods and strategies may differ depending on pack size of hunting, prey base type and habitat conditions (Johnsingh and Manjrekar, 2013). Diet profile of dholes contains a diverse prey species which range from large ungulate such as Gaur, Sambar to smallest prey species even small rodents (Karanth and Sunquist, 1995; Andheria *et al.,* 2007; Selvan *et al.,* 2013b). However, they prefer large prey base of 40-60 kg body weight (Selvan *et al.,* 2013b). The food habits of dholes have been studied in south India like Bandipur Tiger Reserve (Johnsingh, 1982; 1984; 1985; Venkataraman *et* *al.*, 1995; Karanth and Sunquist, 2000), Mudumalai Wildlife Sanctuary in Tamil Nadu (Johnsingh, 1984; Cohen *et al.*, 1978; Venkataraman *et al.*, 1995), Pench Tiger Reserve in Madhya Pradesh (Acharya, 2007), Khangchendzonga Biosphere Reserve, Sikkim (Bashir, 2015) and Pakke Tiger Reserve in Arunachal Pradesh (Gopi *et al.*, 2010; Selvan *et al.*, 2013b). Seasonal changes are reflected in dhole's diets due to variations in the number and abundances of prey species (Thinley *et al.*, 2011). The mating season starts from November to February (Burton, 2003), most of the littering occur during January to February (Prater, 1980). The gestation period is about nine weeks and gives birth once in year. The litter size of dhole varies 2 to 6 (Burton, 1940), 4 to 6 (Prater, 1980), 5 (Inverarity, 1901), 6 (Hood, 1895), 8 (Johnsingh, 1984), 7 to 9 (Adams, 1949; Middleton, 1951). Litter size varies within the pack (Venkataraman *et al.*, 1995) such as in Mudumalai two packs gave 8 and 5 to 10 (Venkataraman *et al.*, 1995). Largest litter size 12 reported by L. Durbin in Kanha.

2.2.4 Population Ecology

Dholes are obligate cooperative breeders, making it challenging to estimate the number of mature individuals (Johnsingh, 1982; Venkataraman, 1998). Among the pack, the most surviving pups are the litters of alpha male and female (Venkataraman, 1998). Limited study on the population estimation of dholes exists. In India, estimation of dhole's population is studied from the few protected areas (Kamler *et al.*, 2015). The pack size of dholes has fluctuated widely, variable in composition, fragmenting because of individual migrations from one to another packs, death rate and birth (Johnsingh, 1983; Venkatraman *et al.*, 1995).

Inter-specific competition, capture efficiencies, prey base size and prey biomass determined the pack size of dholes (Johnsingh, 1982). In Nagarahole, average pack size was seven individuals (Karanth and Sunquist, 2000). 40 individual sighted by Davidar (1975), Cohen, (1977) found that eight individuals in southwest India. One to five individuals by Cohen *et al.*, 1978. Eighteen individuals by Johnsingh (1979). Three to 26 individuals by Ramanathan (1982). Eleven individuals in Mudumalai Wildlife Sanctuary by Zarri (2003) and 14 individuals by Acharya, (2007). According to Johnsingh (1992), dholes pack size varied from 7 -18 individual in Bandipur Tiger Reserve.

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CHAPTER III

STUDY AREA

3.1 Arunachal Pradesh

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 forests with low human population densities of 17 people per km^2 (Census of India, 2011), in the northeastern state of India. In general, it comprises of foothills and lofty mountain topographies with varied climatic condition ranging from wet summer to a cool dry winter. Rainfall occurs almost throughout the year. High-elevation areas have rugged terrain, gorge mountains and sub-mountainous areas. 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 (Olson and Dinerstein, 1998; Myers *et al.,* 2000). The area is classified as a 2D biotic province – "The Eastern Himalaya" in the classification for protected area in India (Rodger and Power, 1988). The Eastern Himalaya consists of Bhutan, India (Sikkim and Arunachal Pradesh), China (Tibet and Yunnan) and northern Myanmar (WWF). The entire 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, which are home to numerous flora and fauna. The state is harbor many species of endangered, endemic, rare, primitive and relict flora and fauna. Studies have reported that 54 % of threatened mammals occur in northeast India, (Choudhury, 2006), of which, 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, 1997; Choudhury, 2003; Macdonald, 2004; Dada and Hussain, 2006). According to

Forest Survey of India (2017), the state has a forest cover of about 66,964 km^2 (79.96 %) of 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).

The state is surrounded by Bhutan to the west, Tibet to the north and Myanmar to the east. Inside the Indian territory, Assam and Nagaland border the southern region of Arunachal Pradesh. The state has remained relatively isolated from the rest of the country by virtue of its geographical position and inaccessible terrain. There are 26 major indigenous communities and over 110 minor indigenous communities inhabit the state and each of them has their own language and cultural identity (Dawar, 2008). Majority of these communities are practicing shifting cultivation or *jhum*, wet rice cultivation, terraced rain-fed cropping and hunting. Rice is the principal agricultural crop. Other important crops are maize, millet, wheat, buckwheat pulses, potato, sugarcane, ginger and oil seeds (Mishra *et al.*, 2004). These indigenous communities have been actively involving in hunting for subsistence food, for medicine, traditional rituals and customs as well as a source of cash income (Aiyadurai, 2013).

3.2 Study Area

3.2.1 Dibang Valley District

The Dibang Valley District is named after the “Dibang River”, one of the three main tributaries, *viz*., Dihang (Siang), Dibang and Lohit Rivers of the mighty Brahmaputra. The district has an area of 9,129 km^2 and is the one of the largest district in the state of Arunachal Pradesh. It has a total population of 8,004 of which male and female were 4,414 and 3,590 respectively. The district has a population density of less than 1 inhabitant per km^2 and it is the least populated district in India. The population growth rate over the decade (2001–2011) was 9.3% with sex ratio of 808 females for every 1000 males and a literacy rate of 64.8% (Census of India, 2011). The Dibang Valley of Mishmi hill has a unique landscape in having tiger population at over an altitude of 3630 meters above mean sea level (AMSL) in the Indian part of the Eastern Himalaya Biodiversity hotspot (Adhikarimayum and Gopi, 2018).

The district shares International boundaries in the north and eastern sides with Tibet, the western region is bounded by Upper Siang district and southern side bounded by Lower

Dibang Valley district. The Dibang Valley district is administered under the 1 sub-division, 3 blocks, 6 circles, with Anini as the district headquarter, which is located at an elevation of 1968 m amsl. Idu Mishmi, the main inhabiting tribe of Dibang Valley district which is one the four sub-tribes of Mishmi, the three sub-tribes are Digaru Mishmi, Miju Mishmi and Deng Mishmi. Idu Mishmi tribes are Schedule Tribes (ST) under The Constitution (Scheduled Tribes) Order, 1950; they also inhabit other districts such as Lower Dibang Valley, Upper and East Siang districts of Arunachal Pradesh. The Idu Mishmi tribes follow 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 ceremony. The majority of households in this community are subsistence farmers, seasonal hunters and few are the government employees, contractors and businessmen. Most of them practice shifting cultivation at different seasons for various crops. The shifting cultivation is the only practicable way of cultivation in such kind of rugged terrain in Dibang Valley district. The major harvested crops are rice, buckwheat, maize, millet and a variety of vegetables. They maintain some horticulture plantation along with aromatic plants such as apple, kiwi, orange, plum, pear, cardamom etc., for the local consumption and sale in the local market. Additionally, some villagers go for hunting such as barking deer, serow, goral, wild pig, takin, musk deer, Himalayan black beer, etc., for wild meat and to support their income. However, they follow a unique traditional ecological culture and taboos system to control overexploitation of wild animals, which help in wildlife conservation.

3.2.2 Dibang Wildlife Sanctuary

Dibang Wildlife Sanctuary (DWLS) is second largest Protected Area (PA) in India. It covers an area of 4149 km^2 and situated in Dibang Valley District of Arunachal Pradesh. The sanctuary partially falls in Dihang Dibang Biosphere Reserve. The name “Dibang Wildlife Sanctuary” has been derived from the Dibang River. The sanctuary is located at the northern part of Mishmi hills range in between 28° 38′ and 29° 27′ North latitudes and 95° 17′ and 96° 38′ East longitudes with altitude varying from 1800 to 5500 m amsl. The northern and eastern parts of Wildlife Sanctuary share an international boundary with the Tibet Autonomous Region.

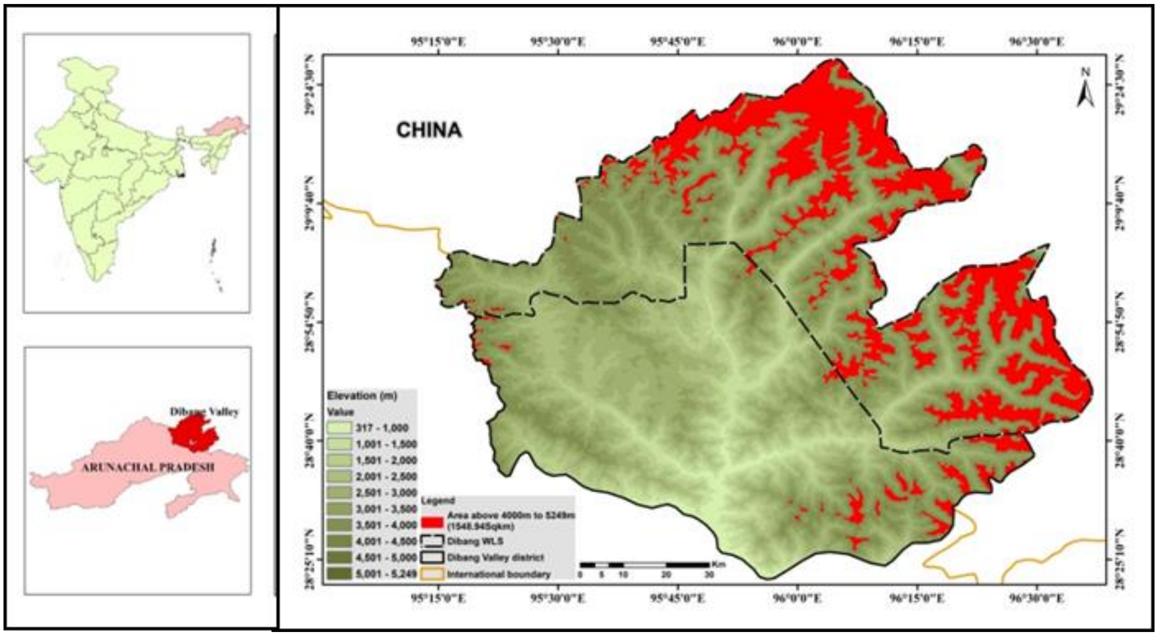

Figure 3.1: Map showing the Dibang Valley district and Dibang Wildlife Sanctuary, Arunachal Pradesh

3.3. Edaphic characters

3.3.1 Geology and soil

The Arunachal Himalaya extends from the eastern part of Bhutan to the easternmost part of the Dibang and Lohit valleys. The present study area, Dibang valley, lies in the Trans Himalaya on the eastern limb of the Eastern Himalayan Syntaxis (Gururajan and 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 geo-dynamically active resulting in many landslides and other mass movements due to high rainfall. The average rainfall of Dibang valley (headquarter at Anini) is about 2866 mm per annum which promotes chemical alteration in the region (Vyshnavi *et al.,* 2013). Therefore, physical, chemical and biological weathering process, have played a major role for the development of soil profile. Soils of this valley generally contain high humus and nitrogen due to thick forest cover. In the downstream valleys, it is clayey in nature and rich in organic matter. Generally, the soil is mainly acidic in nature and acidity increases with the amount of precipitation and heaviness of the soil (CGWB, 2013).

3.3.2 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.

3.3.3 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, average maximum temperature goes up to 24˚C, and 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 (May-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 (Vyshnavi *et al.*, 2013).

3.3.4 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 at 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).

3.4 Ecological attributes

3.4.1 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 and 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 occur here. 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.

3.4.2 Faunal diversity

The Sanctuary and adjoining landscapes harbor a high diversity of faunal species, including endangered, rare, endemic, and threatened faunal species like the Bengal tiger (*Panthera t. 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).

3.5 Administrative, people and livestock

Dibang Wildlife Sanctuary is surrounded by three circles *viz.*, Anini, Mipi and Etalin circles at southern and western portion of the protected area, respectively. Anini is the district headquarters and there are three roads to connect directly toward the protected area which are Anini -Dambuen at northeastern, Anini-Mipi towards northwestern and Etalin-Maliney at southwestern. Acheso, Agrim Valley, Gipulin, Alinye, Mihundo, Aropo etc., are the majors' villages located along the Anini- Dambuen road which are under the Anini circles. At the Mipi circle, along the Anini-Mipi road, the major villages are Beyanli, Mipido, Mipi, Brango, Emuli, Maroli etc. At Etalin circle along the Etalin-Maliney road, the major villages are Maliney, Apayee, Sunli, Ayin, Achii, Athuli, Hunli, Punli, Ek kilo etc. Villagers belong to Idu Mishmi which is the dominant local community of Dibang valley. The major livestock are semi-domesticated free-ranging Mithun (*Bos frontalis*) and pig. Mithun, a crossbreed between Gaur (*Bos gaurus*) and domesticated cattle (*Bos indicus*), is an integral part of their ritual, culture and living property of Idu Mishmi. Single Mithun may cost around Rs. 50000-60000. They are mainly practicing slash and burn cultivation (*jhum* cultivation), hunting of wild animals and extracting of non-timber forest products (NTFP) collection, including wild medicinal plants.

3.6 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.

3.6.1 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 (Fig 3.2). 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.

Figure 3.2: Grassland habitat in the rugged terrain in Dri valley (*Dri-mro*) at Dibang Wildlife Snactuary, Arunachal Pradesh

3.6.2 Angi-pani Valley (*Angi-mro*)

The Angi-pani valley was named after Angi-pani river which 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 28º 51' 38.1" N latitude and 95 º 58' 50.2" E 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.

Figure 3.3: Riverine habitat in Angi pani valley (*Angi-mro*) at Dibang Wildlife Sanctuary, Arunachal Pradesh

3.6.3 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.

Figure 3.4: Riverine habitation in Mathun valley (*Mathun-mro*) at Dibang Wildlife Sanctuary, Arunachal Pradesh

3.6.4 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.

Figure 3.5: Diverse type of forest along the narrow Enjoo river (*Enjoo-mro*) channel inside the Dibang Wildlife Sanctuary, Arunachal Pradesh

3.6.5 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.

Figure 3.6: A hilly terrain with miscellaneous forest of Tallon valley (*Tallon-mro*) at Dibang Wildlife Sanctuary, Arunachal Pradesh

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CHAPTER IV

POPULATION ESTIMATION OF LARGE CARNIVORES

4.1 Introduction

Population estimation of large carnivores is a statistical tool that facilitates the understanding of their ecology and conservation needs (Gibbs, 2000). Globally, large carnivores are set to be flagship priority in wildlife conservation. Large carnivores such as tiger, leopard, and dhole are sympatric acting as umbrella species across a wide array of habitats which have been maintaining and balancing the entire population of the ecosystem (Wang and Macdonald, 2009). Large carnivores are generally confined to viable habitats, to satisfy their demands for food, water and denning sites for optimizing survival and reproduction. Low prey base availability, habitat fragmentation and high human interferences are also critical factors to coexistence of carnivores in the habitat (Pereira *et al.,* 2012; Schuette *et al.*, 2013). Large mammalian carnivore populations are drastically declining both locally and globally in the past few decades (Ripple *et al.*, 2014). Human-induced developmental activities affect the viable population of large carnivores and its habitat (Karanth *et al.,* 2010). Habitat loss and forest fragmentation are the main challenges in conservation, management and monitoring of carnivore population (Andren, 1994). Moreover, low food resources cause starvation of carnivores leading to higher migration rates and mortality chance of inter and intraspecific killing (Schaller, 1972; Mech, 1977). Habitat fragmentation can lead to habitat loss, increasing the isolation of habitat patches and bottleneck corridor which become increasingly vulnerable to the extinction of biological diversity within the original habitat (Wilcox and Murphy, 1985; Sankar *et al.*, 2013). Illegal trade and poaching is another factor for driving wild species to extinction (Karanth and Sunqusit, 1995). To decelerate this process, it is essential to emphasize the monitoring of large mammalian carnivores in a human-dominated landscape to understand the population structures, their dispersal opportunities, and connectivity between the populations (Harihar *et al.,* 2009a; Harihar and Pandav, 2012). Owing to factors such as nocturnal cryptic habits, low density in the tropical rainforest, the highlight of population structure for carnivore’s species is an issue in the field of ecology and conservation biology (Eisenberg and Seidensticker, 1976;

Caughley, 1977; Seber, 1992; Kawanishi and Sunquist, 2004; Sharma *et al.,* 2005; Kelly, 2008; Vine *et al.,* 2009).

Population estimation requires a rigorous and robust methodology (Dougherty and Bowman, 2012) for estimation of carnivore population. Many techniques with sophisticated instruments like camera traps for photographic capture-recapture of identifiable animals (Karanth and Nichols, 1998; 2000; 2002; O'Brien *et al.,* 2003, Kawanishi and Sunquist, 2004; Karanth *et al.,* 2004a; 2005; Johnson *et al.,* 2006; Jhala *et al.,* 2008; Kelly, 2008; Harihar *et al.,* 2009 a & b; Kalle, 2009; Wang and Macdonald, 2009), radio-telemetry (Acharya, 2007), were being applied to monitor the elusive carnivores. For non-individually recognizable species, an index of animal abundance based on camera trapping data in term of photo-capture rates can be estimated (Carbone *et al.,* 2001; O'Brien *et al.,* 2003; Johnson *et al.,* 2006; Datta *et al.,* 2008; Rowcliffe *et al.,* 2008). Royle and Nichols (2003) have been used to develop robust results in the population estimation without individual identification (Royle and Dorazio, 2006; Royle *et al.,* 2005).

Ecological studies on large carnivore have been poorly conducted in Indian part of Eastern Himalaya region. Particularly in Arunachal Pradesh, an ecological study on carnivores and prey are of great challenge, due to rugged terrain, the low population of carnivores and their prey, elusive nature of an animal, shy and secretive behavior and prolong hunting on wild animals. Answering the ecological queries through robust and rigorous methodology is not extended to this region. Hence, carnivore sign survey and camera traps were used to see the surrogate of carnivores' abundance in terms of sign encounter and photographic encounter rates based indices respectively. This study has established the ecological baselines of tigers and wild dog (dhole) in the temperate forest of Mishmi ills of Arunachal Pradesh using camera trap data and abundance indices technique for an effective monitoring and conservation planning in this biologically and socio-culturally rich hotspot.

4.2 Methodology

The presence of tiger and wild dog (dhole) along the trails, ridges, and rivulet, was confirmed through sign surveys in different valleys which served as travel routes (Sathyakumar, 1994; Karanth and Nichols, 2000). Based on the reconnaissance surveys, the intensive study area was selected for the deployment of camera traps (Mackenzie and Royle, 2005).

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 a quantitative technique that has relatively low labor costs, incurs minimal environmental disturbance (Henschel and Ray, 2003), and is robust to variation in ground conditions and climate. Most importantly, it can 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). Camera trap provides an opportunity to collect additional information on species distribution and habitat use, population structure and behavior (Henschel and Ray, 2003). 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.,* 2004a) and relative abundance index (RAI) was used for individually unrecognizable species (Carbone *et al.,* 2001; Royle and Nichols, 2003; Nag, 2008).

Using occupancy-based modeling, abundance estimation of individually unrecognizable species has been carried out from camera trap data (Royle and Nichols, 2003; Nag, 2008). However, in northeastern states of India particularly in Arunachal Pradesh, the Indian part of Eastern Himalayan have challenges from the conventional camera trap methods due to rugged terrain, weather conditions, logistic constraint, and lack of manpower. In such constraints, camera trap data were adopted and relative abundance index (RAI) was used (Carbone *et al.,* 2001) based on the photographic encounter rates (number of tiger or wild dog photographs/ 100 traps nights of effort).

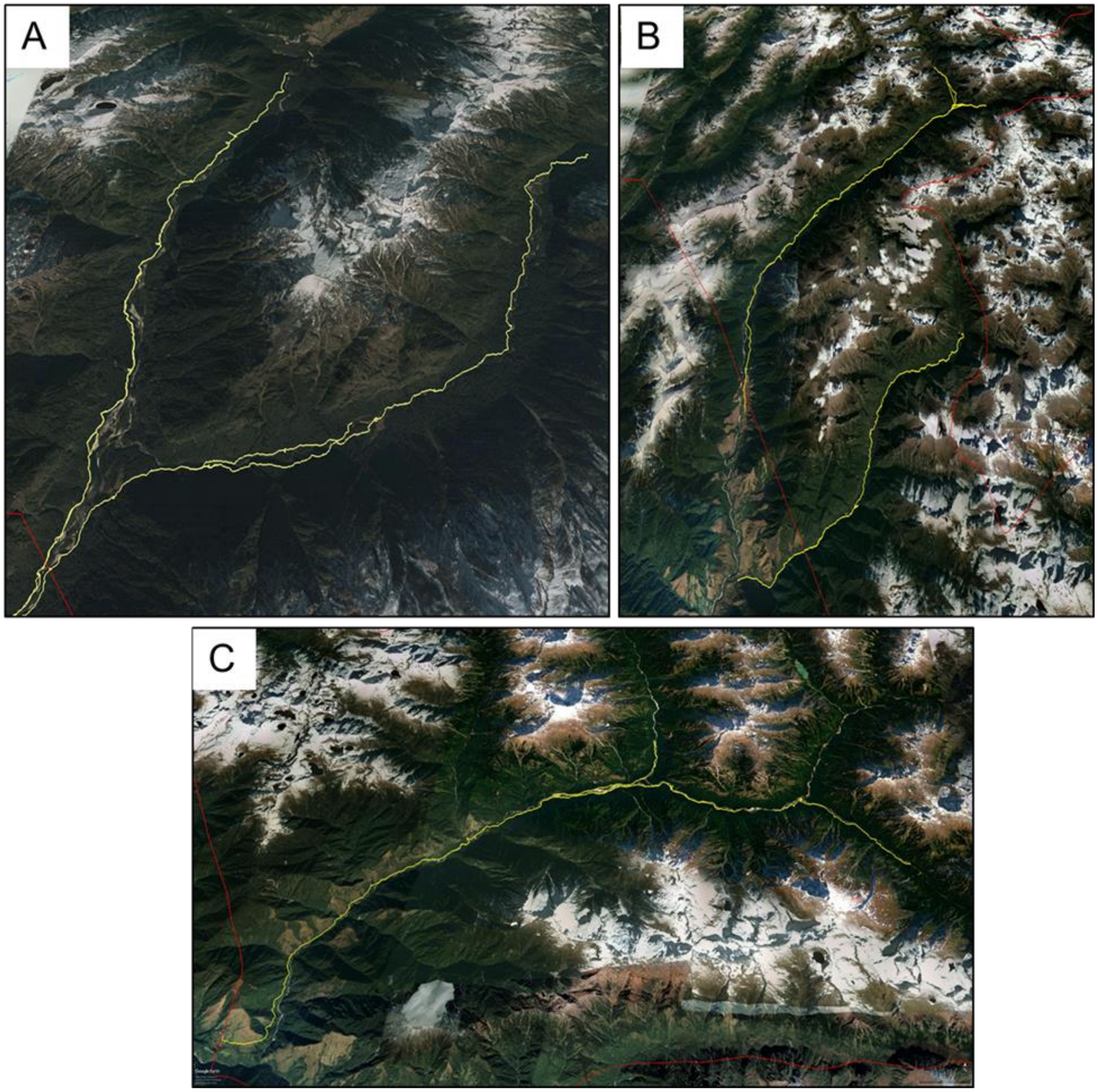

Figure 4.1: Sign survey trails at (A) Mathun and Enjoo Valleys; (B) Dri and Angi-pani Valleys and (C) Tallon Valley in Dibang Wildlife Sanctuary during 2015-2017

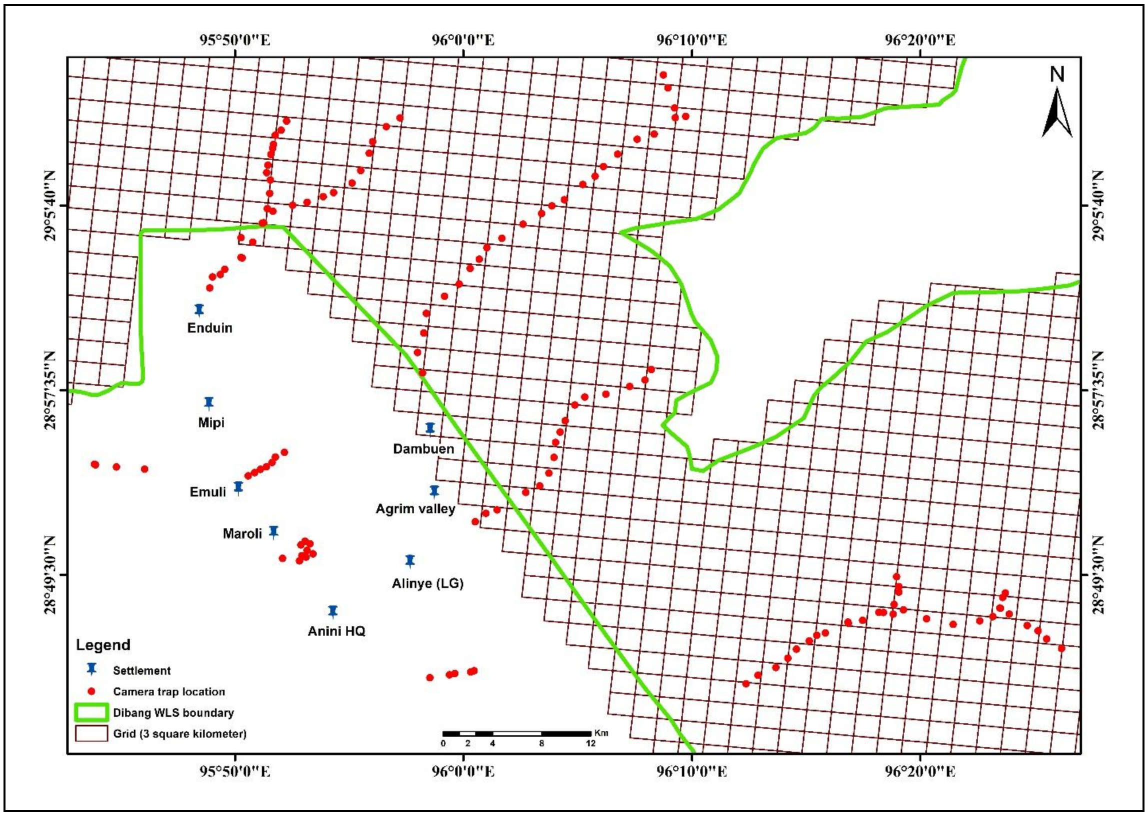

Figure 4.2: Camera traps locations in and around the Dibang Wildlife Sanctuary of Dibang Valley district of Arunachal Pradesh

4.2.1 Carnivore sign survey

Mammalian carnivore 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, pugmark, track, rack mark, scrap, hairs, kill, etc. can offer cost-effective and rapid methods for tiger, co-predators relative abundance (Jhala *et al.,* 2011). The intensive survey was performed at an imaginary beat level in the five major river valleys *viz.*, Dri valley, Angi-pani valley, Enzoo valley, Mathun valley and Tallon valley with a minimum 5 km length along the trails, ridges, banks of dry riverbed, and near rivulets (Karanth and Nichols, 2000) (Fig 4.1). The encounter signs of any indirect evidence of tiger and dholes were recorded. Their signs like pugmark, scats, rake marks, scrap, kill, etc., were identified based on their general features such as size, shape and substrate and habitat of occurrence. Tiger scats were easily identifiable than other carnivores which are a less coiled and larger size. Dhole scats can be differentiated by size and are clustered in appearance (Johnsingh, 1983; Karanth and Sunquist, 1995; Ramesh, 2010). Each trail was monitored 2-3 times in every session and information on the encountered signs were recorded along with 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 also recorded.

4.2.2 Camera traps

Camera trapping was carried out in a 336 km^2 stratified area in five river valleys and outside the sanctuary. The intensive study area was divided into 3 km^2 (1.73×1.73 km) uniform grid were overlaid on a map of the study sampling area. The scale is to match with the other camera trapping surveys conducted elsewhere in Southeast Asia (O'Brien *et al.,* 2003; Kawanishi and 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 4.2). 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 (Karanth and Nichols, 2002), with a minimum distance of 500 m and a maximum of 1500 m was maintained between two consecutive camera trap units. Camera traps were active throughout the day and camera delay time was 1 second fast as possible (FAP) during both day and night time. The memory card was marked properly and changed after every check and thereafter the data were downloaded to the computer. 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).

4.2.3 Camera trap parameter

A 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.

4.3 Analytical methods

4.3.1 Estimation of encounter rate through conventional sign survey method

Encounter rates based on sign survey sampling were attained for tiger and dhole and estimated using the formula:

Encounter rate= n/L

where **'n'** is the total number of sign encountered belonging to a species during each trail surveys and **'L'** is the length of trail walk in kilometer 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 and dholes. Mean sign encounter rate of tigers and dholes 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.

4.3.2 Estimation of Relative Abundance Index (RAI) of tiger and dhole

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 in the study (Carbone *et al.,* 2001). Captured images of tiger and dhole were used to calculate an index of relative abundance (RAI). The number of days required for obtaining a photo capture of a species (RAI 1) (Carbone *et al.,* 2001) and 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 (RAI 2) were estimated (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 hours (hrs) apart, and (iii) non-consecutive photos of individuals of the same species (O'Brien *et al.*, 2003). Mean photo capture rate of tigers and dholes at each valley and overall photo capture rates were calculated. Kruskal-Wallis χ^2 and Mann- Whitney U tests were used to test significant differences among the estimates of the tiger and dholes in different valleys and seasons.

4.3 Results

4.3.1 Sign survey: Tiger and dhole sign's encountered rate

Tiger and dhole (wild dog) sign surveys were carried at five sampling river valleys of the protected area, 28 number of sign surveys were carried out with total efforts length of 231.85 km during 2015 to 2017 (Table 4.1). The overall signs encountered rate of tiger (0.099 km^{-1}) was highest followed by dhole (0.069 km^{-1}) (Table 4.2).

Table 4.1: Tiger and dhole sign survey inside the protected area

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 4.2: The sign encounter rate of tiger and dhole inside the protected area

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
Dhole	231.85	16	3.2	1.56	0.069

Average sign encounter rates of tiger and dhole (the number of sign encountered/total effort length) in the different valley in different seasons were estimated. The mean sign encounter rates of the tiger were highest at Dri valley in autumn (0.04 ± 0.01), followed by Mathun and Enjoo valleys in winter (0.03 ± 0.02) and Tallon valley in spring (0.03 ±

0.02) during the first year survey. Continuation survey in next year, encounter rates of the tiger were highest at Tallon valley in winter (0.02 ± 0.01), followed by Dri and Angi pani valleys (0.004 ± 0.002) and Mathun-Enjoo valleys (0.002 ± 0.002). No dhole sign was encountered from these valleys during the first year survey. But during the second-year survey, wild dog encounter signs were highest at Tallon valley in winter (0.03 ± 0.01), followed by Dri valley in spring (0.008 ± 0.004) and Mathun-Enjoo valleys during autumn (0.007 ± 0.004). Kruskal-Wallis χ^2 revealed that across the surveyed valleys, no significance among the mean sign encounter rates of the tiger (p = 0.09) while wild dog (p = 0.00) were significant along these river valleys. The mean sign encounter rates of tiger and wild dog was associated with high standard error (SE) which is due to the high degree of variability in signs encountered (Table 4.3).

Table 4.3: Tiger and dhole sign encounter rates with SE at different valley and seasons inside the DWLS

Carnivore Species	Year 1 (2015-2016)			Year 2 (2016-2017)			K-W $\chi2$	*df*	*p*
	Autumn (*Dri & Angi Valley*)	Winter (*Mathun & Enjoo Valley*)	Spring (*Tallon Valley*)	Autumn (*Mathun & Enjoo Valley*)	Winter (*Tallon Valley*)	Spring (*Dri & Angi Valley*)			
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
Dhole	0	0	0	0.007 (±0.004)	0.03 (±0.01)	0.008 (±0.004)	61.9	5	0.00

The mean sign encounter rates of tiger and dholes in different seasonal temporal scales at the same valleys were calculated using the Mann-Whitney U test and tested for significant difference (Table 4.4).

a) In **Dri and Angi pani** valleys, eleven sign surveys with a total effort length of 100.69 km in two seasons i.e., autumn and spring were carried out. The sign surveys were covered from at an elevation of 1736 m up to 3001 m above mean sea level (amsl). The mean sign encounter rates of tiger (0.04 ± 0.01) were highest and followed by wild dog (0.008 ± 0.004). The encounter rates for tiger (p=0.02) was found to be significant.

b) ***Mathun*** **and** ***Enjoo*** valleys monitored in two seasons i.e., winter and autumn. A total of ten carnivore signs surveys were carried out from an elevation of 1697 m up to 2017 m amsl with a total effort length of 73.9 km. The mean sign encounter rates of tiger (0.03 ± 0.02) were highest, followed by wild dog (0.007 ± 0.004). In these valleys, there were no significant seasonal differences in mean sign encounter rates of tiger and dholes.

c) *Tallon* valley was monitored during the spring and winter seasons. Seven sign surveys were conducted from an elevation of 1633 m up to an elevation of 2934 m amsl with a total efforts length of 57.26 km. Only tiger (0.03 ± 0.02) signs were encountered during the spring season. In winter, sign encounter rates were highest for wild dogs (0.03 ± 0.01) followed by tiger (0.02 ± 0.01). No significant seasonal difference was observed from this valley for encounter rates of tiger and wild dog.

Table 4. 4: Mean sign encounter rates for tiger and wild dog across different seasonal temporal scale in the different valleys within the protected area

Carnivore 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**
Dhole	0	0.008 (±0.004)	0	0.11
Carnivore 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
Dhole	0	0.007 (±0.004)	0	0.19
Carnivore 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
Dhole	0	0.03 (±0.01)	0	0.09

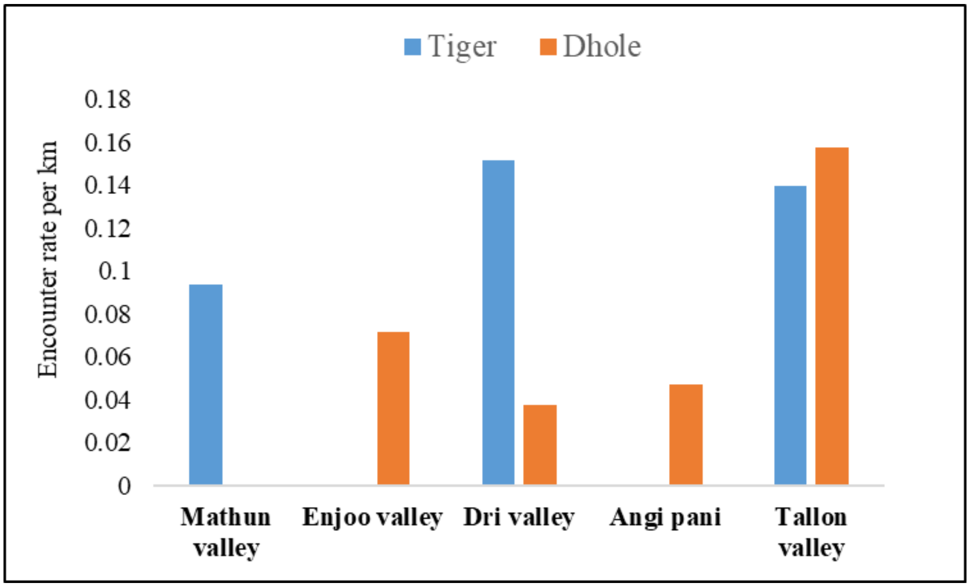

Figure 4.3: Tiger and Dhole signs encounter rates along the five major river valley of DWLS.

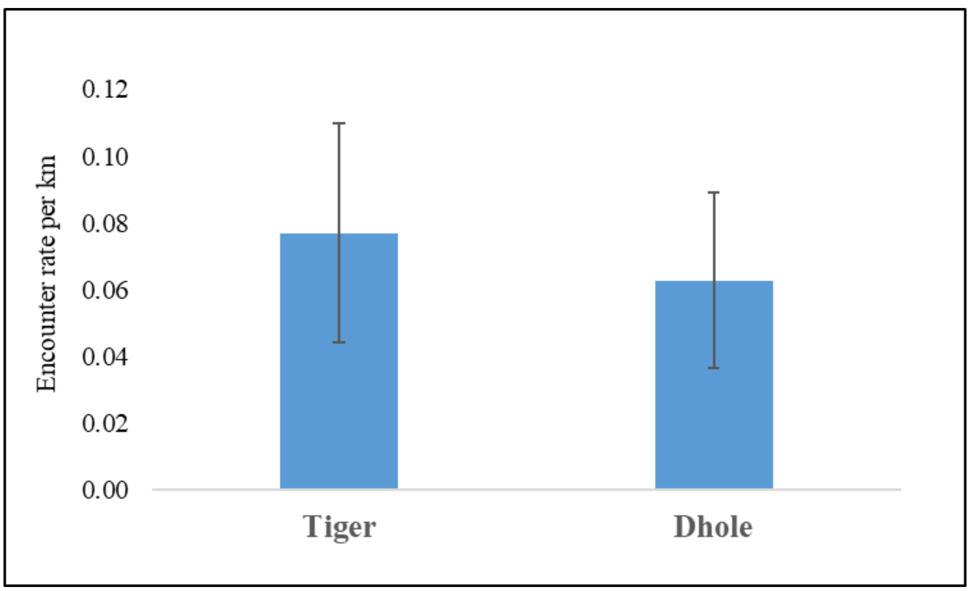

Figure 4.4: Mean signs encounter rate of tiger and dhole with standard error (SE) at DWLS.

4.3.2 Camera traps: Photo-capture rate as indices of carnivore relative abundance

This study on the aspects of ecology of tiger and wild dog covers Dibang Wildlife Sanctuary and its adjoining landscape of community forests during October 2015 to July 2017. Camera trapping exercise was conducted for twenty-eight months, which covered six sessions with three sessions in each year (Table 4.5). 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 4.6). The photo-capture rates (photographs/100 days) were estimated for tigers and dhole present only inside the protected area. The photo-capture rates of these sympatric mammalian carnivore 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.

Photographic rates were calculated for tiger and dholes, relative abundance index (RAI1) decline as follow tiger (284.57) > dhole (85.37). Overall, the mean photo-capture rates of the tiger were 0.34 ± 0.06 (SE), which was calculated from the forty-two left-sided photographs while the mean photo-capture rates of dhole were 1.19 ± 0.20 (SE) highest among these two sympatric large carnivores. The mean photo-capture rates of dholes were associated with the high standard error (SE) which indicating a high degree of variability in the capture of dholes in different camera traps in the DWLS (Table 4.8).

Table 4.5: 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 4.6: 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 4.7: Comparative photo-captures of different taxa within and outside DWLS

Sampling area	Total photo captures	Wild/Semi domestic animals/Humans							
		Carnivore	Ungulate	Bird	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**

Table 4.8: Overall mean photo-capture rates of tiger and dhole (photographs /100 days) inside DWLS

Carnivore Species	N	Photo-capture Rate	SE
Tiger	42	0.34	0.06
Dhole	140	1.19	0.20

The mean photo-capture rates (the number of photographs/100 days) of tigers and wild dogs in different seasons were estimated and tested for significance by using the Kruskal-Wallis χ^2 test (Table 4.9).

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). Kruskal-Wallis χ^2 revealed that the photo-capture rates of the tiger were significant along the different valleys in different seasons, while the photo-capture rates of dholes were not significant.

Table 4.9: Valley and season wise mean photo-capture rates with SE of tiger and dhole inside DWLS

Carnivore Species	**Year 1 (2015-2016)**			**Year 2 (2016-2017)**			K-W che ²	*df*	*p*
	Autumn (*Dri & Angi Valley*)	Winter (*Mathun & Enjoo Valley*)	Spring (*Tallon Valley*)	Autumn (*Mathun & Enjoo Valley*)	Winter (*Tallon Valley*)	Spring (*Dri & Angi Valley*)			
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*
Dhole	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

The mean photo-capture rates of tiger and dholes in different seasonal temporal scales across the different valleys were also estimated and tested for significant differences (Table 4.10).

a) Dri and Angi pani valleys were monitored in two seasons i.e., autumn and spring. Comparatively, the mean photo-capture rate of tiger was low in both season i.e., autumn (0.11 ± 0.06) and spring (0.12 ± 0.07) but there were significant seasonal differences in the photo-captures of tiger (p = 0.05). While the photo-capture rates of wild dog were higher comparatively during spring (1.19 ± 0.35) and autumn (0.58 ± 0.30) but no significant seasonal differences.

b) Mathun and Enjoo valleys were monitored in two seasons i.e., winter and autumn. Comparatively, the mean photo-capture rates of wild dog were highest followed by tiger both in winter and autumn. Photo-capture rates of tiger (p = 0.00) had significant seasonal differences but no significant in seasonal differences of wild dog.

c) Tallon valley was observed during spring and winter seasons, the tiger was only photo-capture during the winter season (1.09 ± 0.27). However, dhole was photo-captures both spring (1.60 ± 1.29) and winter (0.11 ± 0.11). The photo-capture rates of tiger and dholes were not significant across seasons.

