ECOLOGY OF MALAYAN SUN BEAR (*Helarctos malayanus*) WITH SPECIAL REFERENCE TO HUMAN-SUN BEAR CONFLICT IN AND AROUND NAMDAPHA TIGER RESERVE, ARUNACHAL PRADESH.

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By

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Certificate

I have great pleasure in forwarding the thesis of Mr. Janmejay Sethy entitled "Ecology of Malayan Sun bear (*Helarctos malayanus*) with special reference to human-sun bear conflict in and around Namdapha Tiger Reserve, Arunachal Pradesh" for the acceptance for the degree of Doctor of Philosophy in Wildlife Science (Zoology). The thesis embodies original findings of the research work on sun bear and interpretation of facts. The research work carried out by Mr. Janmejay Sethy under my supervision has not been submitted in part or full to any other University/Institution for the award of any degree.

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Summary

Sun bear (*Helarctos malayanus*) is the smallest bear species and remains the least known bear species in the world. The name of sun bear is derived from the golden colour crescent shaped patch of fur on its chest. It is also known as the honey bear because of its extreme fondness for honey, the dog bear because of its size, and the Malay bear for its geographical location. Out of all species of bears, the sun bear is the least is known because they are so rare.

In India, the historic distribution of sun bears was in the lowland tropical rainforest habitats of Arunachal Pradesh, Nagaland, and south of the Brahmaputra River, state of Manipur and Assam and the upper Chitwan district in India. In most of these areas, the species was reported to be extinct. Even there were reports of its occurrence in north-eastern hilly region during sixties and seventies. Thereafter, sun bear population rapidly declined, and its occurrence became doubtful in this region.

Recently sun bears were reported to occur in mainland South-East Asia as far west as Bangladesh and north-eastern India. Occurrence of sun bear was reported in Manipur, Mizoram, Nagaland, Arunachal Pradesh and Assam. During 1996-97, a sun bear was photographed in a camera trap in Namdapha. Again in 2005, sun bears were captured in camera trap in Namdapha National Park. The status and distribution of sun bear was studied in Chandel and Ukhrul districts of Manipur, and also information on human-sun bear conflict and conservation threats was collected. Recently a study conducted in different protected areas in Arunachal Pradesh has also confirmed the presence of sun bear. This in-depth systematic scientific research on ecology of sun bear has been undertaken for the first time in and around Namdapha Tiger Reserve in Arunachal Pradesh. This will help develop an action plan for conservation and management of sun bear and also to mitigate the human-sun bear conflict effectively on long term basis.

Chapter 1 deals with the Introduction, problem statement and objectives of the study on sun bear. The **chapter 2 and 3** include the Review of literature and the Study area respectively.

In **Chapter 4**, distribution of sun bear in Namdapha Tiger Reserve has been studied. Sun bear (*Helarctos malayanus*) remains the least known bear species in the world. The historic distribution of sun bears in India was in the tropical rainforest habitats of Manipur and Assam states south of the Brahmaputra River. During the 1980s and 1990s, sun bear population apparently declined, and its occurrence became doubtful in the north-eastern hilly region. The reasons for the dwindling sun bear population are probably increased human population with its attendant activities. Rapid deforestation resulting in habitat destruction and fragmentation coupled with indiscriminate hunting has threatened sun bears with extirpation in India. Due to increase in human populations, loss, degradation and fragmentation of forests, sun bear populations have sharply declined to low levels in most of its range. They are found in the forest of Laos, Thailand, Myanmar, Bangladesh, Kampuchea, Southern China, Vietnam, Peninsular Malaysia and the Islands of Sumatra and Borneo

In India, there is no information on the population status, distribution and ecology of sun bear. Reliable estimation of sun bear population and knowledge about its status and distribution pattern are very important for the field managers to develop management plan of sun bear populations and also for mitigation of human-bear conflicts on long term basis. This is the first study of its kind in India to study the status and distribution of sun bear based on direct and indirect evidences in Namdapha Tiger Reserve, Arunachal Pradesh.

From 2008 to 2010, field surveys were carried out and questionnaire surveys were conducted in 18 fringe villages to know the occurrence and distribution of sun bears. Line transects were laid in different parts of the reserve to collect information on distribution of sun bear based on direct sightings of bears and their indirect evidences (tracks, scats, claw marks, nests and others). Through intensive surveys and transect study, sun bear nesting and den sites were located and identified as active sites and temporary ones. In addition to direct sightings and indirect evidences, information on occurrence of crop raids in different jhuming areas was also collected.

Out of 785 respondents interviewed, 265 respondents (33.6%) confirmed the presence of sun bear based on direct sightings. Highest number of respondents confirming presence of sun bear was from Gandhigram (n=108), followed by Vijoynagar (n=27), 52 Mile (n=22), 77 Mile and Sidikha (n=21 each), 38 Mile (n=19) and Hazulu (n=11). The respondents observed sun bears them maximum times in the Tropical wet-ever green forest (30.5%), followed by Semi-ever green forest. Altogether 379 bear signs were identified in the study area; number of claw marks was found to be the highest as compared to number of scats, nests, diggings, dens and footprints. Based on sign surveys, distribution of sun bear was found quite widespread in Gandhigram range as compared to Namdapha and Deban ranges. All these bear signs were recorded in summer, monsoon and winter months. The percentage occurrence of bear signs was highest in winter, followed by monsoon and summer. Distribution of sun bear signs showed seasonal variation in different forest types in Namdapha Tiger Reserve**.** During winter season, sun bear signs were highest in Tropical wet-ever green forest, followed by Tropical semi-ever green forest. In summer season, bear signs were highest in Temperate forest. Whereas in monsoon season, sun bear signs were highest in Tropical semi-ever green forest. Based on camera trapping efforts, the animal capture was highest in Gandhigram range as compared to capture in Deban range (n=7), and capture in Namdapha range (n=4)**.** Out of total 32 animal captures, only three sun bear captures were from within Gandhigram range. The occurrence of bears signs also varied along transects laid along different altitudinal gradients. And there was marked difference in occurrence of bear signs in disturbed and undisturbed areas. Number of sightings of sun bear was high in the Tropical wet-ever green forest and Semi-ever green forest because there was plenty of food available in these low disturbed areas.

The **Chapter 5** deals with the assessment of the habitat use by sun bear. In India, the increase in human and livestock population has created pressures on all natural resources. Most of the protected areas are fragmented, degraded, and disturbed from anthropogenic activities. Forests, pastures and wastelands were brought under cultivation to sustain increased demand of cereals and other food products. This habitat modification has caused wildlife species to become ecologically dislocated. For the management of wildlife and its habitat, information on food, water and shelter and conditions suited to a particular animal species have to be known accurately. The quality of habitat is generally reflected in the status of vegetation cover and its seasonal variation. The site characteristics like fruiting trees and shrub availability, location of dens, water availability and presence of termite mounds and ant nests are directly related to the habitat use. The habitat utilization by bear species showed varied patterns in different places. Sun bears rely mainly on tropical forest habitat. Sun bears also have been reported in mangrove forest, although their occurrence in this forest type probably depends on proximity to other more favoured habitats. No information is available on the habitat use, its seasonal variation and nesting activities of sun bear in Namdapha Tiger Reserve. The study therefore envisages assessing the habitat use pattern of sun bear in this Tiger Reserve.

Bear sign information was gathered along 43 transects with a length of 2-3 km each. In the study area, vegetation showed high degree of heterogeneity and variable degree of biotic pressure. After the reconnaissance survey, 43 linear transects were laid at random encompassing in six different habitat categories viz. Mix forest, Tropical semi-ever green forest, Tropical wet-ever green forest, Semi-ever green forest, Temperate forest and Bamboo forest in Namdapha Tiger Reserve.

The habitat use by sun bear was assessed based on direct sightings and indirect evidences such as claw marks, scats, nests, dens, digging sign and foot prints etc. in Namdapha Tiger Reserve. Six variables, namely elevation, slope, vegetation cover, distance to water, human disturbance and terrain type were used to measure habitat conditions for the bear sign locations sampled during the field surveys. The data on habitat use by sun bears collected from the 430 sample plots along the 43 transects showed maximum number of plots with bear signs in Tropical semi-ever green forest. Although sun bears showed some preference for Tropical semi-ever green forest and Tropical wet-ever green forest habitat categories, but as such there was no preference or avoidance by bears for rest of the habitat types. Density of bear signs per hectare was found highest in Mix forest and Temperate forest (140.1/ha each), followed by Semi ever-green forest with (131.0/ha). Among various habitat categories, the proportional availability of Tropical semi-ever green forest was found to be highest. In comparison to the availability of various habitat types, the expected use of these habitat categories was found in proportion.

Sun bear were found to use disturbed and undisturbed habitats to varying extent along different elevations. The majority of bear signs (74.1%) were observed in undisturbed. In areas with higher intensities and extents of disturbance, fewer bear signs (25.9%)

were observed. The habitat use by sun bear was found to be largely dependent on the availability of food resources, variety of food plants and shelter in different habitat types.