Table 4.10: Seasonal photo-capture rates of tiger and wild dog inside protected area

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
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
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

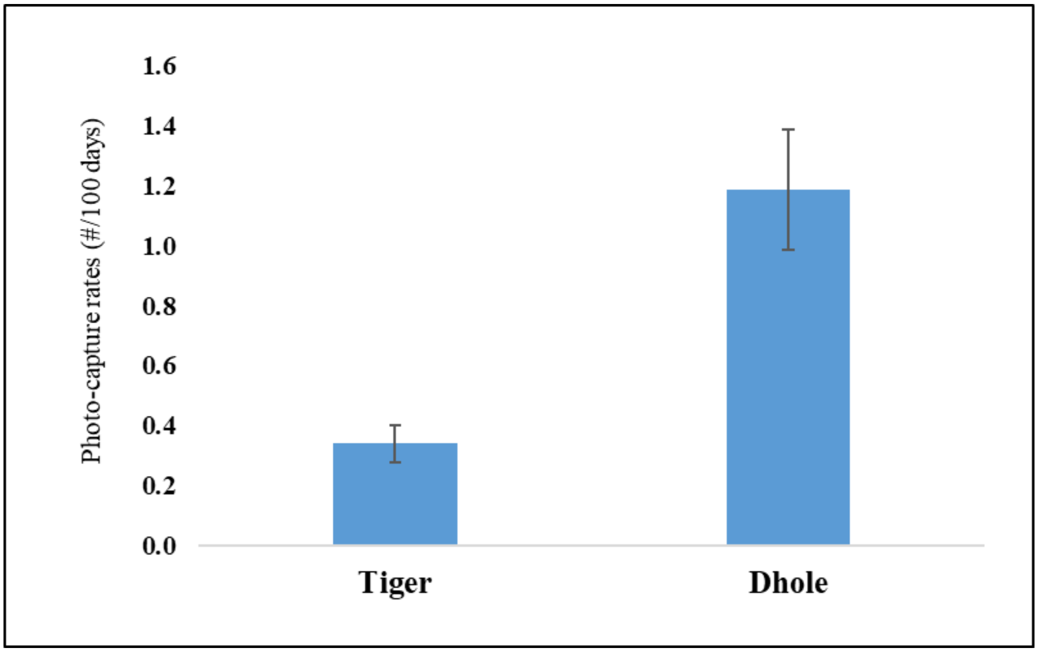

Figure 4.5: Overall photo-capture rates with SE of tiger and dhole inside the DWLS

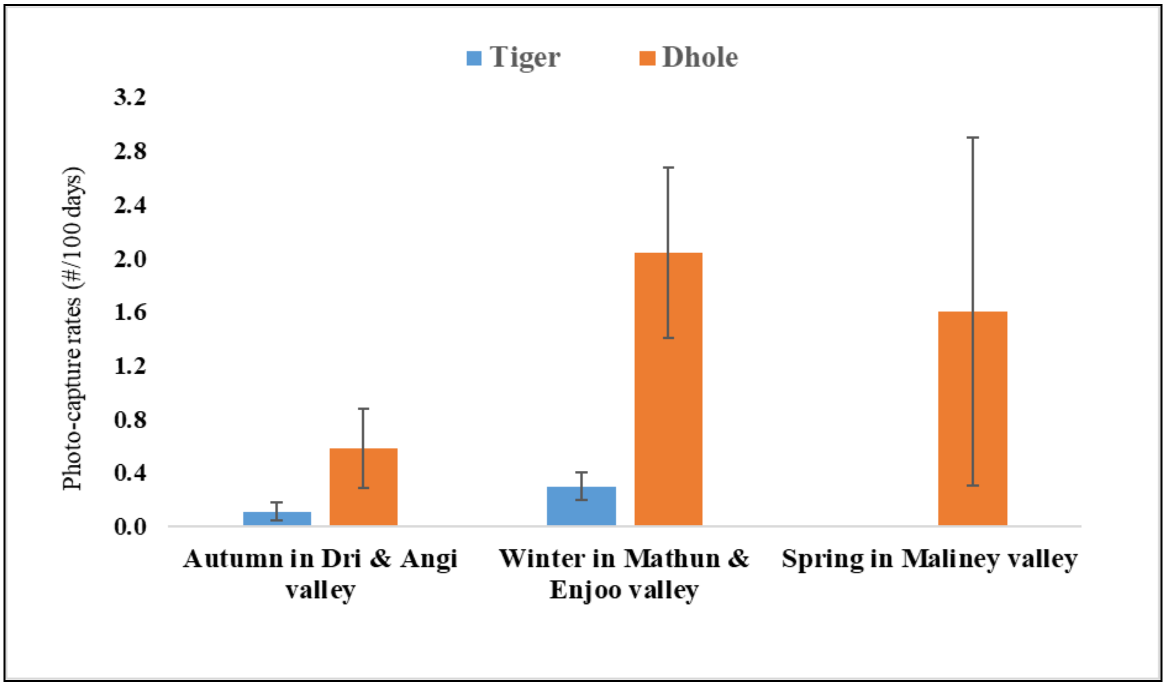

Figure 4. 6: Mean photo-capture rates (with SE) of tiger and dhole at different temporal scale during first year observation in DWLS, 2015-16

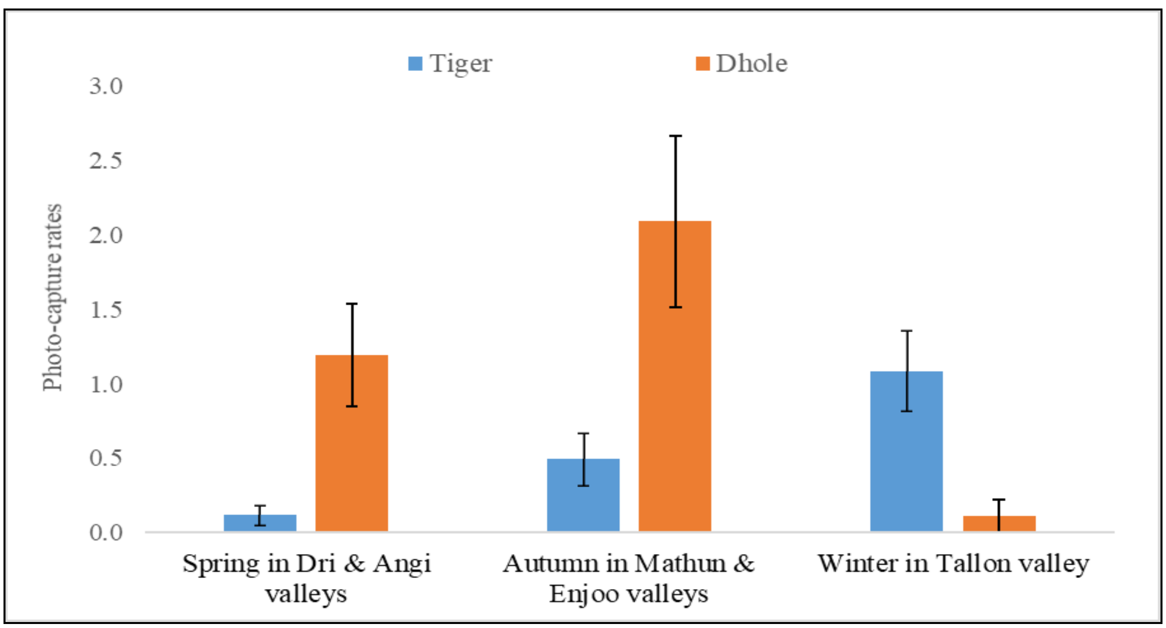

Figure 4.7: Mean photo-capture rates (with SE) of tiger and dhole at different temporal scale during second year observation in DWLS, 2016-17

4.3.3 Mean group sizes and population structure of dhole and tiger

A total of 140 dhole photographs were captured from 42 camera trap locations. Only one camera trap location was outside the protected area in community forest. From the overall photo-capture images, 101 (72.14%) were single adult individuals, 24 (17.14%) contained two individuals, only one photograph comprised of three individuals (2.14%) and 12 (8.58%) 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.

During the study period, 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 4.1) 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.

Table 4.11: The percentage of individual(s) photo-captures of tiger and dhole during the study

Mammal Species	Total # of capture	Single Individual (%)	Two Individuals (%)	Three Individuals (%)	Four Individuals (%)	Five Individuals (%)	> Five individuals (%)
Tiger	42	85.71	14.29	-	-	-	-
Wild dog	140	72.14	17.14	2.14	8.58	-	-

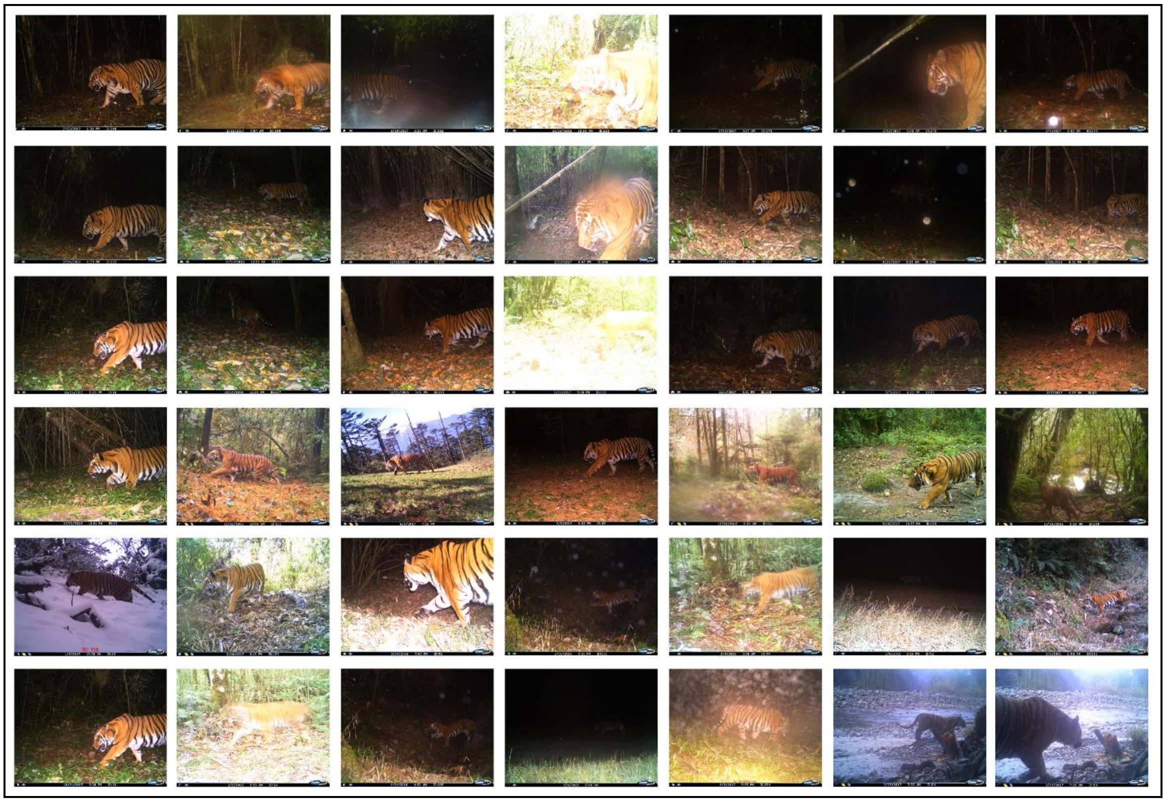

Image 4.1: Since the sampling was to identify the tiger occupied areas, we placed single-sided cameras to cover the maximum area of Dibang Wildlife Sanctuary and its adjoining landscapes. We got 42 photographs of tigers. From these, we have identified 9 adults and 2 cubs

4.3.4 Spatial distribution patterns of tiger and dhole

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 4.8, 4.9 & 4.10).

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 4.12 & 4.13). The tiger and wild dog were found through photo capture within the elevation range of 1749 to 3783 m amsl. The photo-capture rate index of tiger and wild dog was represented with a high, medium, and low frequency of presence in a 9 km^2 (3x3 km) grid over the digital elevation model map (DEM) (Fig 4.8; 4.9 & 4.10). 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.

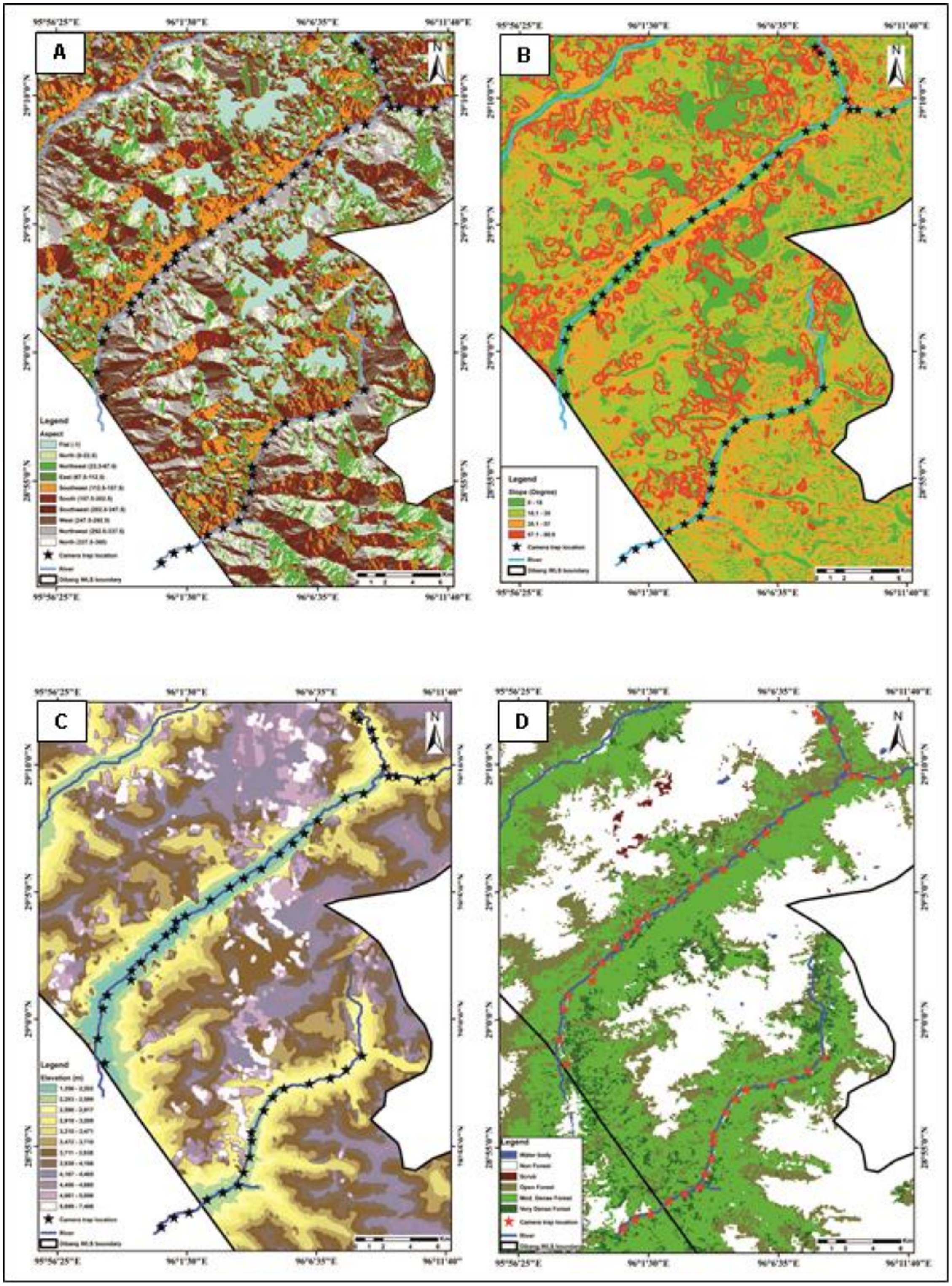

Figure 4.8: Camera trap locations at (A) different aspect classes, (B) different slope categories, (C) different elevation, and (D) different habitat categories in Dri and Angi valleys

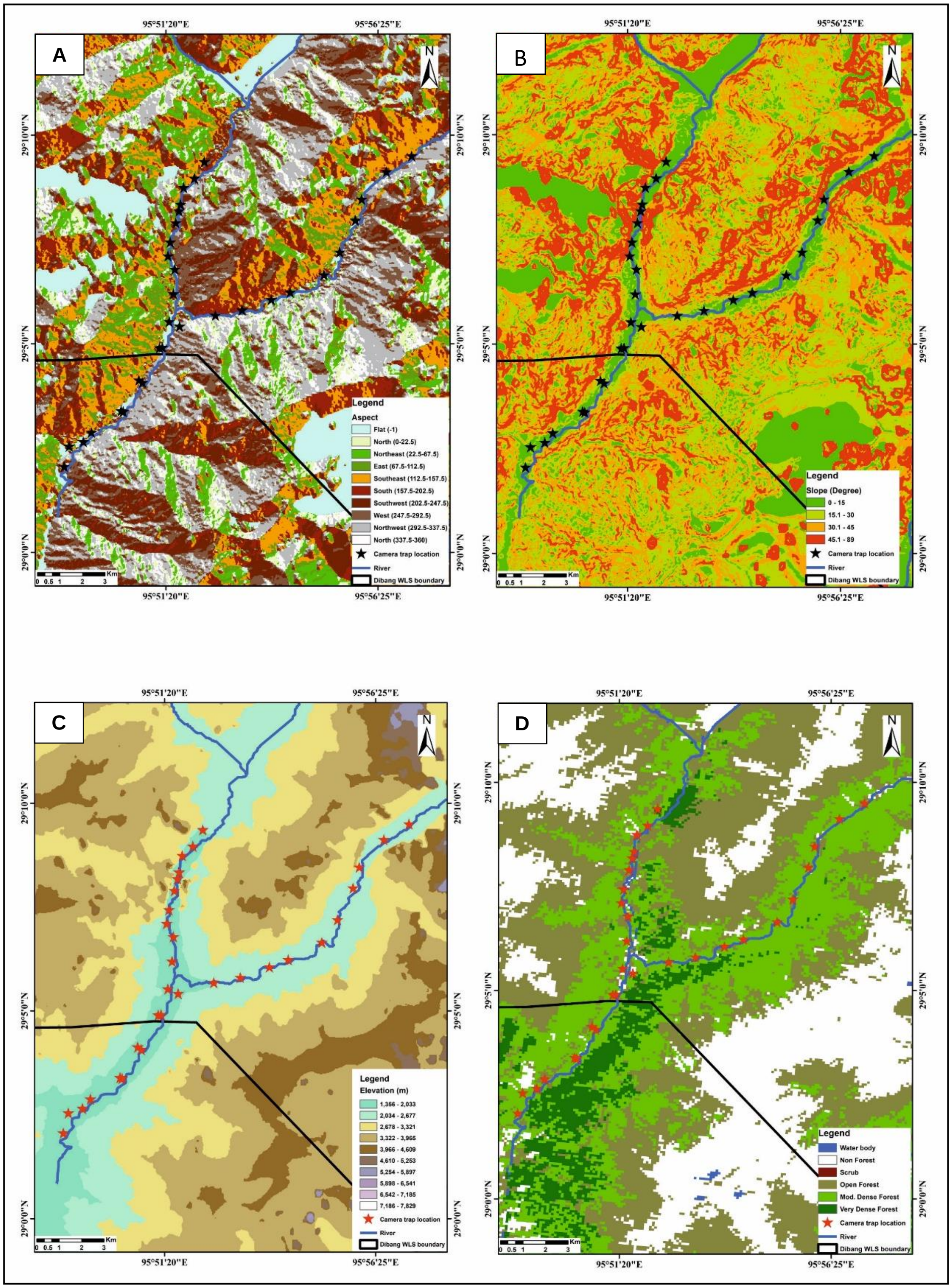

Figure 4.9: Camera trap locations at (A) different aspect classes, (B) different slope categories, (C) different elevation, and (D) different habitat categories in Mathun and Enjoo valleys

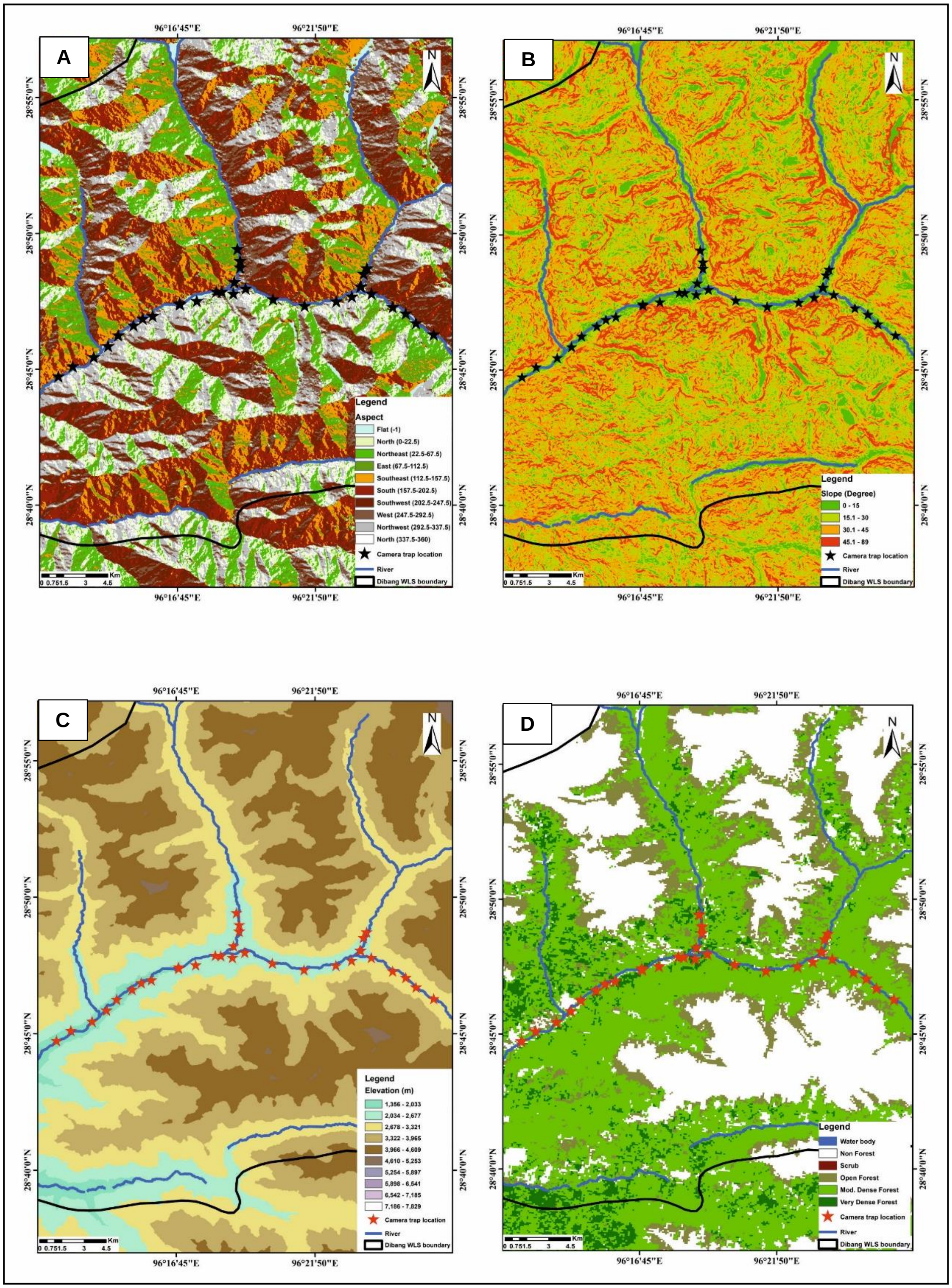

Figure 4.10: Camera trap locations at (A) different aspect classes, (B) different slope categories, (C) different elevation, and (D) different habitat categories in Tallon valley

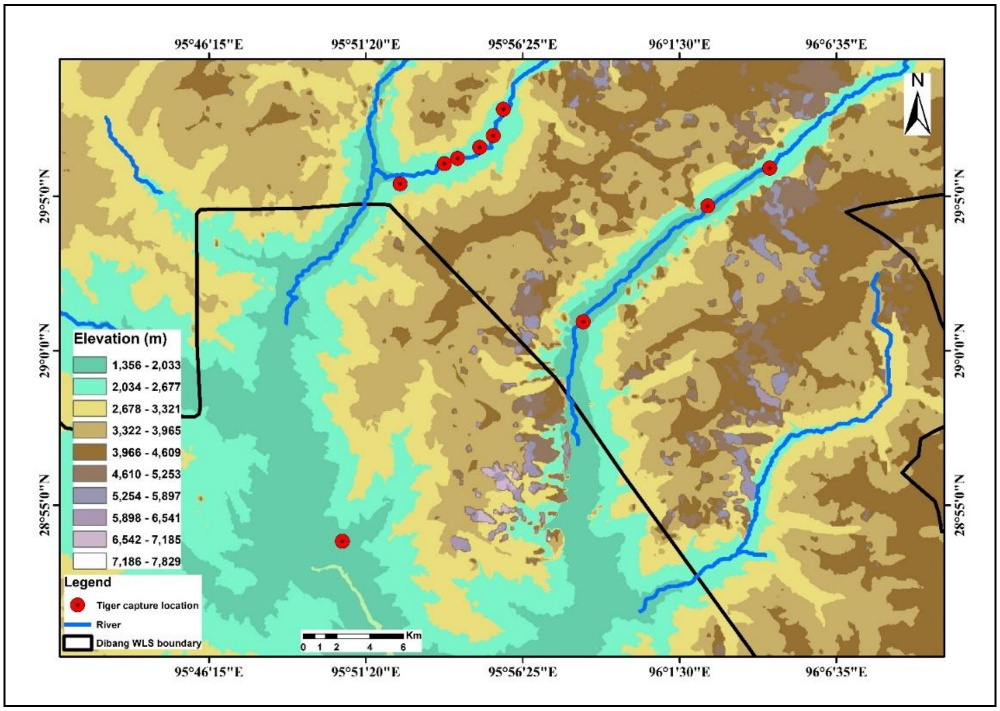

Figure 4.11: Tiger capture location in and around the Dibang Wildlife Sanctuary during 2015-16 camera trapping

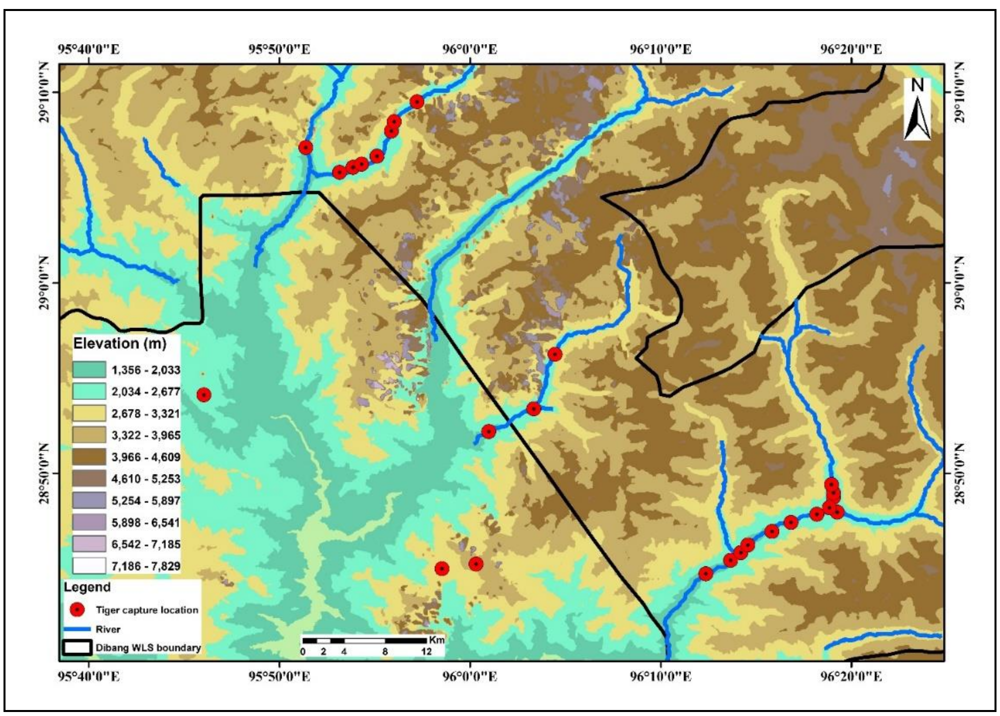

Figure 4.12: Tiger capture location in and around the Dibang Wildlife Sanctuary during 2016-17 camera trapping

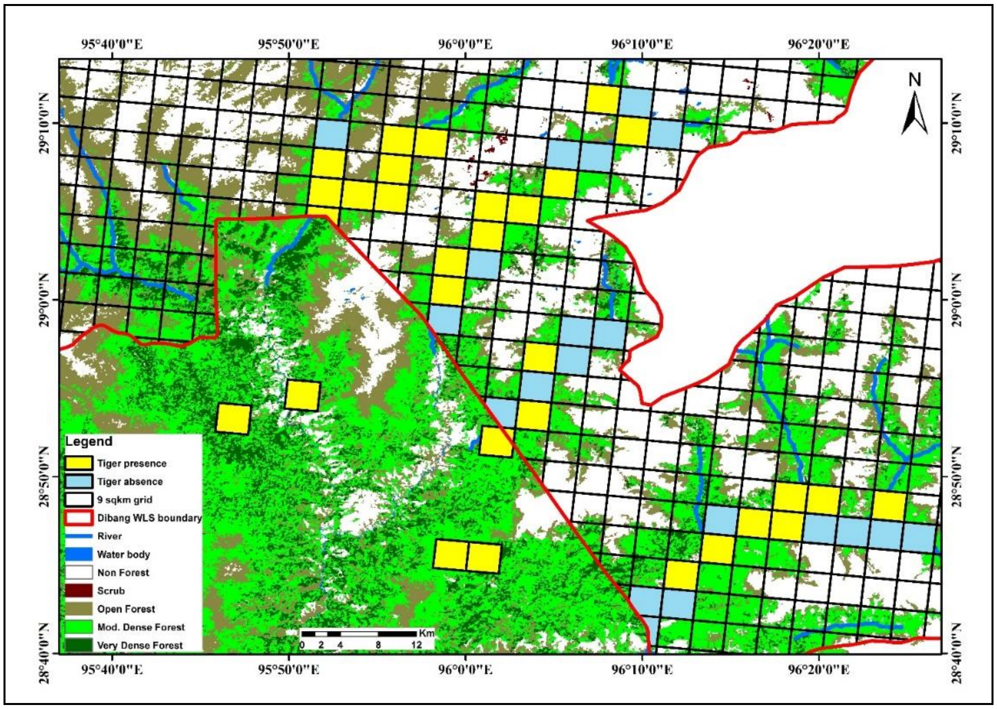

Figure 4.13: Tiger presence location in and around the Dibang Wildlife Sanctuary during 2015-17 camera trapping

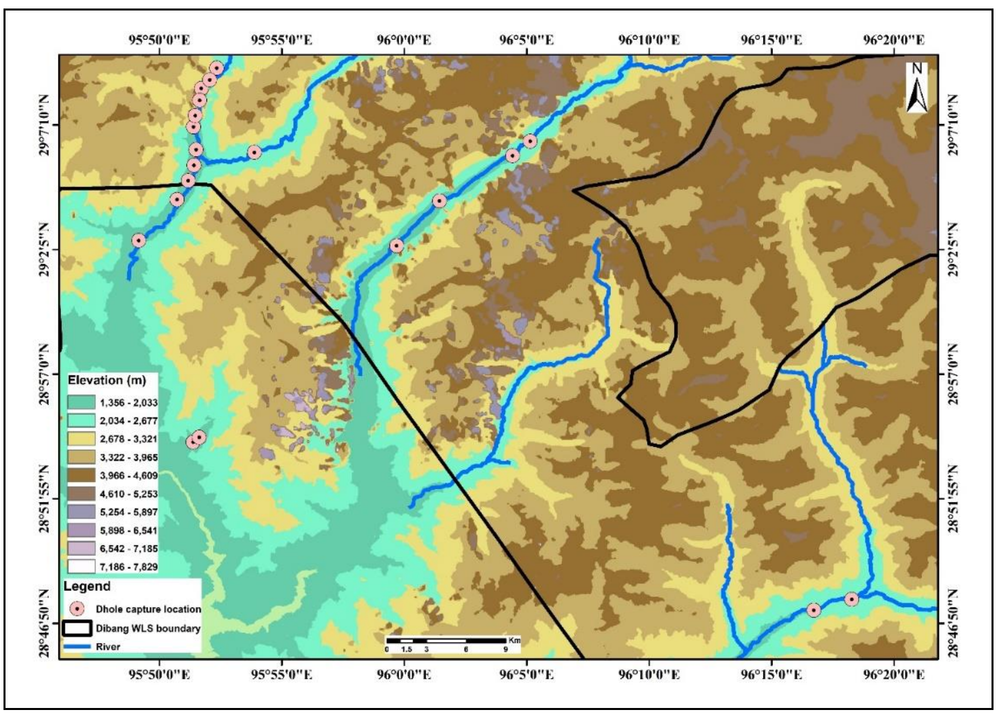

Figure 4. 14: Wild dog capture location in and around the Dibang Wildlife Sanctuary during 2015-16 camera trapping

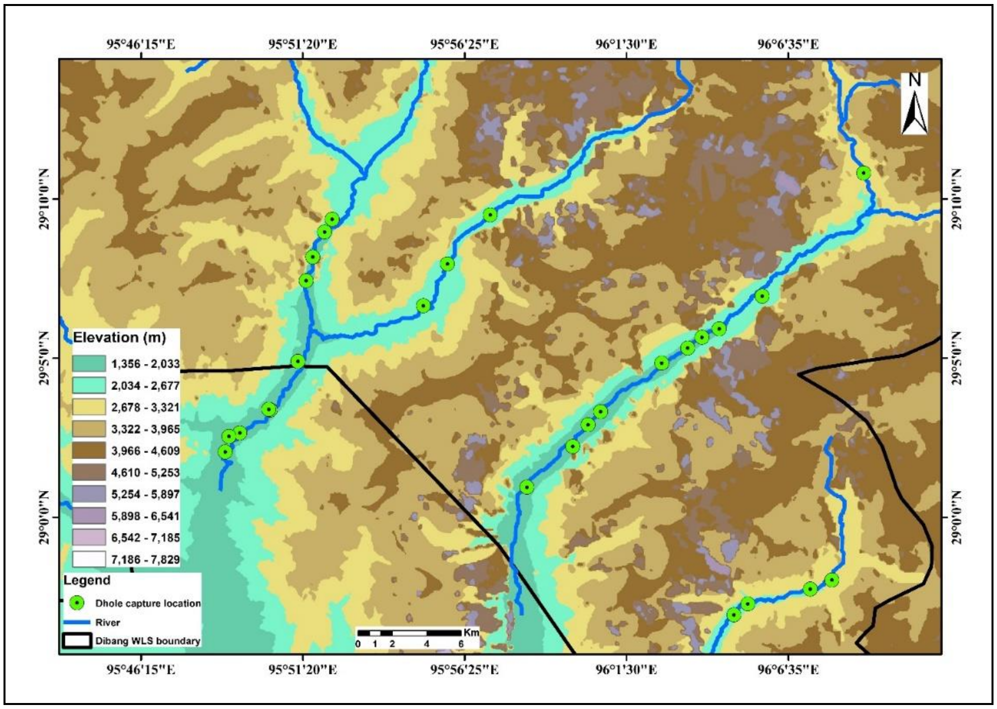

Figure 4.15: Wild dog capture location in and around the Dibang Wildlife Sanctuary during 2016-17 camera trapping

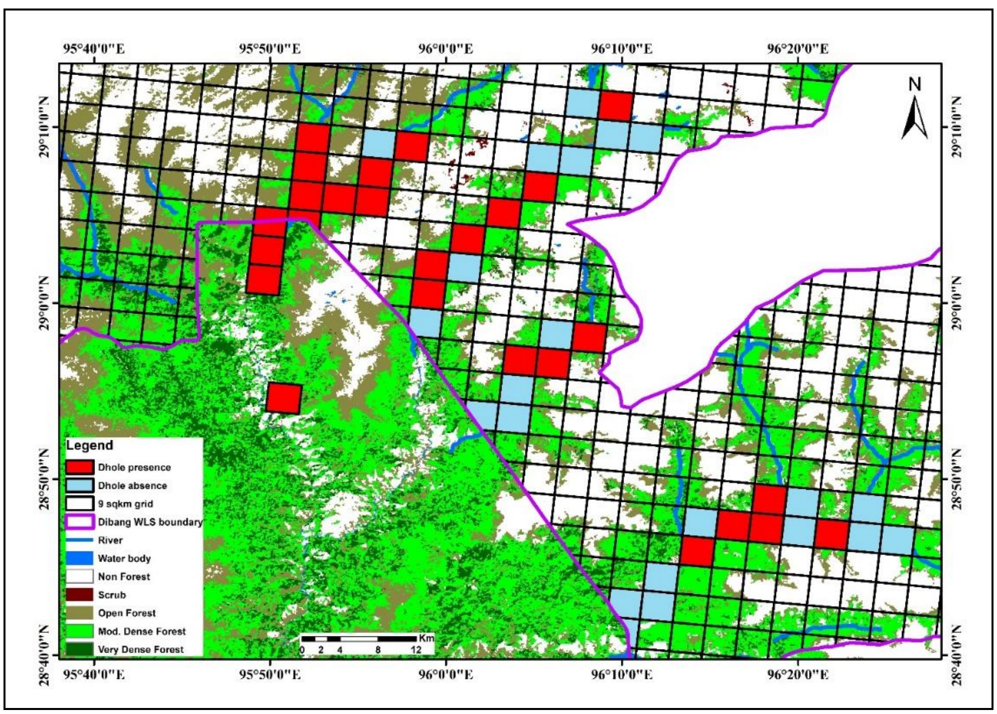

Figure 4.16: Wild dog presence location in and around the Dibang Wildlife Sanctuary during 2015-16 camera trapping

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 (A) and 29th May 2017 (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 (C) in an area with different vegetation types (Image 4.2). 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 4.2: 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°.

Table 4.12: 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	
		Camera trap location	Individual image	Camera trap location	Individual image
Slope	0-10	72.92	67.14	57.58	57.14
	10-20	20.83	22.14	27.27	30.95
	20-30	4.17	5.00	12.12	9.52
	30-40	0.00	0.00	3.03	2.38
	40-50	0.00	0.00	0.00	0.00
	50-60	0.00	0.00	0.00	0.00
	60-70	0.00	0.00	0.00	0.00
	70-80	0.00	0.00	0.00	0.00
	80-90	2.08	5.71	0.00	0.00
Aspect	East	6.25	0.07	3.03	2.38
	North	25.00	0.26	27.27	26.19
	West	8.33	0.04	6.06	7.14
	South	12.50	0.13	18.18	16.67
	NE	4.17	0.04	3.03	2.38
	NW	18.75	0.16	12.12	14.29
	SW	8.33	0.10	12.12	11.90
	SE	16.67	0.19	18.18	19.05
Elevation (m)	1600-2100	81.25	0.84	45.45	47.62
	2100-2600	12.50	0.14	54.55	52.38
	2600-3001	6.25	0.03	0.00	0.00
Canopy (%)	0-25	11.36	9.68	18.75	15.00
	26-50	31.82	36.29	34.38	32.50
	51-75	31.82	36.29	34.38	40.00
	76-100	25.00	17.74	12.50	12.50
Habitat	Misc.	43.75	46.43	60.61	60.98
	Riverine	8.33	9.29	6.06	7.32
	Bamboo	25.00	24.29	9.09	7.32
	Alnus nepalensis	4.17	3.57	0.00	0.00
	Oak spp.	4.17	2.14	3.03	2.44
	Pine	8.33	9.29	12.12	14.63
	Rhododendron	4.17	1.43	3.03	2.44
	Grassland	2.08	3.57	6.06	4.88
Shrub (%)	0-25	6.90	12.00	21.43	16.67
	26-50	3.45	2.67	3.57	2.78
	51-75	6.90	4.00	3.57	2.78
	76-100	82.76	81.33	71.43	77.78

Low High

Table 4.13: 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 elevation medow, 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,*
			Dominated by the species of		Undulating and	

		2500 to 2700	*Pinacea* family, Rhododendron forest, etc.	42.5 %	moderate slope	*Acer hookeri*
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	
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 elevation meadow, moderate slope, undulating and steep incline	

4.4 Discussion

4.4.1 Coexistence of tiger and dhole

Dibang Wildlife Sanctuary and its adjoining landscapes have been confirmed with the co-occurence of tiger and dhole (wild dog). Both tiger and dhole are categorized as endangered by the International Union for Conservation of Nature and Natural Resources (IUCN), place under Appendix I in Convention on International Trade in Endangered Species (CITES) and Schedule I for tiger and Schedule II for dhole in the Indian Wildlife (Protection) Act 1972.

The aspects of ecology of tiger and dhole study was focused mainly on prioritized ways to cover maximum areas of the protected and its adjoining landscape for tiger and dhole occurrence. Hence, we chose the five major river valleys in the central, northeastern, and southern portion of the protected area to enrich ecological baseline information and find out effective areas used by tiger and dhole. 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. 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 Dibang Wildlife Sanctuary 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 dhole (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.,* 2013a), the Khangchendzonga Biosphere Reserve have reported leopard and wild dog (Bashir *et al.,* 2014). The pack size of wild dogs' ranges from 50 individuals to 1 individual in the Indian subcontinent (Johnsingh and 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, 2013). In this study, 4 individuals were recorded in a pack from the protected area.