The **Chapter 6** deals with food habits of sun bear in Namdapha Tiger Reserve. The survival of bears and their physiological activities are governed by the availability of food items and dietary components in their habitat. Most bears are opportunistic omnivores and their diet varies from fruits, other vegetative material, insects, fishes and mammals. In most bear species including Asiatic black bear, sloth bear, American black bear, grizzly bear and brown bear, it has been found that in addition to the animal matter, plant matter constituted a major part of diet. Sun bear remains the least known bear species in the world. Even basic biology such as food habits, activity and ranging pattern and reproductive biology is unknown. Food habits of Malayan sun bear are poorly documented, but have been briefly described by many authors.

Based on claw marks on trees, direct feeding signs, scat analysis and indirect signs, the dietary composition of sun bears and seasonal difference in their food habits was studied. Scats were collected along the transects as well as opportunistically. Eighty five scats were collected from August 2008 to November 2010 during the field survey. Scats were analysed both qualitatively and quantitatively. The contents were manually separated and examined.

Sun bear were found to use 33 tree species. During the study period, we found 155 trees with sun bear claw marks, 69 trees were climbed repeatedly, as indicated by healed scars and overlapping of claw marks on tree bark. From all 155 trees, *Ficus* spp. were used maximum. We also recorded 11 trees of *Spondias axillaris* with bear claw marks and tree cavities with a shattered entrance, which probably had bee nests. We found 10 confirmed sun bear feeding sites; there were seven types of sun bear feeding sites in the study area. The items/species area curve was developed to find minimum number of scats required to study the dietary composition. Food of animal origin comprised of Arachnida, Insecta, Mammalia and Osteichtyes classes. Insects consumed by sun bear were mainly from order Coleoptera, Hymenoptera and Isoptera. Presence of rodents and scorpions in food of sun bear was also recorded. There were 15 families of insects used by sun bear. Among these, 8 families of beetles (Coleoptera), one family of stingless bee (Apidae), one family of ants (Formicidae) and one wasp (Vespidae) could be identified. Among 15 families, 14 insects were identified as food items of sun bear. Plants consumed by sun bear were of 10 different species. The frequency of occurrence of plant matter was higher (55.3%) than the animal matter (44.7%) in the scats of sun bear. Presence of food items in the scat of sun bear showed marked monthly variation. The animal matter, namely, bees, termites and beetles occurred in the scats during most of the months. Presence of remnants of different food items in the scats of sun bear was found to be directly correlated with the availability of food items in different months in the scats of sun bear**.**

The **Chapter 7** deals with the assessment of the nature and extent of human-sun bear conflict. Most species of bears are opportunistic omnivores that may be considered pests when attracted to human-related foods. Contact with man has naturally affected the habits of bears. Where subjected to constant menace from man, they become much more alert, shyer, and more rigidly nocturnal in habit. Contact with man also gives bears the opportunity to raid his fields and orchards. Individuals developing this habit may become notorious pests. Ordinarily, bears fear and avoid human, except when defending their young, or when wounded. Attacks on man are usually sudden and unprovoked. Human-sun bear interactions include attacks on people, crop depredation and hunting for consumption and sale of bear parts and effects of human resource extraction activities on bears. Scattered information is available in India on status of bear species and human casualties, livestock predation and agricultural crop damage by them. In this chapter, the nature and extent of human casualties and damage to agricultural and horticultural crops by sun bear in Namdapha Tiger Reserve is presented and mitigation strategies to reduce the conflicts have been suggested.

By conducting questionnaire surveys, information on human-sun bear conflict: human casualties, cropping pattern, nature and extent of damage to agriculture and horticultural crops etc. was collected from affected villages in and around the Namdapha Tigre Reserve during 2008 to 2010. During the study period, a total of 18 villages were surveyed. The human casualties were caused by black bear and sun bear. Out of the total 18 villages, 17 villages were affected from these conflicts. There were more incidences of human casualties in Gandhigram range than in Deban range.

A total of 31 human casualties were caused by Malayan sun bear in and around the Tiger Reserve. Incidences of male mauling (58.1%) and killing (12.9%) were higher than female mauling (22.6%) and killing (6.4%). Among 31 human casualties by sun bear, highest number of the victims (51.6%) was in the age group of 21-30 years, followed by 9 cases (29.0%) in the age group of 31-40 years. Sun bear were found to attack on people and cause injuries on their head, face, chest, hands, abdomen and legs. Highest number of victims had head injuries. Maximum human casualties (61.3%) occurred in forest areas. Most of the attacks were in the morning and day time, and few incidences took place in the evening time. The victims were found to be engaged in different activities; incidences of human mauling and killing were highest when the victims were engaged in NTFP collection. In the vicinity Namdapha Tiger Reserve, paddy, maize, jack fruit, Chinese apple, pineapple and banana were the main crops grown. According to respondents, highest number of crop raids by sun bear was to jack fruits followed by crop raids in maize crop, Chinese apple, pine apple, bananas and paddy crop.

All farmers who reported sun bear visits to their gardens stated that sun bears entered their gardens during the night time. Mitigation strategies to reduce the conflicts have been suggested. Most of the farmers used dogs to guard their gardens, followed by small wooden fences, scarecrows or dummy, drum beating, and regular night patrolling or check-ups of their gardens.

Chapter 8 provides suggestions for mitigation of human-sun bear conflict, and recommendations for long term conservation of sun bear population. Conservation of sun bears should be accorded both International and National priority to deal with poaching for illegal trade of bear body parts. People are required to be alert and vigilant moving in wildlife areas. To reduce crop depredation by sun bear, protection measures such as co-operative crop guarding, use of barriers, scaring sounds or frightening devices: scare-crows and dummies, or fire sticks and crackers. Public education and awareness programmes towards conservation and natural history of sun bear are important.

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Introduction and Objectives

Chapter 1

Introduction

1.1 Bear Phylogeny

The bear family Ursidae includes seven species and is comprised of two to seven genera (Eisenberg, 1981; Ewer, 1973; Hall, 1981 and Nowak, 1991). Even though the closest relatives of the giant panda are the bears, it is still controversial if the giant panda is a bear (Davis, 1964; Goldman *et al.*, 1989; Hashimoto *et al.*, 1993; Nash and O'Brien, 1987; Nash *et al.*, 1998; O'Brien *et al.*, 1985; Sarich, 1973; Van Valen, 1986; Wayne *et al*., 1989 and Zhang and Ryder, 1993).

Up till now, the taxonomic classifications and phylogenetic relationships within the Ursidae remain subjects of controversies. The main problem is that the family Ursidae represents a typical example of rapid evolutionary radiation and recent speciation events, dating back to mid-Miocene about 20 million years ago (Goldman *et al.*, 1989; Kurten, 1968 and Waits *et al.*, 1999).

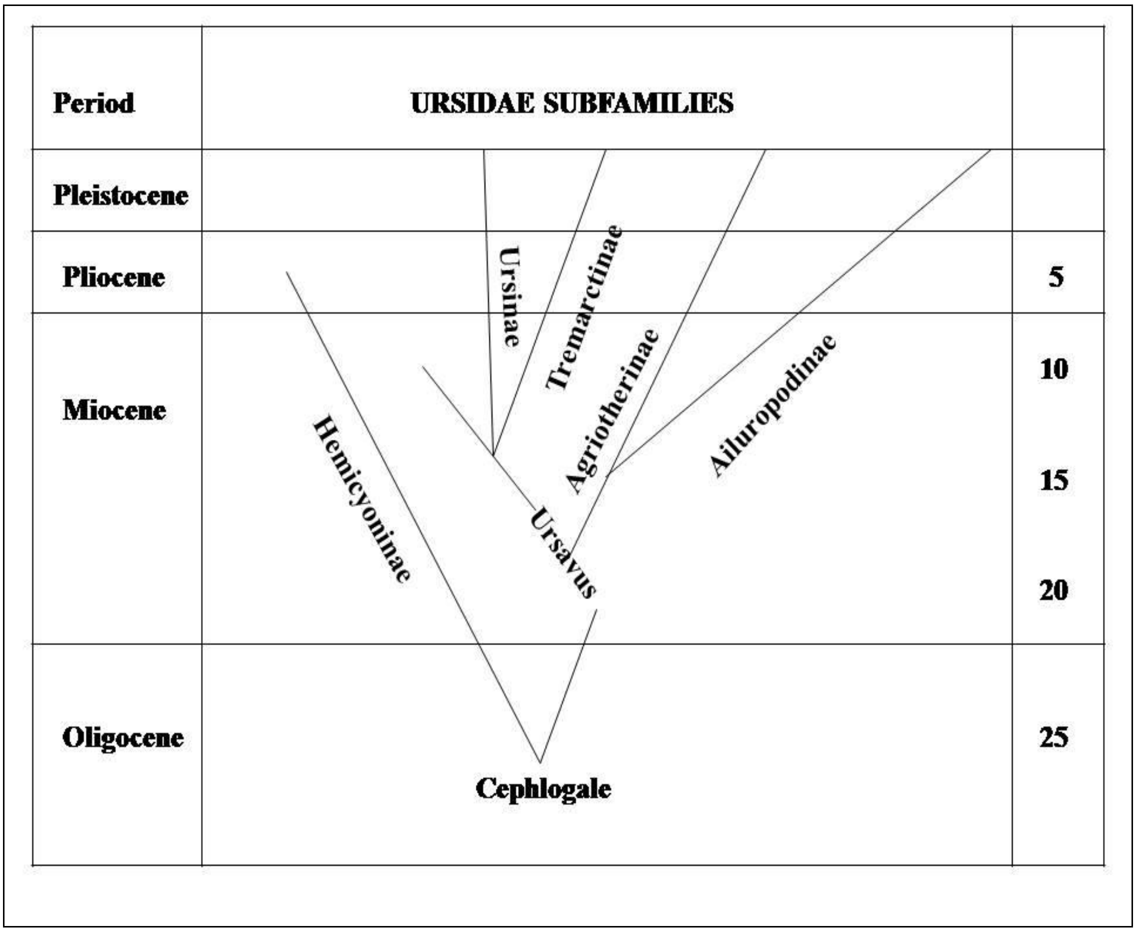
Bears are a young family, evolving from early canids during the late Oligocene and early Miocene, about 20-25 million years before present (MYBP). So recent is this divergence that some taxonomists believe that canids and ursids should be considered as one family and dividing them is due to 'custom of more than a century' (Simpson, 1945).