4.4.2 Indices of relative abundance of tiger and dhole

Estimation of large carnivore such as tiger and dhole 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 and Sunquist 2004; Johnson *et al.,* 2006; Datta *et al.*, 2008; Ramesh *et al.*, 2011; Sankar *et al.*, 2013). Before intensive camera trapping, a sign survey was conducted to ensure the capture of tiger and dhole. 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 dhole. The overall sign encounter rates were highest for the tiger and followed by dhole.

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 tiger and wild dogs 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. Comparatively, the photo-capture rates of dhole (1.19 ± 0.20) were highest then the capture rates of tiger (0.34 ± 0.06) in Dibang WLS. According to Selvan *et al.,* 2013, the photographic encounter rate of the tiger was 2.7 ± 0.49/ 100 trap nights and for the dhole 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.*, 2011).

After the assessment for strengthening of baseline ecological information on tiger and wild dog (dhole) through indices of relative abundance, both camera traps and sign survey methods, has been carried out for first time in and around Dibang Wildlife Sanctuary situated in the Mishmi Hills range of the Indian part of the Eastern Himalayan Biodiversity hotspot. With limited resources, estimates through RAI can yield crucial information required for management, as demonstrated in this study.

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CHAPTER V

POPULATION ESTIMATION OF PREY ABUNDANCE

5.1 Introduction

The population estimation of prey abundance has apparent and efficient approach to derive the reliable quantitative information about the distribution and population of large carnivore (Karanth and Nichols, 1998). Mostly large carnivore population has limited resources with the fitness of a predator population depending on the availability of suitable prey species (Sunquist and Sunquist, 1989). Ungulate distribution, density and biomass embodies quantifiable amounts of energy hypothetically accessible as food to carnivores. Prey-predator relationships have complex interactions in ecological systems (Gasaway *et al.*, 1983). The mortality risk of less preferred prey is reduced when it co-occurs with a favored prey as the predator essences on the preferred species (Fairweather, 1985) while in the abundant presence of preferred prey species, the density of each predator species is highest (Schmit, 1987). The growth rate of carnivore population ought to depend on the density of prey and prey co-specific (Fryxell *et al.*, 1999). Several studies have suggested to maintain a healthy herbivore population both in terms of biomass and community structure (Sunquist, 1981; Karanth and Sunquist, 1995; Karanth and Stith, 1999). In South East Asia, over hunting in tropical forests is a major problem as there is minimal knowledge on population ecology of large ungulate species (Steinmetz *et al.*, 2010). Prey depletion and depredation by carnivores is common in Arunachal Pradesh (Aiyadurai and Verma, 2003; Gopi *et al.*, 2012). Aim of the present study is to strengthen the dynamic ecological baseline information on ungulates prey species available for large carnivores in DWLS and its adjoining landscape.

The DWLS and its adjoining landscape of Dibang valley district is remote with difficult terrain, topographically fragile and lack of infrastructure such as poor road connectivity has set aside the areas from scientific exploration. For achieving the ecological baseline gap, a rapid study was carried out in 2014 by the WII in collaboration with forest department of Arunachal Pradesh and NTCA in this protected area. Such rapid scientific exploration had been made after the rescuing of two tiger cubs from this valley close to DWLS in 2012 December. The rapid survey revealed that the first photographic image of tiger was captured on camera traps at an elevation of 1765m amsl and also reported the presence of others carnivores and ungulates through camera traps and sign survey predicting the viable population of tiger and prey species (Gopi *et al.,* 2014). The large carnivore such as tiger and wild dog conservation is depends on the availability of prey population in a habitat region as depredation of prey population results in the carnivore population decline particularly tiger (Wikramanayake *et al.*, 1998; Karanth *et al.*, 2004b). Subsequently, more comprehensive and reliable ecological knowledge is required in undertaking the scientific management of ungulate populations. In this chapter, I focus on relative abundance index and composition of the major prey species in DWLS and recommended measures for conserving the ungulate populations.

5.2. Methodology

The ungulate species along the trails, ridges, and rivulet, was confirmed through sign surveys in different valleys. Based on the reconnaissance surveys, the intensive study area was selected for the deployment of camera traps (Mackenzie and 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.,* 2001). However, the direct counting of ungulate (density estimation) in the Mishmi hills of the Indian part of Eastern Himalaya 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 such as sign survey is conducted for estimation of encounter rates of ungulates inside the protected area at Dibang Valley district.

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.,* 2004a; 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.

5.2.1 Signs survey

Most prey can potentially be monitored using field methods that employ direct sighting of animals by distance sampling method which is used for the estimation of prey density. However, in areas where prey species are difficult in direct sighting due to wariness of various factors such as dense vegetation, rugged terrain type, low density of prey and human disturbances. Indices of relative abundance based on sign such as dung/pellets, hoof marks, hairs, digging signs and alarm calls rather than direct sightings were used. Within the intensive study area, the sign survey along trails, ridges and streams (*nullahs*) was carried out (Sathyakumar, 1994). The sign surveys were conducted at imaginary beat level along trails of minimum 5 km length and encounter of indirect evidences (pellet group or hoofmarks, hairs, digging signs) were recorded (Fig 5.1). Each trail was monitored 2-3 times in every season and information on the encountered signs were collected and recorded in the GPS co-ordinate (using GERMIN Etrex 20x) of each signs. Also, covariates such as forest types, canopy cover, shrub density, ground cover, distance from stream or *nullahs* and anthropogenic activity in and around the encountered signs were recorded.

5.2.2 Camera trap

Camera trap survey offers yet another option to estimate relative abundance of ungulate species where animals are difficult to direct sighting, low density, more cryptic and those species which cannot be individually identified from photographs (O'Brien *et al.*, 2003). Relative abundance index (RAI) is the most widely used method for individually unidentified species from camera-trapping data (O'Brien *et al.*, 2003; Carbone *et al.*, 2001). Based on the knowledge acquired through reconnaissance sign surveys, camera trap locations were selected for the intensive study from October 2015 to June 2017. The study area was divided into 3 km^2 (1.73 km x 1.73 km) grid size using Geographic Information System (GIS) (ARC GIS 9.1). For the convenience of camera deployments, the area was categorized into three blocks comprising of five different river valleys based on the accessibility, habitats, elevation variation and remoteness. The maximum accessible grids were randomly selected for deployment of a single sided Cuddeback Model "C" camera trap. A minimum distance of 700 meter and maximum of 1500 meter was maintained between two camera traps points. Cameras were placed perpendicular to the expected direction of the animal movement. the camera was placed at around 3-4 meters away from the trail and 30 cm to 45 cm above from the ground (Fig 5.2). Head-on, oblique and side-view camera configurations were used to obtain photographs at varying body orientations (Jackson *et al.,* 2006). Since the study area is vast and targeted species were rare, the priority emphasis was given to the river valleys and I surveyed more sampling units for gathering the baseline information of ungulates (Mackenzie and Royle, 2005). Camera traps were operated with a minimum 65 days in each session which included changing the batteries and memory card. Vegetation and covariate sampling were carried out around the camera traps to quantify the various habitat parameters. During the summer, field work was not carried out due to heavy rainfall.

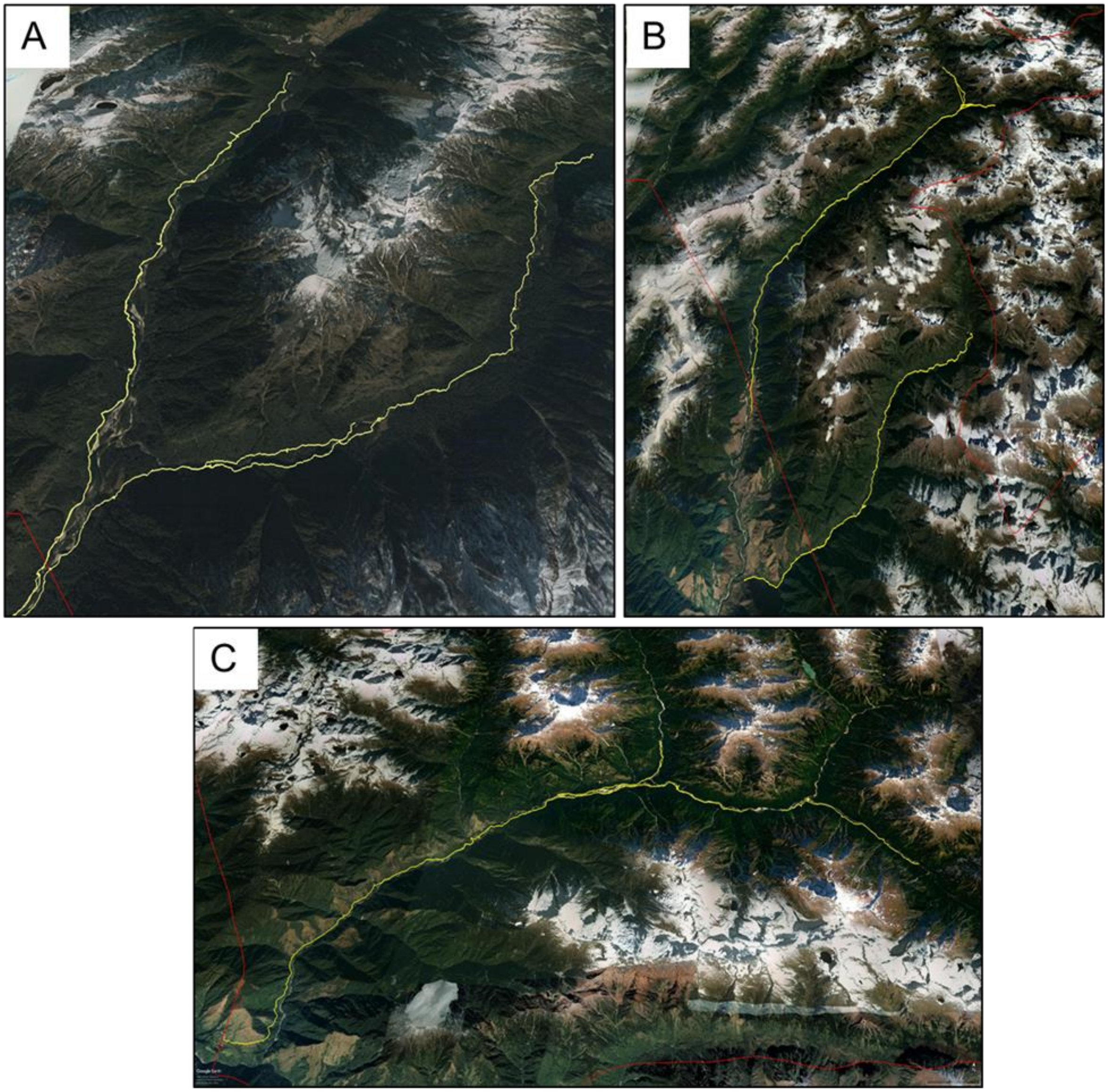

Figure 5.1: Sign survey trails at (A) Mathun and Enjoo Valleys; (B) Dri and Angi-pani Valleys and (C) Tallon Valley in Dibang Wildlife Sanctuary during 2015-2017

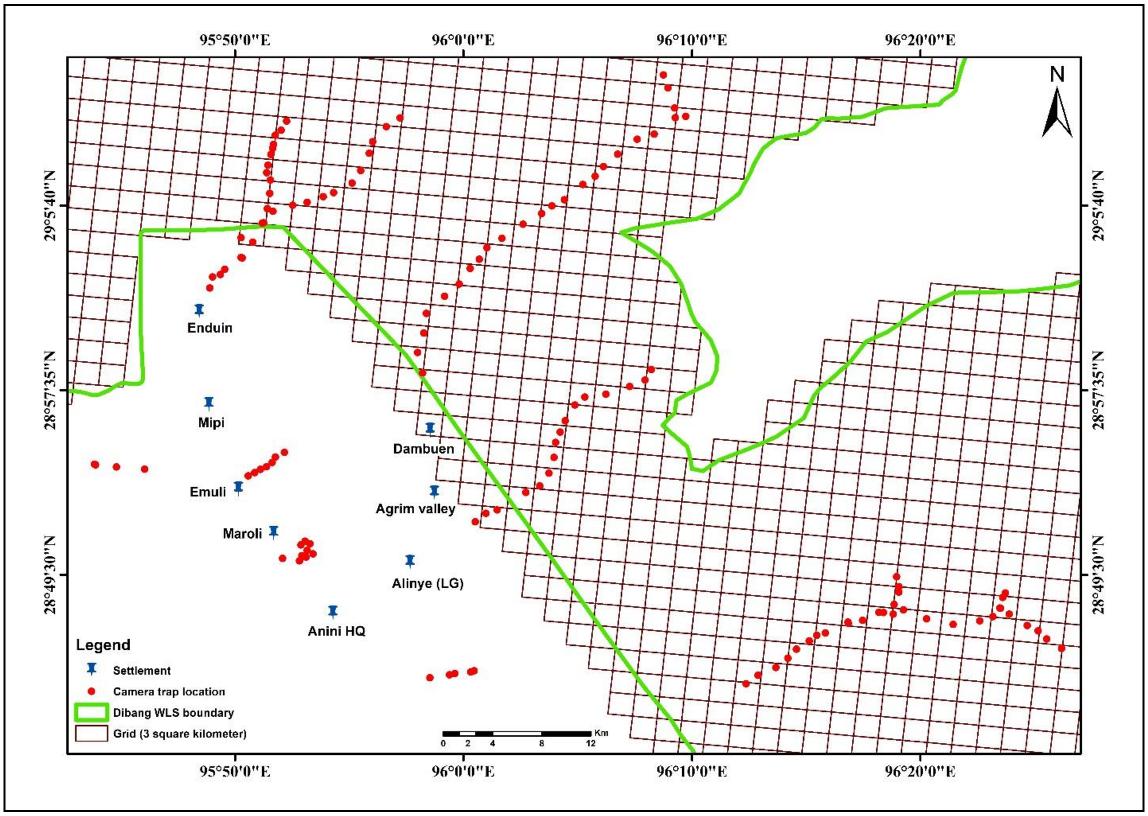

Figure 5.2: Camera traps locations in and around the Dibang Wildlife Sanctuary during 2015- 2017

5.3 Analysis

5.3.1 Ungulate sign encounter rate

The ungulate sign survey data was summarized for the encountered rate and used to supplement camera trap data on species in the area (Datta *et al.,* 2008; Karanth and Nichols, 2002).

During the sign survey, ungulate signs were acknowledged and identified according to previous field experiences, with help of local assistants and collected for secondary validation by the local experts. The ungulate signs encountered during sampling, such as hoof marks, track, hairs, digging signs etc., were collected and photographed and examined afterwards in Wildlife Institute of India, crossed check with the reference and respective species identity were assigned wherever possible. Encounter rates based on sign survey sampling were obtained for ungulates species. Encounter rates may be defined as the number of ungulate signs 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 ungulate species. Distance was used as the sample effort and the encounter rate were estimated from the given formula:

Encounter rate= n/L

Where **'n'** is the total number of signs encountered of ungulate species and **'L'** is the length of trail walk in kilometer (km) used as a sampling effort

Mean sign encounter rate of 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.

5.3.2 Estimation of relative abundance index

Camera trap images of forest dwelling ungulate species were used to calculate an index of relative abundance (RAI). The number of days required for obtaining a photo capture of a species (RAI 1) (Carbone *et al.,* 2001) and 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 (RAI 2) were estimated (Kawanishi *et al.,* 1999; Carbone *et al.,* 2001; O'Brien *et al.,* 2003). Species were identified with the help of hitherto published literatures (including photographs) based on mountain ungulates and taxonomy after judicious examination and separation of ungulate photographs of camera trap (Prater, 1980; Menon, 2009). Each photographs were identified for species and rate as a dependent or independent event, with an independent capture event defined as (1) consecutive photographs of different individuals of the same or different species, (2) consecutive photographs of individuals of the same species taken more than 0.5 hrs. apart and (3) non-consecutive photos of individuals of the same species (O'Brien *et al.,* 2003). Photographic rate is defined as the number of camera days (24 hrs.) per study species (≥ 1-year-old) photograph were summed across all camera traps in the study (Carbone *et al.,* 2001). Mean photo capture rate of forest dwelling ungulate species at each valley and overall photo capture rates were calculated. Kruskal-Wallis χ^2 and Mann- Whitney U tests were used to test significant differences among the estimates of the ungulate species in different valleys and seasons.

5.3.3 Camera trap parameter

A 10 m radius plots at intervals of 500 to 1000 m along the trail and also around the camera traps 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 plant phenology in percentage and the average height of most dominated shrub cover was measured by a calibrated pole. Ground cover percentage such as grass density, dry grass percentage, dry leaves percentage and open ground were monitored within 1 m radius plots. Human presence and disturbance factors were recorded around the sampling plots.

5.4 Results

5.4.1 Sign survey: Ungulate sign encounter rates

During October 2015 to July 2017, 28 number of sign surveys of forest dwelling ungulate were carried at five river valleys with a total effort length of 231.85 km (Table 5.1). The overall signs encounter rate of the barking deer (0.125 km^{-1}) was highest followed by wild pig (0.06 km$^{-1)}$, Himalayan serow (0.06 km^{-1}), Mishmi takin (0.022 km^{-1}), and goral (0.009 km^{-1}) (Table 5.2).

Table 5.1: Forest dwelling ungulate 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 5.2: Forest dwelling ungulates sign encounter rate inside DWLS

Ungulate Species	Total effort length (km) (L)	Total # of encounter (n)	Mean	SE	Encounter rate (km^{-1})
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

Mean sign encounter rates of forest dwelling ungulate (the number of sign encountered/total effort length) in the different valley in different seasons were calculated. During first year surveyed, the ungulate signs encountered were minimal due to frequent rainfall. Only signs of three ungulate species such as serow (0.024 ± 0.01), barking deer (0.014 ± 0.008) and wild pig (0.005 ± 0.005) were encountered. During the second year, the encounter rates of wild pig (0.04 ± 0.02) were highest at Mathun and Enjoo valleys in autumn, followed by barking deer (0.03 ± 0.008) at Dri and Angi pani valleys in spring season and serow (0.02 ± 0.001) at Mathun-Enjoo valley in autumn season. Goral and Takin encounter signs were comparatively very low from these valleys. Kruskal-Wallis $\chi 2$ revealed that across the surveyed areas, only barking deer (p = 0.04) sign encounter rates were significant. Overall mean sign encounter rates of forest dwelling ungulates were associated with high standard error (SE) which is due to the high degree of variability in signs encountered (Table 5.3).

Table 5.3: Forest dwelling ungulate mean sign encounter rates (per km) with SE at different valley and seasons within the DWS during 2015-17

Species	**Year 1 (2015-2016)**			**Year 2 (2016-2017)**			K-W che ^{2}	*df*	*p*
	Autumn (Dri & Angi Valley)	Winter (Mathun & Enjoo Valley)	Spring (Tallon Valley)	Autumn (Mathun & Enjoo Valley)	Winter (Tallon Valley)	Spring (Dri & Angi Valley)			
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 average sign encounter rates of forest dwelling ungulate species in different seasonal temporal scale at same valley were estimated and tested for significances difference (Table 5.4). **a) Dri and Angi pani valleys:** 11 ungulate sign surveys were conducted with a total effort length of 100.69 km in two seasons i.e., autumn and spring from at an elevation of 1736 m up to 3001 m amsl. The mean sign encounter rates of barking deer were highest in spring season (0.035 ± 0.008), and followed by serow in autumn season (0.024 ± 0.01). Goral and takin sings were not encountered during autumn from these valleys. The encounter rates for barking deer were comparatively highest among the forest dwelling ungulates and showing significant difference (p= 0.002) across the valleys.

b) Mathun and Enjoo valleys: In these valleys 10 ungulate sign survey were carried out in two seasons i.e., winter and autumn with a total effort length of 73.9 km from an elevation of 1697 m up to 2017 m amsl. No ungulate sings were encountered from Mathun and Enjoo valleys in winter. Only signs of barking deer, serow and wild pig were encountered during autumn. Among these, the wild pig (0.04 ± 0.02) had comparatively highest mean sign encounter rates. In these valleys, there were no significant seasonal differences in mean sign encounter rates of forest dwelling undulates.

c) Tallon valley was observed for ungulate sign survey during spring and winter seasons. Seven sign surveys were conducted from an elevation of 1633 m up to an elevation of 2934 m amsl with a total efforts length of 57.26 km. No ungulate signs were encountered during the spring season. In winter, the mean sign encounter rates were comparatively highest by barking deer (0.015 ± 0.009) followed by serow (0.008 ± 0.008), takin (0.005 ± 0.003) and goral (0.003 ± 0.003). No significant seasonal difference was observed from the valley in the encounter rates of forest dwelling ungulates.

Table 5.4: Mean sign encounter rates for forest dwelling ungulate species in different seasonal temporal scale at same valleys within the protected area

Species	**Dri & Angi Valley**		**Mann-Whitney U test**	**Significance**
	Autumn (2015-16)	Spring (2016-17)		
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
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 Valley		Mann-Whitney U test	Significance
	Winter (2015-16)	Autumn (2016-17)		
Barking deer	0	0.02 (±0.007)	0	0.25
Goral	0	0	-	-
Serow	0	0.02 (±0.01)	1	0.06
Takin	0	0	-	-
Wild pig	0	**0.04** (±0.02)	0	0.25
Species	**Tallon Valley**		**Mann-Whitney U test**	**Significance**
	Spring (2015-16)	Winter (2016-17)		
Barking deer	0	0.015 (±0.009)	0	0.4
Goral	0	0.003 (0.003)	0	0.3
Serow	0	0.008 (±0.008)	0	0.3
Takin	0	0.005 (±0.003)	0	0.6
Wild pig	0	0	-	-

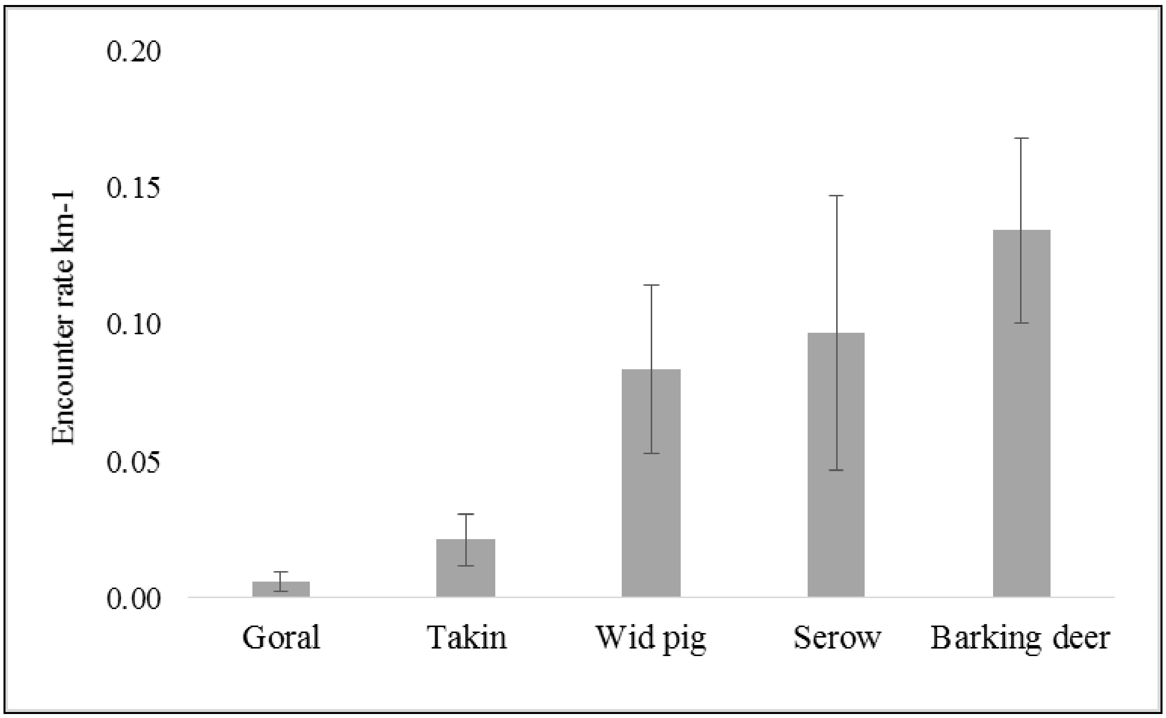

Figure 5.3: Ungulates sign mean encounter rate inside the DWLS

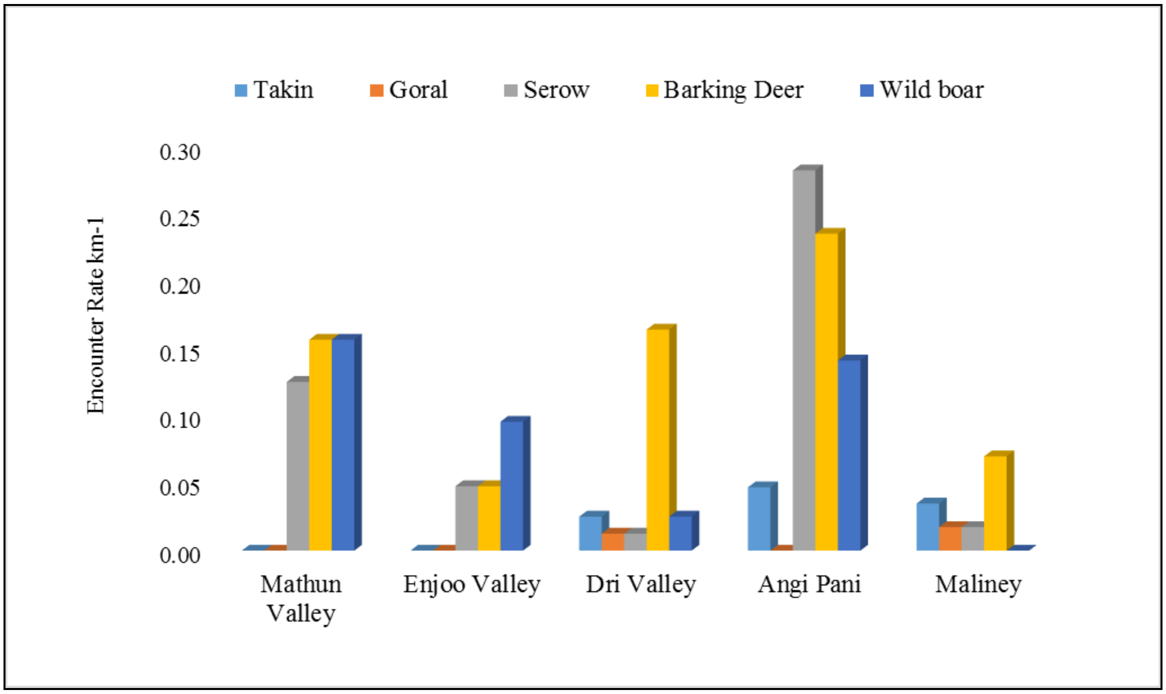

Figure 5.4: Ungulate sign encounter rates along the five major river valleys of DWLS

5.4.2 Camera traps: Indices of ungulate relative abundance (RAI)

Two-year comprehensive camera traps sampling effort both inside and outside the protected area (Table 5.5). Overall, there were 112 camera trapping locations with 13761 trap nights, covering an area of 336 km^2. A total of 11952 trap nights across 90 sampling sites covering and area of 270 km^2 within the sanctuary was accomplished from the five river valleys *viz*., Dri valley (3274 camera-days), Angi pani (1822 camera-days), Mathun valley (2176 camera-days), Enjoo valley (2067 camera-days) and Tallon valley (2613 camera-days). Outside the sanctuary, a total of 1809 trap nights across 22 sampling camera trap locations covering an area of 66 km^2 were monitored in community forests (Table 5.6).

The photo-capture rates (photographs/100 days) of forest dwelling ungulate species present inside the sanctuary were only analyzed. The photo-capture rates of ungulate 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 photo-capture rates 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 protected area.

Photographic rates were calculated for all ungulates species inside the protected area. Relative abundance index (RAI1) declines as follow: serow (217.30) > wild pig (206.06) > red goral (178.38) > Mishmi takin (145.75) > barking deer (34.24). Comparatively, the overall mean photo-capture rates of barking deer (2.99 ± 0.47) were highest 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). The mean photo-capture rates of Mishmi takin were accompanied with high standard error (SE) due to high degree of variability in capture of Mishmi takin in different camera traps (Table 5.8).

Table 5.5: Comprehensive camera traps sessions at different valleys of DWLS

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

Table 5.6: Comprehensive camera taps locations both inside and outside the protected area

Name of valley	**Camera traps**	**Area covers (km^2)**	**Trap nights**
Inside PA			
Dri valley	28	84	3274
Angi pani valley	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 5.7: Comparative photo-captures of different taxa within and outside the protected area

Sampling area	Total photo captures	Wild/Semi domestic animals/Humans							
		Carnivore	Ungulate	Bird	Mithun	Non-human primate	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**

Table 5.8: Overall photo-capture rate of ungulates (#/100 days) inside the DWLS

Ungulate Species	N	Mean photo-capture rate	SE
Barking deer	349	2.99	0.47
Red goral	67	0.61	0.13
Serow	55	0.50	0.08
Mishmi takin	82	0.62	0.26
Wild pig	58	0.49	0.18

Mean photo-capture rates of ungulates (number of photographs/100 days) in different temporal scale at the same spatial river valleys within three blocks were estimated and also tested for significance using Kruskal-Wallis χ^2 test (Table 5.9). Photo-captures rates of barking deer were comparatively high in Dri and Angi pani valleys spring (5.98 ± 1.61) and in autumn (3.56 ± 1.05), followed by wild pig (1.77 ± 1.10) in Tallon valley during winter, red goral in Dri and Angi pani valleys in autumn (1.69 ± 0.42), Mishmi takin (1.46 ± 1.03) in Mathun-Enjoo valleys during autumn and Himalayan serow in Dri and Angi pani during autumn. Kruskal-Wallis χ^2 revealed that the photo-capture rates of the barking deer, red goral and Mishmi takin were significant along the different valleys in different temporal scale, while the photo-capture rates of Himalayan serow and wild pig were not significant.

Table 5. 9: Valley and season wise photo-capture rates (#/100 days) with SE of ungulates inside PA

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*			
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 average photo-capture rates of forest dwelling ungulate species in different seasonal temporal scale at same valleys were estimated and tested for significances difference (Table 5.10).

a) Dri and Angi pani valleys: These valleys were monitored in two seasons i.e., autumn and spring. Comparatively, the photo-capture rates of barking deer were highest in spring (5.98 ± 1.61) followed by red goral (1.69 ± 0.42), Himalayan serow (0.90 ± 0.21) in autumn, Mishmi takin (0.88 ± 0.88) in spring and wild pig (0.48 ± 0.48) in autumn respectively. The photo-capture rates of red goral ($p = 0.02$) had significant in seasonal differences.

b) Mathun and Enjoo valleys: These valleys were monitored in two seasons i.e., winter and autumn. Comparatively, Mishmi takin (1.91 ± 0.42) had highest mean photo-capture rates in winter followed by barking deer (1.81 ± 0.51), red goral (0.91 ± 0.32), Himalayan serow (0.40 ± 0.14) and wild pig (0.20 ± 0.12) in autumn. The photo-capture rates of barking deer ($p = 0.01$) and red goral ($p = 0.03$) were significant in seasonal differences.

c) Tallon valley: In this valley, camera traps were operated during spring and winter seasons. Comparatively, the mean photo-capture rates of barking deer (1.99 ± 0.86) were highest and followed wild pig (1.77 ± 1.10), Himalayan serow (0.47 ± 0.26) and red goral (0.06 ± 0.06) in winter respectively. No Mishmi taken was photo-capture in both seasons. Only wild pig ($p = 0.03$ had significant photo-capture rates in the different season.

Table 5.10: Mean photo-capture rates of ungulate species in different seasonal at same valleys within the protected area

Ungulate species	Dri & Angi pani valleys		Mann-Whitney U test	*p*
	Autumn (2015-16)	Spring (2016-17)		
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
Ungulate species	**Mathun & Enjoo valleys**		**Mann-Whitney U test**	***P***
	Winter (2015-16)	**Autumn (2016-17)**		
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
Ungulate species	**Tallon valley**		**Mann-Whitney U test**	***P***
	Spring (2015-16)	**Winter (2016-17)**		
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**

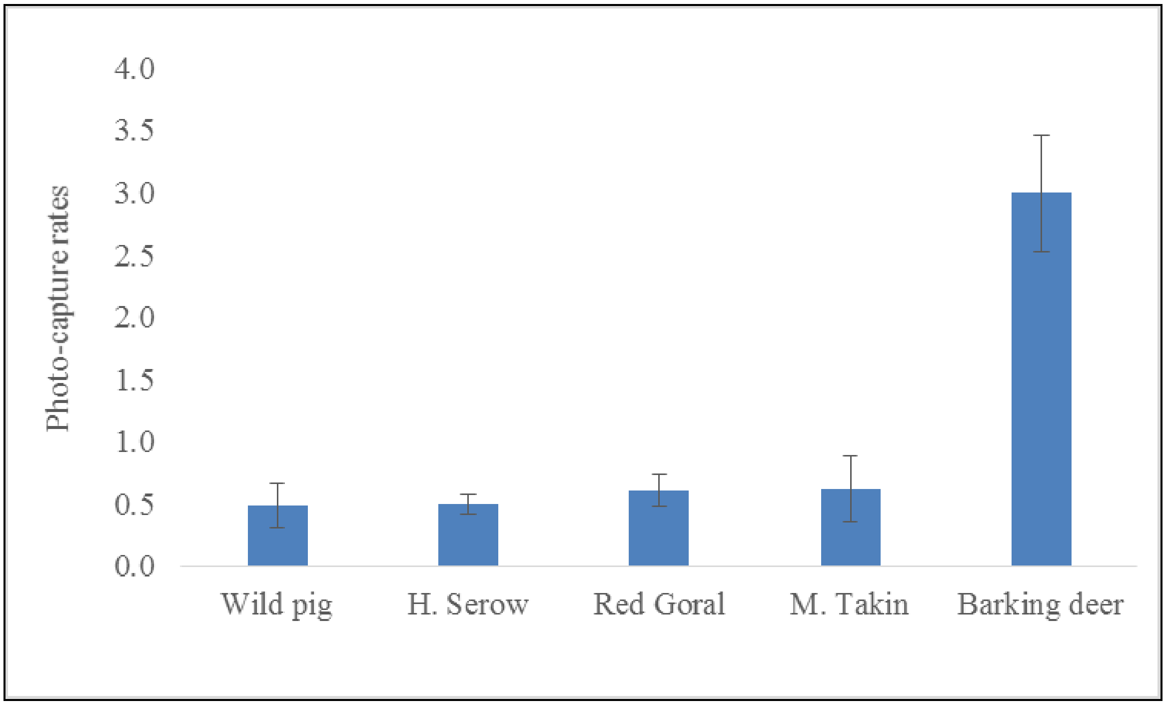

Figure 5.5: Overall photo-capture rates of forest dwelling ungulate species inside

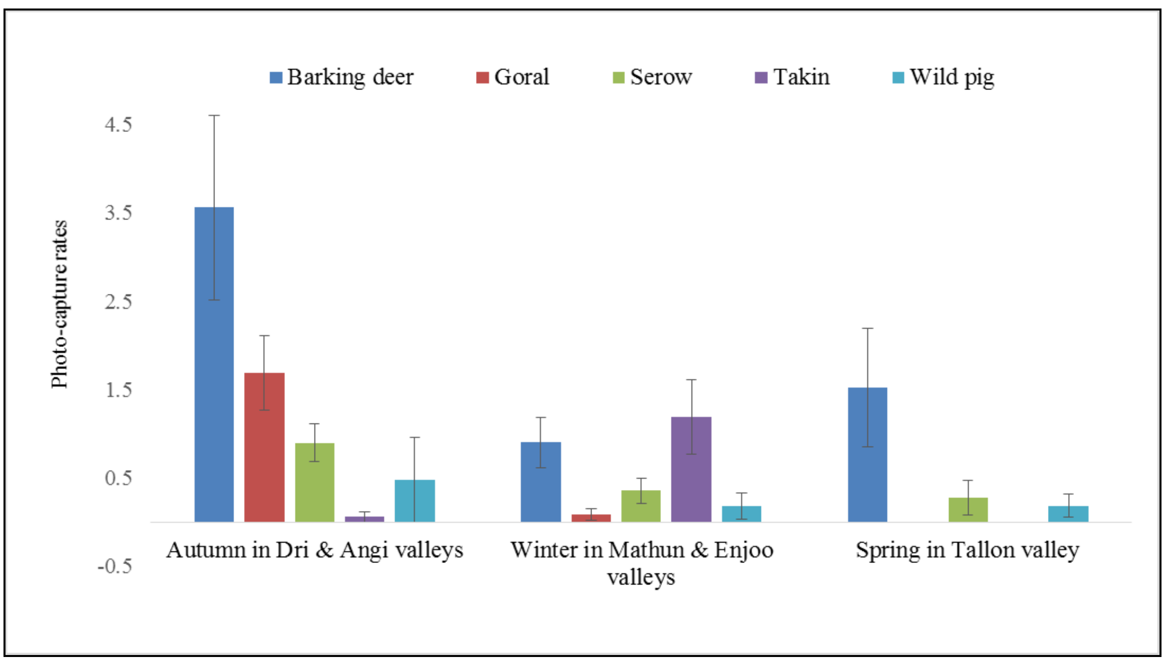

Figure 5.6: Mean photo-capture rates of forest dwelling ungulate species at different temporal scale during first-year observation

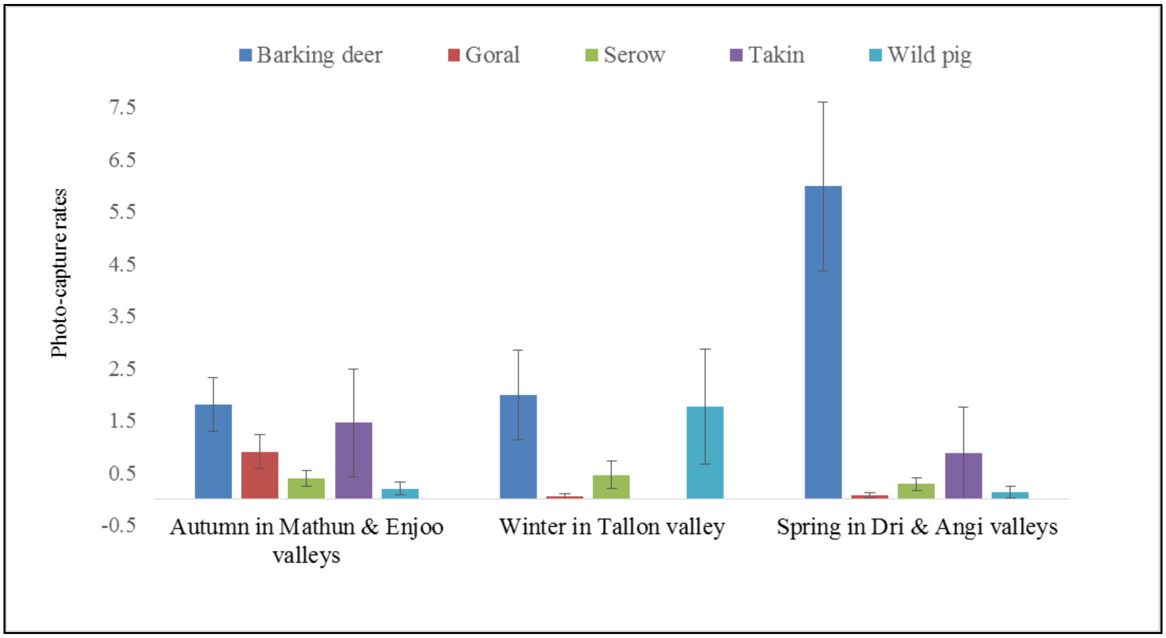

Figure 5.7: Mean photo-capture rates of forest dwelling ungulate species at different temporal scale during second-year observation

Relationship between the mean photo-capture rates (# photographs/100days) and sign survey encounter rate (per 100 km) of forest dwelling ungulate species across the surveyed river valleys in different season were revealed using results of respective different methodologies output. Sign survey encounter rates of the forest dwelling ungulate species were positively correlated ($R^2 = 0.83$) with photo capture rates (Fig 5.8).