1.2 Sub-families of Ursidae

Although two major contributors to bear taxonomy, Simpson (1945) and Erdbrink (1953), did not favour sub-family divisions as suggested by Kragavlich (1926), most of the systematicians divided the bear family into three subfamilies without including Ailuropodidae, the subfamily that included the giant panda (Kragavlich, 1926 and Kurten, 1966) or four subfamilies (Pilgrim, 1932 and Thenius, 1959).

These authors did not agree over the inclusion of the subfamily Hemicyoninae or dog-like-bears (or bear-like-dogs) with either the canids or ursids. Hendey (1980) splits the bears into five subfamilies and seven tribes; his groups include different genera than other students. He includes the giant panda as a bear and discussed five subfamilies: (i) Hemicyoninae, (ii) Agriotheriinae, (iii) Tremarctinae, (iv) Ursinae, and (v) Ailuropodidae **(Figure 1)**.

Figure 1: A tentative phylogeny of Ursidae subfamilies. *Cephalogale* and *Ursavus* are base genera for these subfamilies.



1.3 Sub-family Ursinae

The sub-family Ursinae has been divided into different phylogenetic groups in the past. Until recently, five genera, *Melursus* (sloth bear), *Helarctos* (sun bear), *Thalarctos* (Polar bear), *Selenarctos* (Asiatic black bear), and *Ursus* (brown bear and American black bear) have been recognized. Molecular and cytological methods (O'Brien *et al.,* 1985 and Goldman *et al.*, 1989) plus successful crossing between several of the species in captivity (C. Servheen, U.S. Fish and Wildlife Service, pers. commun.) suggests that these bears are congeneric. The evolution of Ursinae over the past five million years is well documented from their fossils found in Europe. Early Ursinae likely evolved from Ursavus of the Miocene, perhaps through the genus *Protursus* of the mid-Miocene (Thenius, 1959 and Crusafont and Kurten, 1976) **(Figure 2)**. Climatic conditions in Europe during the late Miocene were dry, and savannahs and deserts were common. Such conditions were poor for bears, and their fossils were scarce until the Pliocene began, 5-6 MYBP.

1.3.1 Sun bear and sloth bear

Bear creatures showed different evolutionary records **(Figure 3)**. The fossil records of south Asian bears, the sun bear (*Ursus malayanus*) and sloth bear (*U. ursinus*) are poor, and their origins are more speculative than other species (Kurten, 1966). Sun bear is first found in the late Pliocene and sloth bear in the Pleistocene. Thenius (1959) considered that they got separated from the other Ursinae even before *Protursus*, whereas Hendey (1972) speculated that the split was after *Protursus* but before *U. minimus*. Electrophoretic analysis indicated a more recent split, not significantly different from that of other extant members of the sub-family except the polar bear (Goldman *et al.*, 1989). Recent analyses of mitochondrial DNA indicated that the six ursine species originated sequentially during the past six million years, beginning with *U. ursinus* and ending with the polar bear (Waits *et al.*, unpubl.). Now it became increasingly evident that *U. ursinus*, *malayanus, thibetanus*, *americanus* and *etruscus* all branched from the primitive *U. minimus* or *U. abstrusus* that radiated through Eurasia near the Miocene/Pliocene boundary and into North America shortly after. The great morphological differences between *U. malayanus, U. ursinus* and other bears might likely be due to recent adaptive change as the south Asian bears exploited new niches.

Figure 2: A tentative phylogeny of the subfamily Ursinae.

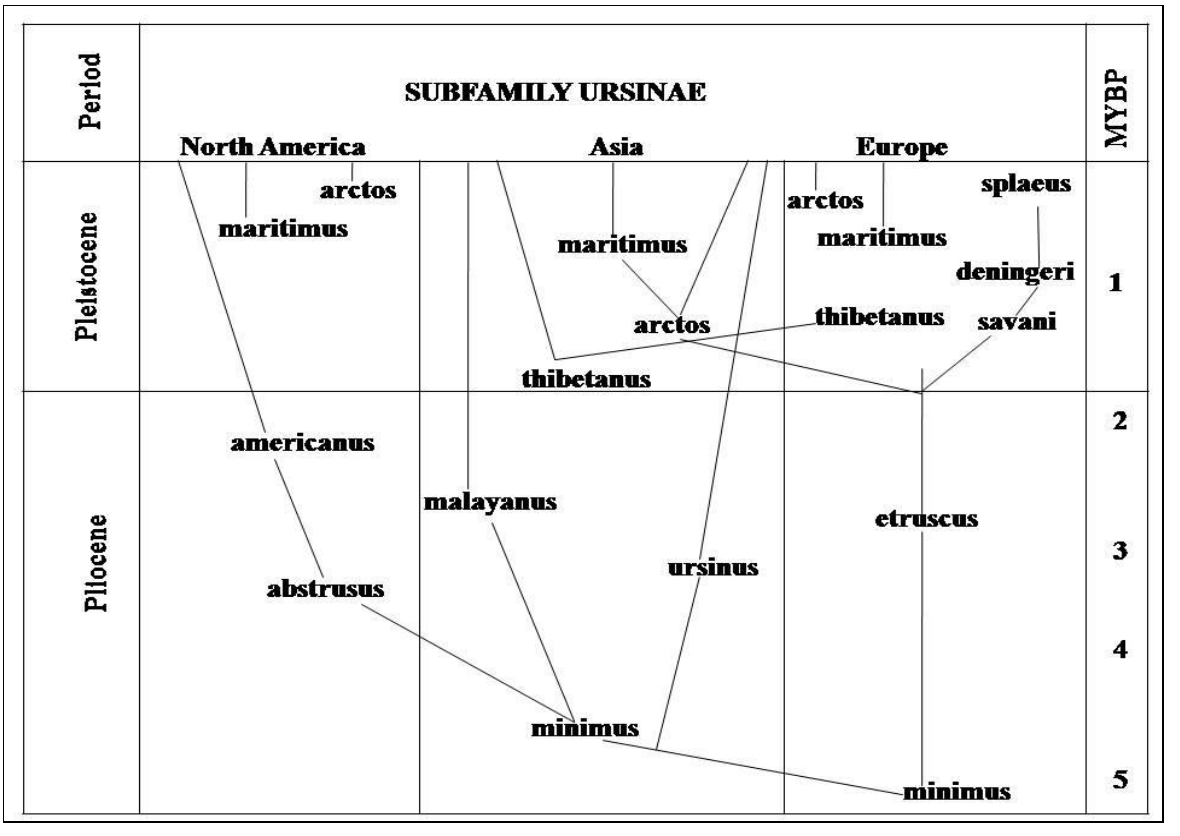
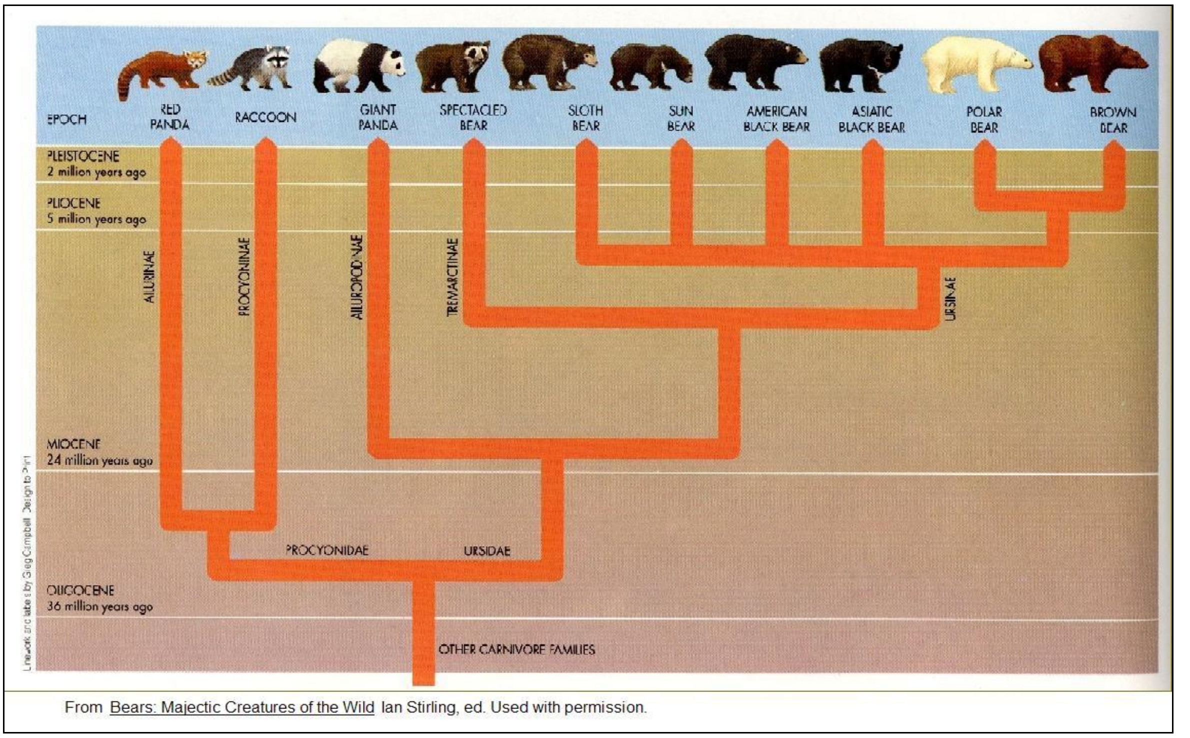


Figure 3: Bear creatures of the wild.