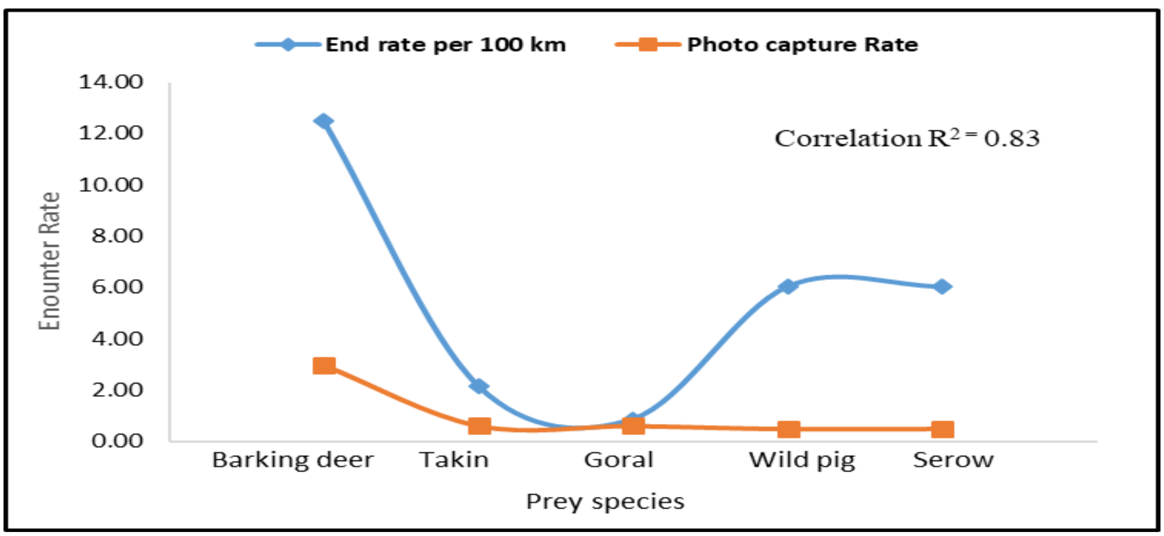

Figure 5.8: Relationship between sign encounter rates (per 100 km) and photo-captures rates (per 100 days) of different ungulates

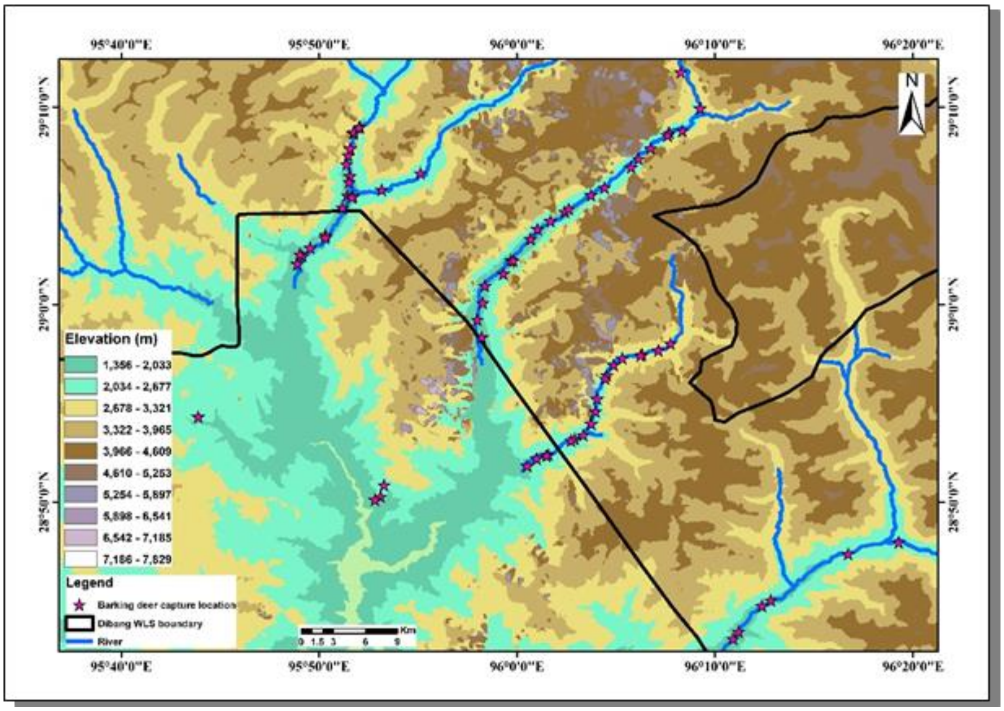

Figure 5.9: Barking deer capture locations along the five valleys of protected area during 2015-17

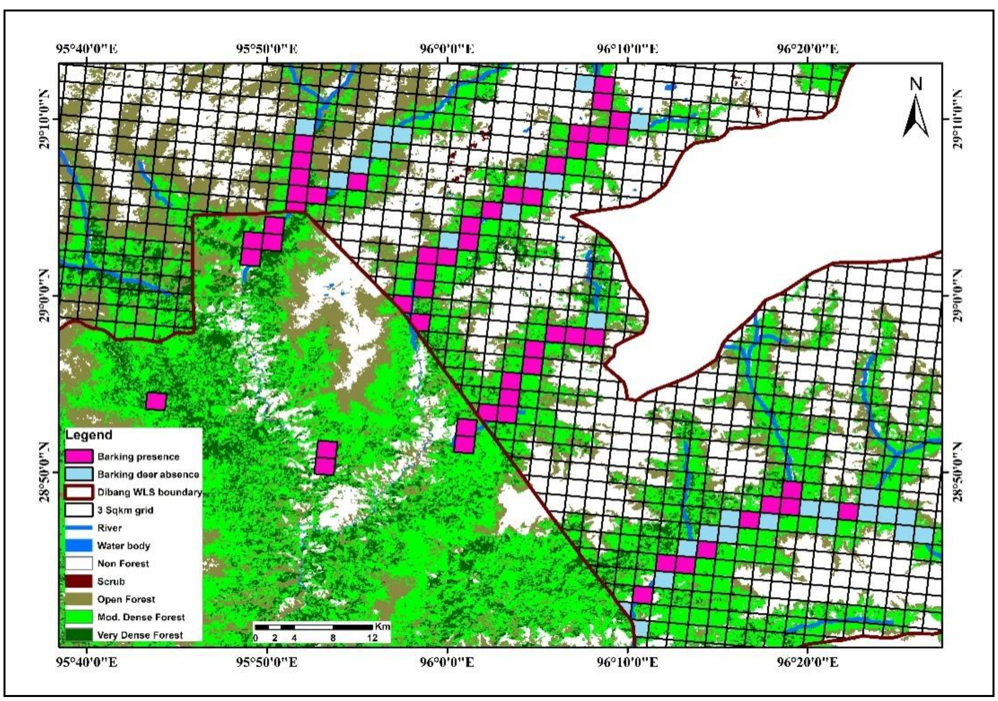

Figure 5.10: Barking deer presence locations along the five valleys of protected area during 2015-17

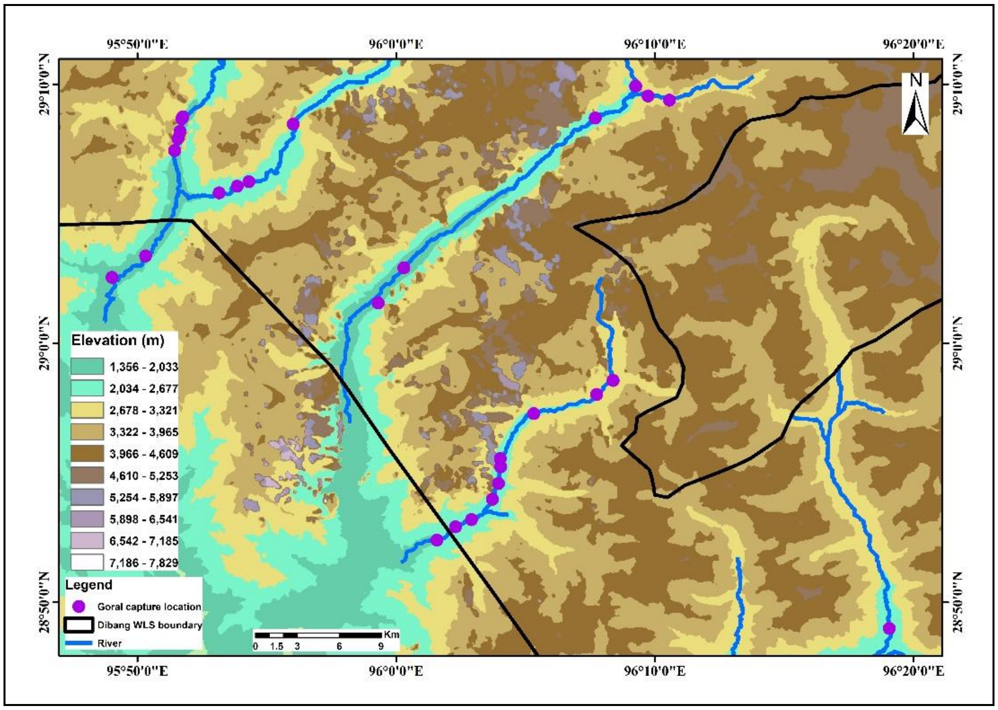

Figure 5.11: Red goral capture locations along the five valleys of protected area during 2015-**17**

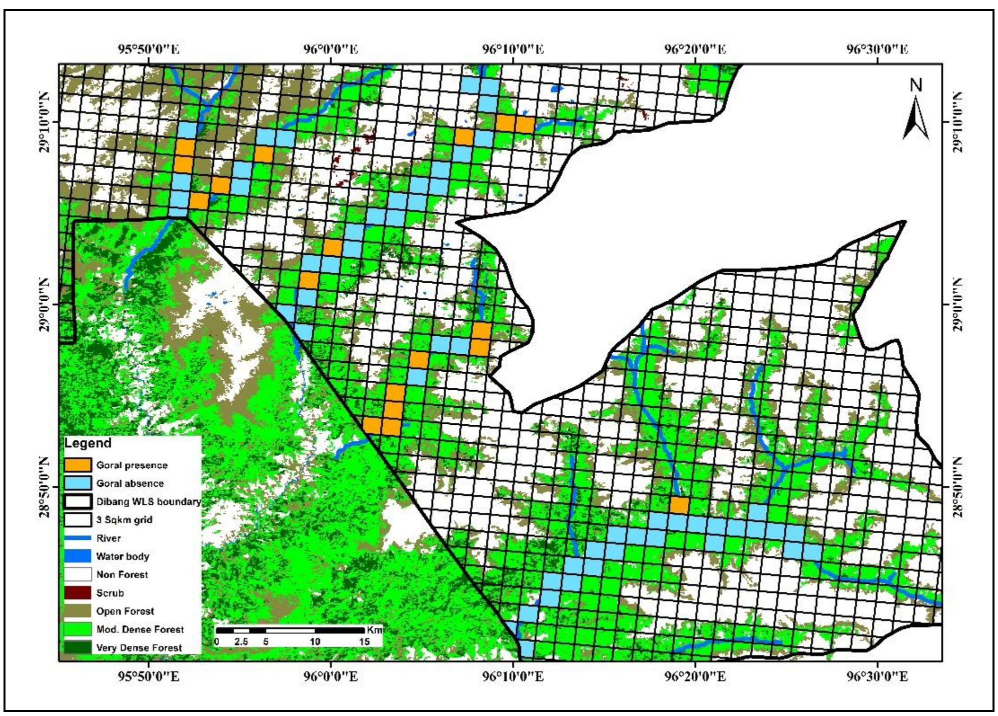

Figure 5.12: Red goral presence capture locations along the five valleys of protected area during 2015-17

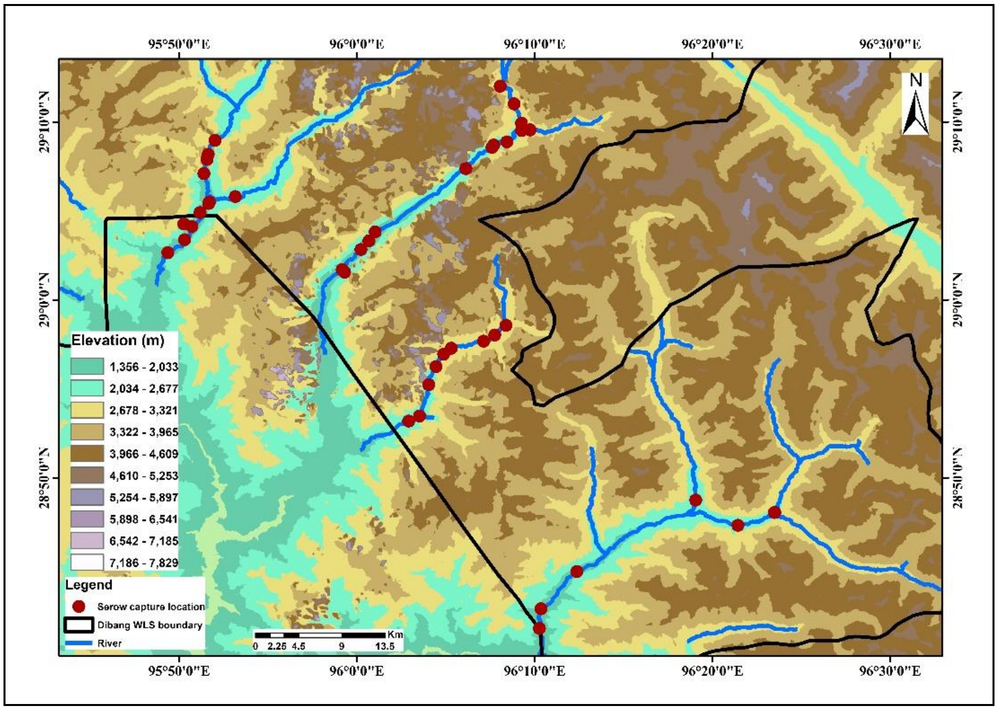

Figure 5.13: Himalayan serow capture locations along the five valleys of protected area during 2015-17

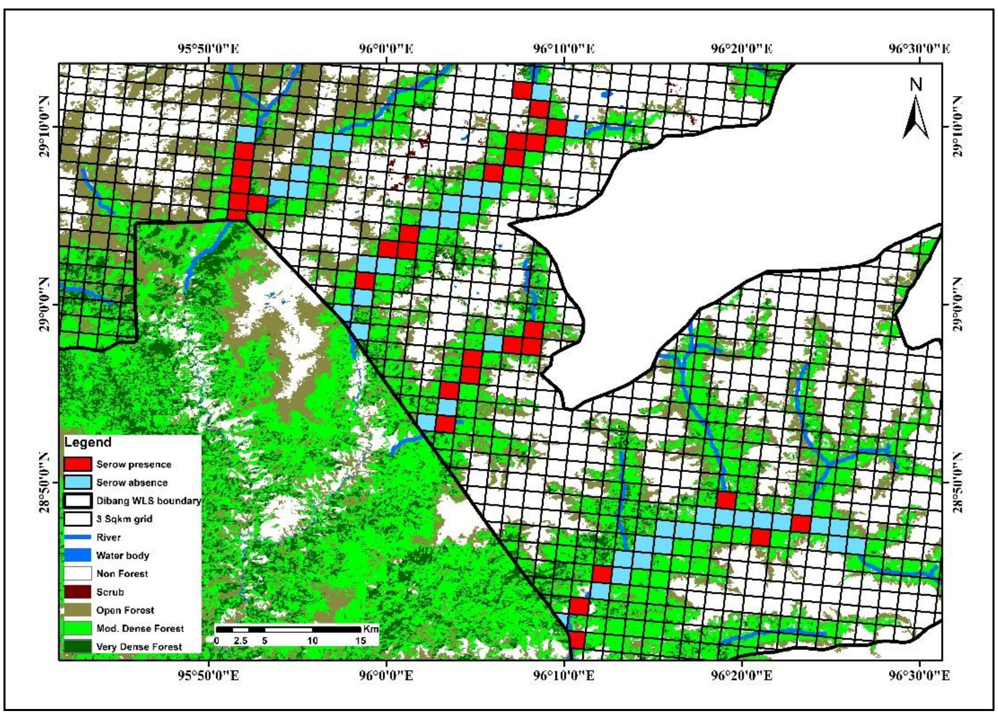

Figure 5.14: Himalayan serow presence locations along the five valleys of protected area during 2015-17

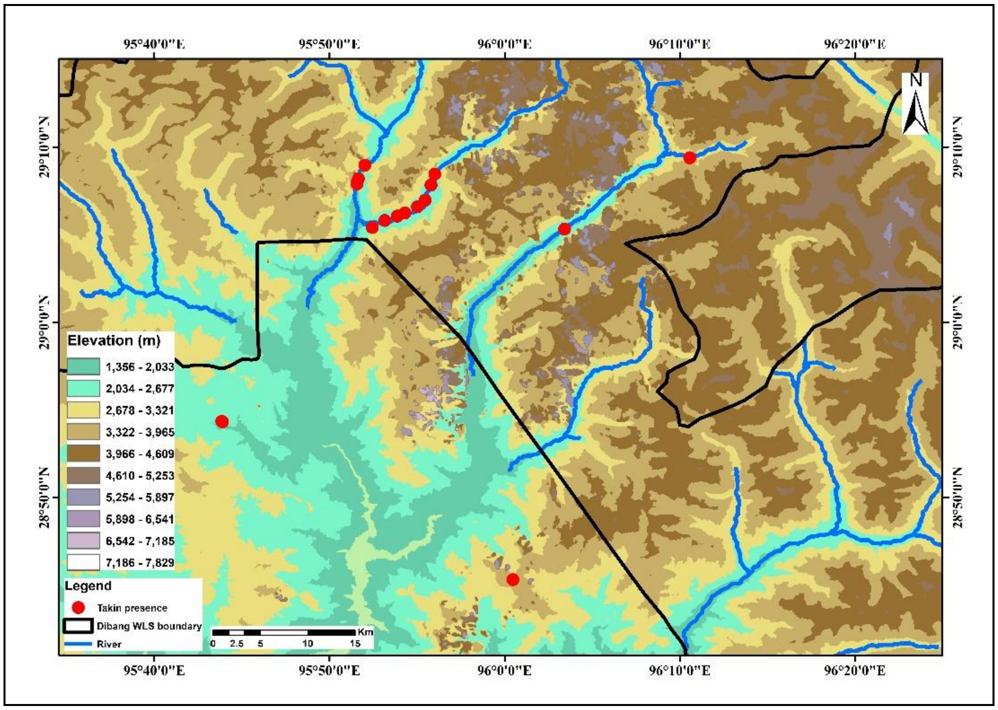

Figure 5.15: Mishmi takin capture locations along the five valleys of protected area during 2015-17

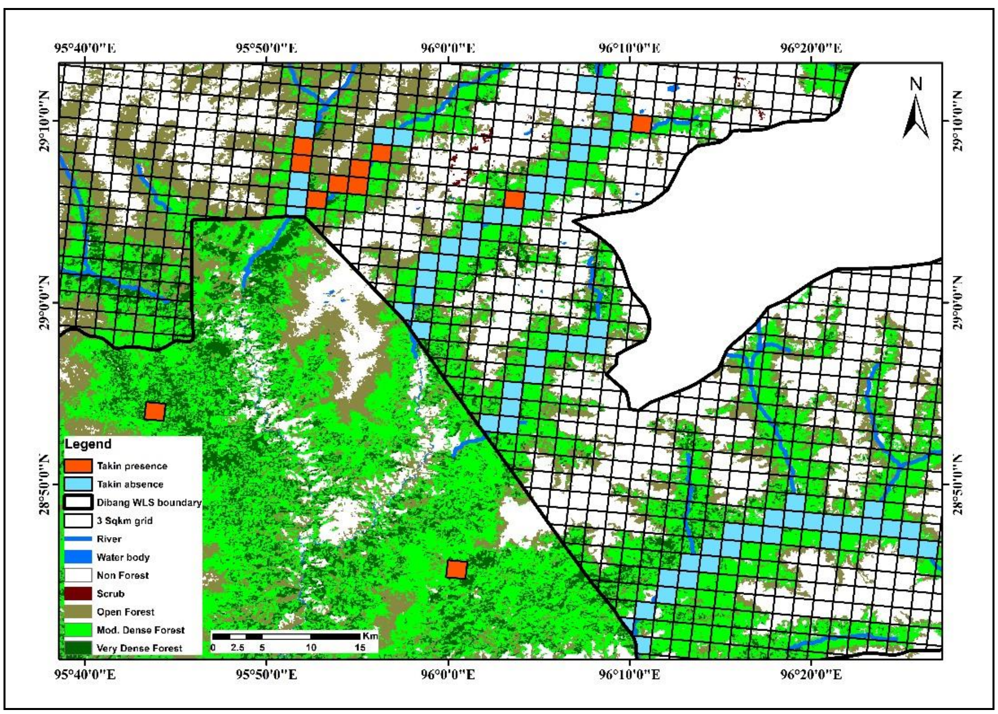

Figure 5.16: Mishmi takin presence locations along the five valleys of protected area during 2015-17

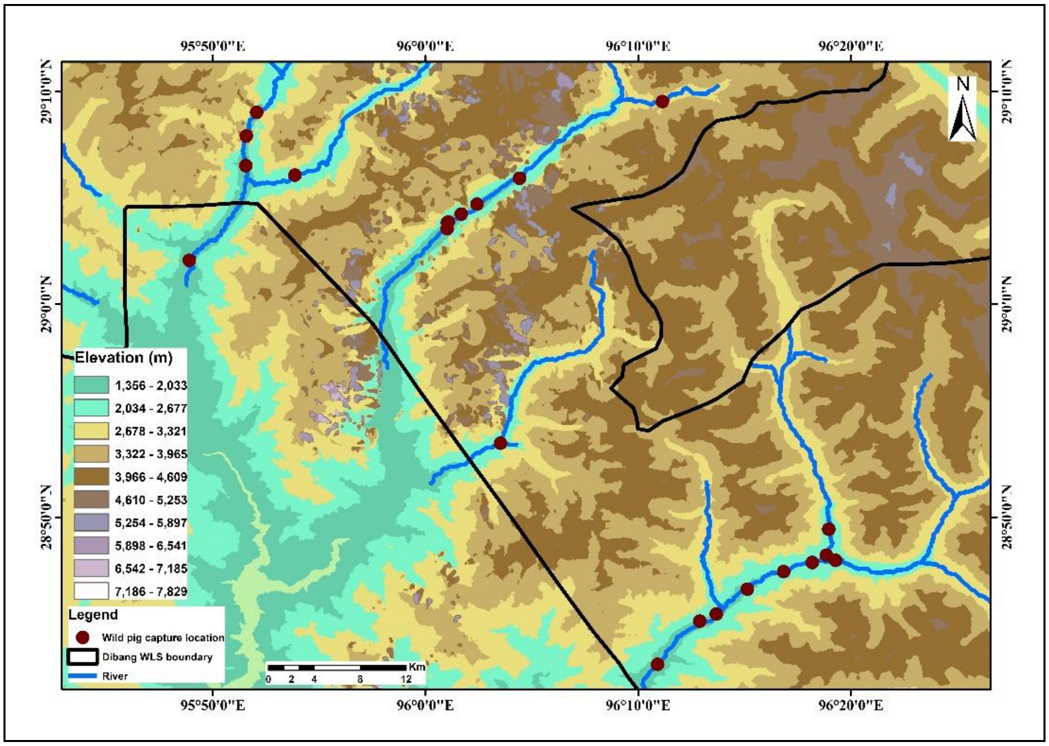

Figure 5.17: Wild pig capture locations along the five valleys of protected area during 2015-17

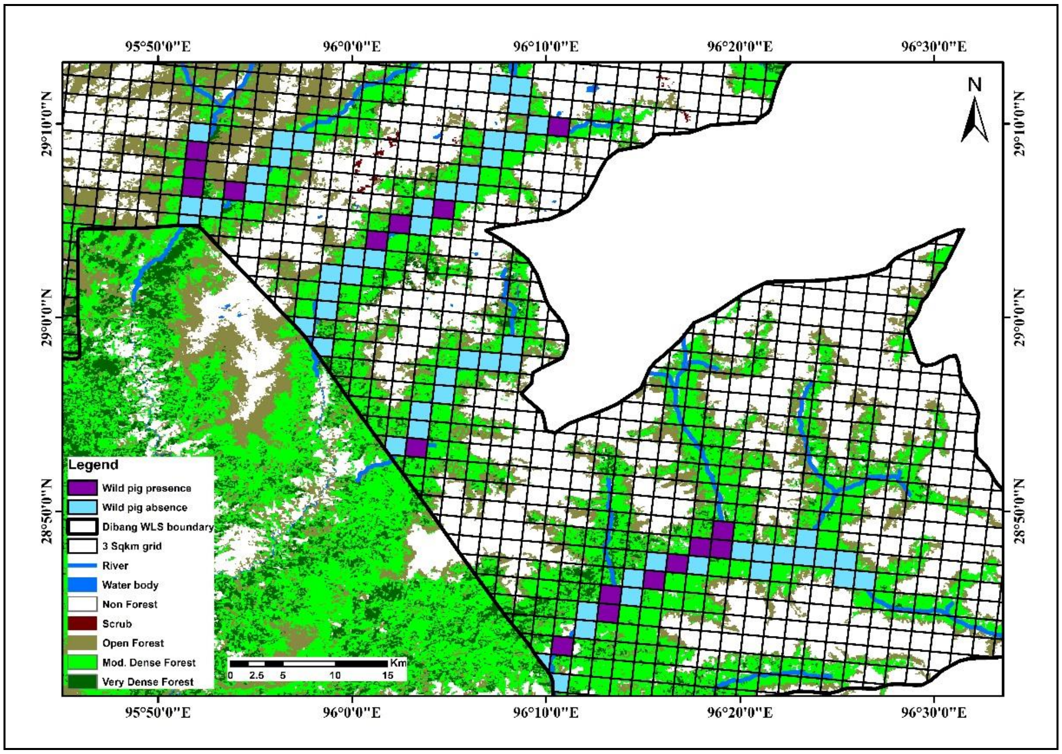

Figure 5.18: Wild pig presence locations along the five valleys of protected area during 2015-17

5.4.3 Mean group sizes and population structure of forest dwelling ungulate species

A total of 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.

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

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

The social behavior was recorded in Mishmi takin. A total of 82 individuals of Mishmi takin were photo-captured. 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 adults, eight sub-adult and two calves). The mean group size of Mishmi takin was 4.82 ± 1.65.

Amongst 58 photo-captured of wild pig individuals; 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 5.11).

Table 5. 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 (%)
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	-	-	-

5.4.4 Spatial distribution patterns of ungulates in the study area

The presence of forest dwelling ungulate species were provided by camera trap images at different geographical locations both inside and outside the Dibang WLS (Fig 4.8; 4.9 & 4.10). The photo-capture rate of forest dwelling ungulates species was represented with a high, medium, and low frequency of presence.

A total of 93.10 % of camera traps were deployed at slope between 0°-30° and 6.90% between 31°-87° slope classes. The maximum number of camera traps were at aspects of 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 5.12).

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. (Abies 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 5.19).

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° (Fig 5.20 & Fig 5.21).

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° (Fig 5.22).

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 5.23 & Table 5.12).

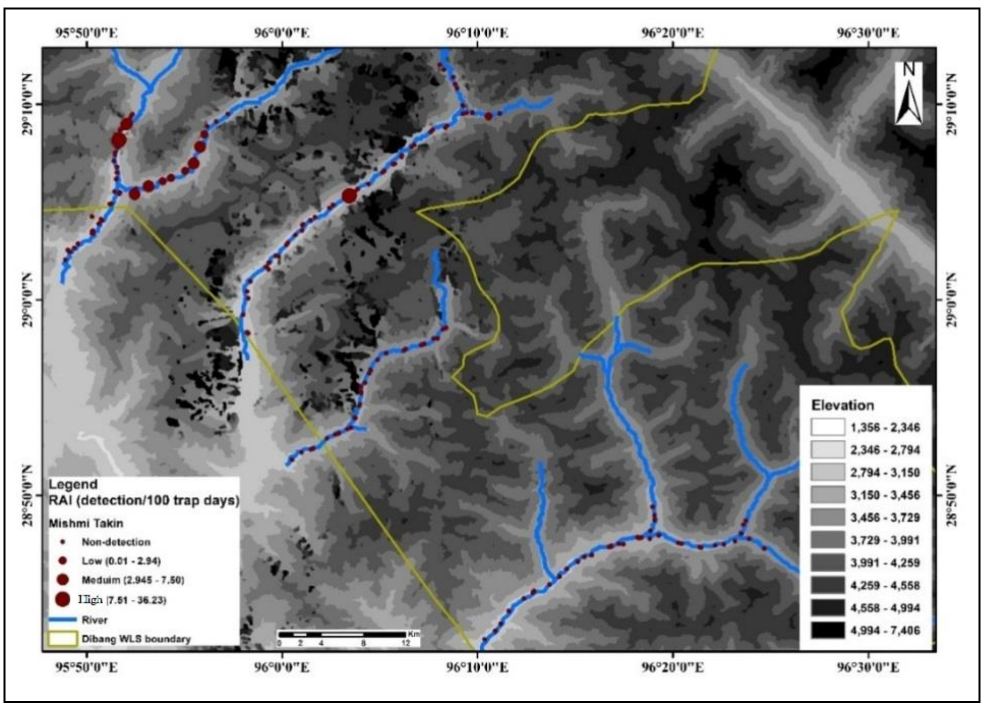

Figure 5.19: The frequency of photo captures rate of locations where Mishmi takin was found

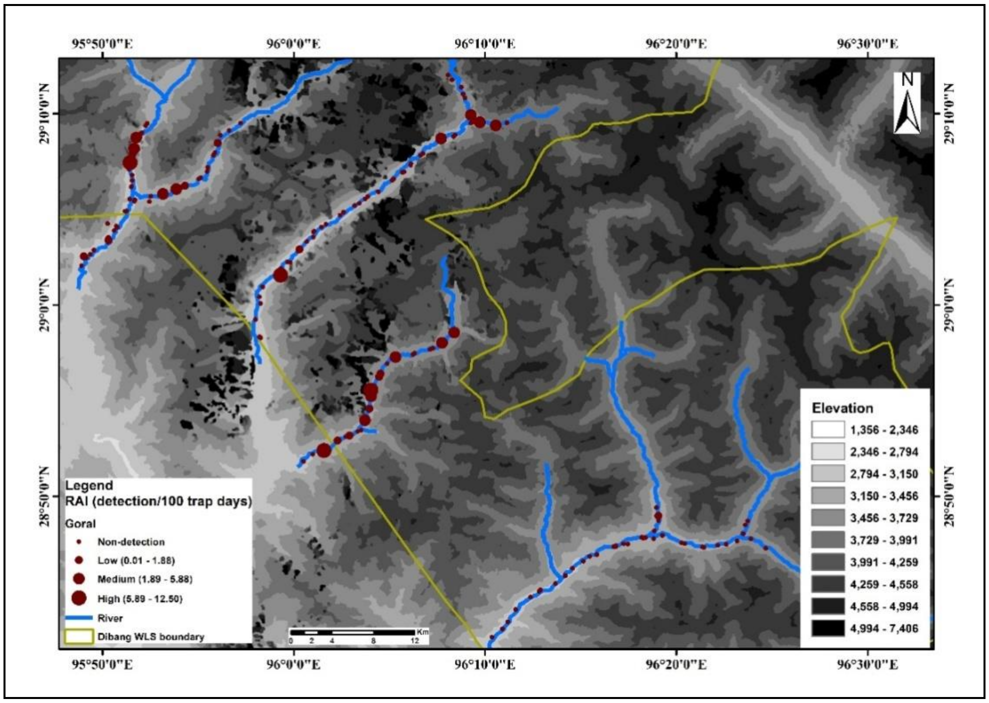

Figure 5.20: The frequency of photo captures rate of locations where red goral was found

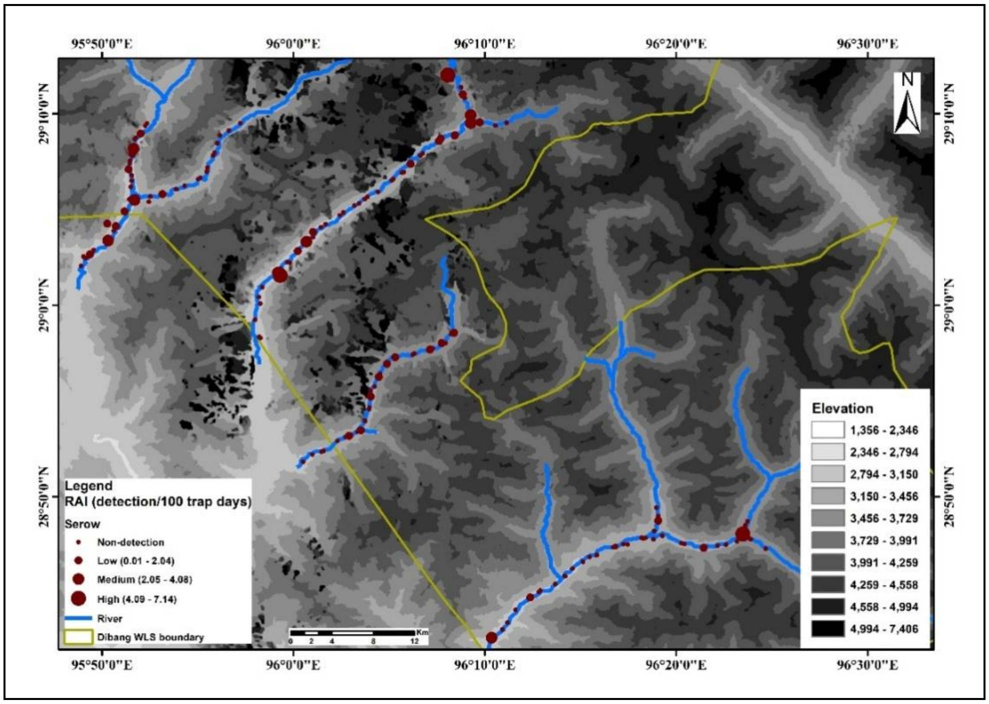

Figure 5.21: The frequency of photo captures rate of locations where serow was found

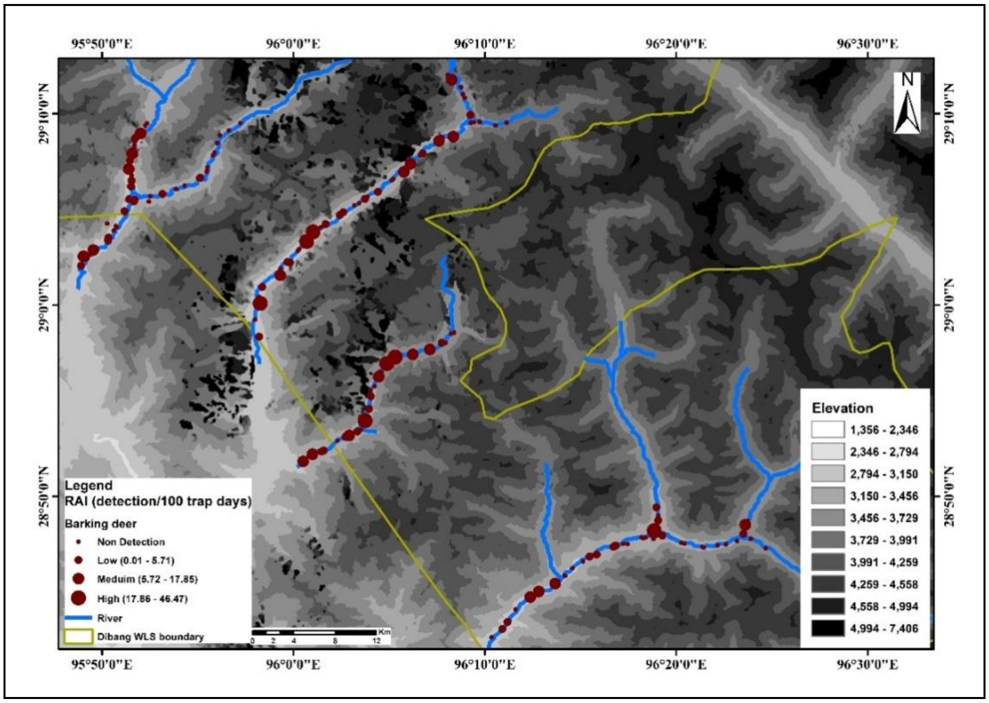

Figure 5.22: The frequency of photo captures rate of locations where barking deer was found

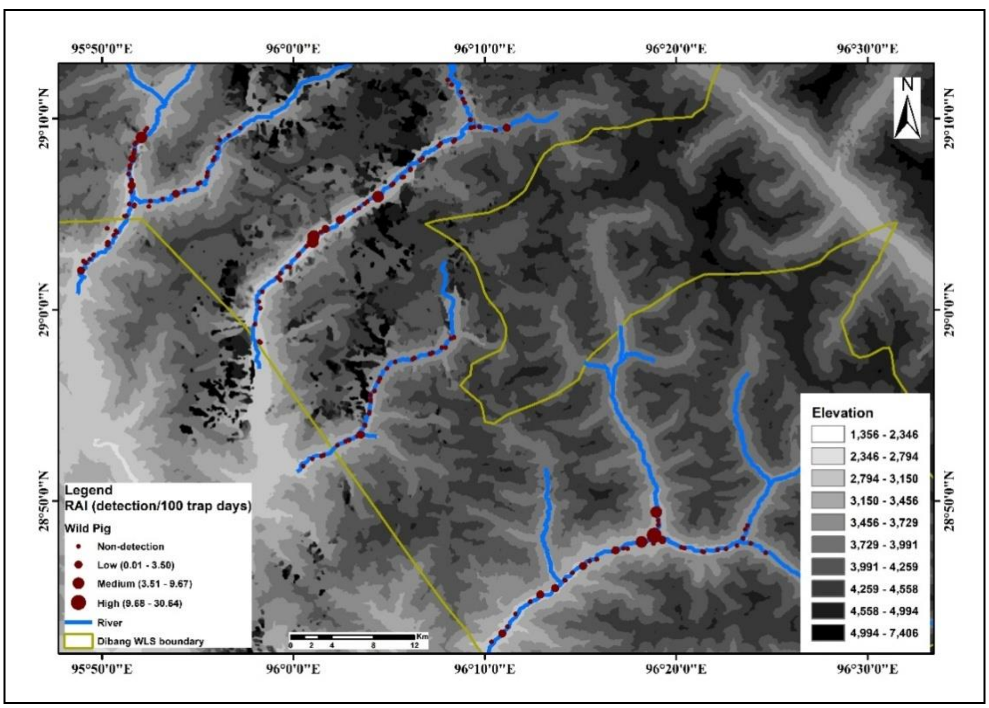

Figure 5.23: The frequency of photo captures rate of locations where wild pig was found

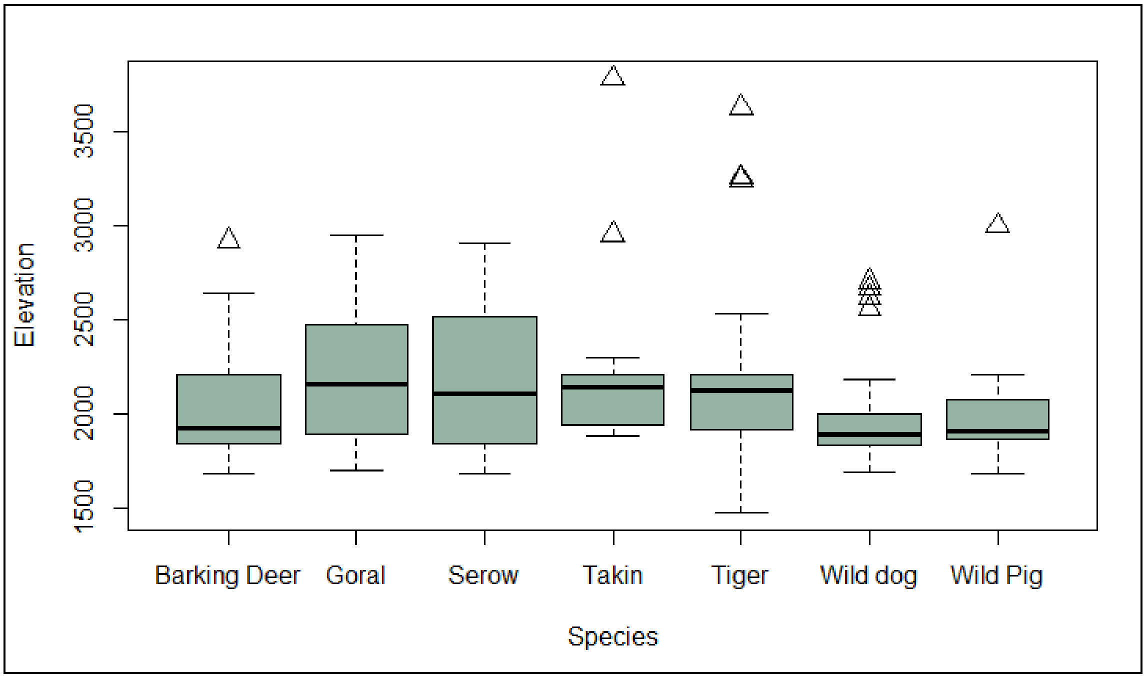

Figure 5.24: Use of elevation by tiger, wild dog and their prey species in DWLS

Table 5.12: 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	Barking deer		Red Goral		Himalayan Serow		Mishmi Takin		Wild pig	
		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	59.76	56.16	53.33	49.25	53.49	52.73	53.33	53.7	50	29.3
	10-20	20.73	26.36	16.67	11.94	25.58	23.64	26.67	37.8	36.36	56.9
	20-30	13.41	11.17	16.67	16.42	9.3	7.27	13.33	2.44	9.09	12.1
	30-40	2.44	3.72	3.33	10.45	9.3	12.73	6.67	6.1	4.55	1.72
	40-50	0	0	0	0	2.33	3.64	0	0	0	0
	70-80	1.22	0.86	3.33	2.99	0	0	0	0	0	0
	80-90	2.44	1.72	6.67	8.96	0	0	0	0	0	0
Aspect	East	6.1	4.58	10	14.93	11.63	9.09	0	0	4.55	1.72
	North	15.85	11.75	16.67	11.94	16.28	18.18	40	23.2	27.27	19
	West	17.07	24.93	20	13.43	18.6	16.36	0	0	9.09	5.17
	South	14.63	10.89	6.67	4.48	16.28	18.18	20	8.54	18.18	41.4
	NE	0	0	6.67	10.45	2.33	1.82	0	0	0	0
	NW	24.39	23.5	16.67	22.39	16.28	20	6.67	30.5	13.64	8.62
	SW	6.1	3.44	6.67	7.46	4.65	5.45	13.33	7.32	4.55	1.72
	SE	15.85	20.92	16.67	14.93	13.95	10.91	20	30.5	22.73	22.4
Elevation (m)	1600-2100	67.07	62.18	40	43.28	48.84	52.73	40	72	77.27	81
	2100-2600	25.61	31.23	46.67	43.28	37.21	34.55	53.33	26.8	18.18	17.2
	2600-3001	7.32	6.59	13.33	13.43	13.95	12.73	6.67	1.22	4.55	1.72
Canopy (%)	0-25	7.89	7.49	16.67	30.91	18.42	23.4	23.08	12.1	14.29	8.93
	26-50	32.89	35.63	37.5	34.55	34.21	34.04	23.08	56.9	28.57	16.1
	51-75	38.16	37.43	37.5	30.91	31.58	29.79	53.85	31	28.57	28.6
	76-100	21.05	19.46	8.33	3.64	15.79	12.77	0	0	28.57	46.4

Variable	**Categories**	**Barking deer**		**Red Goral**		**Himalayan Serow**		**Mishmi Takin**		**Wild pig**	
		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.	45.12	54.73	36.67	31.34	39.53	36.36	46.67	42.7	45.45	56.9
	Riverine	13.41	6.88	13.33	14.93	13.95	14.55	6.67	4.88	9.09	8.62
	Bamboo	10.98	12.03	6.67	2.99	13.95	14.55	13.33	36.6	18.18	17.2
	Alnus nepalensis	10.98	12.32	13.33	16.42	6.98	5.45	0	0	4.55	1.72
	Oak spp.	7.32	4.3	10	13.43	6.98	7.27	13.33	8.54	9.09	3.45
	Pine	9.76	6.59	3.33	1.49	4.65	3.64	0	0	4.55	5.17
	Rhododendron	0	0	6.67	2.99	4.65	3.64	6.67	1.22	4.55	3.45
	Grassland	2.44	3.15	10	16.42	9.3	14.55	13.33	6.1	4.55	3.45
Shrub (%)	0-25	10.2	7.86	9.09	26.32	11.11	14.29	40	21.2	0	0
	26-50	2.04	3.49	9.09	5.26	0	0	20	3.03	0	0
	51-75	0	0	9.09	15.79	0	0	0	0	7.14	2.38
	76-100	**87.76**	**88.65**	**72.73**	**52.63**	**88.89**	**85.71**	40	75.8	92.86	97.6

Low High

Table 5.13: 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 elevation meadow, 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,	42.5 %	Undulating and moderate slope	

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
			Rhododendron forest, etc.			
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	
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 elevation meadow plain, moderate slope, undulating and steep incline	

Table 5. 14: 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	Barking deer	*Manjo*	*Muntiacus muntjak*	Cervidae	LC	III	Locally common
2	Himalayan Serow	*Ma(r)y*	*Capricornis s. thar*	Bovidae	VU	I	Occasional
3	Red goral	*Ami*	*Nemorhaedus baileyi*	Bovidae	VU	III	Rare
4	Mishmi takin	*Awkru*	*Budorcas t. taxicolor*	Bovidae	VU	I	Rare
5	Wild pig	*Amme*	*Sus scrofa*	Suidae	LC	III	Abundant
6	Assamese macaque	*Ameh*	*Macaca assamensis*	Cercopithecidae	NT	II	Locally common
7	Pallas's squirrel	*Adash*	*Callosciurus erythraeus*	Sciuridae	LC	II	Locally common
8	Rat spp.	*Asha(n), Kahoh*	NA	Rodentia	NA	NA	NA
9	Sclater's Monal	*Peba eche*	*Lophophorus sclateri*	Phasianidae	VU	I	NA
10	Temminck's Tragopan	*Peba ala*	*Tragopan temminckii*	Phasianidae	LC	I	NA
11	Kalij Pheasant	*Aro*	*Lophura leucomelanos*	Phasianidae	LC	I	NA
12	Hill Partridge	*Perah*	*Arborophila torqueola*	Phasianidae	LC	IV	NA

5.5 Discussion

5.5.1 Ungulates assemblage

Our study was focused into two parts, firstly within the protected area and secondly outside the protected areas of adjoining landscape. Within the protected area our study was confined into temperate forest within the elevation ranges of around 1600 to 3001m amsl. Whereas, at the adjoining area of the protected area mainly in community forest, the study area covered alpine forest up to an elevation of 3783 m. The study has confirmed the presence of five ungulates species from the temperate forest of Dibang Wildlife Sanctuary, which proves that the sanctuary 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 the long-term conservation. Two species of muntjak were found, one is Indian or Red muntjac (*M. muntjak)* and another is Gongshan or Black muntjak (*M. gongshanensis crinifrons*) (further species identification need 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 during winter season and low elevation to high elevation in summer (Choudhury, 2013).

Secondary information during the questionnaire survey and evidence from local hunters confirmed the presence of musk deer in the high elevation areas of the valley; however, there was no photographic and indirect evidence obtained for the presence of musk deer 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 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, 2015), and Dhorpatan Hunting Reserve of Nepal with seven species of ungulates (Aryal *et al.*, 2010).

5.5.2 Indices of relative abundance of ungulates inside the protected area

The conventional distance sampling which has been one of the most popular methods for assessing the density of ungulates in tropical and temperate forest was inapplicable in the study area. The assumptions of distance sampling methods are hard to meet in mountainous landscapes and are thus constrained by many field conditions (Singha and Milner- Gulland, 2011). For example, three assumptions are essential in incurring the reliable estimation of density from the transect line or point: (a) detection of objects on the transect line or point, (b) initially objects are being detected at their location and (c) accurate measurement of distances and relevant angles (Buckland *et al.,* 2001). This study was aimed to improve the precision of the estimates. Hence, sign survey method was selected to estimate the encounter rates of mountain ungulates over distance sampling (line transect). Moreover, camera traps were used to cover the maximum area for developing an ecological baseline information. The relative abundance index (RAI) of all ungulates were estimated from the photo-capture rate. Therefore, in this study we focused across the river valleys to meet the objectives.

Among the relative abundance indices of forest dwelling ungulates species inside the DWLS through camera traps, barking deer were the highest photo-capture rates followed by Mishmi takin, red goral, Himalayan serow, and wild pig. Even in the sign surveys barking deer is the most encountered forest dwelling ungulate and followed by Wild pig, Himalayan serow, Mishmi takin and red goral respectively. 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 and Barruel, 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 and Johnsingh, 1996).

The ungulates sign survey along the major river valley was always accompanied with sampling biased due to dense vegetation, less walkable and open area, frequent rainfall and bad weather condition. Rainfall and less open ground cover affects the sign encountered along the forest trail. Forest dwelling ungulate signs were 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.

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, forest dwelling ungulates species signs and photo-captures have been found from all the surveyed valleys. However, during the replicate sampling, some ungulate signs and photo captures were not found due to conducting surveys in a season different than the previous year.

After the assessment for strengthening the ecological baseline information of forest dwelling ungulate species through indices of relative abundance, both camera traps and sign survey methods is first hand documentation for DWLS. It can be suggested that for estimation of ungulates abundance, intensive camera traps in both higher and lower elevation forest areas have to cover simultaneously with conventional methodologies, may give better outputs in term of accuracy. Long term monitoring of migratory ungulates with special focus to Mishmi takin should be carried out for better understanding and to develop corridors for sustaining the viable population of this long ranging migratory ungulate species.

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CHAPTER VI
FOOD HABITS AND PREY SELECTION

6.1 Introduction

Species co-existing in the same community sharethe available resources which are required in maintaining the stability and accomplishing their life cycle. Species co-existence stability has been determined by the mechanisms of inter-specific competition through the resource partitioning in the existing niche (Schoener, 1974). Different carnivores have different diet profile and food resource selectivity facilitates the co-existence by multiple factors such as the resource partitioning along with prey size, temporal patterns, spatial patterns and inclination of habitat use in the existing communities (Krebs, 1978; Bekoff *et al.*, 1984; Gittleman, 1985; Sunquist and Sunquist, 1989; Palomares *et al.*, 1996; Durant, 1998; Fedriani *et al.*, 1999; Karanth and Sunquist, 2000). The population of other species at lower trophic level gets distressed when carnivores compete (Terborgh, 1992) and partaking similar resources leads to exploitative competition (Caro and Stoner, 2003).

The tiger and dhole are sympatric, sharing the same prey species and habitat preference, played a chief role in influencing the prey communities in the ecosystems. The large prey species such as bovids, cervids and suids are mainly predated by tiger and dhole (Johnsingh, 1992; Venkataraman *et al.*, 1995; Karanth and Sunquist, 1995). In the tropical forest of India, tiger and dhole co-exist because of behavioral association, predation on different species, selection of different prey base body size and age classes (Johnsingh, 1992; Karanth and Sunquist, 1995; Karanth and Sunquist, 2000). Morphologically, the tiger and dhole are expert in predating on prey species which is larger than their body size (Schaller, 1967). Tiger ambush in solitary, preferring to bigger prey-sized (Karanth and Sunquist, 1995). Dholes hunt in group, often selecting the intermediate-sized prey but some time they also kill large-sized prey (Johnsingh, 1992). In India, studies on food habits of these sympatric carnivores have been carried out recently in South India (Andheria, 2007; Ramesh, 2010), central India (Biswas and Sankar, 2002; Acharya, 2007), western India (Bagchi *et al.*, 2003; Mondal, 2012) and northeast India (Selvan *et al.*, 2013, Bashir 2015).

The tropical forests of the northeastern regions of India have been poorly studied on the ecology of large carnivore (Karanth and Sunquist, 1995) particularly in Arunachal Pradesh. The region is inhabited by more than 26 major indigenous tribal and 110 sub-tribe communities who are dependent on forest resources. Most of the indigenous tribes practice shifting cultivation and are dependent on forest resources for their sustenance. Hunting is the major source of income generation and subsistence food for those who are remotely inhabited in this region (Aiyadurai, 2011). Carnivore survival is threatened by such illegal hunting and anthropogenic activities. DWLS have sympatric carnivores like tiger and dhole. and existence of common leopard from this valley has not been recorded yet. Existing literatures have no record on food habits of these large carnivore in Dibang Valley district of Arunachal Pradesh. Aim of the study are (1) to determine the food habits of tiger and dhole, (2) to quantify the dietary overlap between tiger and dhole (3) to determine the prey selectivity by tiger and dhole and (4) to estimate the temporal activity pattern of tiger, dhole and their prey species.

6.2 Methods

Diet preference of tiger and wild dog (dhole) are determined using remains of prey in their scats (Reynolds and Aebischer, 1991). The diet profile of tiger and dhole were examined and draws the outlines of their food habits through scats sanysis which is a non-invasive tool (Johnsingh, 1992; Mukherjee *et al.,* 1994). We analyzed the relative frequency of occurrence of prey remains in the scats and besides this, scat analysis provide the information of different prey consumed by tiger and dholes (Sankar and Johnsingh, 2002). Reynolds and Aebischer (1991), reviewed the methodology of scat analysis and applied in the studies of carnivore’s food habit.

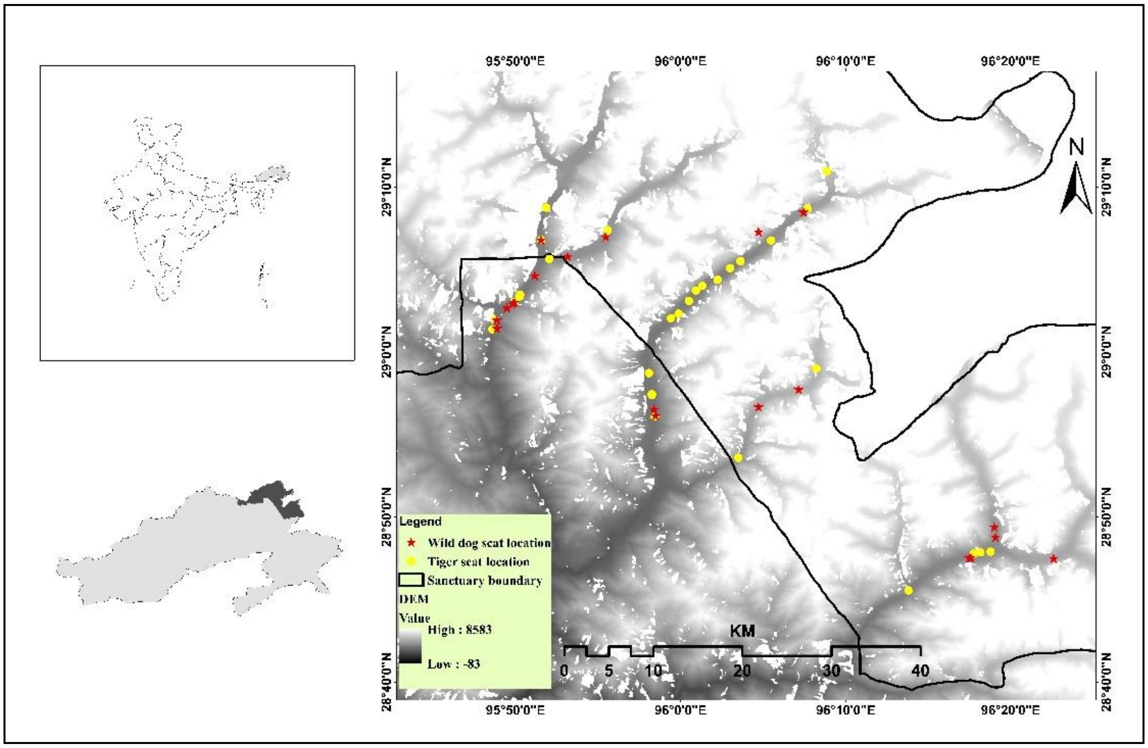

Figure 6.1: Tiger and wild dog scat collection locations

6.2.1 Scat collection

Scats of targeted carnivores i.e., tiger and wild dog (dhole) were collected from the study area during October 2015 to July 2017 (Fig 6.1). Scat condition, terrain types, habitat in around the defecation sites and date and time were documented and also recorded the Global Positioning System (GPS) coordinates. The others relative covariates such as distance from water source, villages distance, anthropogenic pressure, signs of domestic animals and human presence were also recorded. Tiger scats were easily distinguished from the other sympatric carnivore's scat by size, tracks and sign associated with scats. The tiger scat was defecated at open and prominent area mainly on forest trail having large size and less coiled on the tips of scat while dhole scats are defecated collectively, deposited as a cluster and scats sizes are smaller and non-sticker compared with tiger (Johnsingh, 1983; Biswas and Sankar, 2002). At the field, the scat was identified and confirmed through their shape, size and pug marks tracks nearby the scats encountered (Johnsingh, 1992). From each dropping sites a maximum scat was collected in ziploc and paper bag with the proper leveling of parameters such as scats condition, GPS location, forest types of dropping site, terrain etc.

6.2.2 Scat processing and laboratory procedure

Prior to analysis, scats were washed in a 1-millimeter sieve with water and oven-dried at 56°C for at least 24 hours (Jethva and Jhala, 2004). Randomly a minimum of 20 hairs were taken from the each washed and dried scats for preparing of slides and then examined for prey species identification under compound microscope (Mukherjee *et al.,* 1994). Micro-historical features of hair sample of prey species were observed and matched with the reference slides available in the laboratory of Wildlife Institute of India, Dehradun (Schaller, 1967; Sunquist, 1981; Selvan *et al.,* 2013 a&b). Other undigested prey remains such as teeth, feathers, quill, hooves, bone etc., were used to identified the types of prey species consumed by tiger and wild dog.

6.3 Analytical method

6.3.1 Estimation of prey biomass consumed by tiger and wild dog

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 diets were quantified by undigested prey remains in scats (Putman, 1984). 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 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 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 prey-sized can be used for accurate estimation of diet (Jethva and Jhala, 2004). Actual consumed biomass was converted from the presence of prey remains in scats through biomass model (Jethva and Jhala, 2004).

Estimating the prey relative proportion of biomass consumed and its contribution to tiger and dhole diet, the generalized model and the linear model was used for tiger and the correction factor model for dhole. Presuming that tigers have a diet similar with cougar and dhole (wild dog) to that of wolves. The biomass estimation equations for tiger and dhole are given below:

For tiger the Generalized model: $\mathbf{Y = 0.033 - 0.025exp^{-4.284X}}$ (Chakrabarti *et al.,* 2016) and **the Linear model:** $\mathbf{Y = 1.980 + 0.035X}$ (Ackerman *et al.,* 1984)

For dhole the Correction factor model: Y = 0.035 + 0.020X (Floyd *et al.,* 1978) where Y(kg) is the weight of the prey consumed per scat and X (kg) is the average weight of the prey species.

6.3.2 Estimation of prey selectivity

Jacobs' index was utilized to estimate the prey selectivity by tiger and dhole (Jacobs, 1974). This index standardizes the relationship between the relative proportion that each species makes up of the carnivore's diet *r* and prey relative abundance *p* (Hayward *et al.,* 2006; 2014). The Jacobs' index is calculated as:

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

where r_i is the proportion of prey species *i* in the carnivore scats and p_i is the proportion abundance of prey species *i* in population. The values range from +1 i.e., strongly preferred to -1 i.e., strongly avoided.

Expected observed biomass consumed and expected available biomass in the population were evaluated through chi-square ratio test. The expected available biomass was calculated from the camera traps data as relative abundance index i.e., number of detections per 100 camera trap days for every species and considered the independent captures at 0.5-hrs duration (Carbon *et al.,* 2001). The available biomass was derived from this index after multiplying it with the individual body weight of prey species. If carnivores eaten calves and sub-adults then used the ¾ × average body mass of female of prey species (Hayward and Kerley, 2005).

6.3.3 Estimation of niche breath and dietary overlap

. Niche breadth and dietary overlap of tiger and dhole was estimated from the frequency of occurrence in percentage and relative proportion of diet categories in the diet profile. Standardized Levins' index (B_{sta}) calculated the trophic niche breadths of tiger and wild dog (Levins, 1968) and its calculated as:

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

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

Standardized Levins' index is calculated as: $\mathbf{B_{sta} = (B - 1) / (B_{max} - 1)}$

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

Dietary overlap among the tiger and wild dog was estimated through Pianka index (Pianka, 1973). Diet overlapping of Tiger and wild dog valuing form 0 i.e., no overlap to 1 i.e., 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".

6.3.4 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 images of camera trap. The activity of carnivore and prey species were correlated with the number of images recorded in the camera trap (Kawanishi, 2002). At a site, an independent record is regarded when the capture events of species are of 0.5-hour (half hrs) duration (Carbone *et al.,* 2001; Bowkett *et al.,* 2007). Individual species can be considered as independent capture at 0.5-hrs and their mean activity was estimated using the program Oriana 4.0 (Kovach, 2011). Tiger, wild dog and prey species can be determined as nocturnal or diurnal based on the time-activity pattern.

Analytical method

Rayleigh test was applied to analyze whether the activity pattern of tiger, wild dog and prey species were uniformity or non-uniformity activity pattern. Further, Watson's U^2 test (for single species and pairwise) also tested to see the differences within the activity pattern of tiger, wild dog and prey species in program Oriana 4.0 (Kovach, 2011).

6.4 Results

6.4.1 Diet profile of tiger and wild dog

During the survey, 222 scats were collected from the river valleys of Dibang WLS. Among these, 47 scats were of tigers, and 38 were of wild dog. 54 were of meso or small-carnivores, 33 scats were unidentified and 50 scats had no undigested prey remains.

Six prey remains such as Mishmi takin, serow, goral, wild pig, barking deer and rodent were identified from the 47 tiger scats. In the analyzed tiger scats, 82.98% (n=39) were found only single prey items and 17.02% (n=8) had two prey items of prey species composition.

In the 38 dhole scats, six prey items were found such as Mishmi takin, serow, goral, barking deer, mithun, and rodent. Prey species composition in the scats, 86.84% (n=33) were single prey items, 10.53% (n=4) had two prey items and 2.63% (n=1) were found more than two prey items. Other felids species such as meso and small carnivores' scats had found six prey items *viz*. Mishmi takin, serow, goral, wild pig, barking deer, and rodents spp. However, collected meso or small carnivore scats were unable to be segregated properly due to the scat's conditions were very poor, as they were very old as well as deformed in structure. Therefore, the biomass model was not applied in the other felids' scats.

The diet composition of tiger and wild dog, goral, serow and Mishmi takin remain as the highest in frequency of occurrence (%) and biomass contribution (Tables 6.1, 6.2, 6.3 & 6.4). According to generalized model (Chakrabarti *et al.*, 2016), goral contributes highest both in frequency of occurrence (46.81%) and relative proportion of diet (37.74%) to the tiger diet (Fig 6.1 & 6.4). In contrast, the linear model (Ackerman *et al.*, 1984), frequency of occurrence was highest for goral (46.81%) followed by serow (24.47%) and takin (19.15%) but in relative proportion of tiger diet, Mishmi takin (44.87%) was highest, followed by goral (25.82%) and serow (23.09%) (Fig 6.2 & 6.5).

For wild dogs, according to Floyd et al. 1978 equation, rodent spp. (46.97%) had the highest frequency of occurrence (in percentage) 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 6.6 & 6.3).

Table 6.1: The occurrence of prey base in the tiger and wild dog scats

Mammalian Species	Tiger		Wild dog	
	Frequency of Occurrence (F)	Frequency of Occurrence (%)	Frequency of Occurrence (F)	Frequency of Occurrence (%)
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 6. 2: Generalized model (Chakrabarti *et al.*, 2016) of prey species composition in tiger diet

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 6.3: Linear model (Ackerman *et al.*, 1984) of prey species composition in tiger diet

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 6.4: Correction factor model (Floyd *et al.*, 1978) of prey species composition in wild dog diet

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

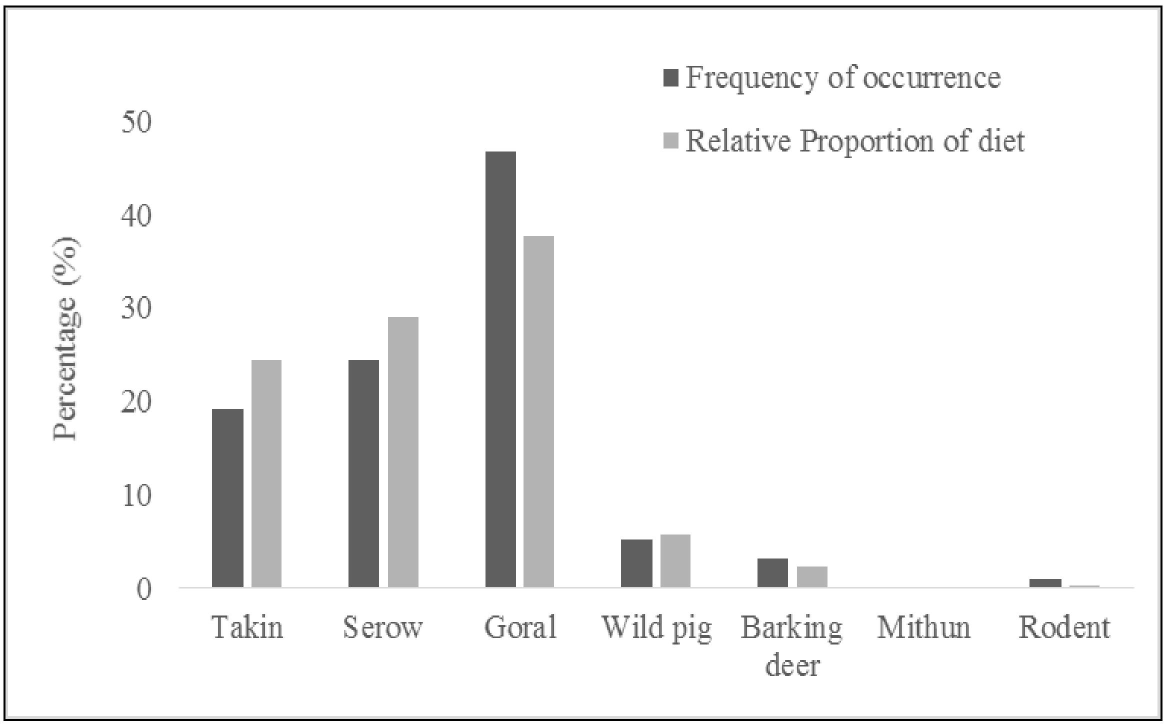

Figure 6.2: Percentage of prey species composition in tiger's diet through generalized model (Chakrabarti *et al.*, 2016)

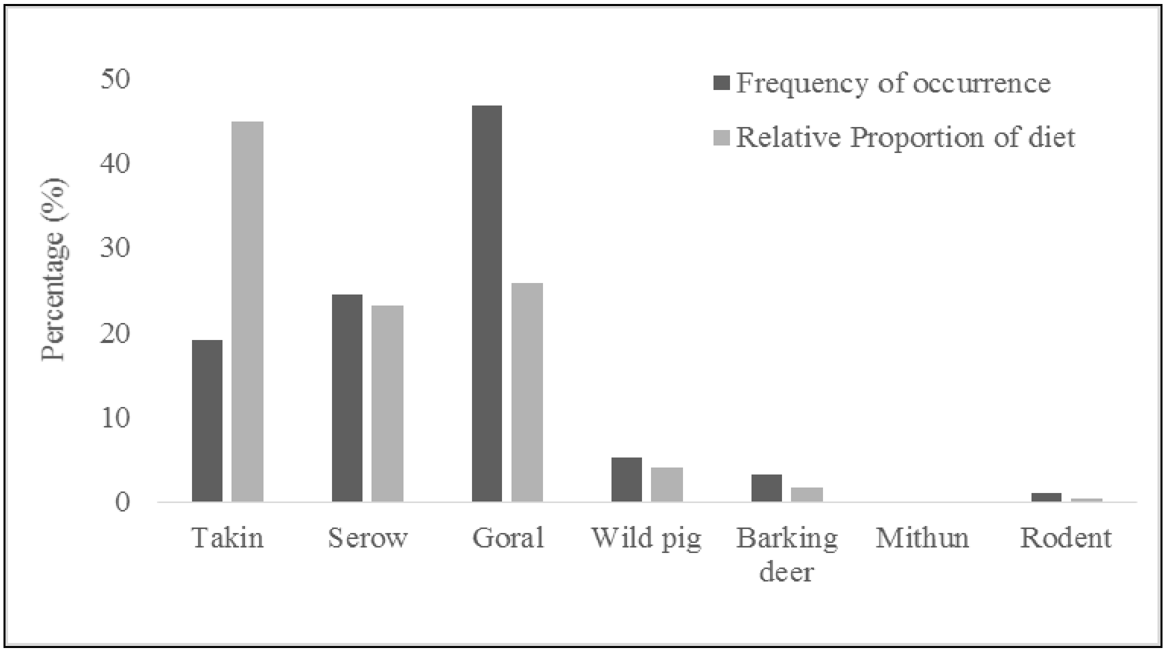

Figure 6.3: Percentage of prey species composition in tiger's diet through linear model (Ackerman *et al.*, 1984)

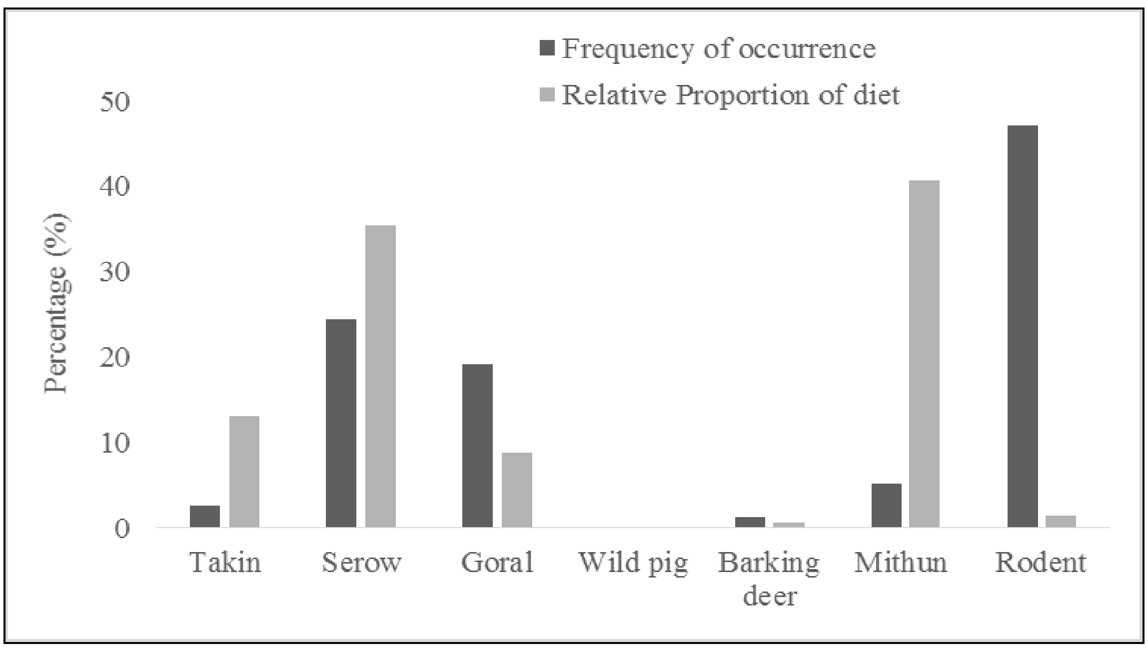

Figure 6.4: Percentage of prey species composition in dhole's diet through correction factor model (Floyd *et al.*, 1978)

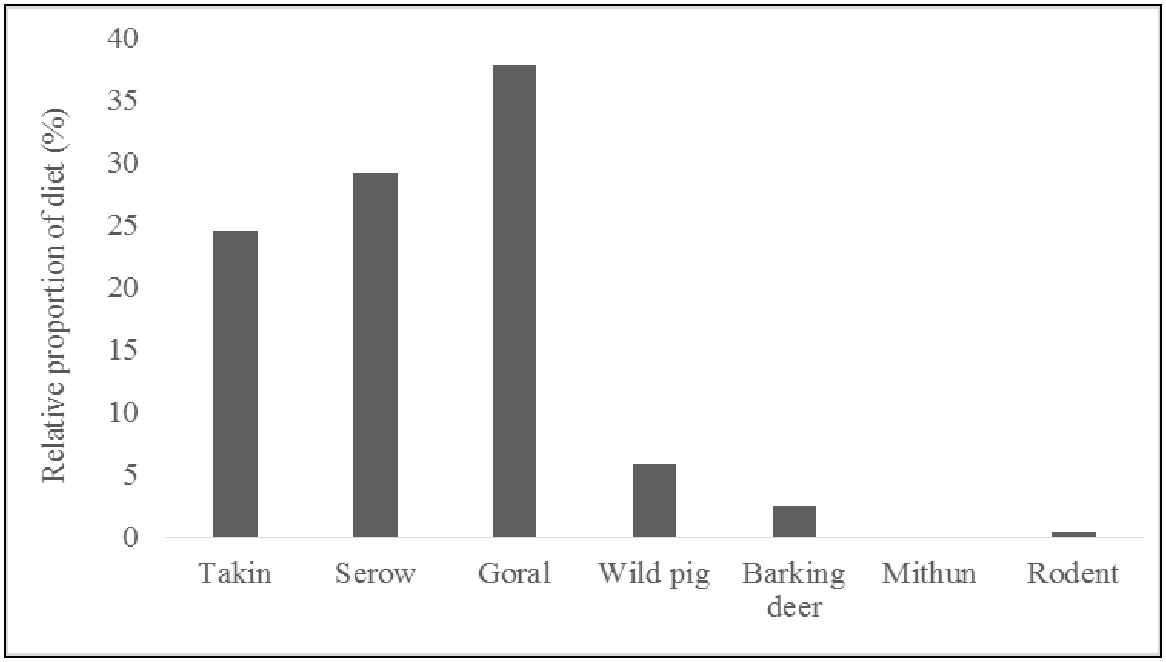

Figure 6.5: Generalized model (Chakrabarti *et al.*, 2016) showing the relative proportion of diet of tiger

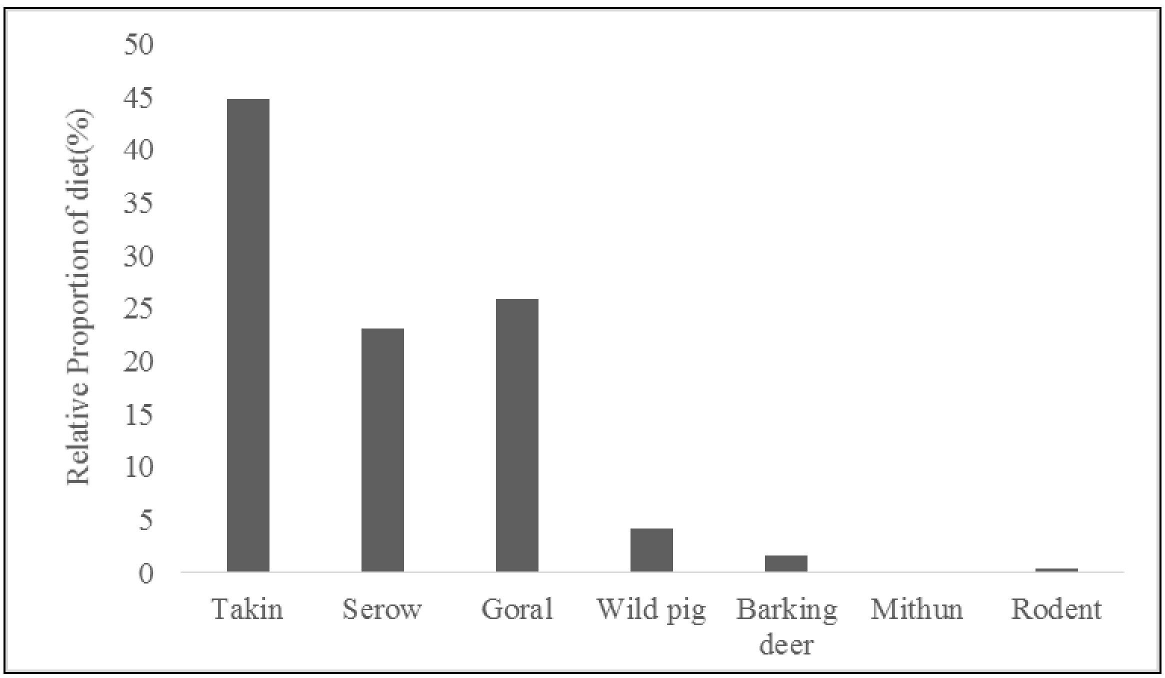

Figure 6.6: Linear model (Ackerman *et al.*, 1984) showing the relative proportion of diet of tiger

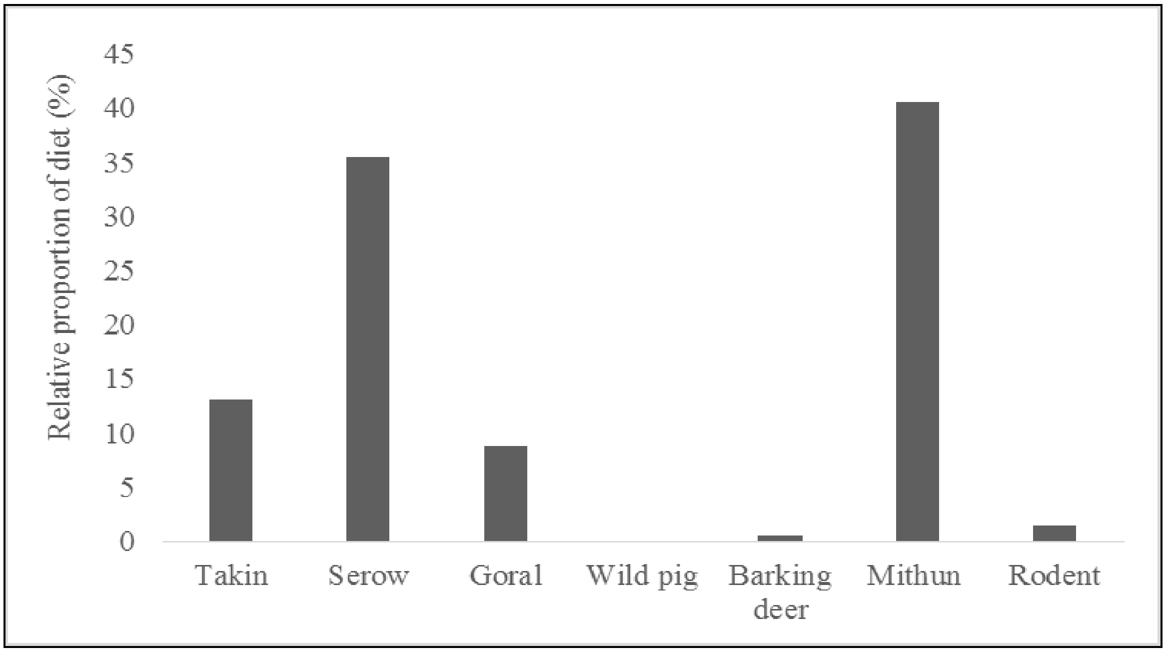

Figure 6.7: Correction factor model (Floyd *et al.*, 1978) showing the relative proportion of diet of dhole

6.4.2 Prey selectivity

Prey selectivity by tiger and wild dogs was assessed through Jacob's index. Likelihood ratio test reveals that significant prey selection for tiger (χ^2=43.31, df=5, p<0.01) and wild dog (χ^2=43.31, df=5, p<0.01) respectively. Generalized model revealed that serow and gorals were consumed more than their availability while Mishmi takin, wild pig and barking deer was less consumed than its availability. Linear model showed 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 6.5).

Table 6.5: Jacobs's index showed the prey selection by tiger and dhole

Ungulate	Tiger (Biomass model)	*p* value	Wild dog	*p* value
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 pig	-0.2107	0.99	-1.0000	0.99
Barking deer	-0.8141	0.99	-0.9575	1.00

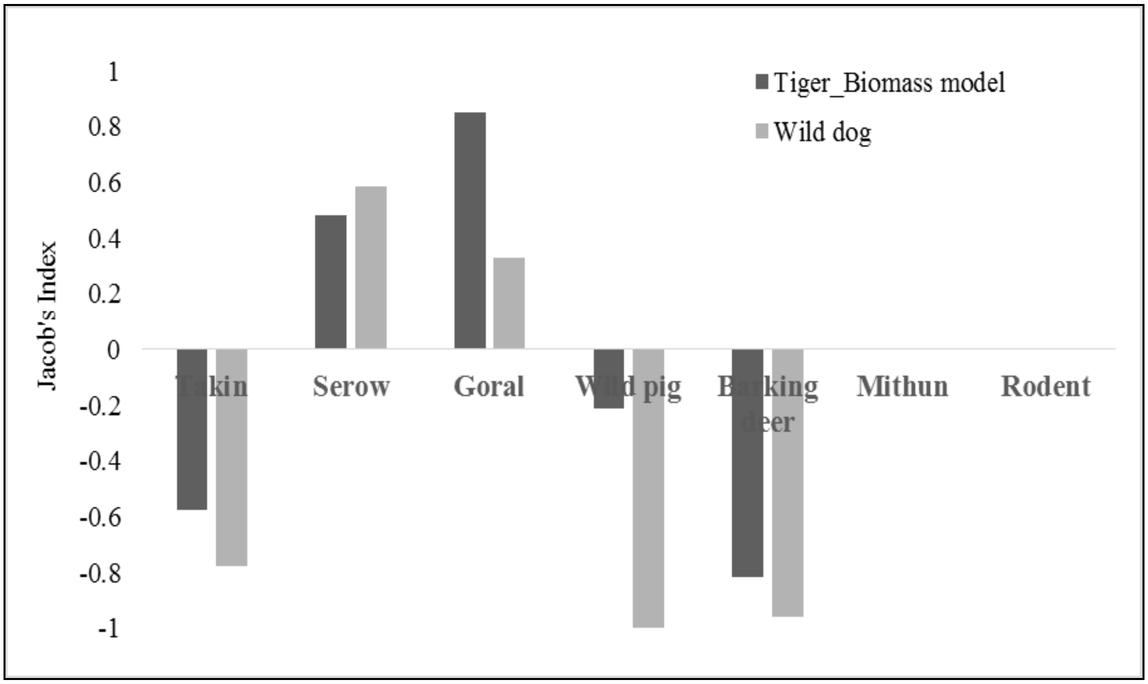

Figure 6.8: Prey selection by tiger and wild dog based on the generalized and correction factor models respectively

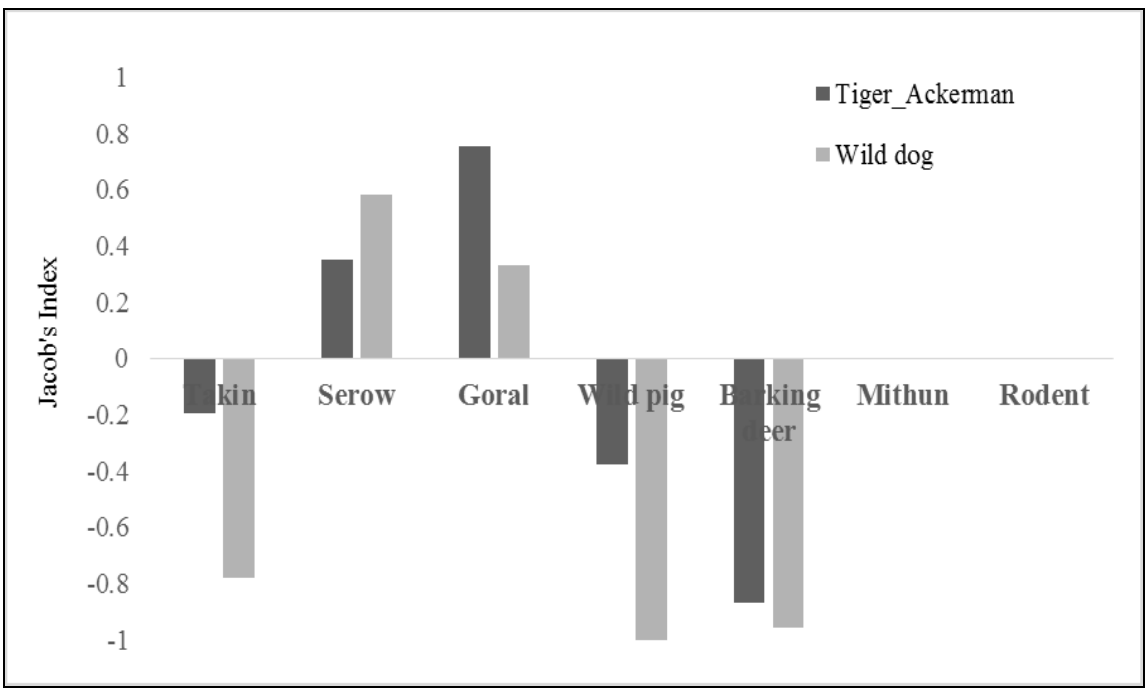

Figure 6. 9: Prey selection by the tiger and wild dog based on the linear and correction factor models respectively

6.4.3 Niche breadth and dietary overlap of tiger and wild dog

Levin's standardized index measure the dietary niche breadth of tiger and wild dog. The standardized Levins' index (B_{sta}) of tiger and wild dog was 0.4258 and 0.4205 respectively (Table 6.6). Both tiger and wild dog had medium diverse dietary niche breadth *i.e.*, neither generalist nor specialist. Pianka niche overlap index shown 50 % dietary overlaps among the diets of tiger and wild dog. However, no significance overlap was observed in prey item of tiger and wild dog in the scats (Table 6.7).