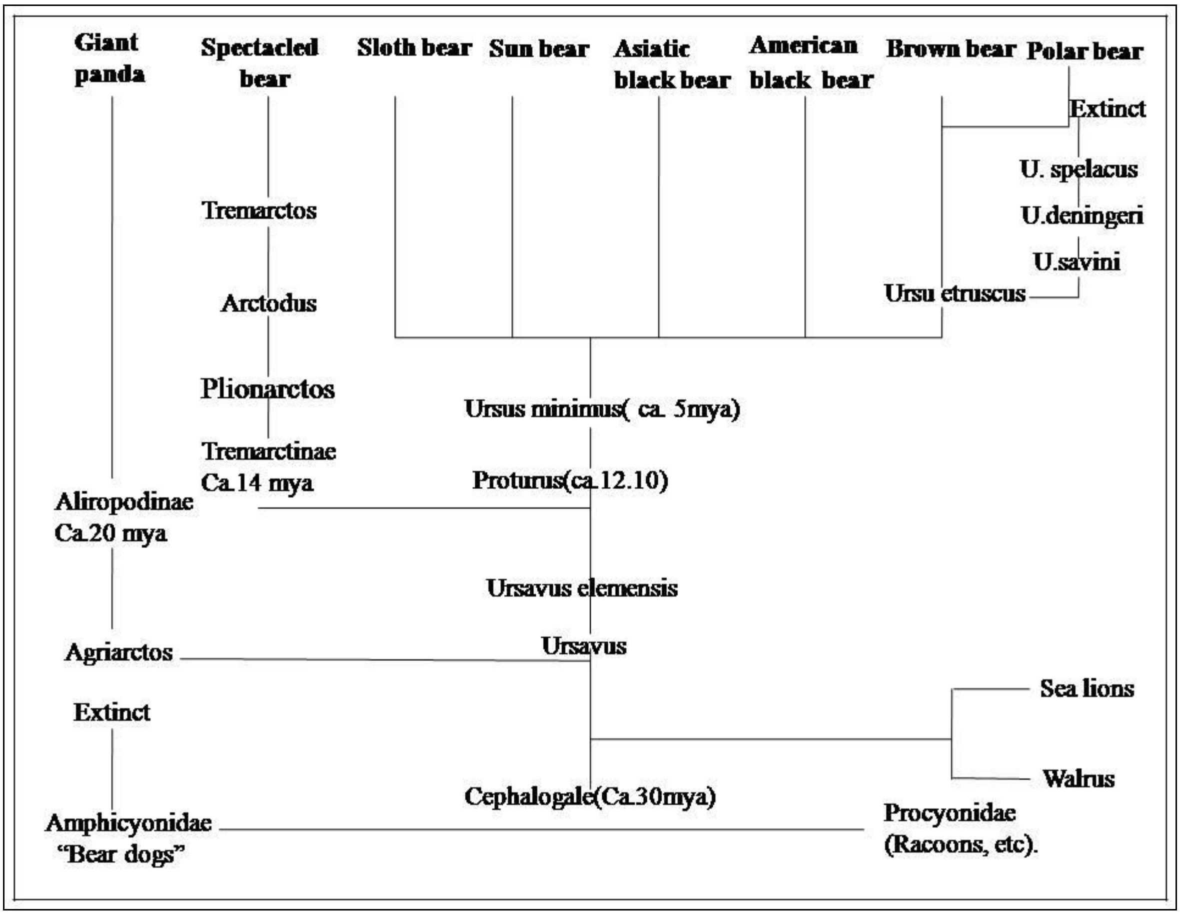


From Bears: Majectic Creatures of the Wild Ian Stirling, ed. Used with permission.

1.3.2 Bear species

There are eight living species of bears found in the world **(Figure 4)**. Family Ursidae can be divided into two sub families viz. Ailurinae (Giant panda and Red panda) and Ursine (Eight species of true bears). In the world, there are eight species of bears (Waits *et al*., 1999). They are Asiatic black bear (*Ursus thibetanus*), polar bear (*Ursus maritimus*), American black bear (*Ursus americanus*), brown bear (*Ursus arctos*), sloth bear (*Melursus ursinus*), spectacled bear (*Tremarctos oratus*), giant panda (*Ailuropoda melanoleuca*) and sun bear (*Ursus malayanus*). The members of family ursidae do not occur in Africa, Madagascar, Australia, various oceanic islands and the Antarctica, with the exception of polar bear, inhabiting the Arctic region. Spectacled bear (*Tremarctos oratus*) is found south of the equator. Malayan sun bear and Alaskan

Figure 4: Bears groups.



brown bears are the smallest and largest respectively in the bear family. Four species of bear's viz. sloth bear, Asiatic black bear, Himalayan brown bear and Malayan sun bear, have been reported in India (Prater, 1980).

Common characteristics of modern bears include a large body with stocky legs, a long snout, shaggy hair, plantigrade paws with five non retractile claws, and a short tail. While the polar bear is mostly carnivorous and the giant panda feeds almost entirely on bamboo, the remaining six species are omnivorous, with largely varied diets including both plants and animals. With the exceptions of courting individuals and mothers with their young, bears are typically solitary animals. They are generally active during the night (nocturnal). Bears are aided by an excellent sense of smell, and despite their heavy build and awkward gait, they can run quickly and are adept climbers and swimmers. In autumn some bear species forage large amounts of fermented fruits which affects their behaviour. Bears use shelters such as caves and burrows as their dens. Bears have been hunted since prehistoric times for their meat and fur. To this day, they play a prominent role in the arts, mythology, and other cultural aspects of various human societies. In modern times, the bear's existence has been pressured through the encroachment on its habitats and the illegal trade of bears and bear parts, including the Asian bile bear market. The IUCN lists six bear species as vulnerable or endangered, and even least concern species such as the Malayan sun bear are at risk of extirpation in certain countries. The poaching and international trade of these most threatened populations is prohibited, but still ongoing.

Bears are generally bulky and robust animals with relatively short legs. Bears are sexually dimorphic with regard to size, with males being larger. Larger species tend to show increased levels of sexual dimorphism in comparison to smaller species, and where a species varies in size across its distribution range. Bears are the most massive terrestrial members of the order Carnivora, with some polar bears and brown bears weighing over 750 kilograms (1,700 lbs). As to which species is the largest may depend on whether the assessment is based on which species has the largest individuals (brown bears) or on the largest average size (polar bears). The smallest bears are the sun bears of Asia; on average male's weight 65 kilograms (140 lbs) and females weight 45 kilograms (99 lbs) unlike other land carnivores. Their body remain heavier toward the hind feet which make them look lumbering when they walk. They are still quite fast with the brown bear reaching 30 miles per hour (48 km/h) but they are slower than felines and canines. Bears are plantigrade; bears can stand on their hind feet and sit straight upright with remarkable balance. Bears have non-retractable claws which are used for digging, climbing, tearing and catching prey. Their ears are rounded. Bears have an excellent sense of smell, a better sense of smell in fact than the dogs (canids) or possibly any other mammal. This sense of smell is used for signalling between bears, either to warn off rivals or detect mates, and for searching food. Smell is the principal sense used by bears to find most of their diet.

1.4 Status bear species

All bear species are listed as endangered, threatened, or potentially facing a precarious future (Schoen, 1990). The North American black bear (*Ursus americanus*) and giant panda (*Ailuropoda melanoleuca*) are significantly impacted by change in the habitat composition (Schaller *et al*., 1985). Servheen (1990) mentioned that the Asiatic black bear (*Ursus thibetanus*), sun bear (*Ursus malayanus*) and sloth bear (*Melursus ursinus*) are in jeopardy because of degradation and loss of habitat. Mortality of threatened black bear of northern America, brown bear in Europe and spectacled bear in South America is very common because of forest fragmentation and insularisation. Knight (1984) mentioned that low density, secretive behaviour and high mobility make census of grizzly bear (*Ursus arctos horribilis*) difficult. Poaching and deforestation have been slowly eroding the existing population of sun bear and its habitat.