Table 6.6: Levin's Standardized index showed the niche breadth of tiger and wild dog scats. RO = Relative frequencies of Occurrence and RB = Relative proportion of Biomass

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

Table 6.7: Painka index shown the dietary overlap between the tiger and wild dog. RO = Relative Occurrence, RB = Relative Biomass and Significance value p = 0.05

Carnivore	RO		**RB** (Generalized model)		**RB** (Linear model)	
	Pianka Index	***P***	**Pianka Index**	***P***	**Pianka Index**	***P***
Tiger-Wild dog	0.4993	0.18	0.5563	0.29	0.5117	0.19

6.4.4 Activity patterns from camera trap photo-captures

6.4.4.1 Temporal activity profile of tiger and wild dogs and its prey species

The temporal activity profile of tiger, wild dog and its prey species such as barking deer, red goral, Himalayan serow, Mishmi takin, wild pig, and kalij pheasant were documented. The uniformity in the activity pattern of tiger and wild dog was determined by Rayleigh test (Z) and the differences within the activity pattern of tigers, dholes and their prey was calculated by Watsons U^2 test, p in both tests is the probability of significance.

The temporal activity profile of tiger and wild dog was nocturnal and diurnal respectively (Figure 6.9). The mean activity time of tiger was at 23:29 ± 01:34 hrs. with 95% confidence interval (CI) of 20:25-02:34 hrs. (Table 6.8). The activity pattern of tiger was distributed un-uniformly (Rayleigh Z = 2.91, p = 0.054) and the intensity of activity throughout different times of the day was significant difference (Watson's U^2 = 0.191, p <0.05) (Table 6.9). On the contrary, wild dog's 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) and the intensity of activity during different times of the day was significant difference (Watson's U^2 = 1.807, p <0.005) (Table 6.9).

Table 6.8: Circular statistic of temporal activity patterns of tiger, wild dog and their prey species

Mammalian 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
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 case of ungulates temporal activity profile, barking deer and red goral were crepuscular (Figure 6.10). Barking deer and red goral shown the mean activity time from 17:58 ± 00:16 hrs. and 06:38 ± 02:42 with 95 % confidence interval (CI) of 17:26-18:31 hrs. and 01:20-11:56 hrs. respectively (Table 6.8). Barking deer was un-uniformly distributed throughout the activity day (Z= 82.84, p <1E-12) whereas red goral had distributed uniformly in their activity pattern (Z= 0.993, p = 0.37) (Table 6.9) and both the ungulate species had significant difference in their activities.

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 all throughout the day and significant difference in the activities patterns (Table 6.9). Wild pig showed a typical diurnal and its mean time activity range from 07:05 ± 00:28 hrs. with 95 % confidence interval (CI) of 06:09-08:01 hrs. The wild pig was distributed un-uniformly and significant difference during the activity.

Table 6.9: The activity pattern of tigers, wild dog and their prey, p is the probability of significance

Mammalian 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
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

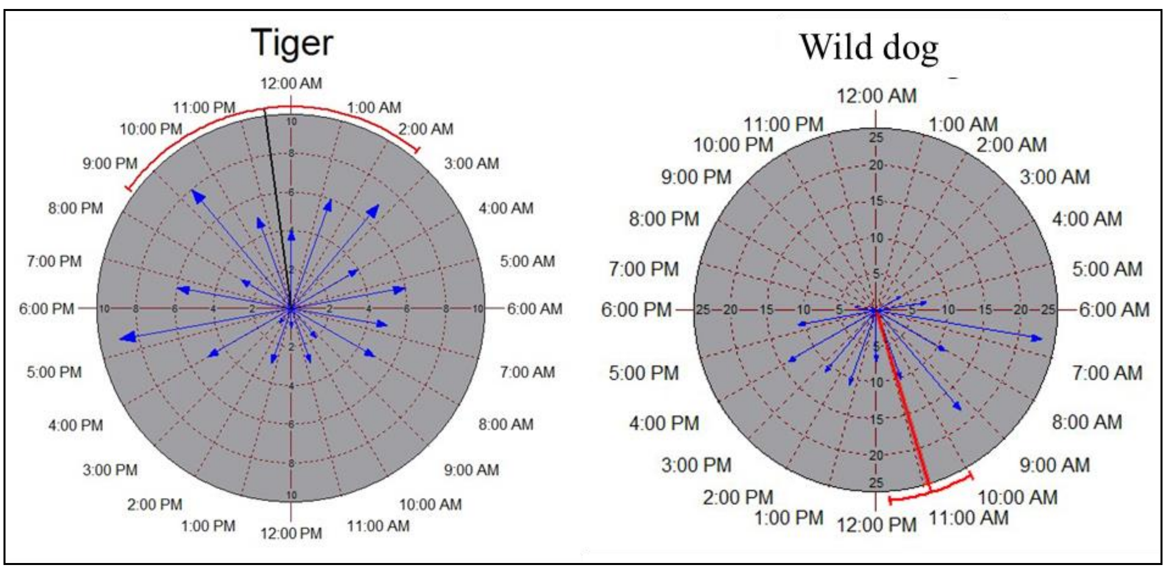

Figure 6.10: Diel activity patterns of tiger and wild dog in Dibang Wildlife Sanctuary during 2015-2017

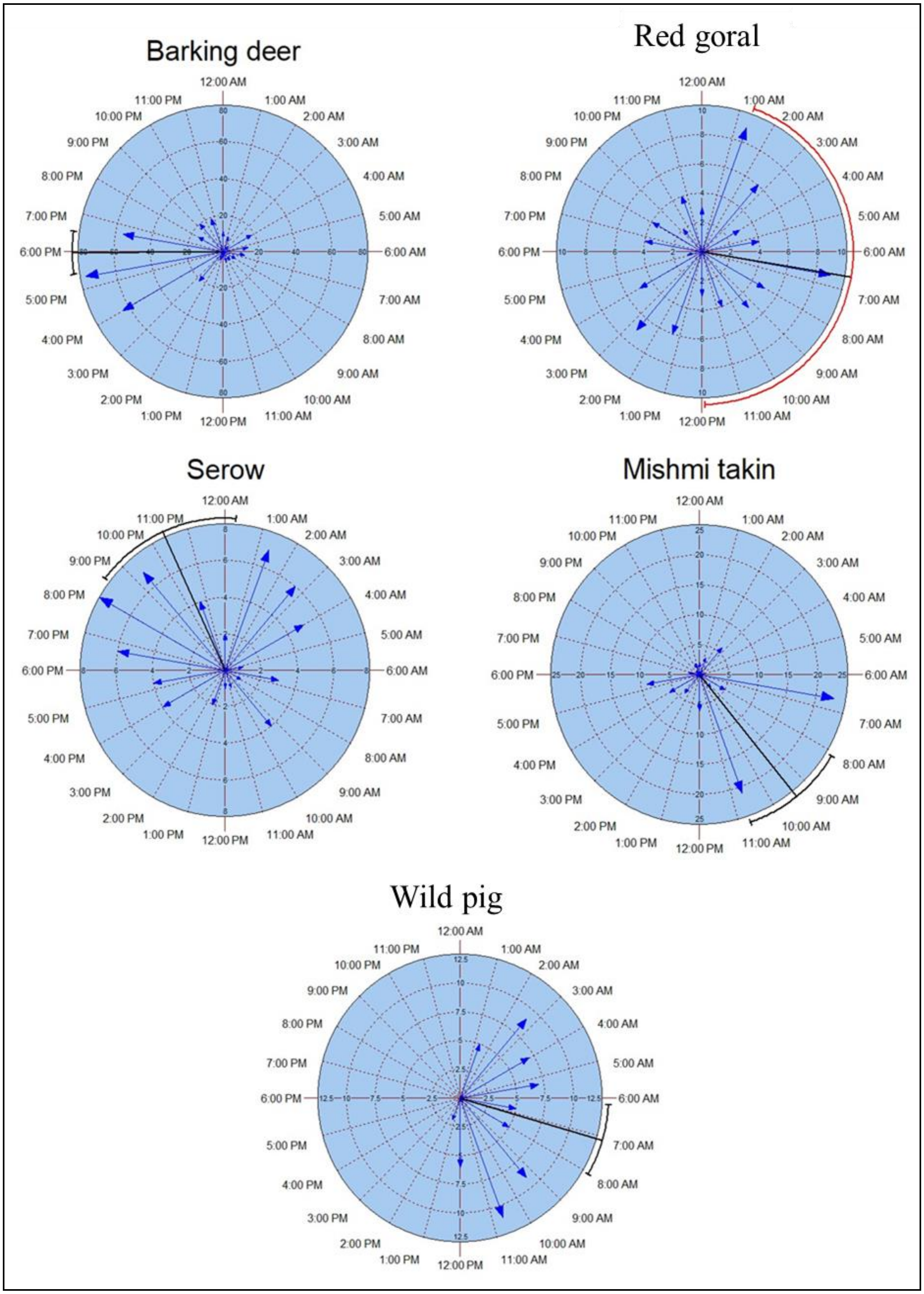

Figure 6. 11: Diel activity patterns of forest-dwelling ungulates in Dibang Wildlife Sanctuary

6.4.4.2 Temporal overlap of tiger, wild dogs and its prey species

Watson's U^2 test unveiled the activity profiles of tiger, wild dog and their prey species (Table 6.10). The activity pattern of tiger and wild dog were significantly different as reveal in Watson's U^2 test ($U^2 = 1.471$, $p < 0.001$). In carnivores and prey activity pattern, the most significant differences were observed between tiger and wild pig ($U^2 = 0.854$, $p < 0.001$), and tiger and Mishmi takin ($U^2 = 0.812$, $p < 0.001$) respectively. Whereas in wild dog, the most significant differences were observed with serow ($U^2 = 1.782$, $p < 0.001$) and barking deer ($U^2 = 3.071$, $p < 0.001$) respectively.

Similarly, Watson's U^2 test was also applied to test the activity profile between the ungulates (Table 6.11). The activities patterns of Serow-Mishmi takin $U^2 = 1.025$, $p < 0.001$); serow-wild pig ($U^2 = 0.096$, $p < 0.001$) and barking deer- red goral ($U^2 = 1.406$, $p < 0.001$) had highly significant differences (

Table 6.10: The activity patterns of tiger, wild dog and ungulate species

Mammalian 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 6.11: The activity patterns among the ungulate species

Ungulate 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

6.5 Discussion

6.5.1 Diet profile of tiger and wild dogs

In the existing niche, the food habits of carnivores play an important function in occupaying trophic niche, their behavior, affects in the sympatric predator's density and population viability (Fuller and Sievert, 2001). The ecology and management of carnivore species is also affected by the competitive interaction amongst them (Creel *et al.*, 2001). Consequently, understanding of life history approaches and developing sound conservation recommendations of carnivores is mandatory especially for those species which are found at the least explored fragile high-altitude ecosystems of Himalaya (Miquelle *et al.*, 1996).

Tiger and wild dogs mainly depend on large to small-sized ungulates such as Mishmi takin (*Budorcas t. taxicolor*), Himalayan serow (*Capricornis s. thar*), red goral (*Naemrhedus bailey*), wild pig (*Sus scrofa*), 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.*, 2013a, Johnsingh and Manjrekar, 2013). Among sympatric carnivores', supplementary prey such as livestock, act as a buffer and potentially enhance coexistence (Kok and Nel, 2004; Wang and Macdonald, 2006).

Both the biomass estimation models *i.e.*, generalized model (Chakrabarti *et al.*, 2016) and linear model (Ackerman *et al.*, 1984) reveal that tigers have specifically selected more of Mishmi takin, serow, goral but less towards the wild pig, barking deer, smaller prey items, and no livestock *i.e.*, Mithun in diet composition, however from the nearby places of the valley, there has been reports of Mithun depredation by tigers. The resident tigers of Indian subcontinent *(P. t. tigris*) are specifically selective of large prey to medium-sized prey as revealed from the studies of diet composition throughout India. The main prey items are sambar, gaur, wild pig (Sunquist, 1981; Karanth and Sunsquit, 1995; Stoen and Wegg, 1996; Andheria *et al.,* 2007; Ramesh *et al.,* 2009) and small to very smaller prey such as mouse deer, porcupine, hare, rodent (Reddy *et al.,* 2004; Ramesh, 2010; Selvan *et al.,* 2013 a&b). However, along the high elevated Mishmi Hills range, there is no report of the presence of sambar particularly in the Dibang Valley. Hence, Mishmi takin is the only selective large prey for tigers in the study area. Apart from this large size prey base to medium-sized one, remains of barking deer and rodents in 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 wild prey base such as serow> Mishmi takin > goral > barking deer > small rodent and 40.60 % of the relative proportion of diet were contributed by free-ranging semi-domesticated mithun (livestock) according to biomass estimation model adopted by Floyd *et al.,* 1978

Wild dogs have ability to hunting the smaller and cryptic prey species and therefore the remain of small rodents have the highest frequency of occurrence in the wild dog scats (Venkataraman, 1996; Kumaraguru *et al.,* 2011). Presence of a high occurrence of small rodents in wild dog food habits was supported by the studies from Kanchendzonga Biosphere Reserve (Bashir, 2015) and for tiger and wild dog from Pakke Tiger Reserve from Arunachal Pradesh (Selvan et al., 2013a). As mithun is easily accessible in a large number from the adjacent villages of the study area, they are preyed upon by wild dog and contributed in the highest relative proportion (40.68%) in their diet. Biswas and Sankar, (2002) reported that the possibility of livestock depredation is minimal when wild ungulates prey population are found in abundance.

Tiger and wild dog shows 55.63% of diet overlap i.e., almost similar dietary niche breadth which is contrasting to Pakke tiger reserve where high overlap between tiger and wild dog (77.5%) was found. Many studies have shown that, tiger specialized on large prey-sized *viz.,* gaur and adult sambar (Selvan *et al.,* 2013 a&b; Johnsingh and Manjrekar, 2013) while wild dog preferred medium-sized prey (Karanth and 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-sized prey, 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 due to differential prey preference, hunting habits, different temporal activity patterns and habitat selection (Karanth and Sunquist, 2000; Husseman *et al.*, 2003; Selvan *et al.,* 2013a; Karanth *et al.,* 2017). Tiger is solitary hunters, and prefer on large prey (Karanth and 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 diversity creates high feeding competition 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 (Mills, 1984; Breuer, 2005), large predators are known for competing for food resources (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 smaller prey species as well. This is possible only if the availability of appropriate size classes of prey is not a limiting resource (Karanth and Sunquist, 1995).

The sympatric association of large carnivores is affected by prey selection (Seidensticker, 1976). The findings of our study inferred that coexistence of tiger and Asiatic wild dog in Dibang Wildlife Sanctuary is due to the availability of different prey base *viz.*, Mishmi takin (large-sized), serow, wild pig (medium-sized) and goral and barking deer (small-sized).

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 livestock and smaller-sized prey such as Mithun and small rodents in wild dog diet and small rodents only in tiger diet which is indicative of low ungulate population in and around the DWLS and makes it evident that wild dog has tried to sustain on smaller prey species and livestock *i.e.,* Mithun (Reddy *et al.,* 2004). The hunting issue needs to be addressed by engaging with local peoples; 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 or semi-domesticated animals.

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CHAPTER VII

HUMAN WILDLIFE INTERACTIONS

7.1 Introduction

Human and wildlife are integral components of forest ecosystems which share the same resources in diverse magnitudes for their survival (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, 2016). When the interaction impact negatively on either humans or wildlife, it results in conflict (Rodgers, 1989; Treves and Karanth, 2003; Madden, 2004). 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 on the environment" (Sarpo, 2005). These conflicts may arise from any action by humans or wildlife that has 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 and Karanth, 2003).

The rapidly expanding human population, and subsequent increase in human's demands for natural resources have led to loss of wildlife habitats leading to increased chances of conflict (Pimm *et al.,* 1995; Balmford *et al.,* 2001; Lamarque *et al.,* 2008). Declines in wildlife population can be attributed to a variety of causes, but for large carnivores, direct human causes of mortality pre-dominate (Ripple *et al.,* 2014). As a result, human–wildlife conflict is one of the most critical threats facing many wildlife species today (Dickman, 2010).

The conflicts among human and wildlife poses threats to both sides, which is challenging to address as a global issue predominantly in large carnivore conservation (Nowell and Jackson, 1996; Conover, 2002). Many rare and endangered species face critical threat to their survival and such conflicts affect not only their populations but also have extended environmental impacts on ecosystem equilibrium. On the other hand, over the past few decades many human lives have been lost and economic losses have been incurred (Oli *et al.,* 1994; Gittlemam *et al.,* 2001; Woodfoffe *et al.,* 2005; Ogra, 2008; Loveridge *et al.,* 2010). Wildlife, especially large carnivores have been known to prey on domesticated cattle and other pets. Crop depredation by wild ungulate such as wild pig, barking deer and even damaged by macaque, bear etc. are also frequent within the protected area, buffer zone or even outside the buffer zone (Kothari *et al.,* 1989; Mishra, 1997; Hussain, 2003). The prime form of human-carnivore conflict would rise due to the depletion of wild prey population and loss of its natural habitat (Aiyadurai and Verma, 2003). As such, frequency of conflict have been reported more often in those villages located in and around the periphery of protected areas or reserve forest. Thus, human-wildlife conflict can be particularly serious, where rural people live in close association with protected areas (Mishra, 1997; Conforti and de Azevedo, 2003). The remaining lands are no less trouble as there is bound to be a conflict between wildlife and human, a significant problem in many parts of the world (Saberwal *et al.,* 1994). The management of these negative impacts of human-wildlife interaction and promoting co-existence is a challenging task for conservation scientists, wildlife managers and policy makers alike (Terborgh *et al.,* 2002).

The north-eastern states of India are undoubtedly the richest regions of the country in term of its terrestrial biodiversity. However, the hunting practices are more frequent as compared to the rest of the country. People living in the remote areas of the states are economically backward as compared to mainland population, and they depend on hunting wild meat and gathering of forest resources for their sustenance (Hart, 1978; Payne, 1992; Lahm, 1993; Noss, 1995). In consequence, the major sources of protein for these indigenous people are derived from the consumption of wild meat. Any increase in hunting pressure could lead to depletion of wild prey for large carnivores resulting in their preying on livestock, thus raising the incidences of human-wildlife conflicts (Mishra, 1997; Conforti and de Azevedo, 2003). Hunting leads to decline in wild prey population that drives more livestock depredation by the large carnivores (Aiyadurai and Verma, 2003). Due to less availability of cultivable lands in the rugged and hilly terrains of the north-eastern part of India, the indigenous people practise subsistence farming through shifting cultivation locally known as *jhum* cultivation which is an integral part of the tribal life. *Jhum* cultivation is widely practiced and has in a major land-use impact upon tropical forest ecosystem of the northeast even in Arunachal Pradesh. These land use practices are believed to be responsible for the loss of biodiversity and forest cover in northeast India (Rao and Hajra, 1986; Lal and Prajapathi, 1991; Raman *et al.*, 1998).

Arunachal Pradesh harbour diverse intact forests of tropical rainforests, sub-tropical forests, semi-evergreen forests, temperate broad-leaved forests, temperate forest and alpine forests which are inhabited by 26 major tribes and more than 110 minor sub-tribes (Proctor *et al.*, 1998; GoAR, 2005). These tribes are agro-pastoralist's and dependent on forest resources. Their activities are slash-burn cultivation, grazing livestock in the forest or leaving in the forest, collection forest products, wild meat hunting and fishing which are major drivers for negative wildlife interaction in the area. Tiger, dhole, snow leopard and wolf depredation and persecution killing of these larger carnivores were reported from this region (Aiyaduari, 2004; Mishra *et al.*, 2006).

To get a better understanding of the human-wildlife interactions in the area, and the dimension of negative and positive interfaces between the Idu Mishmi community and wild animals in and around Dibang Wildlife Sanctuary (DWLS), a questionnaire survey was conducted. The main objectives of this chapter 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.

With the above objectives, an endeavour was made to answer the following key research questions and testing the hypothesis:

1 What is the nature and extent of human-wildlife interaction among the Idu Mishmi community?

2 What are the magnitude of Mithun depredation and possible reason?

3 What is the status of awareness, attitudes, and perceptions among the local community about large carnivores' conservation?

4 What is the role of traditional norms and taboos in wildlife conservation?

Hypothesis

Variable	Hypothesis	Supporting literatures
H-7.1: Livestock depredation	Depredation is higher in areas of low prey densities.	Biswas and Sankar 2002

H-7.2: People perception	Peoples' perception of a carnivore in conflict is likely to be influenced by (and in turn influenced) their attitude towards the carnivore species.	Suryawanshi *et al.,* 2013; Lyngdoh *et al.,* 2014.

7.2 Methodology: Household questionnaire survey

Questionnaire surveys were conducted at randomly selected households from each village and maximum accessible households were targeted. Before carrying out the survey, the respondents were briefed in detail about my research work, and the field assistant usually introduced me 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 and also 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 was collected. Information on religious profile, social norms, and taboos about the wildlife from the village headman, local naturalists, elderly persons, *Igu* (shaman), women, and local hunters were also collected (Aiyadurai *et al.,* 2010).

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 7.1).

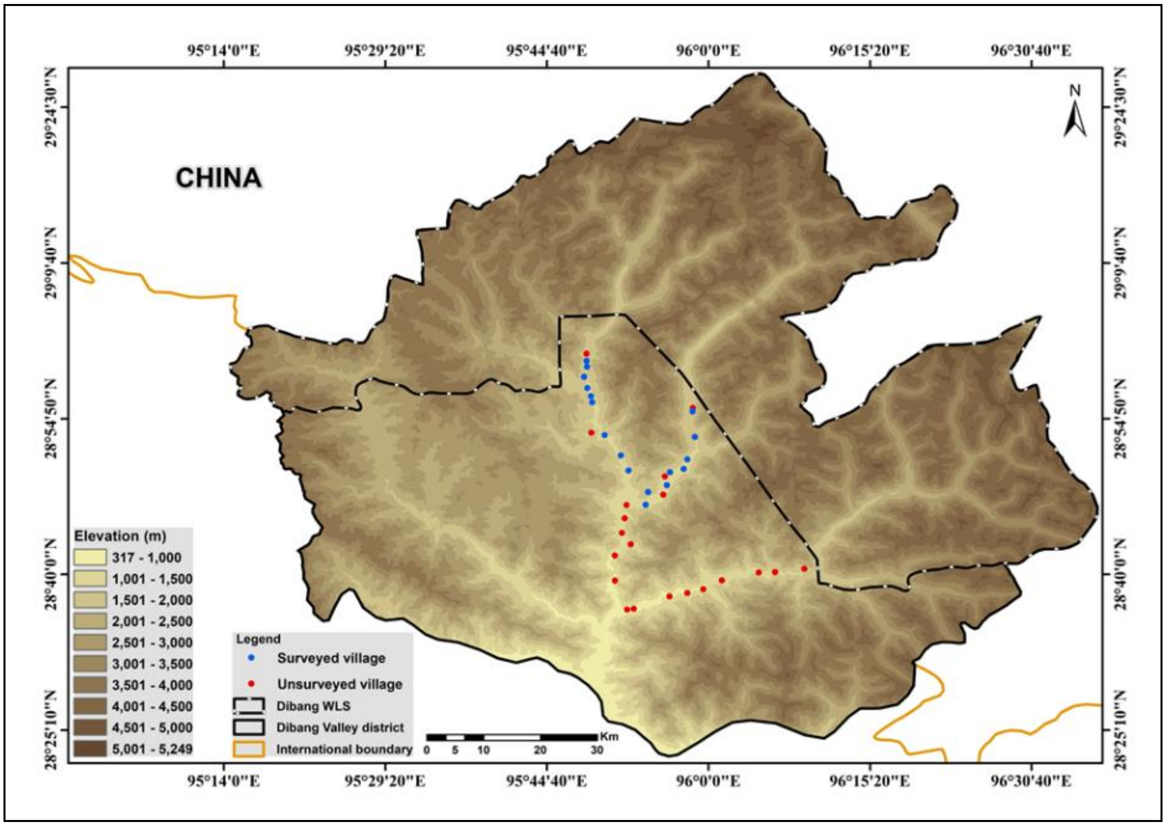

Figure 7. 1: The socio-economic surveyed villages in Mipi and Anini circle of Dibang Valley district during 2015-2017

7.3 Analysis

The analysis was carried out to reveal the socio-economic profile of local communities, crop damage by wild animals, livestock depredation by carnivores, hunting by local people and attitude of local people towards the wild animals. All these analyses were done using SPSS 12.0 and Excel 2013 with a significance level of 0.05.

7.4 Results

7.4.1 Socio-economic and religious profiles of Idu Mishmi

A total of 104 households in the 28 villages of Mipi and Anini circle were surveyed. Out of which 12 villages and 16 settlements/villages were covered from the rural area and Anini township respectively. However, 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. Interview covered on average 50-100% of the households from each village in those two circles of the district which situated around the DWLS. 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 7.2).

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 7.3).

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 7.4). 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 7.5). 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 7.6). Horticulture is also practiced and the horticultural plants cultivated are apple (39.13%), kiwi (26.09%) orange (26.09%) and cardamom (8.70%) (Fig 7.7).

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, and meat is served 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 7.8).

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 7.9). 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 7.10 & 7.11).

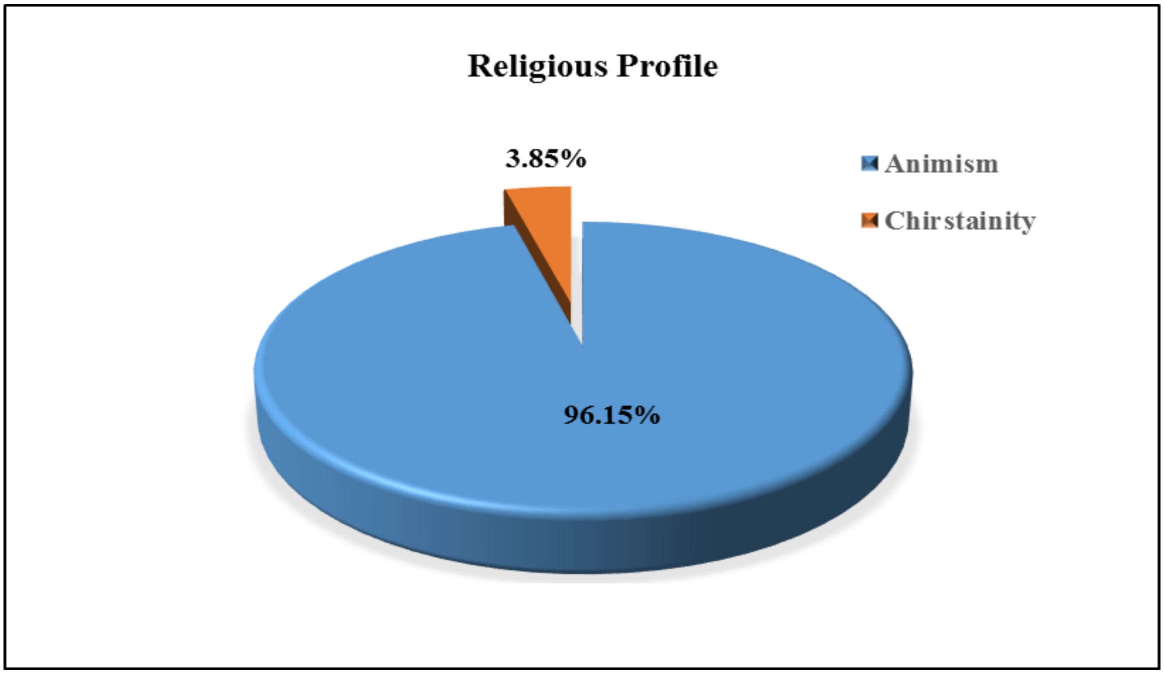

Figure 7.2: The religious profile of the surveyed respondents

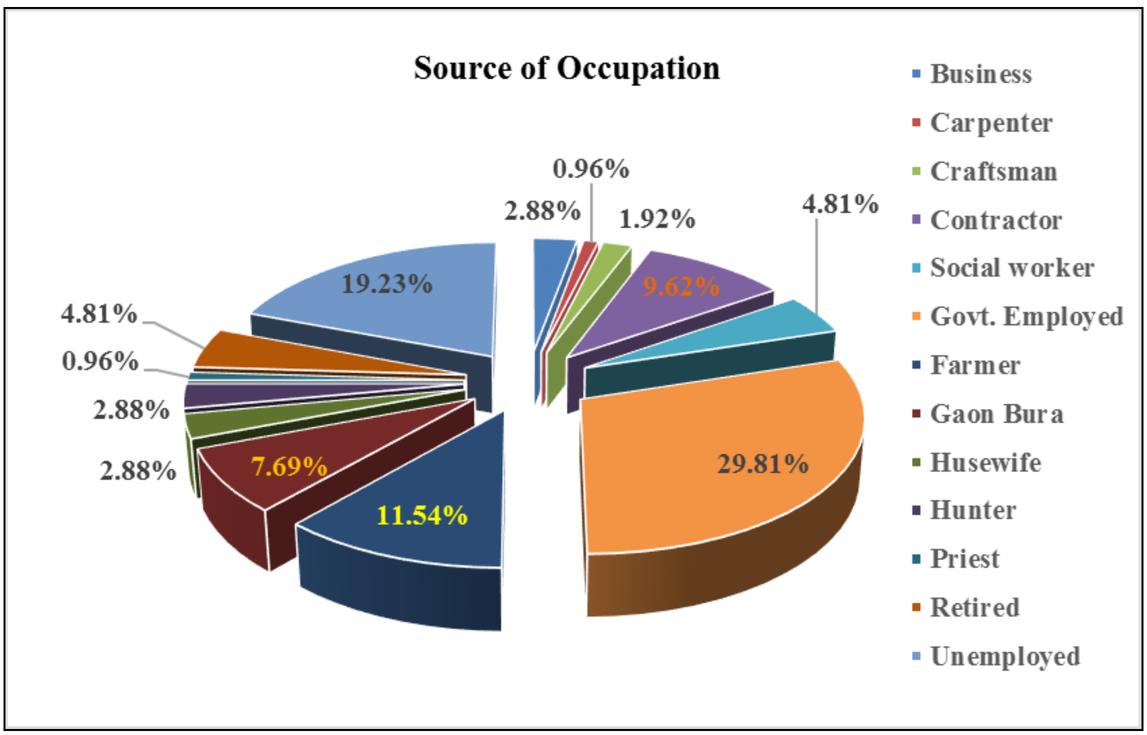

Figure 7.3: The major source of occupation of surveyed villages of Mipi and Anini circles

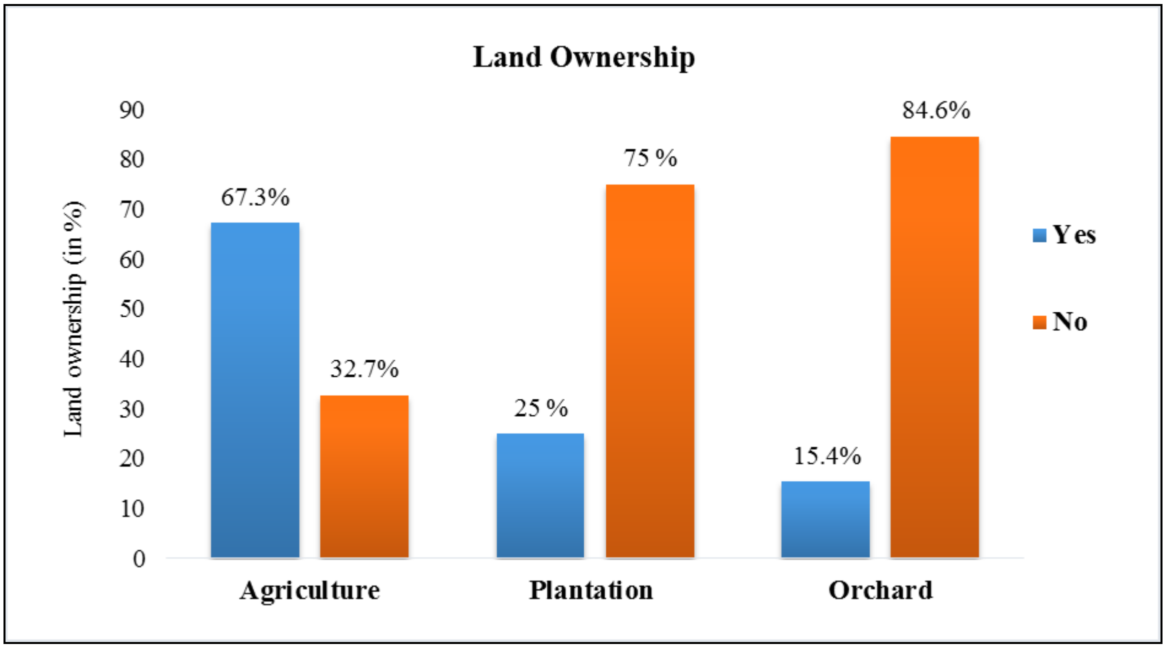

Figure 7.4: Land ownership (%) in surveyed villages of Mipi and Anini circles

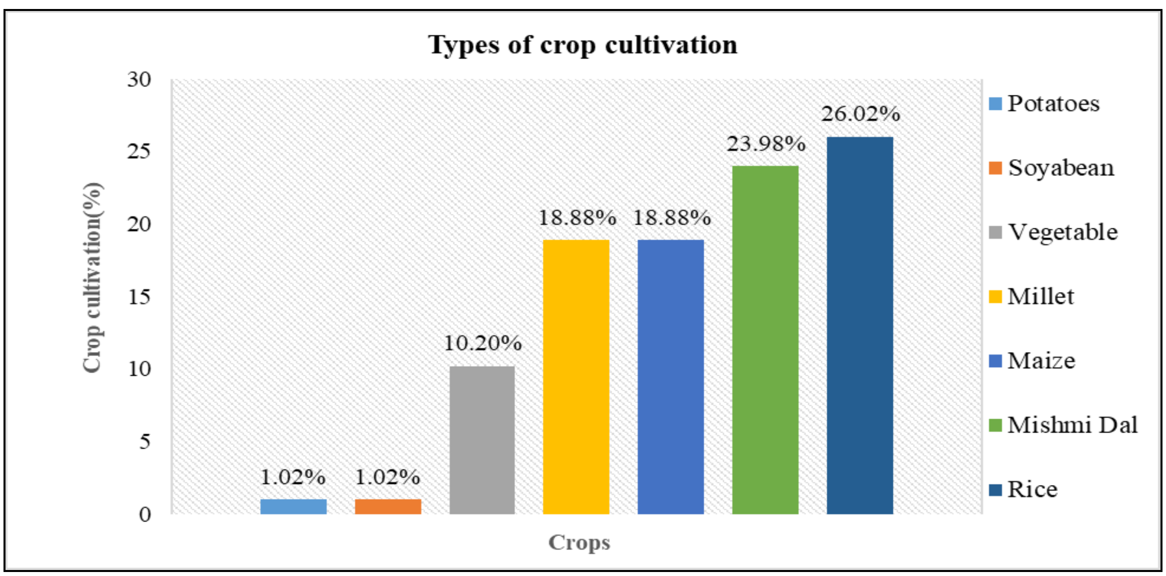

Figure 7.5: Types of crop cultivation in Mipi and Anini circles

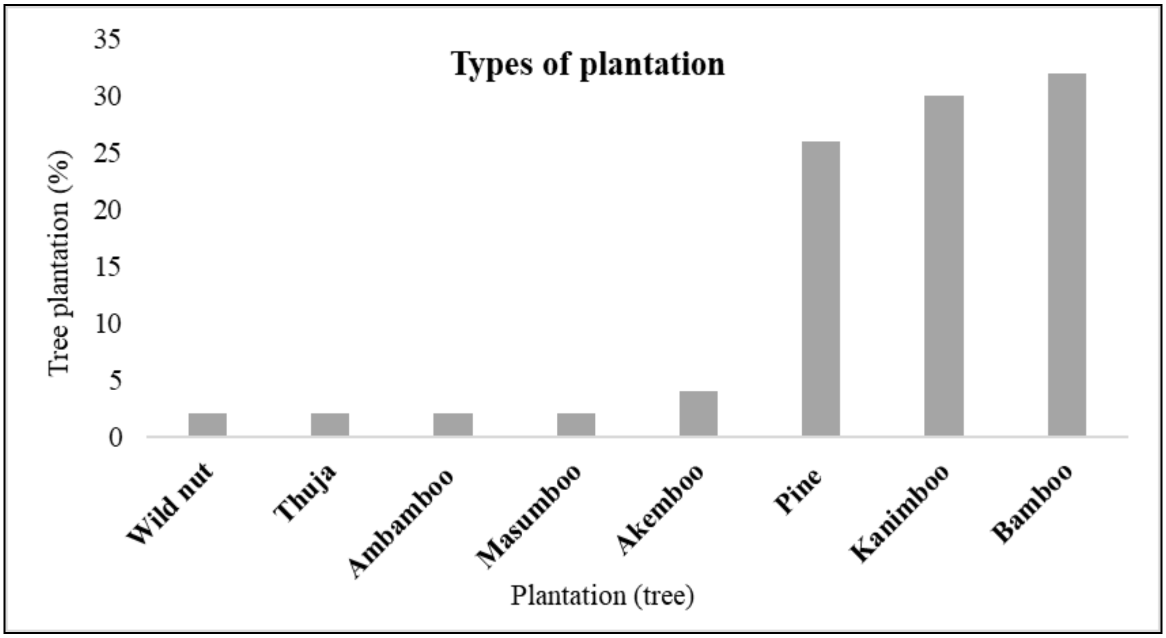

Figure 7.6: Types of plantation in the surveyed villages of Mipi and Anini circles