1.5 Bear distribution

Bears have a wide global distribution and they are found in every continent except Africa, Australia and Antarctica (Nowak and Paradiso, 1983). There are significantly more bears in the northern hemisphere than in the southern hemisphere. The members of family Ursidae do not occur in Africa, Madagascar, Australia, various oceanic islands and the Antarctica, with the exception of polar bear, inhabiting the arctic region. Spectacled bear is found south of the equator. Bears are found in around 62 countries. Two species occur in Europe, three in North America, one in South America, and six in Asia.

1.6 Major threats to bear species

1.6.1 Population threats

Use of firearms and subsistence hunting are very widespread in world, and it is likely that sun bears are killed or wounded whenever opportunity permits. There were reports of some trade in bear gall bladders, paws, skins, and live cubs, both internally and to neighbouring China, Maynmar and Thailand (Salter, 1988, 93; Chazee, 1990; Martin, 1992 and Srikosamarata *et al.*, 1992), although as virtually all of this was unregulated, the volume and value of trade were not been determined. Prior to 1900, anthropogenic impacts on sun bears were primarily related to direct killing, but impacts from habitat loss over the past 100 years had increased substantially and had become a major threat to sun bears throughout their range (Santiapillai and Santiapillai, 1996; Servheen, 1999a; Augeri, 2003 and Meijaard *et al*., 2005). The latter was found to be a consequence of increasing human populations and the demand for timber, gas, oil, precious metals, jewels, agricultural lands, roads, and living space (Santiapillai and Santiapillai, 1996; MacKinnon *et al*., 1996; Herrero, 1999; Cincotta and Engleman, 2000; Whitten *et al*., 2000 and WRI, 2004). Based on analyses of habitat loss across the sun bear's range over the previous 100 years, the IUCN Bear Specialist Group stressed that the sun bear population was significantly below its historic population and range levels and was threatened by increasing mortality (Servheen, 1999). As a result, Servheen (1989) indicated that in the late 1980's, sun bears were seriously threatened primarily due to increases in human-induced mortalities and habitat loss and less than 25% of its population survived (Servheen, 1999). The most recent public estimate by the IUCN Bear Specialist Group for the global sun bear population was < 5,000 individuals (Servheen, 1999a, and b). But considering that sun bear is listed as "Data Deficient" on the 2009 IUCN Red List of Threatened Animals, more data is required needed to validate the estimate (Hilton-Taylor, 2003).

India over some of the largest contiguous blocks of sun bear habitat remaining in the world and, therefore, they probably steward the largest sun bear populations (Santiapillai and Santiapillai, 1996; Servheen, 1999a). Data on status of sun bear population is available from four north-eastern states, and have indicated patchy distributions (Chauhan and Jagdish, 2005a and 2006b; Chauhan and Sethy, 2011). Sun bear population data is sparse from Borneo and Sumatra (Santiapillai and Santiapillai, 1996 and Servheen, 1999a). The persistence of these populations depends on large protected areas (Santiapillai and Santiapillai, 1996; MacKinnon *et al.*, 1996; Leuser Management Unit, 1999 and Servheen, 1999a), two of which (Kayan Mentarang and Gunung Leuser national parks) provided opportunities to compare remote undisturbed populations as control against disturbed areas within the same ecosystems.

Many factors influence the distribution and abundance of animals, including forage, competition, predation, topography, and the location of suitable habitats. For some species and individuals these influences predominate. Yet in some regions, bears have adapted to constant variation in such conditions as well as to human influences. Such information regarding sun bears has been very limited. Previous studies indicated that sun bears were found to occur in primary forests (Wilson and Wilson, 1975; Wilson and Johns, 1982 and Santiapillai and Santiapillai, 1996), while Wong *et al.* (2004) stated that the importance of primary forests in sun bear survival was uncertain. Meijaard (1997) and Mills and Servheen (1994) stated that conflicts with humans, hunting, and illegal trade of bears and bear parts were the key factors affecting sun bear abundance, but several other studies concluded more pervasive influences in form of habitat loss and disturbances (MacKinnon *et al*., 1996; Santiapillai and Santiapillai, 1996; Momberg *et al*., 1998; Servheen *et al*., 1999; Whitten *et al*., 2000; Augeri, 2001 and 2003 and Meijaard *et al*., 2005). Herrero (1999) and Waits *et al*. (1999) indicated that the three primary factors that resulted in the loss or decline of bear populations, as well as their genetic and evolutionary viabilities, were habitat loss, habitat fragmentation, and human-induced mortality. Although in some areas direct human-caused mortalities were notable, but most bear studies indicated that these mortalities were directly correlated with increased human access from deforestation, resource extraction, road network and development (Mattson *et al.*, 1987; McLellan and Shackleton, 1988; Kasworm and Manley, 1990; Mattson and

Knight, 1991; Noss *et al.*, 1996; Mattson, 1998; Servheen *et al.*, 1999; Bader, 2000; Murrow, 2001 and Larkin *et al.*, 2004).

Many sun bear populations have already become extinct due to a combination of habitat loss and excessive human caused mortality. It is likely that populations in many areas are now fragmented and isolated into small sub-populations that are sustaining increasing mortality. In many areas of sun bear range such as Burma, Laos, Cambodia and Vietnam, poaching of bears for sale or for food was found to be unregulated and increasing (Mills and Servheen, 1991). For the remaining sun bears, the size, character, distribution and availability of suitable habitat might either facilitate or limit their use of critical resources, which ultimately might affect their fitness, genetic viability, and persistence (Saunders *et al*., 1991; Frankel and Soule, 1992; Servheen *et al.*, 1999 and Waits *et al.*, 1999).

The geometry of an organism interacting with its environment was reported to plays a major role in determining its optimal use of landscape (MacArthur and Pianka, 1966). Loss of resources and habitat disturbance from drought, fire, floods or fragmentation could affect survival rates of bears and other large carnivores and could lead to genetic, demographic and population level impacts (Rogers, 1976; Harris, 1984; Augeri, 1994; Noss *et al.*, 1996; Craighead *et al.*, 1995; Craighead and Vyse, 1996; Seidensticker *et al.*, 1999; Merrill *et al.*, 1999; Waits *et al.*, 1999; Laidlaw, 2000; Murrow, 2001; Crooks, 2002 and Larkin *et al.*, 2004). Until recently, little research has been conducted to investigate ecology of sun bear, no organized surveys of the home range, distribution and population densities have been conducted (Meijaard, 1997). The lack of biological information on sun bears has been a serious limitation to conservation efforts (Servheen, 1999). Therefore, basic research on sun bears is the highest priority needs worldwide (Servheen, 1999).

1.6.2 Habitat threats

Threats to sun bear habitat include degradation and loss of dense forest cover, this is result from logging, shifting cultivation, locally intensive grazing, and annual fires over large areas. These factors often occur in combination and can result in rapid degradation of forests areas. But due to habitat loss, disturbance and human caused mortalities its global population may be less than 25% of historic records and it is restricted to isolated and fragmented sub-population (Servheen, 1999b, c)

Deforestation has been found the primary cause of habitat loss and fragmentation in South-East Asia with consequent species extinctions and biodiversity declines (Whitmore, 1997; Laurance and Bierregaard, 1997; Bierregaard *et al*., 2001; Laidlaw, 2000 and WRI, 2004). Results of a 22-year investigation by Laurance *et al*. (2002) clearly demonstrated that the effects of fragmentation on tropical forests were substantial, altering forest dynamics, community-wide trophic structure, connectivity, insularity, ecological and ecosystem processes, species richness, and species abundances. Analyses of satellite imagery of Amazonian forest fragmentation over a 10 years period showed that the area affected by fragmentation and edge effects was more than 150% larger than the actual disturbed area Skole and Tucker (1993). Couvet (2002) demonstrated that restricted tree gene flow might have deleterious effects on fragmented populations. Hamilton (1999) confirmed similar effects on tropical tree gene flow, which were found to influence the distribution and abundance of major fruit bearing species and, thus a large number of frugivores like sun bears. In general, significant damage could occur in both edge and interior forest communities, particularly within the first few months and years of edge creation up to 300-500 m interior (Laurance *et al.*, 2000, 2002). This was especially true in patches smaller than 1,000 ha (Lovejoy *et al.*, 1986 and Laurance *et al.*, 2001, 2002). Furthermore, the synergistic interactions between fragmentation and the ecological changes caused by logging, fire, environmentally stochastic events, and hunting imposed a more significant threat on particular tropical forest species and communities. Crooks (2002) demonstrated that fragment area and isolation were the two most dominant predictors of mammalian carnivore abundance and distribution in fragmented habitats.

In Indonesia, tropical forests were primarily converted and lost to commercially or locally-valuable timber harvests; extraction processes for minerals, precious metals, jewels, and other resources; transmigration projects; family and industrial agriculture; urbanisation; development; living space; and roads (MacKinnon *et al*., 1996; Whitten *et al*., 2000; Robertson and van Schaik, 2001 and WRI, 2004). Any remaining forest fragments were often bordered or are isolated in a surrounding landscape matrix of degraded habitat, commercial plantations, mines, industry, urban centres, villages, trails, and roads, and were influenced by both biotic and a biotic factors. The later included substantial increases in edge effect insularisation, community composition and structural changes, and human activities such as hunting, poaching, resource harvesting and extraction, trails, forest camps, and settlements (Augeri, 1995; Laurance and Bierregaard, 1997; Whitmore, 1997 and Wiens, 1997). While each of these factors was found to decrease biodiversity, each might also affect various aspects of sun bear fitness, genetic viability, and evolutionary potential (Servheen *et al.*, 1999 and Waits *et al.*, 1999).

Overall these effects include impacts on (i) demography; (ii) population dynamics, abundances, densities, and distributions; (iii) mating, fecundity and reproductive potential; (iv) physiological stress, physical condition, and survival; (v) recruitment and mortality rates; (vi) dispersal; (vii) habitat selection; (viii) home ranges and movement patterns; (ix) immigration and emigration rates and processes; (x) resource and habitat availabilities and uses; (xi) diet; and (xii) inter-specific interactions (Soulé, 1980; Gilpin and Soulé, 1986; Allendorf *et al*., 1991; Holt, 1997; Hedrick and Gilpin, 1997; Craighead and Vyse, 1996; Noss *et al.*, 1996; Craighead *et al*., 1998; Servheen, 1999; Waits *et al.*, 1999; White *et al.*, 1999; Murrow, 2001; Frid and Dill, 2002; Larkin *et al.*, 2004 and Meijaard *et al*., 2005). In the diverse niche of sun bear, particularly as a fauni-frugivore, it was found to maintain many functional services for the larger community that could also be affected (Fredriksson, 1998; Augeri, 2003 and Meijaard *et al*., 2005). For example, because frugivorous vertebrates and their digestive systems were found to be the primary vectors for tropical seed dispersal and establishment (Terborgh, 1990 and Redford, 1992), seed dispersal by sun bear was found to play an important role in forest regeneration and maintenance. Sun bear foraging actions for termites and other insects (Fredriksson, 1998 and Augeri, 2000, 2003) were also found to aid ecosystem processes, such as nutrient mixing and breakdown, as well as facilitating soil turnover and generation.

The diverse ecology of bears also was stated to help maintain trophic relationships, as well as community structure and dynamics (Jonkel and Cowan, 1970; Glasser, 1979; Jonkel, 1984; Kasworm and Manley, 1988; Augeri, 1994; Craighead *et al*., 1995; Mace and Waller, 1997 and Powell *et al.*, 1997). High-order relationships that could be influenced by disturbance included altered or lost ecological interactions like predation and competition, which could lead to lateral, hierarchical, and cascading changes across trophic levels (Augeri, 1994, 1995, 2003; Soulé and Terborgh, 1999; Terborgh *et al.*, 1999 and Harrison and Bruna, 1999). Though biogeographic conditions and disturbances could cause substantial influences on bear food availability and diversity, environmentally-stochastic events like primary food resource failures could also influence bear health, movements, mating, recruitment, and population dynamics (Jonkel and Cowan, 1970; Rogers, 1976, 1987; Craighead *et al.*, 1995 and Powell *et al.*, 1997), some of which were recorded in Borneo (Wong, 2002).

Fruit availability has clearly been found an important factor for sun bears and drought/rain have notable influences on fruit productivity in the tropics, (Bebber *et al*., 2004 and Condit *et al*., 2004), which could affect dioecious (pioneer) species like figs that was found to be an important resource for sun bears throughout the forest and year (Fredriksson, 2001; Augeri, 2002 and Wong, 2002). The effects of such stochastic events, however, could be exacerbated by logging, forest loss, fire, and other disturbances (Laurance, 2001; Peres, 2001; Laurance and Williamson, 2001; Cochrane, 2001 and Meijaard *et al*., 2005). Biogeographic conditions could affect the distribution of primary sun bear foods, but timber harvesting was found to produce degraded areas or secondary forests that ultimately found to change the availability and abundance of key sun bear resources, while plantation development was found to reduce heterogeneous forests to monocultures incapable of supporting sun bears and many other threatened and sensitive species (Servheen, 1999a; Laidlaw, 2000 and Augeri, 2003). As a result, carrying-capacities for sun bears and other tropical species could be altered (Servheen, 1999a and Laidlaw, 2000). Thus, in 1999, the IUCN Bear Specialist Group recommended that information was required on how species like sun bears and other large carnivores cloud adapt to or were impacted by such habitat and landscape changes. For sun bears, forest clearing could: (i) prevent access to more seasonally productive areas or those relatively unaffected by drought or other stochastic events; (ii) reduce the diversity, abundance, and availability of key food sources, such as fruit, bee hives, and termites in logged areas, border habitats, and in the core zones of disturbed or disturbance affected home ranges; (iii) exacerbate the effects of drought both locally and regionally by inducing micro-climatic changes;

(iv) create the effects of drought or influence other local micro-climate conditions, such as changes in temperature, humidity, wind, and light incidence, which could impact plant biology and, thus, seed, flower, and fruit productivity in interior and edge forests; (v) provide access for hunters. These effects can influence the nutritional stability of sun bears and where they can move and forage across the landscape, particularly for those bears that are restricted to small forest reserves or patches.

1.6.3 Conservation actions and recommendations

Helarctos malayanus has been listed as Data Deficient on the IUCN Red List since 2003 (Hilton-Taylor, 2003), Vulnerable on the IUCN Red List 2008 and it has been listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) since 1979. Malaysia, Indonesia, and Brunei became parties to CITES in 1978, 1979, and 1990 respectively, and the sun bear has been protected by Indonesian law since 1973, but several researchers in the region pointed out that these laws and their implementation did not properly address sun bear habitat conservation, and its poaching and trade (MacKinnon *et al.*, 1996; Santiapillai and Santiapillai, 1996; Momberg *et al.*, 1998; Meijaard, 1999; Whitten *et al.*, 2000; Meijaard *et al*., 2005 Sethy and Chauhan, 2011 and Sethy and Chauhan, 2012a, 2012b). There have been no conservation strategies, mechanisms, or plans actually implemented specifically for sun bears, nor any habitat conservation exclusively focused on sun bears. Essentially, conservation plans in the areas of occurrence did not adequately address these issues, lack enforcement, and were devoid of much scientific data.

According to the IUCN Bear Specialist Group, the goals for most of the world's bear populations, including for sun bears, have been to maintain habitat and linkages between populations, minimise direct and indirect human-caused mortalities, and increase public support for bear conservation (Servheen *et al.*, 1999). It has also been recommended by many conservationists and organisations in the region that both scientific and conservation information should be available for the local people who both directly and indirectly affect conservation (Meijaard, 1997; Saeed *et al*., 1998; Augeri, 1998, 2000, 2001, 2003; Servheen *et al*., 1999; Herrero, 1999; Peyton *et al.*, 1999; Leuser Management Unit, 1999). Such information should be provided in the form of public presentations and fora, posters, brochures, videos, and other multi-media sources (Augeri, 1999; Leuser Management Unit, 1999 and Servheen (1999a) strongly recommended the need for methods to quantify presence/absence and encounter frequency, as well as site-specific methods to assess distribution, density and the impacts of forest harvest on all aspects of sun bear populations across their range. This has been particularly important for assessing sun bear relative abundance and distribution in undisturbed *versus* disturbed habitats. In addition Peyton *et al.* (1999) pointed out that information was needed on how and to what degree human activities impacted the capacity of habitat to provide critical needs for bears, such as the distribution and seasonality of bear foods, availability of cover, size and shape of habitats, and presence of corridors to connect sub-populations and resource needs. In 1999, the Bear Specialist Group report also recommended that obtaining multiple genetic samples throughout the sun bear's range was a high priority (Waits *et al*., 1999). Such information will be highly useful for conservation of sun bears and other Ursidae, as well as for many other carnivores and forest dependent mammals.

1.7 Sun bear: Background

Sun bear (*Helarctos malayanus* Raffles, 1821) is the smallest bear species in the world, and it is also one of the rarest species. The name of sun bear is derived from the golden colour crescent shaped patch of fur on its chest. It is also known as the honey bear because of its extreme fondness for honey, the dog bear because of its size, and the Malay bear for its geographical location. Out of all species of bears, the sun bear is the least is known because they are so rare. The smallest bear species with its long claws possibly has an adaptation for its habit of climbing trees for feeding and resting (Meijaard, 1999). Adults are about 120 to 150 cm long and weigh 27 to 65 kg. Males are 10 to 20 % larger than females (Sterling, 1993). They have short, sleek and black coat with a crescent-shape white or yellowish ventral patch. Often this ventral patch is dotted with black spots, and varies in size, shape and colour. The name of the sun bear in Thailand and Malaysian Chinese translates to 'dog bear' probably because of their small size, short hair, and smaller head which is more like a dog than the Asiatic black bears (Servheen, 1990). While climbing trees, it is adopted to use its strong jaws and claws to tear into trees or other structures, and uses its long tongue to extract food such as insects, larvae or honey from cavities. Usually sun bears are encountered solitary and most common social grouping is a female with cub(s). Sun bears are primarily diurnal (Wong *et al*., 2004).