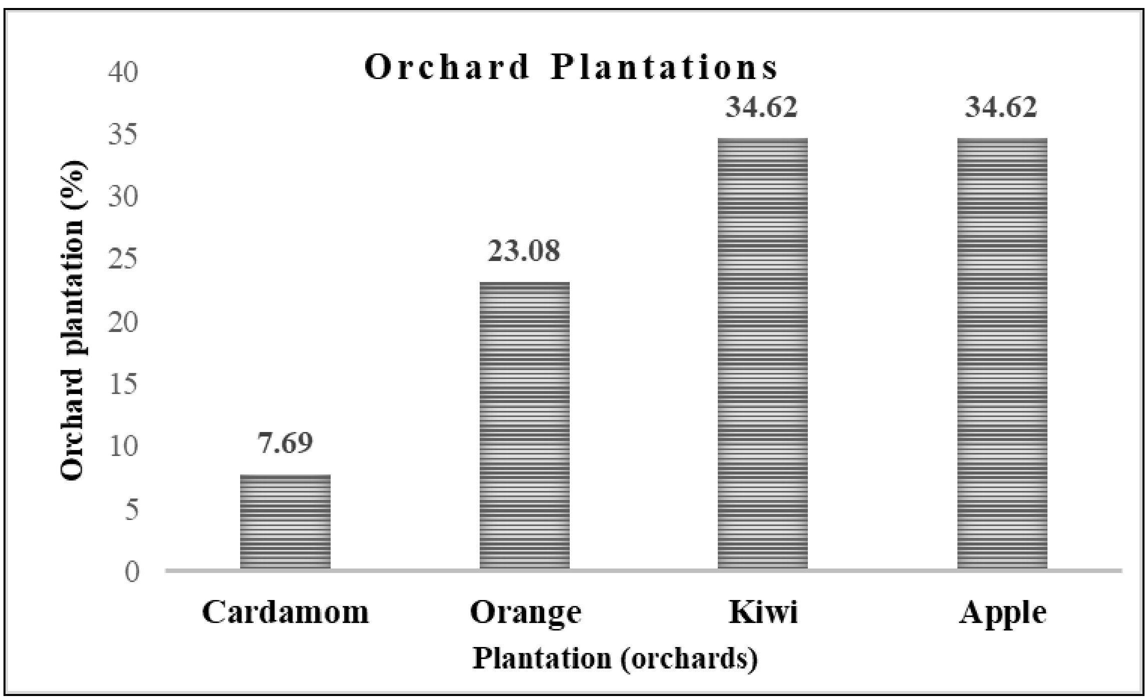

Figure 7.7: Different orchard plantations in the surveyed villages

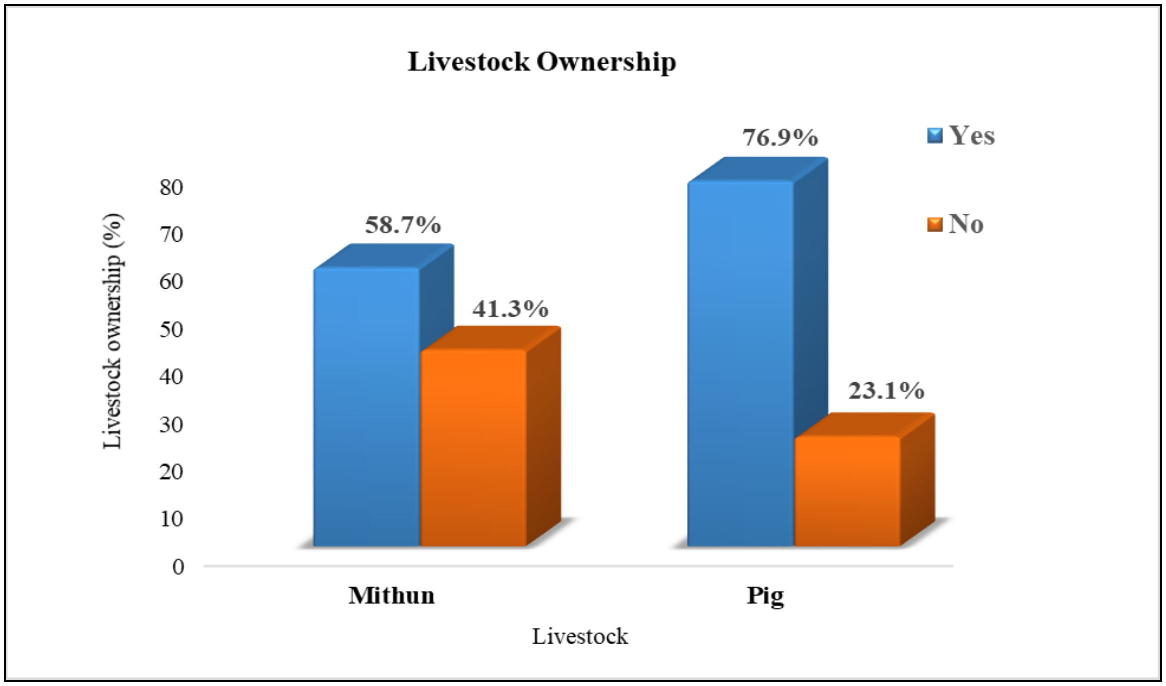

Figure 7.8: Livestock ownership (%) in surveyed villages

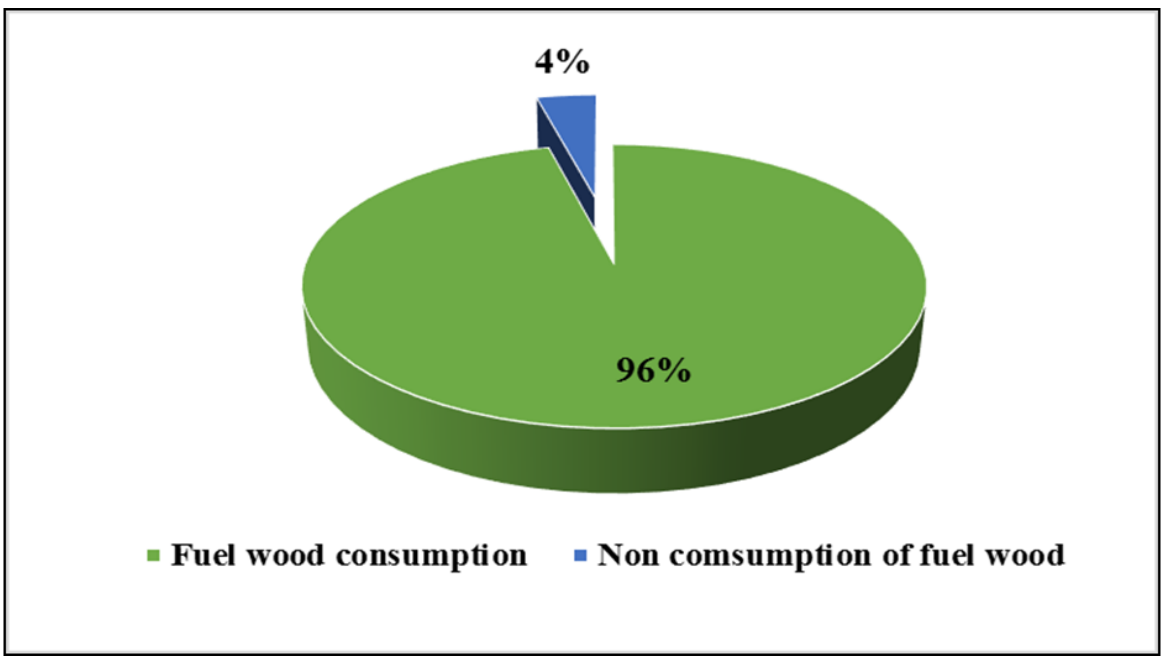

Figure 7.9: The fuelwood consumption and non-consumption percentage of respondents

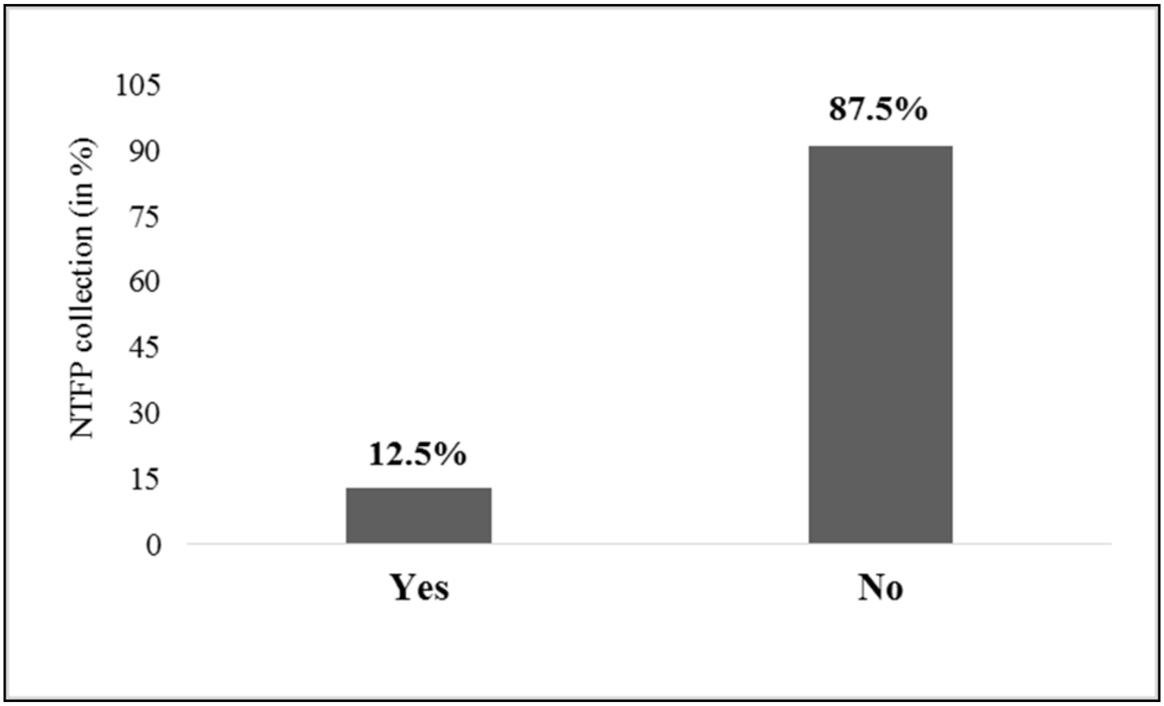

Figure 7.10: Non-Timber Forest Product (NTFP) collection by local people

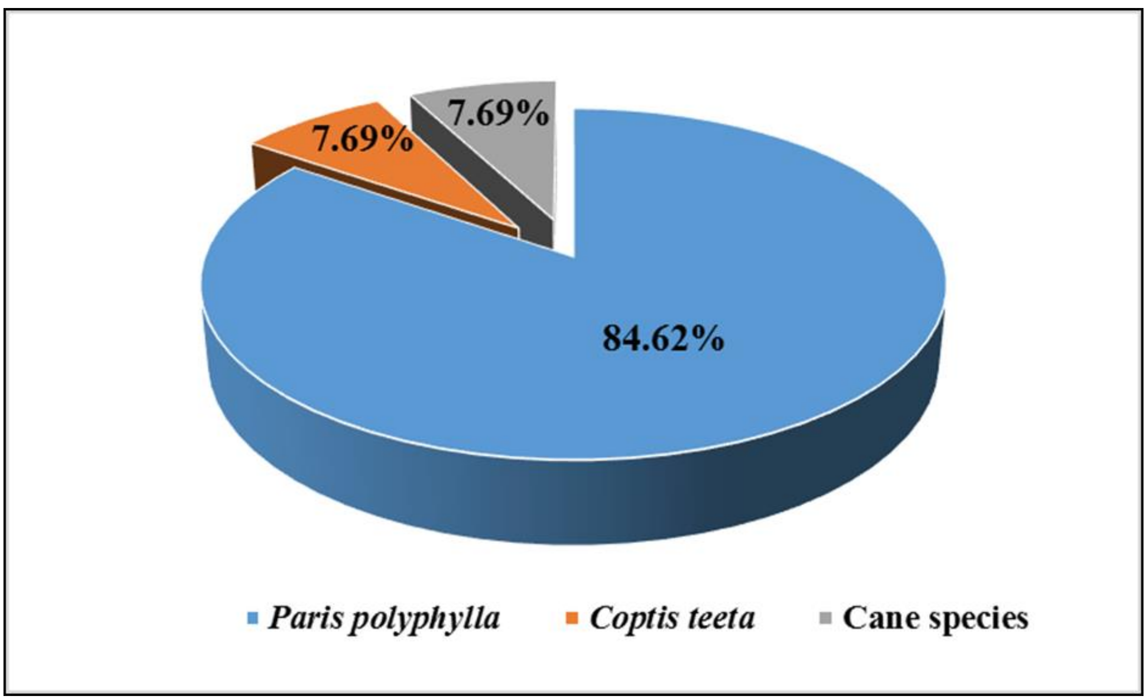

Figure 7.11: Collection of NTFP such as Medicinal plants and cane species

7.4.2 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 7.12). 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 7.13). 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 7.14). 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 7.15).

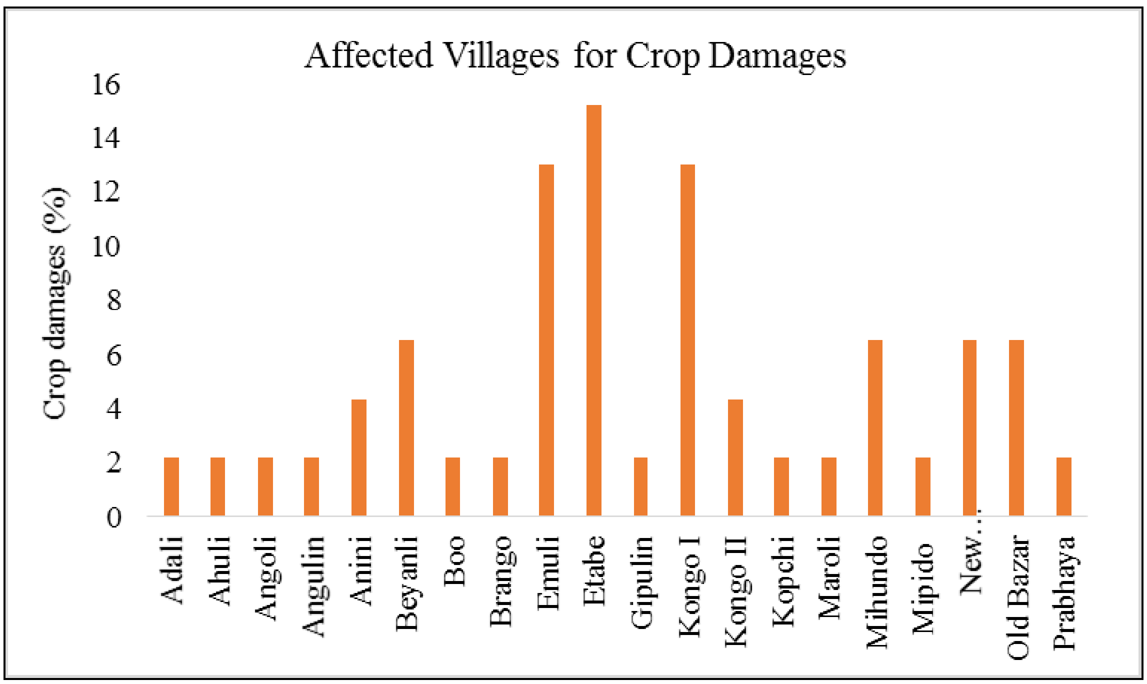

Figure 7.12: Crop damages in surveyed villages

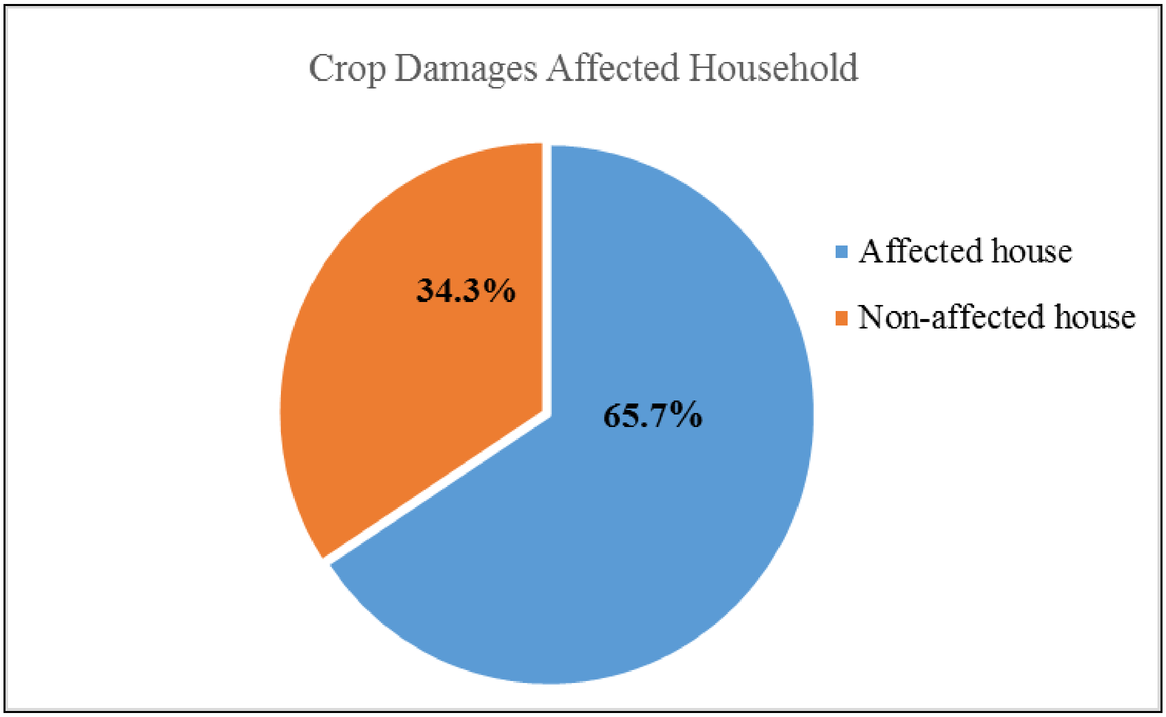

Figure 7.13: Affected and non-affected households in surveyed villages

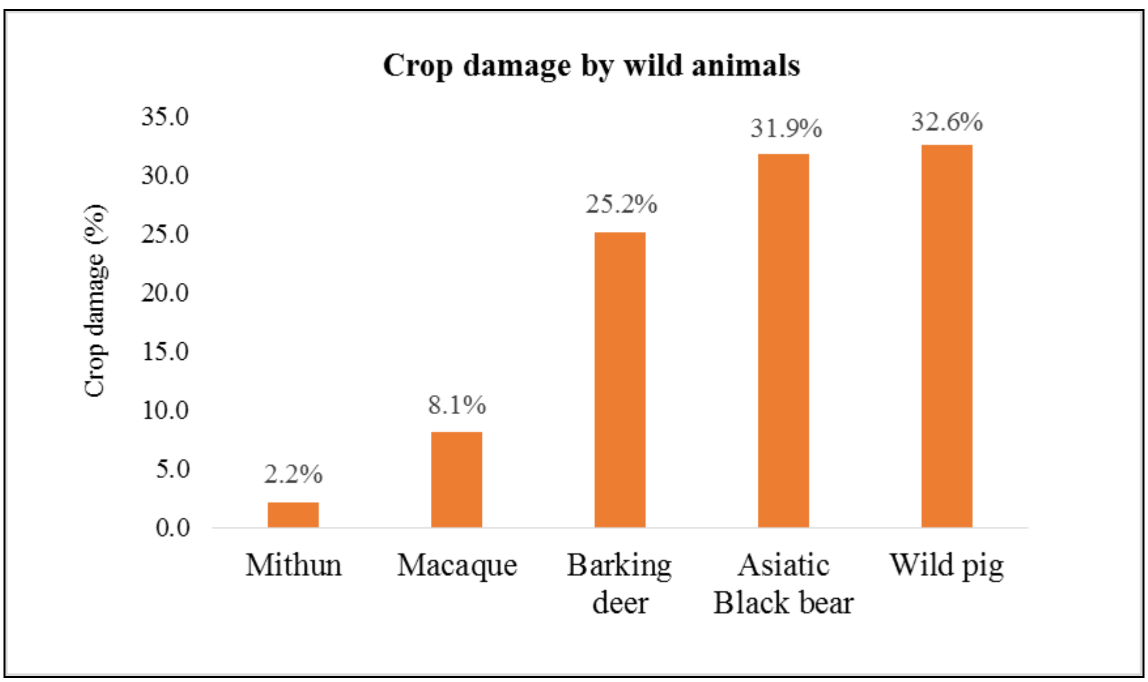

Figure 7.14: Crop damage due to wild animals including semi-domesticated Mithun

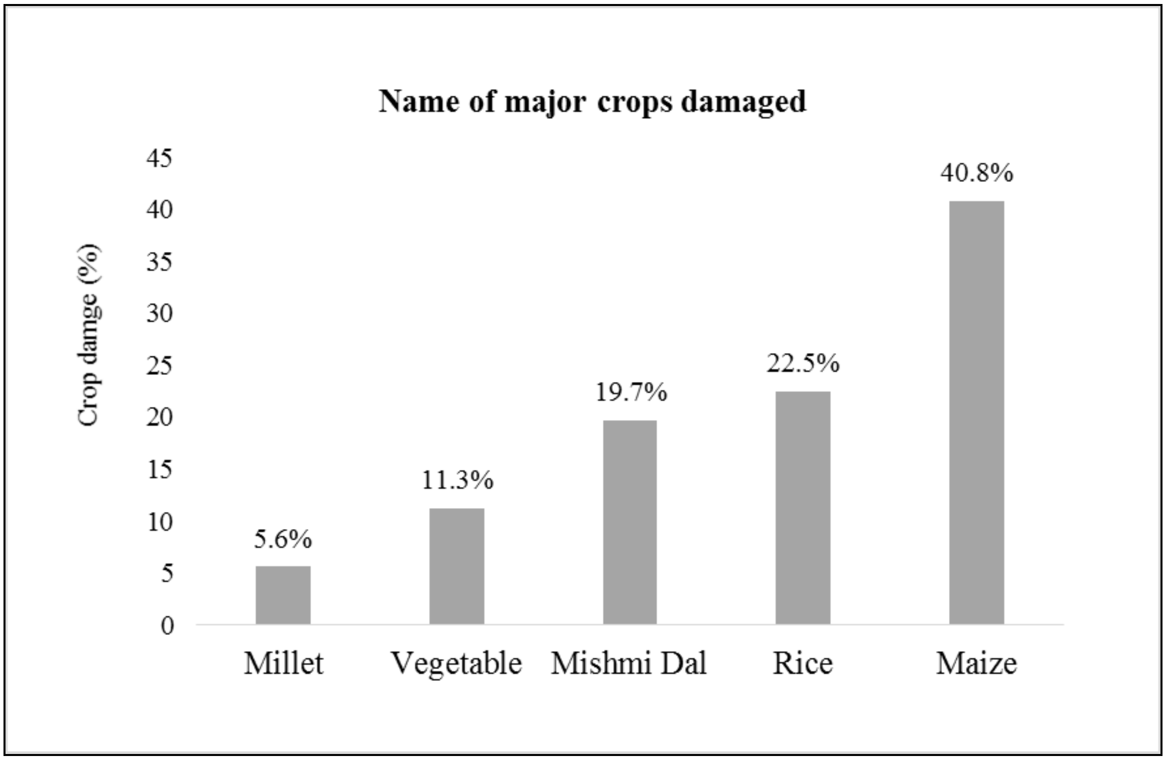

Figure 7.15: Major crops damaged by wild animals in surveyed villages

7.4.3 Depredation

Predation of Mithun by wild animal 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 7.16). 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 7.17). 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 7.18). No species of livestock, other than Mithun, have reportedly been predated upon.

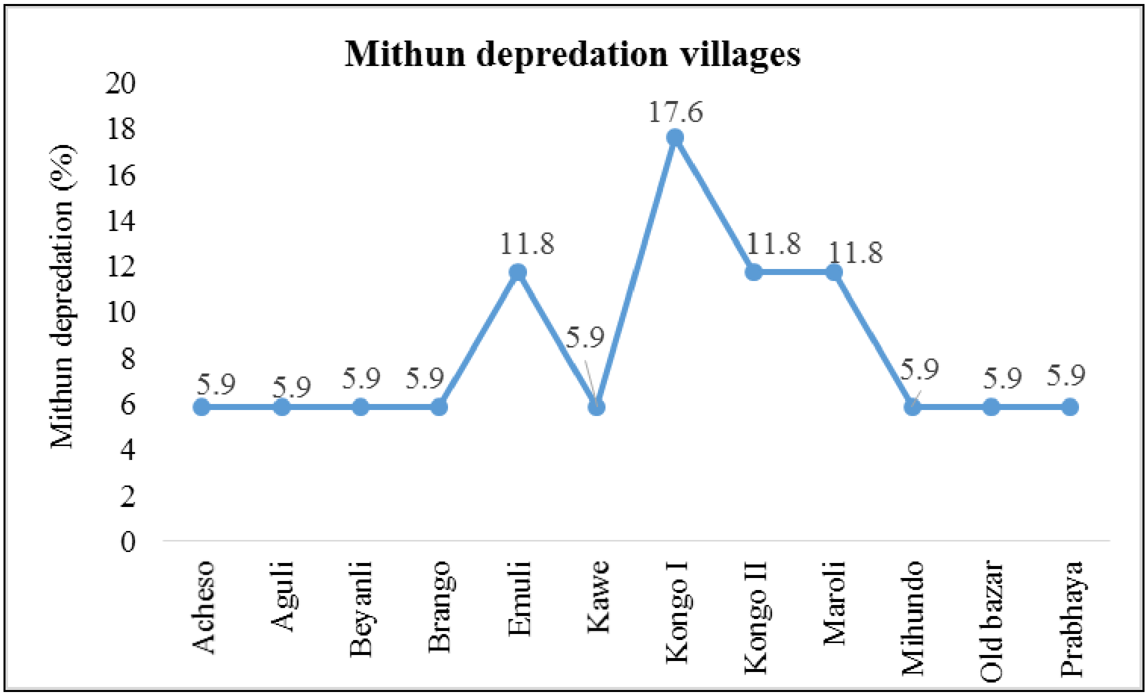

Figure 7.16: Mithun depredation reported across the surveyed villages

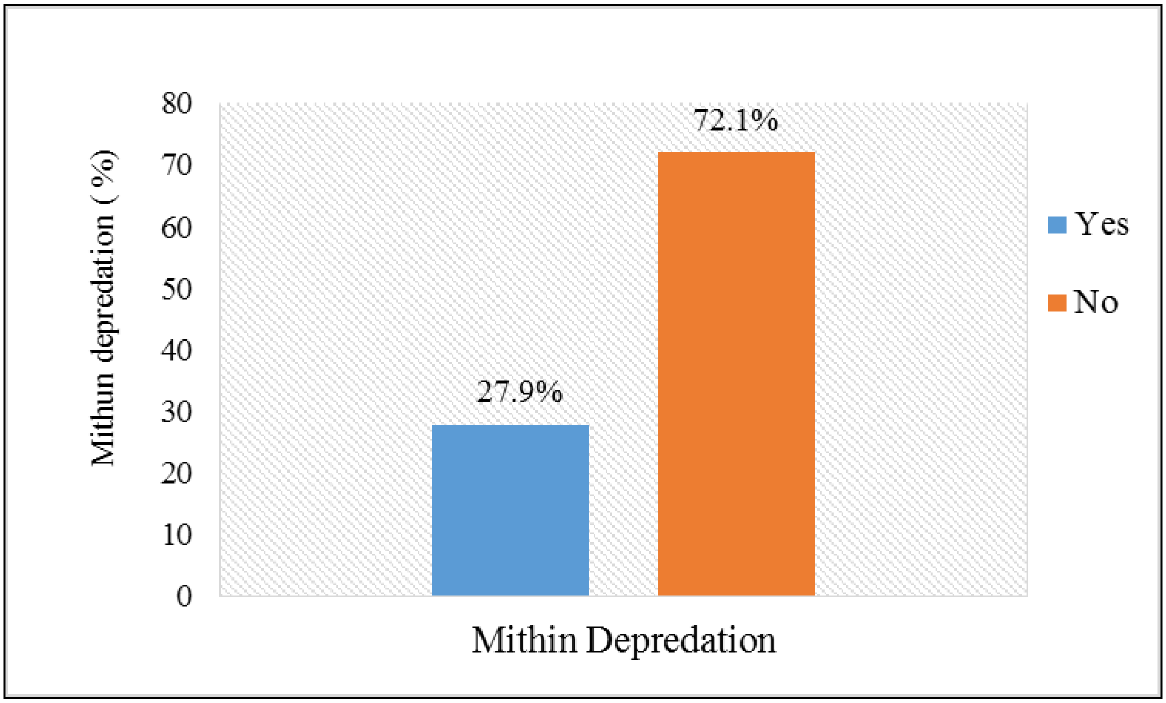

Figure 7.17: Affected household of Mithun depredation by the large carnivores

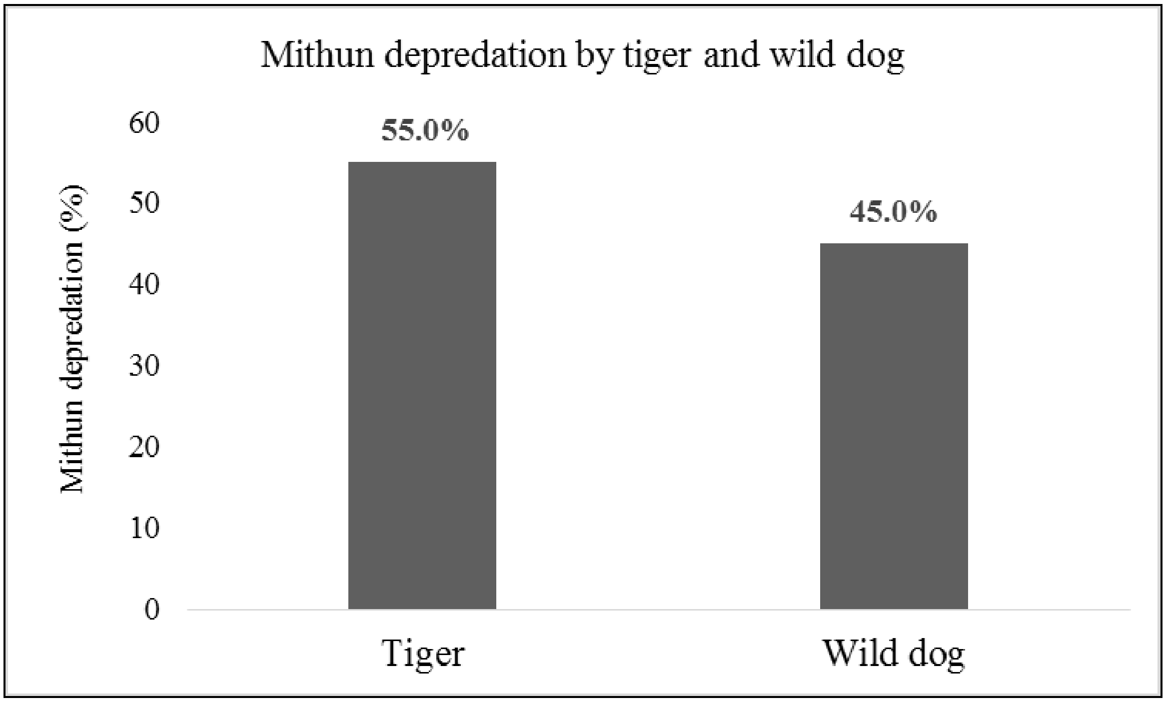

Figure 7.18: Mithun depredation by the tiger and wild dog

7.4.4 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 7.19). 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 pig (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 7.20). 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 7.21 & 7.22).

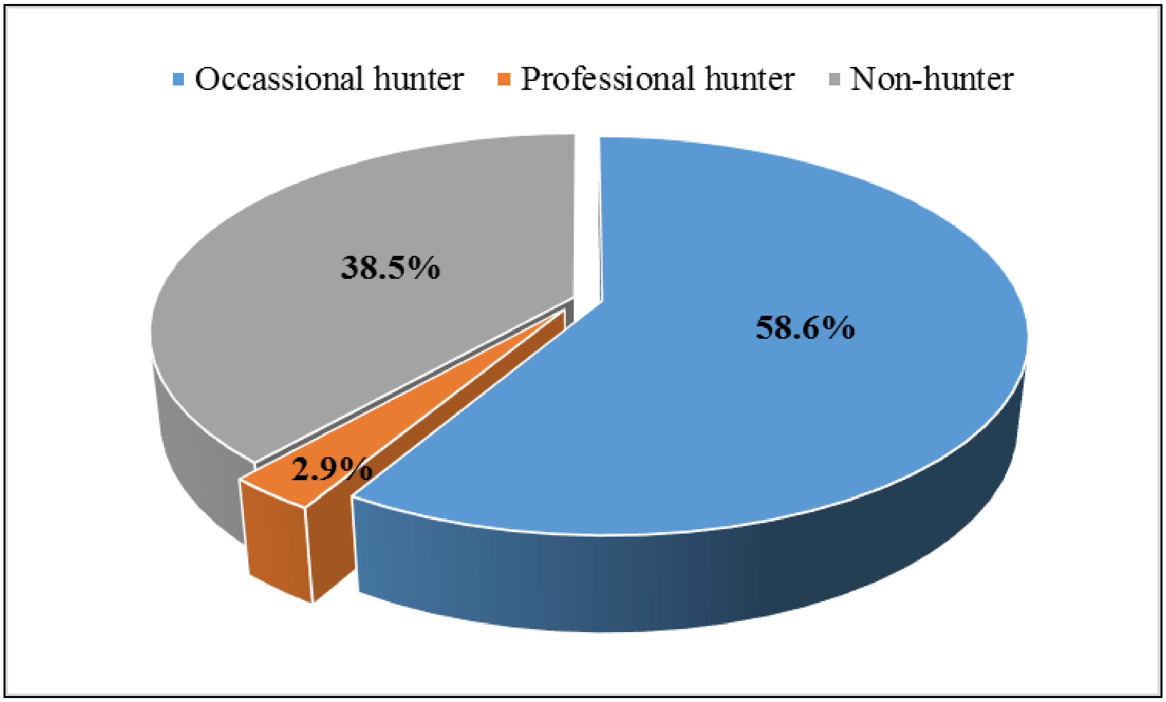

Figure 7.19: Percentage of the hunters, professional hunters, and non-hunters

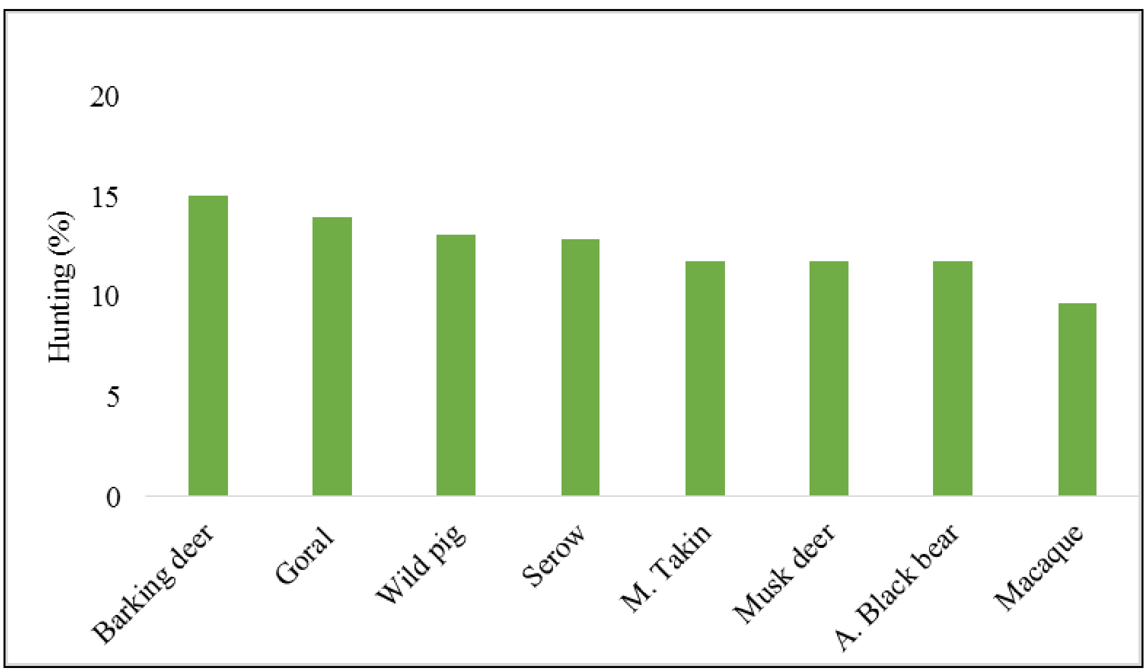

Figure 7.20: Frequency of hunted wildlife

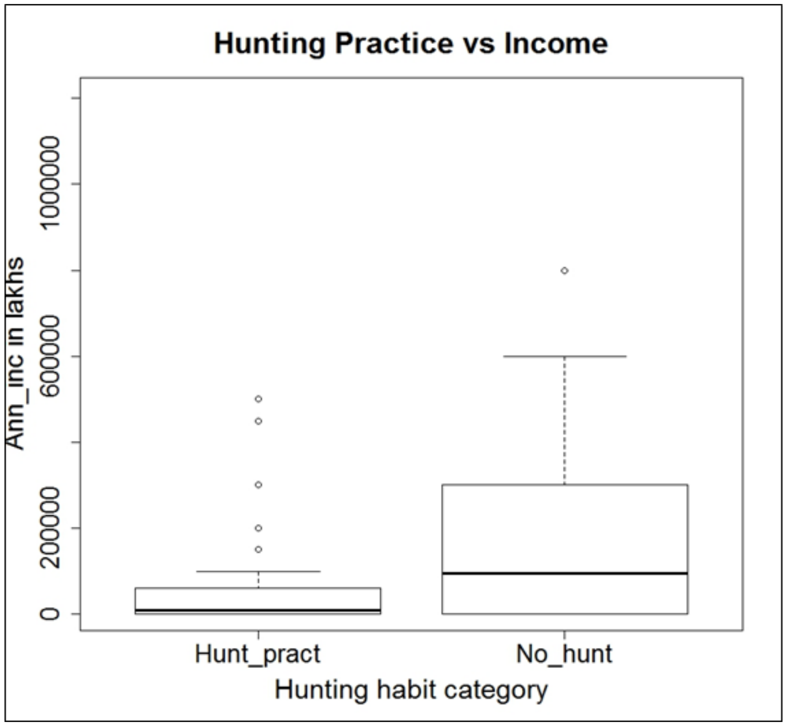

Figure 7.21: Mean box graph showing the income based on hunting

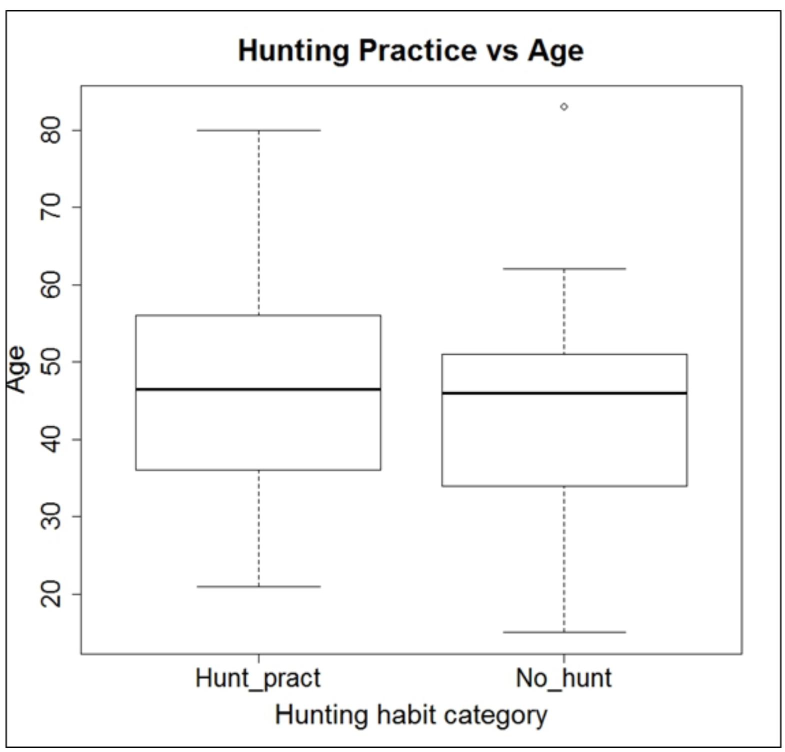

Figure 7.22: Mean box graph showing the age and hunting practiced

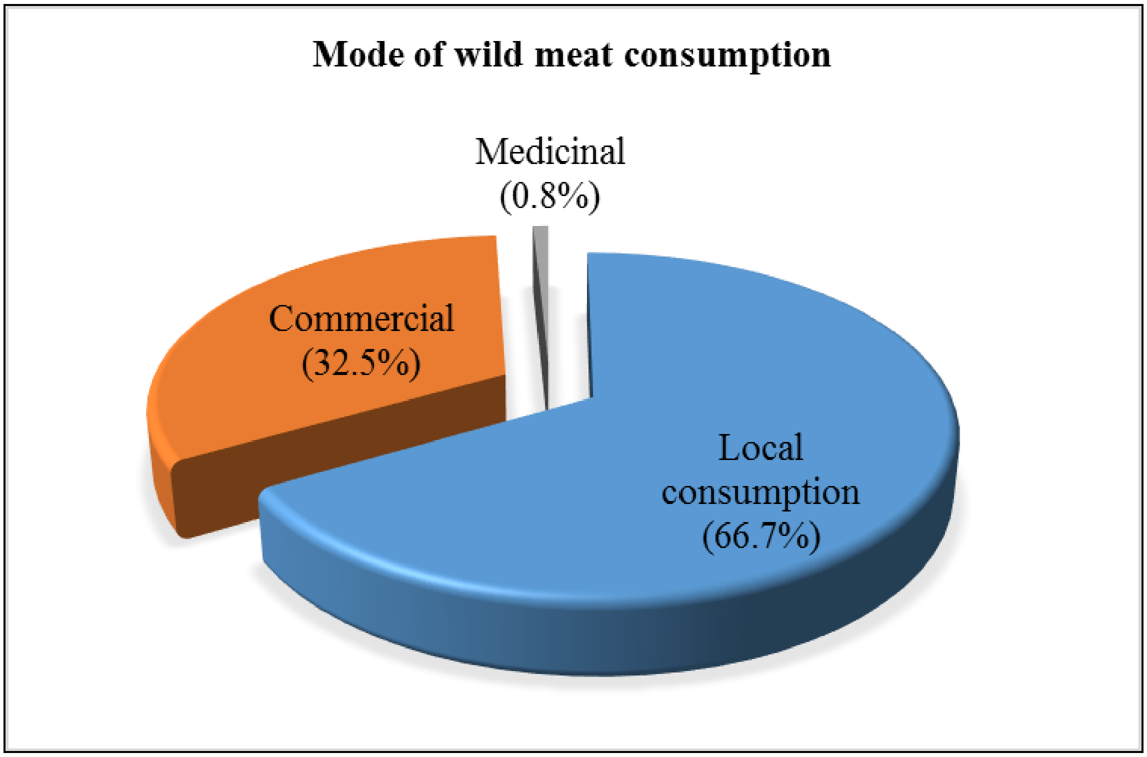

Figure 7.23: Wild meat consumption for a different purpose

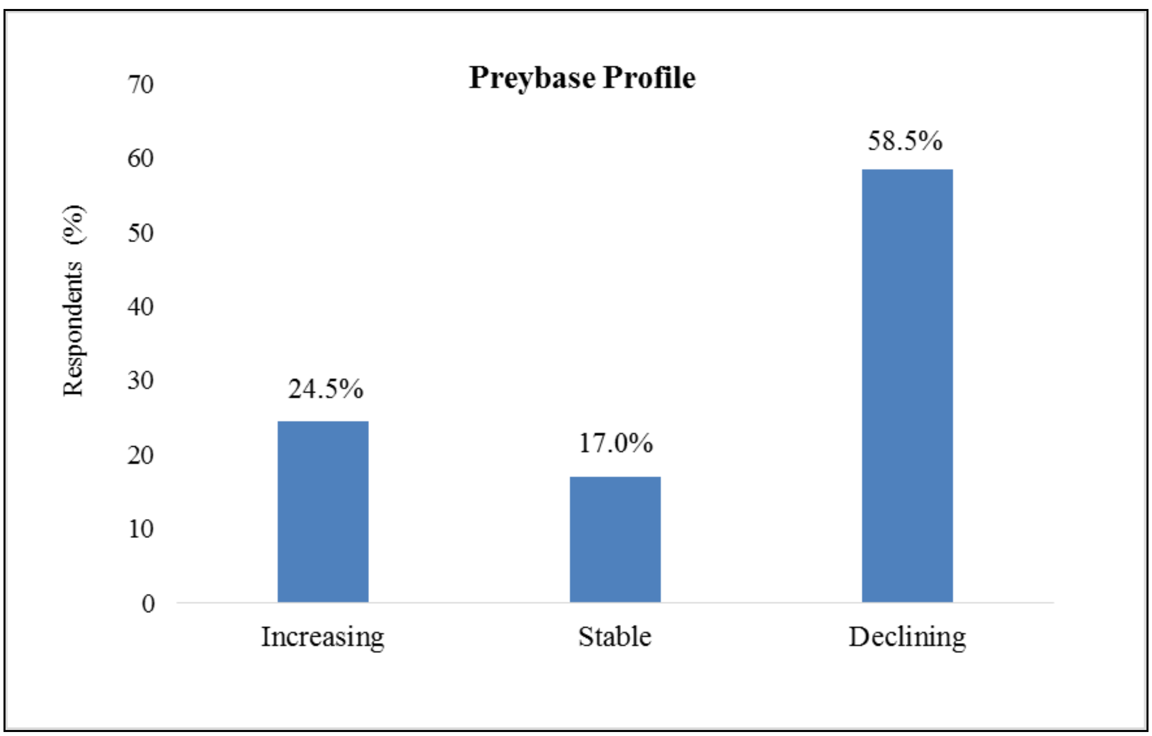

Figure 7. 24: The perception of respondents on ungulates population profil

Table 7.1: 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 the year	Guns & Snare	Meat consumption, Skins used as mat, trophy	Yes	5	DD	NA
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'sTrago pan	*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

7.4.5 People Outlook and role of taboos in wildlife conservation

The household surveys revealed positive perceptions and attitudes towards wildlife conservation (Fig 7.25), 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 7.26). 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.