1.7.1 Sun bear distribution

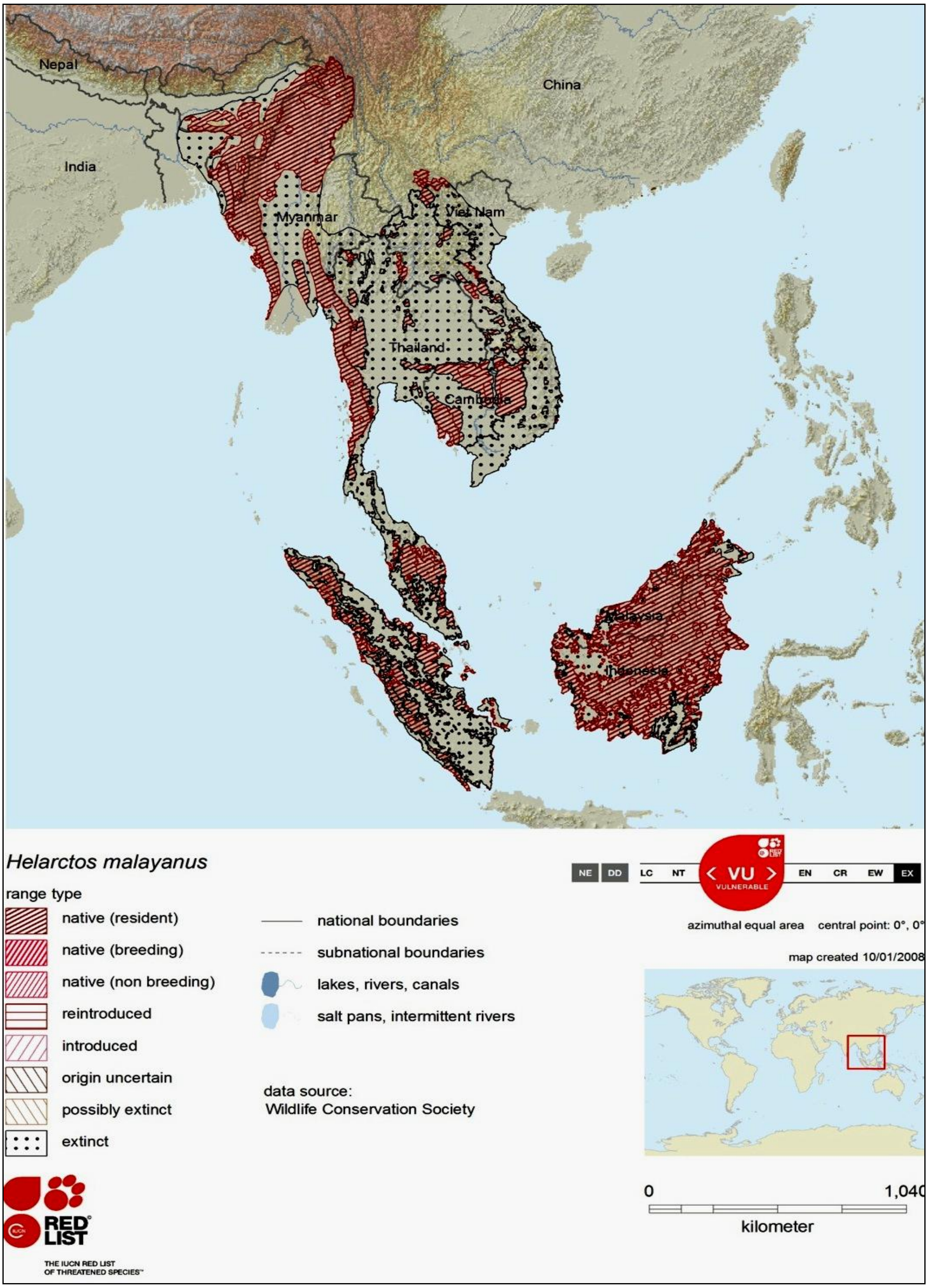
The sun bear is the only bear species inhabiting equatorial lowland rain forest of Bangladesh, Myanmar, Thailand, Laos, Kampuchea, Vietnam, Southern China, Peninsular Malaysia, and the islands of Sumatra and Borneo (Servheen, 1990; Servheen *et al.*, 1999 and Stirling, 1993).

Sun bears are more nocturnal in areas where there is lot of disturbance due to much human presence or biotic pressure (Griffiths and Van Schaik, 1993). They historically ranged throughout most of South-East Asia. as far east as Borneo and Java and north into Nepal, India, Bhutan, southern China, and eastern Tibet (Servheen, 1999), sharing its range north of Malaysia with the Asiatic black bear (*Ursus thibetanus*) and the sloth bear (*Melursus ursinus*) (Garshelis *et al*., 1999; Servheen *et al*., 1999 and Servheen, 1999a). The range of distribution of the sun bear was almost throughout the lowland tropical forest habitat. Due to increase in human populations and loss, degradation and fragmentation of forests, sun bear populations have sharply declined to low levels in most of its range. In long past, sun bears were also reported to occur in places like eastern Tibet and Sichuan, China (Lydekker, 1906 and Meijaard, 1997). There were also reports of occurrence of sun bears on the Island of Java (Greve, 1892; Cuvier, 1834 and Fishcher, 1829), but there was no evidence to prove its presence on this island in historical time. Mills and Servheen (1991) reported that the sun bears now found to occur in Southeast Asia from Burma, eastward through Laos and Cambodia. Occurrence of this species was also reported in lower Montane forests of Sabah, Malayasia from 0 to 1350m, but it was not so common (Davies and Payne, 1982). There have also been persistent reports of sun bears in parts of southern China, especially in Yunan province and it seems likely that small numbers of sun bears still exist in this area. Meijaard (1997) has compiled an excellent summary of the historic distribution records of the sun bear **(Map 1)**.

In India, the historic distribution of sun bears was in the lowland tropical rainforest habitats of Arunachal Pradesh, Nagaland, and south of the Brahmaputra river, state of Manipur and Assam (Higgins, 1932) and the upper Chitwan district in India (Wroughton, 1916). In most of these areas, the species was reported to be extinct (Higgins, 1932). Even there were reports of its occurrence in north-eastern hilly region during sixties and seventies. Thereafter, sun bear population rapidly declined, and its occurrence became doubtful in this region. According to the report of Servheen (1999) also, sun bear no longer existed in Manipur or Assam and their map of current distribution did not include India.

Recently there were reports on occurrence of sun bears in tropical semi-evergreen forest and moist deciduous forest in some parts of Manipur, Mizoram and Arunachal Pradesh. So in order to confirm presence of sun bear in these states, a systematic study on the status, distribution, conflict, threats and conservation of Malayan sun bear has been carried out in North-east India (Chauhan and Jagdish Singh, 2005a; Chauhan and Lanthunpui, 2008; Chauhan and Sethy, 2011a Chauhan and Sethy, 2011b; Sethy and Chauhan, 2011; Sethy and Chauhan, 2012a; Sethy and Chauhan, 2012b and Sethy and Chauhan, 2012c).We have confirmed its occurrence by knowing the status and distribution in all the three states. Sun bear is present in Chandel and Ukhrul districts of Manipur, Dampa Tiger Reserve in Mizoram and Namdapha Tiger Reserve in Arunachal Pradesh. The status and distribution of sun bear was studied in Chandel and Ukhrul districts of Manipur, and also information on human-sun bear conflict and conservation threats was collected (Chauhan and Jagdish Singh, 2005a, b and Jagdish and Chauhan, 2006). Recently a study conducted in different protected areas in Arunachal Pradesh has also confirmed the presence of sun bear (Chauhan and Sethy, 2011). They are found to occur in tropical semi-evergreen forest and moist deciduous forest of the Namdapha Tiger Reserve, Mouling national park and Kamlang wildlife sanctuary in Arunachal Pradesh.

Map 1: Sun bear distribution range in South-East Asia.



1.7.2. Legal status of sun bear

The Malayan sun bear as "Vulnerable" in the Red Data Book (International Union for Conservation of Nature and Natural Resources IUCN 2008) but not listed as "threatened" in the 1996 Red List of Threatened Animals (IUCN 1996). It is also listed in the Appendix I of CITES (Goi, 1992) and a Schedule I of the Indian Wildlife Protection Act (1972) as amended 2003. As sun bear is listed in Schedule I of the Indian Wildlife (Protection) Act 1972, it is an endangered species and is accorded highest protection.

The sun bear is an Appendix I species of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as the species in danger of extinction which is or may be affected by international trade. The sun bear is among the Schedule 1 animals in the Indian Wildlife Protection Act, 1972 and is still listed as 'Data deficient' in IUCN 2009 Red list of Threatened with extinction Species. The sun bear is also listed as vulnerable according to the International Union on the Conservation of Nature and Natural Resources (Corbet and Hill, 1992). Throughout its range, wildlife law enforcement is limited or non-existent (Mills and Servheen, 1991). Malayan sun bears are protected in Laos. In peninsular Malaysia, capture of Malayan sun bears and their trade is prohibited under the Wildlife Act of 1972 (Mills and Servheen, 1991). In Sabah, the sun bear is listed as a game species despite its vulnerable status. In Thailand, the 'Wild Animals Reservation and Protection Act' prohibits hunting, buying, selling and consumption of native bears. The Thailand government under the same act can allows every Thai to keep as pets two of any wild species, thus allowing a legal loophole for wildlife trafficking (Mills, 1991 and Mills and Servheen, 1991). In Burma the 'Wildlife Protection Act' of 1936 protects all species within reserve forests; however, neither *Helarctos malayanus* nor *Ursus thibetanus* was protected outside those reserves as of 1988. The 'Wildlife Protection Ordinance' of 1931 prohibits hunting, capture, trade, transit, export and possession of Malayan sun bears in Indonesia. In China, the Malayan sun bear is a Class I protected species under the 'Wildlife Protection Law' and therefore it is protected by the central government (Mills and Servheen, 1991).