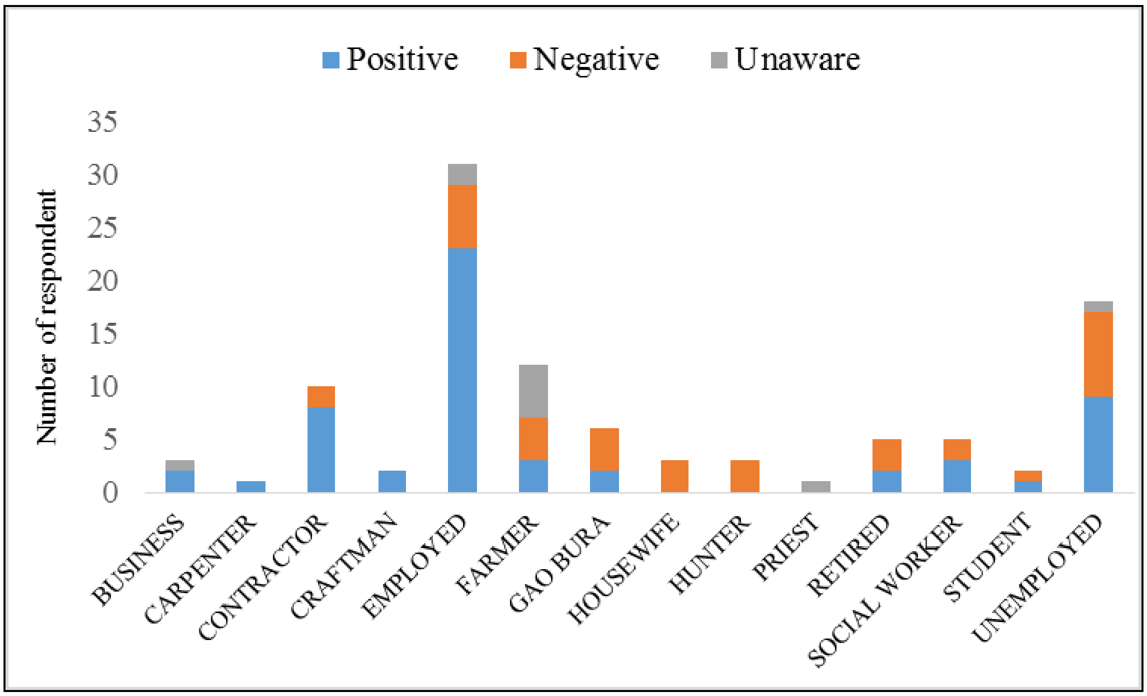

Figure 7.25: The surveyed people's perception towards tiger conservation

In the surveyed villages, 59.6% of respondents believed in tiger conserved by traditional taboos, 18.3% were negative responded and 22.1% were unaware but comparatively conservation through taboos have higher percent than overall positive responded values.

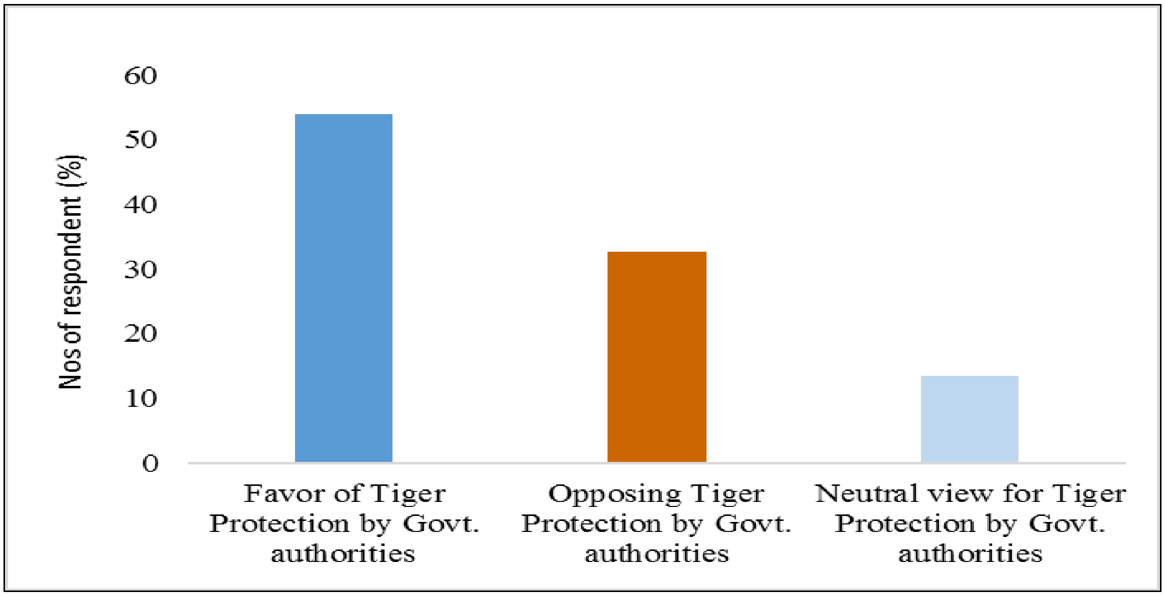

Figure 7.26: The respondent's response to tiger protection

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).

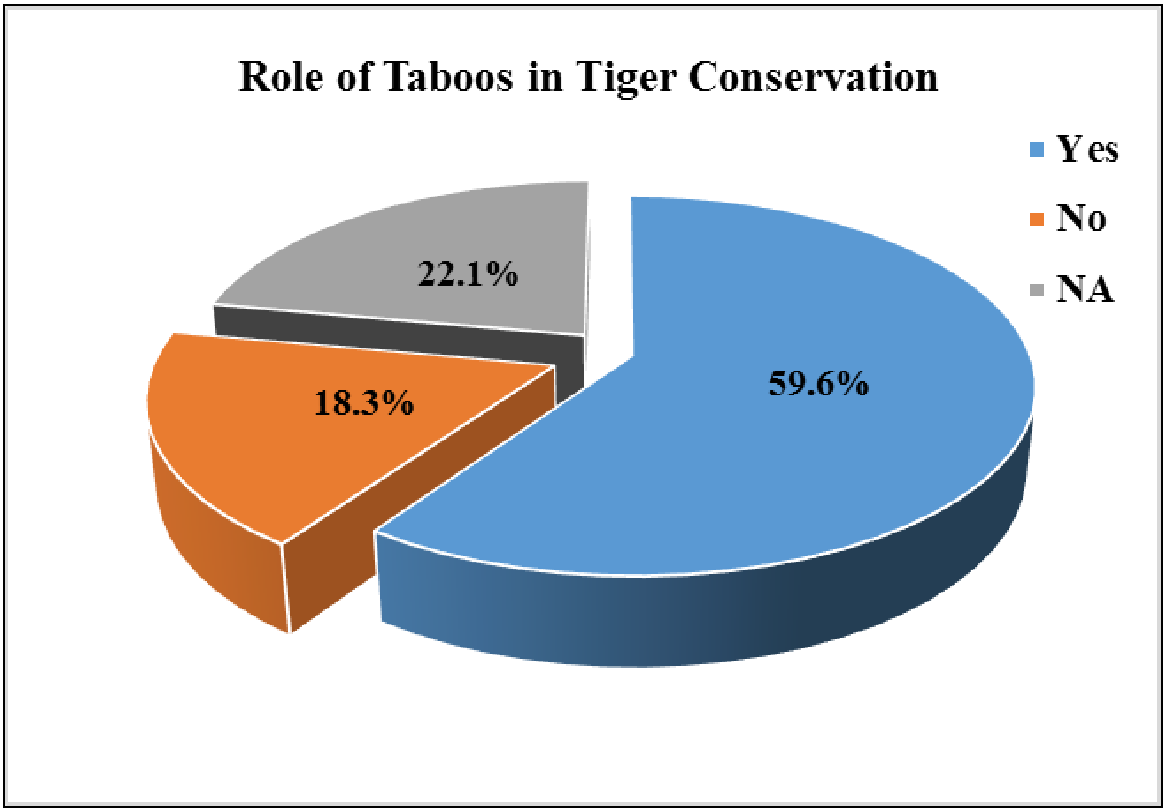

Figure 7.27: Direct role of taboos in tiger conservation by traditional norms

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 Asiatic 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; they can only consume birds, pheasants, rodents, and observe the same set of taboos.

7.4.5.1 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 (a local vegetable), 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.

7.4.5.2 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.

7.4.5.3 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 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.

7.5 Discussion

The study documented that the Dibang Valley have dual religious profile dominated by Animism and followed by Christianity in the Idu community. The Idu Mishmis are animists, believing in the presence of spirits around them and follow their own culture, languages, healing practices 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). However, in Christianity they follow the instruction of Lord Christ. In the north eastern regions, conversion to Christianity have already done by the Christian missionary before Republic of India (Morris, 1996). However, the conversion in the Dibang Valley (early it was known as Upper Dibang Valley) was recently happened by due course of remote areas, inaccessible due to hilly terrain by the missionary and not easy to approach to the tribal people. Currently, converting to Christianity in Dibang Valley is very low comparatively. But in future it would be question to the indigenous identity, social and cultural identity and indigenous right and practises. The conversion which is directly or indirectly linked with the socio economic conditions, life style and human physiological phenomena.

The percent of occupation rates confirm that villagers survive with less government jobs and mainly rely on non-governmental jobs and traditional practices. The primary occupation was agriculture and they cultivated varied crops in different season for sustenance in their own *jhum* and permanent rain fed lands. They also plant pine, bamboo, wild nut, *Alnus nepalensis* (kanimbo in local name) etc., to meet their sustenance in the present and future. The valley has favourable climatic condition for horticulture such as apple orchard, kiwi plantation, orange and cardamom farms. So far kiwi and orange have high productive and cardamom was started to be planted in fast area. Apple orchard need more concern to local weather condition, rainfall, temperature and needs high maintenance. The main livestock of the local people were Mithun and Pig. Idu's people have cultural, traditional and economical direct relationship with Mithun. They reared Mithun in the community grazing land or randomly free as a free-ranging semi-domesticated cattle. However, pig was reared inside enclose near the courtyard of house. The loss a single Mithun results in 75,000 to 85,000 rupees (INR) to a family. Idu people have the custom to buy the Mithun for cultural and social ceremonies.

Crop damage have been reported near the villages by ungulates, bear and macaque. Mostly they raided during the harvesting time however different species attack to different crops in different season. For paddy mostly attacked during the harvesting month *i.e.,* September and October. However, in case of maize, it raided during ripening time *i.e.,* June and July. People were protected from the crop raiding by ungulates and wild animals through various traditional techniques and even trapped or killed. In case of livestock depredation, Mithun depredated have been reported near villages by tiger and dhole whereas loss or depredated of pig was not reported. Mithun was vulnerable to depredated due to free-ranging as well as tiger and dhole were searching easy prey near the villages however pig was not depredated due to safely reared under fence. Aiyadurai and Verma (2003) have suggested that declining of prey population by hunting might be the factor of livestock depredation which in turn increases chance of livestock encounter by carnivores. Studies revealed human density lead to declining ungulate densities due to hunting (Karanth and Stith, 1999; Madhusudan and Karanth, 2002; Johnson *et al.,* 2006) which may be the cause for attack by larger carnivores. There was Mithun predation by dhole, people were responded immediately and was happened retaliatory killing of dhole in the villages because there is not taboos restriction to dhole. Whereas, there was Mithun predation by tiger, the people did not respond instantly because of the restriction by taboos and emotional attachement to tiger as an elder brother. Overall in the surveyed villages, predation by tiger was higher due to tiger's behavior of predation on large prey, solitary hunting as well as it might be the less available of prey species. In general, retaliatory killing was mainly against carnivores for factual and alleged threats to property, safety of game species (Treves and Naughton-Treves 2005; Woodroffe and Frank 2005; Van Eeden et al., 2018).

Although hunting is common in all age group, it was high among the age group of 35 to 58. Among these, professional hunters were very less compared to game hunters. Those who are involved in the skilled hunting they may due cause of economical supportive to their family and source of income generation. They generally used 0.2 gun with handmade bullet but they were used snare frequently in the case of musk deer and takin hunting. Other unskilled or non-professional hunters normally hunted for wild meat, used of skin for household purpose and sometime the wild meat was sold in local market though most of it was for local consumption except musk deer and bail of black bear used for commercial purposes. The hunters maintain their trophy board in the house and considered as a sacred place.

Hunting expedition, crop damage and predation by wild animals happen mostly in winter when the human and animal activities are high. The study revealed demands for wild meat in local markets is motivating people to hunt in the forest. Indian Wildlife Protection Act 1972 prohibits hunting of wild animals but in the case of Arunachal Pradesh these laws are disregarded (Datta *et al.*, 2008). However, the Idu society has following the old age traditional law, social norms, and taboos on hunting from the time of their forefathers which is driving to conserve and maintain the wild animal's population sustainably. They also believe that hunting is one of the foremost occupations for the male members which they cannot take for granted of the Idu society from time immemorial. The *Igu* (shaman), take the major role in shaping the strongholds of social norms and taboos. In Idu community, *Igu* has a dual meaning, one is the priest itself known as *Igu* and the other meaning has been considered the rituals function. The *Igu* (shaman) narrates the story of Idu Mishmi's evolution, migration and rule and regulations of the society in respective ritual functions. Due to lack of written works of literature, Idu's followed the oral traditional knowledge presentations by the *Igu* (shaman) which have been bound the peoples to their beliefs and keep taboos alive in the society. Observing of taboos during and after hunting are more significant in the conservation point of view. In the house of hunter, one can see the head of the animal, horns, antler, jaws etc., from the kill as displayed in the trophy board. They believed that spirit resides in such trophy boards or the place where they are kept as sacred. Thus, the female members who are on their periods or any other person from outside cannot touch or go inside such places.

There are stories related to the mythology associated with the tiger and its associated cat family species with that of the Idu community and they have different opinions on especially regarding tiger and wild dogs. 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-defence or in retaliation to livestock *i.e.*, Mithun predation. Conversely, a ritual is performed after the hunting of a tiger. The ritual is equivalent to that of a human, such as a five day of death ceremony is being observed but the same is not observed in the case of wild dog. Therefore, with such beliefs, the tiger and its associated family member has inhabited and thrived in the region with full respect and in harmony with the local people.

If any local people want to go hunting, he must perform a traditional ritual locally known as *Am-bu* before one day ahead of the hunting excursion. He needs to follow such rules and regulations till five days after he returns from hunting (one day for musk deer in exception case). The rules and regulation include house arrest, not allowed to attend functions like birth ceremony, death ceremony, marriage ceremony, etc., strict food habits, *i.e.,* not allowed to eat garlic, local onion, mushroom, maisena (local name) etc., and also not allowed to have a physical relationship with his wife or woman. Also, he is not allowed to wash his clothes for a month. 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-defence 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 do not kill. With these taboos imposed by customary law, they have co-existed with nature since time immemorial.

Such primeval traditions observing taboos of hunting aren't allowed to hunt in excess. They need to follow specific rules and regulations before hunting expedition as well as after hunting practices. Thus, the wild animal populations in this valley are protected directly or indirectly by traditional taboos. Hence, the people are claiming that the wild animal populations are fully protected by such practices since ancient time. The Idus are proud of such status and without such taboos, traditional protection, 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 DWLS as a future 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.

In this scientific world, many non-governmental organizations (NGOs), government organizations, local bodies are trying their best level for conserving wildlife. We need to bring a relationship between scientific conservation and traditional knowledge system of conservation of wildlife in the near future for the betterment. However, there are some uncertainties regarding scientific community and local indigenous communities, which are as follows: Firstly, in this globalization era, how can we preserve the ancient tradition by the Idu community without any disturbance? Secondly, with the age of religious conversion, Christianity influence has also reached Dibang Valley. After conversion to Christianity, there is a doubt that less chance of observing old-age tradition followed by Idu community and in there might be a decline in observing such rituals and traditions. Thirdly, Dibang Valley is located on the border of China, the demand for tiger's part in China is very high. Thus, there is a high chance that the tiger found in Dibang will be hunted down by the poachers. Fourthly, many commercialized and sophisticated weapons have reached the valley. If 0.2 guns and binoculars weapons replaced the old age bow, arrow, and snare, there will be increased in the hunting of animals.

Thus, with these reasons, there is need to have a mechanism about how traditional indigenous knowledge can be applied along with scientific methods by having a thorough discussion between policymakers, NGOs, central and state government, forest department, social scientists, wildlife experts, scholars, students and stakeholders for the future sustenance. Along with these recommendation, the importance of awareness programme about the wildlife conservation must be taken up because the lack of awareness which possess a potential threat to the wildlife; and also the compensation schemes are very poor in the villages which leads to retaliatory killing or hunting of animals. People living here are mainly forest dependent and they need large area to cultivate, restriction of entry in to the forest and no compensation for damages shows negative attitude against forest department and conservation. Even though the people were primarily dependent on the forest resources for fuel wood and other biomass, they were aware that this extraction was causing harm to the forest but since no alternative was available to them, they had no option. Effective eco-development projects and proper education might help them to understand the value of the forest ecosystems.

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CHAPTER VIII

SYNTHESIS AND CONSERVATION IMPLICATIONS

8.1 Background

In India, the history of tiger conservation can be traced back to the year April 1, 1973 when the Project Tiger was initiated by the Government of India with a vision to conserve this charismatic species. Similarly, the Wildlife (Protection) Act enacted in 1972 conserves the wild flora and fauna of India. The people of this country have high reverence for nature, *viz.*, wild animals, birds, plants, etc., from prehistoric/ancient times till the urbanization era (Tanwar, 2016). In some cultures, maintaining the living legends especially in tribal communities, the aboriginal people and nature share a common bond (Gandile *et al.*, 2017). Paradigms of harmony between aboriginal people and their nature have been associated with mythology and folklore since time immemorial; they have always observed their natural surroundings a sacred place (Vecsey and Venables 1980; Duming, 1992; Bernbaum, 2006). Hence, India occupies an esteemed position in the world in the conservation of wildlife and nature. The nucleus of such is bound by the school of thought, taught by many scriptures and oral literature of aboriginal indigenous tribes (Bernbaum, 2006; Tanwar, 2016; Bithin 2019).

In these few decades, wildlife populations are gradually declining due to unsustainable human activities (Pimm *et al.*, 1995; Daleszczyk *et al.*, 2015). Indeed, India is one of the mega biodiversity hotspot countries in the world contributing to a substantial amount of obligations in the conservation of its natural resources and wildlife (Chaudhuri and Sarkar, 2003). In Indian sub-continent, four biodiversity hotspots are found, each having own characteristic and features. The Eastern Himalaya and the Indo-Burma hotspots located in northeast India bestowed a significant role in the biodiversity of the country. The flora and fauna found in these hotspots are endemic to these regions only (Myers, 2000).

8.2 Status of large carnivore and their prey species in DWLS

The Mishmi Hills are located in the Indian part of the Eastern Himalaya biodiversity hotspot, which is one of the regions of high biological diversity and geographical gateway of India (Bailey, 1992; Chatterjee *et al.*, 2006; 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 Asiatic wild dogs, are some of the flagship animals inhabiting in this region and are also widely distributed in the Dibang Wildlife Sanctuary (DWLS) and its adjoining landscape. The altitude of the sanctuary varies from 1678 to 5500 m amsl with diverse vegetation from temperate to alpine forests. The study has reported the first photographic evidence of tiger presence from the community forest 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 and Gopi, 2018). Thus, further studies are required to understand the favorable conditions or gain insights 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 the neighboring countries like Bhutan (McDougal and Tshering, 1998). Even in other parts of the Indian sub-continent, there have been photographic reports of the occurrence of tigers at this elevation in Uttarakand of Western Himalaya (Bhattacharya and Habib, 2016), and Trans Himalaya of Sikkim (Lachungpa and 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, poaching and habitat fragmentation (Kawanishi, 2002). 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 (Tilson *et al.*, 1984; Karanth and Stith 1999). 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.

Tiger in other parts of the country have sympatric relations with multiple co-predators, however in DWLS Asiatic wild dog (dhole) are only sympatric large carnivores with tiger, they are sparsely inhabited in and around the protected area. No common leopard was recorded from the sanctuary and its surrounding landscape. Hence, tiger and wild dogs have some sort of relief from the high sympatric competition of leopard.

In India, the pack size of a wild dogs ranges from 50 numbers at the maximum to lowest one individual (Johnsingh & Manjrekar, 2013). However, the ecological study on wild dogs in northeast India is limited. The number of individuals in the pack is recorded to be a maximum of 3 numbers as per the study carried out by Selvan 2013 in Pakke Tiger Reserve, Arunachal Pradesh. Interestingly, 4 individuals were recorded in a pack from the present study. If the sampling area will be increased in the future study, the pack size and number of individual might increase.

In DWLS, five prey species of tiger and wild dog are being recorded within the temperate forest zone. They are Mishmi takin, red goral, Himalayan serow, barking deer and wild pig. In India, Mishmi takin is endemic only in Arunachal Pradesh (Anwaruddin, 2006). The primary prey species for tiger is usually large ungulates such as gaur (*Bos gaurus*), sambar (*Cervus unicolor*), nilgai (*Bosephalus tragocamelus*) etc., in other parts of the country (Biswas and Sankar, 2002). However, gaur, sambar and nilgai are not distributed in DWLS and its surrounding landscape, as a result, Mishmi takin is the primary prey species for tiger in this region. Himalayan serow, Red goral, wild pig and barking deer are also the prey species of tiger. As a co-predator, wild dog competes with the tiger in many aspects (Karanth and Sunquist, 2000). There was complexity while determining the accurate abundance of ungulates in the region. The abundance indices were used to determine the relative abundance of ungulates. As per relative abundance index (RAI) based on the photo-capture rates, barking deer was encountered to be abundant followed by red goral, Himalayan serow, Mishmi takin, and wild pig. Barking deer was found to be abundant in low lying areas such as river valley whereas in high altitude Mishmi takin was found to be abundant followed by red goral and Himalayan serow. And also G*ongshan* muntjac was recorded from the sanctuary.

8.3 Carnivore diet profile

The study reveals that around 55% of the diet is similarity in the tiger and wild dog food habits in DWLS. Both these sympatric carnivores are mainly depending upon large to small-sized ungulates as Mishmi takin (*Budocas t. taxicolor*), Himalayan serow (*Capricornis s. thar*), Red goral (*Naemrhedus bailey*), Barking deer (*Muntiacus muntjak*) and semi domesticated free ranging livestock Mithun (*Bos frontalis*) has contributed except to the total biomass consumed by wild dogs. In diet profile of the tiger reflects the prey selectivity of large-size to medium-sized ungulates such as Mishmi takin, goral, serow and wild pig are more in the relative proportion of the diet. On the other hand, wild dog diet composition is made by medium to large-sized prey species. Wild dogs are social and pack hunter; therefore, they can easily hunt large ungulates even Mishmi takin. However, in the diet composition of tiger and wild dogs, there is the presence of small prey, these are possible only if the availability of appropriate size classes of prey is not a limiting resource (Karanth and Sunquist, 1995). 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). Presence of smaller prey and livestock such as small rodents and Mithun in wild dog diet describes the possibility of low densities of wild ungulates in the study area and makes it evident that wild dog has tried to sustain on smaller prey species and consequently starts to depredated on livestock i.e., Mithun (Biswas and Sankar, 2002; Reddy *et al.,* 2004). This illegal hunting needs to be banned and governed by law, else the fate of the tiger and wild dogs will be wispy. Consequently, a time will arise where there will be negative human-wildlife interaction in the region due to the attack on the domesticated animals or humans.

8.4 People's perception and attitudes towards tiger conservation

Idu Mishmi community has been protecting their natural resources through their strong traditional belief systems and practices which have helped them to 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. They take pride in the fact that it is due to their taboos, traditional protection and/or restriction, the 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. *"Doosra tribal community ka jungle mein to ek chidiya bhi nahi milega, hamare yahan to bhut chidiya milega. Hum to niyam karta hai wo logo ka to koi niyam nhi"* said a localite stressing the significance that fact of following of their taboos and respecting them. Without such taboos, traditional protection and/or restriction by their community, without having a kinship with tiger, it is questionable about the abundance of the tiger in this region. While trying to declare as a tiger reserve, they have a strong argument, with their old age traditions and taboos the tigers and other wild animals have been protected and will be protecting in the far future also. The valid points must be kept in our mind, need to look at cultural aspects of protection, the role of taboos which took a distinct role in harmonious concurrence of humans and wildlife. This outstanding practice of harmonious coexistence life of aboriginals, *i.e.*, their way of living, coexistence with nature needs to be learned by the present generation and ought to motivate them.

8.5 Tiger Reserve through community consensus

The abundance of tigers and other wild animals in this region is unparalleled. In India, there are 50 tiger reserves distributed in 18 states that are directly administered under the Tiger Project 1973 by National Tiger Conservation Authority (NTCA), Government of India. A 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 22 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.

8.6 Limitation and 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 limitations, 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.

8.6.1 Over exploitation 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 district 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 around the village are used for Mithun grazing. Their culture has a unique relationship with the forest; they regard it as their lifeline and 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 wild animals such as musk deer hunting was mostly done for basic income generation. Nevertheless, in the present scenario, hunting is getting commercialized as an income-generating occupation resulting in the hunting of many wild animal species. Besides wildlife, many medicinal plants like *Paris* spp., (Adhikarimayum *et al.*, 2020), 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.

8.6.2 Modernizing approach for the hunting of wildlife

The Idu Mishmi believe that hunting of wild animals is one of the major occupations of men in their community. This has been practiced for many generations. Traditional traps, arrow, and bow were the major weapons used during their hunting activities in older times. 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. However, this couldn't be confirmed due to field constraints and limiting factors. There is no rule in buying wild meat by the locals. But, there is a rule in the sharing of the hunted wild animal's meat 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. In future, 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. (Adhikarimayum *et al.*, 2020) 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.

8.6.3 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.

Moreover, the status of the Dibang Valley gets affected negatively due to the construction of highway; more interaction with outsiders; reaching of modern technologies such as used of hi-tech technologies; development in telecommunications and media; change in living standard and lifestyle; change in the religious beliefs; poor economic conditions etc., might also negatively influenced the Idu Mishmi and affect the restoration of the age-old traditions for a long period of time in the near future. Further, if the Idu communities are carried away by these changes, the future for the conservation of tigers and other wildlife is uncertain. However, the Indian Wildlife (Protection) Act, 1972 conserves and preserves the wild flora and fauna in India. Consequently, regions like the northeastern part of India is inhabited by tribal communities, the full implementation of such laws is a challenging task (Gopi *et al.,* 2010). The lack of staff in the forest department, financial problem, economic crisis, less political will power, etc., are some of the major reasons which prevent the proper implementation of such laws. Above all, most of the forest lands are governed by the local tribal right. In such situations, there is a necessity in the conservation of endangered species from every potential mode. The government should be responsible for conservation of such species before they get extinct.

8.7 Future research perspectives

This ecological baseline study has provided insight into the tigers, co-predators, and their prey species abundance as well as reported the photo-captured of 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 depredation. As mentioned, the predated livestock species, Mithun is an important asset to the local people as well as the people of Arunachal Pradesh and forms an integral part of the society. 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 in the IEH 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 mammalian species like tiger and Mishmi takin in Mishmi Hills landscape.

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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*)

Asiatic Wild dog pups (*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*)

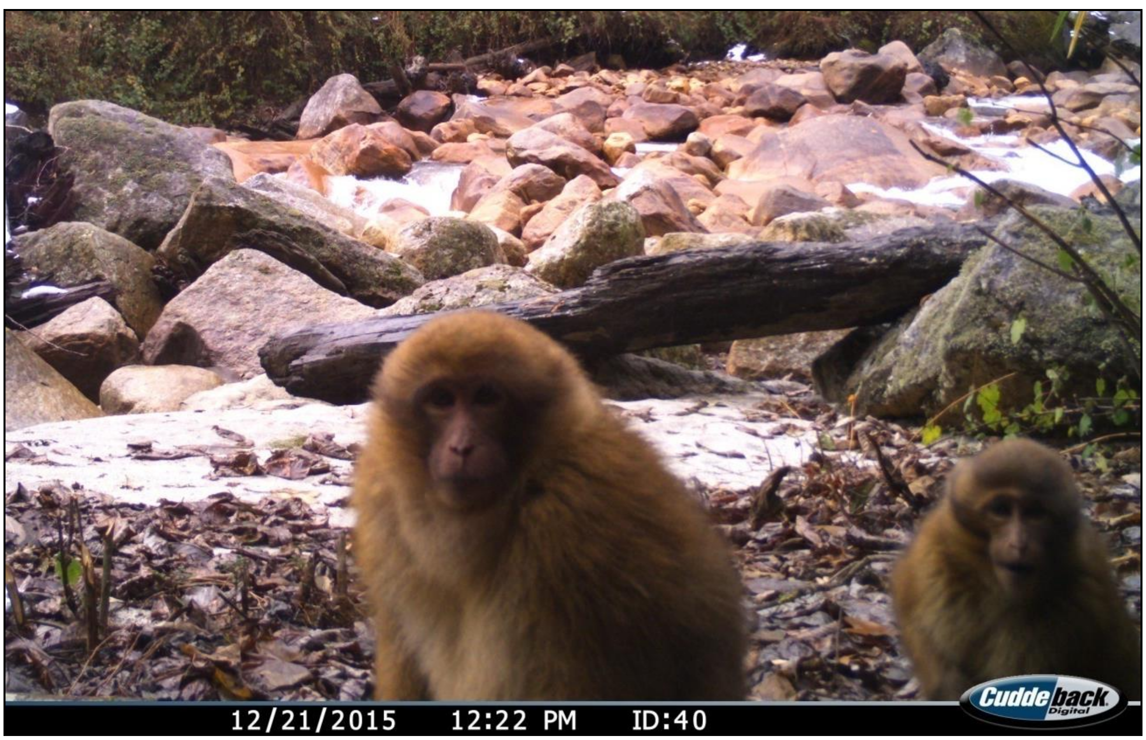
Gongshan Muntjac (*Muntiacus gongshanensis*)

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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Annexure 1: Questionnaire surevey datasheet

Questionnaire Survey Data Sheet

Date: /
/

(Dibang Wildlife Sanctuary, A.R)

Name of Respondent:
Address:

Socio-Economic Status:

Name of headman: .... Age: .... Sex: .... Religion: ....

Occupation: .... Annual Income: .... Main source of Income: ....

No. of family members: .... No of child going to school …..

Livestock's: Yes / NO Name & numbers of livestock: ....

Fodder collection (per day/week/month): ....kg. Name of spp: ....

Shrubs collection (per day/week/month): ....Kg. Shrub spp. name: ....

Purpose of collection: (Vegetable/Medicine/Making Alcohols): ....

Using cooking gas: Yes / No. If no what is alternative means: ....

NTPF collection: Yes / No Amount of NTFP collection (per/d/w/m): ....Kg.

NTFP spp. Name: ....

Names of plants/ trees/ornamental plants etc under the clan/ family taboos: ....

Private forest plantation/gardens: Yes/No. If, yes what are planted & it would help to decrease the pressure on the natural forest: ....

Wildlife status & attitude of peoples:

1) Do you have seen Tiger/ Leopard / Wild Dog / Others...….. Yes / No.

Approximate date/month....................................

Place..Nos...

How many cubs...................................... approximate age of cubs ....….........

2) Do you hunt wild animals? Yes / No. Name of them..

Purpose of hunting for: Food / Selling / Others.......................... Sale at (what amount) ....per kg

3) Do you kill Tigers? Yes/No. Why you killed Tigers?..................How many………………………………

From where……………………………. Approximate date/month……………………………………………….

4) Do you kill Leopard? Yes/ No. Why you killed Leopard?...........How many…………………………….

From where.. Approximate date/month...

5) Do you Wild Dog? Yes/ No. Why you killed Wild Dog? ....How many..

From where... Approximate date/month...

6) Do you want to protect Tiger by law? Yes / No. If No, why..

7) Do you want to protect Wild Dog & Leopard by law? Yes / No. If No, why...

Which of them, Tiger/ Leopard / Wild Dog, do more Mithun depredation? ....

8) What is your view on tiger protection in DWLS? ....

Do you want to make DWLS as a future Tiger Reserve?...

9) What is your view on Wild Dog? ....

Cattle/Livestock lifting:

How many livestock predation events have been recorded in the past 3 months/ within 1 year…………………?

________, by tigers ___________, by leopards ___________, by dholes _______, by other carnivores_______, _______, _____, specify which carnivores if known..

Comment & Remarks...

Do you receive any compensation from forest department: Yes/ No?

If so how much: Rs.....................

Crops Damage:

Name of crops planted...............

....

Name of Damage crops...

Damage by which animals spp

....

Area in hecter/meters: .... Periods/ Months of raiding: ....

Do you receive any compensation from concern authority Yes / No.?

If Yes, how much.......................

Comments & Remarks:

....

Medicinal Plants:

Name some medicinal plants species (grasses/shrubs/herbs/tress/)**:**

..

Harvested from wild/ domestic: ....Quality (per d/w/m): ……….....................kg
Mode of uses (raw/boil/fermented/others): ....
Plant parts use (stem/shoot/leaves/root/bark/others): ....
Purpose of uses (cough/headache/asthma/diabetes/diarrhoea/snake bite/others) ……………...........................
Market values: Yes / No. if, yes amount of market value Rs..…....
Comments: ....

Wild meat consumption:

Name of wild meat's / Bush meats: ....
Amount of consumption (per d/w/m): .... Source of bush meat: ....
Bush meat hunting for: Food/ Medicine/ Selling/ Others: ....
Bush meat consumption Increase/ Decrease. What are the causes of Increase / Decrease…………..…...............?
Your view on hunting for bush meat: ....
What is the prey status now a day? Increase / Decrease / Stable. Why it so ....
How much you killed wild animals till now? .... Name them ....
How can you manage for sustainable hunting? ....
Comments on wild meat consumption: ....

Annexure 2: Camera trap datasheet

CAMERA TRAP SETUP – SITE RECORD

PA/Division:………… Range:………….. Beat:…………………..

DATE: …………….. TIME: ………………RECORDER: …………… Plot Number …………

Trap ID	**GPS Latitude (N)**	**GPS Longitude (E)**	**Camera point location**	**Camera details**		**Ground substrate %**	**Terrain type**
Habitat Type			Animal trail	Memory Card no.	Cam no	Clayey	Flat (<20%)
			Forest Road				
	Miscellaneous	Pine dominated	Stream			Loam	Moderate slope (>20º&<45º)
			Dry River Bed			Silt	
	Oak dominated	Rhododendron dominated	Water hole			Sandy	Steep incline (>45º)
	Riverine	Grassland	Kill			Gravely	Undulating
	Scrubland	others				Rocky	Rugged

TREE SPECIES Tree> 4m height. In **15m radius semi-circular** plot centered at each camera record all the tree.											**SHRUB SPECIES (inclusive of weeds)** In **5m radius** semi-circular plot centered at each camera ,record % cover of all shrub species										
Camera Plot 1	1	2	3	4	5	6	7	8	9	10	**Camera Plot 1**	1	2	3	4	5	6	7	8	9	10
Tree Species											Shrub Species										
Number											% cover										
Tree Phenology (1-8*)											Shrub Phenology (1-8*)										

*Tree & Shrub Phenology codes **1)** no leaves (bare branches), **2)** no leaves plus flowers **3)** no leaves plus fruit, &flower), **4)** leaf bud burst, **5)** green leaves **6)** green leaves + flower, **7)** green leaves plus fruit (& flower), **8)** brown leaves or burnt.

Human Disturbance in 15m radius plot centered at each camera.

No. Of tree cut	No of lopped trees	Grass/bamboo cutting Yes/No	Human/Domestic animal trail Number……….	No. of people seen from the plot……….	No. of domestic anim seen from the plot (Species and number)…………….

Dung/Pellet in 10x2m strip width plot centred at 2m away from camera and at 45^{0}angle on both sides. (Give actual count of pellet.)

Camera Plots	Sambar	Takin	Serow	Goral	Wild Boar	B. Deer	Mithun	Musk Deer	Hare	Others
Plot 1										
Plot 2										
Plot 3										
Plot 4										

Ground/canopy cover on three points 8m away in three directions from the middle of the camera.

Canopy cover % (use densitometer)		In 1m radius plot record ground cover						Grass species (write in Decreasing order of number)					Herb / small plants (write in decreasing order of number)					Grass height
			Ground cover (sum of the following 5 columns should be 100%)															
		Dry leaves %	Dry grass %	Green grass%	Herb%	Weeds%	Open ground%	1	2	3	4	5	1	2	3	4	5	
Plot 1																		
Plot 2																		
Plot 3																		

- If camera trap pair, then semi-circular plots at each camera. If single camera, then circular plot with camera as centre. Pair/Single camera trap, both sides plot need to be done.

Annexure 3: Camera trap locations and habitat characteristic

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

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
							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)
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

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
48		G 576	111	2678	3	S	Pine forest
49	Mathun Valley	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
54		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

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
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	**Tallon Valley**	G 15	72	1744	35	E	NA
82		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

Sl. No.	Sampled valley	Camera ID	Trap days	Elev. (m)	Slope (0)	Aspect	Habitat Type
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
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

Annexure 4: List of Publications and Conferences