Its range was probably greater than what was actually known (Ward and Kynaston, 1995). Studies on the impacts of selective logging on wildlife suggested that sun bears existed only in primary forest; none were found in logged forest (Wilson and Wilson, 1975; Wilson and Johns, 1982; Johns, 1983 and Duff *et al.*, 1984). Malayan sun bear numbers were reported to be declining drastically because of habitat destruction and poaching for bear parts used in exotic foods, medicines or aphrodisiacs (Mills and Servheen, 1991). Sun bear were reported to be threatened by demand in Japan and Korea for bear gall bladders for medicinal uses (Payne and Andau, 1991).

The sun bear remains the least studied bear species in the world and one of the most neglected large mammals in Southeast Asia (Servheen, 1999). Due to lack of knowledge about the numbers of bears, distribution, population fragmentation and mortality rates, sun bears are threatened throughout their range.

1.8 Ecology of Malayan sun bear

There are only few studies conducted on ecology of sun bear including their status and distribution in various countries of its occurrence. Little is known about social structure and reproduction in sun bears. Except for females with their offspring, sun bears are usually solitary. Sun bears do not seem to have a defined breeding season anywhere in their range and usually give birth to only one cub and commonly to two cubs (Schwarzenberger *et al.*, 2004). Female bears use cavities of either stading or fallen large hollow trees as cubbing or birth sites. As sun bears occur in tropical regions with year round available foods, they do not hibernate. Wong *et al*. (2004) studied the home range, movement and activity patterns, and bedding sites of Malayan sun bears in the rain forest of Borneo. Wong *et al.* (2005) evaluated the impacts of fruit production cycles on sun bears in the low land tropical forest of Sabah. Subsequently a report on the status of sun bear was developed for Malaysia (Wong *et al.*, 2006). The biogeographic ecology of the sun bears was studied by Augeri (2005). Fredriksson (2005) studied the human-sun bear conflicts in East Kalimantan, Indonesia. Impacts of El Niño related drought and forest fires on sun bear fruit resources were evaluated in the lowland dipterocarp forest of East Borneo (Fredriksson *et al*., 2006). They may congregate to feed around large fruiting trees, but this behaviour appears to be rare. The Frugivory in sun bears is linked to El Nino-related fluctuations in fruiting phenology, East Kalimantan, Indonesia (Fredriksson, 2006). Sun bears do not seem to have a defined breeding season anywhere in their range and usually give birth to only one cub, and less commonly to two cubs (Schwarzenberger *et al*., 2004). Female bears use cavities of either standing or fallen large hollow trees as cubbing or birth sites. As sun bears occur in tropical regions with year-round available foods, they do not hibernate.

Foods habits of Malayan sun bears are poorly documented, but have been briefly described by many authors (Shelford, 1916; Bank, 1931; Lekagul and McNeely, 1977; Medway, 1978; Tweedi, 1978; Devis and Payne, 1982; Payne *et al*., 1985; Domic, 1988; Nowak, 1991; Servheen, 1993; Mackinnon *et al*., 1996; Kanchanasakha *et al*., 1998; Lim, 1998; Sheng *et al*., 1998; Yasuma and Andau, 2000 and Fredriksson, 2001). Their diet is described as nests termites, earthworms, small rodents, small birds, lizards, animal carcasses, fruits and the heart of coconut palms. Sun bears have also found as seed dispersers by (Leighton, 1990).

The sun bears have evolved a combination of morphological adaptations which make it able to exploit resources in the tropical rain forest, especially for climbing trees etc. (Fredriksson *et al*., 2005). They were reported to feed on invertebrates and wild fruits and were important seed dispersers (McConkey and Galleti, 1999 and Wong *et al.*, 2002). Most species of bears are opportunistic omnivores when attracted to human-related foods. In Southeast Asia, sun bears were reported to resort to crop raiding when attractive foods were planted close to forest habitat. Consequent to habitat degradation and in search of food, straying of sun bears from forest areas into human habitation and crop field was reported (Chauhan and Jagdish Singh, 2005b). Sun bears were known as fierce animals when surprised in the forest, they were found to invade agricultural crop fields and attack on people when encountered suddenly. In north-eastern states in India, sun bear populations were severely affected due to increasing human population, continuous loss of habitat and trade in bear parts (Chauhan, 2006).

Historically habitats for the sun bear encompassed most of the South-East Asian terrestrial ecosystems, from sea-level peat swamps and lowland tropical hardwood forests < 500 m above sea level (asl) to lower and upper montane forests above 1,350 m asl (Payne *et al*., 1985; Stirling, 1993 and Servheen, 1999a). Payne *et al.* (1985) reported occurrence of sun bear as high as 2,300 msl on Gunung Kinabalu in the state of Sabah, Malaysia, and Meijaard *et al*. (2005) reported an upper range of 2,700 msl. Although sun bears still have been found to inhabit many of their historic habitat types and elevations, but Stirling (1993), Santiapillai and Santiapillai (1996) Servheen (1999a) Whitten *et al.* (2000) and Meijaard *et al*. (2005) have suggested that the primary habitat of sun bear is tropical lowland hardwood forests below 750 msl. These forests, however, are highly prized for timber production and are rapidly being logged as well as converted to gardens (primarily fruit and rice), commercial plantation agriculture (e.g. maize, pine apple, Chinese apple and jack fruit), and settlements (MacKinnon *et al*., 1996; Meijaard, 1997; Servheen *et al*., 1999; Whitten *et al*., 2000; Augeri, 2003; van Schaik *et al*., 2001; Robertson and van Schaik, 2001; Meijaard *et al*., 2005 and WRI, 2004).

1.9 Threats to sun bear

The major threats to sun bears are habitat loss and commercial hunting. These threats are not evenly distributed throughout the range of the species. In areas where deforestation is actively occurring, sun bears are mainly threatened by the loss of forest habitat and forest degradation arising from: clear-felling for plantation and unsustainable logging practices (Augeri, 2005; Meijaard *et al*., 2005; Tumbelaka and Fredriksson, 2006 and Wong, 2006), illegal logging both within and outside protected areas (Fuller *et al.*, 2004), and forest fires (Fredriksson *et al*., 2007). These threats are prevalent in Indonesia and Malaysia on the islands of Sumatra and Borneo (Sundaland), where large-scale conversion of forest to oil palm (*Elaeis guineenis*) or other cash crops is going on at the rate of thousands of kilometre per year (Holmes, 2002).

Human-caused fires in parts of Sundaland are also reducing habitat quality for sun bears. These fires are more extensive during El Niño-related droughts. On Borneo island, periods of prolonged droughts have disrupted fruiting patterns (Harrison, 2000), which in combination with reduced habitat availability due to logging and fires, resulted in starvation among sun bears, even in primary forest areas (Wong *et al.*, 2005 and Fredriksson *et al.*, 2006b).

Commercial poaching of bears for the wildlife trade is a considerable threat in most countries (Meijaard, 1999; Nea and Nong, 2006; Nguyen Xuan Dang, 2006; Saw Htun, 2006; Tumbelaka and Fredriksson, 2006 and Wong, 2006), and is the main threat where deforestation is currently negligible (eg. Thailand where nearly all remaining forest is within protected areas (Vinitporsawan *et al*., 2006). Killing bears is illegal in all range countries but is largely uncontrolled. In Thailand, local hunters in one area estimated that commercial poaching reduced the abundance of sun bears by 50% in 20 years (Steinmetz *et al*., 2006).

In Myanmar, Thailand, Lao PDR, Cambodia and Vietnam, sun bears are commonly poached for their gall bladders and bear paws; the former is used as a traditional Chinese medicine, and the latter as an expensive delicacy. In China and Vietnam, bile is milked from commercially farmed bears; however, as there are few sun bears in China, farms mainly have Asiatic black bears. Whereas both sun bears and Asiatic black bears are farmed in Vietnam, in small private enterprises. Bears are routinely removed from the wild to stock or restock these small farms (Nguyen Xuan Dang, 2006, B. Long, MOSAIC and WWF-Vietnam pers. comm.). Other motivations for killing bears include: preventing damage to crops (Fredriksson, 2005), subsistence use, fear of bears near villages, and capture of cubs for pets (the mother being killed in the process). Though small population of sun bears exist in India, villagers increasingly kill both black bear and sun bear for illegal trade and self consumption. (Chauhan and Singh, 2006 and Sethy and Chauhan, 2011a, 2012b).

Despite significant poaching within extant forest areas, sun bear populations appear to persist longer than some other heavily-exploited large carnivores. For example, tiger (*Panthera tigris*) populations were severely reduced or extirpated in 12 of 15 protected areas surveyed in Myanmar, whereas sun bears were still encountered relatively frequently in 13 of these areas (Lynam, 2003 and Saw Htun, 2006). Similarly in Thailand, tigers were reported to be are close to extirpation in the Khao Yai forest complex, but sun bears and their signs were still consistently encountered there (Lynam *et al*., 2006 and Vinitpornsawan *et al*., 2006).

Due to habitat loss, disturbance, and human-caused mortalities its global population may be less than 25% of historic levels and it is restricted to isolated and fragmented sub-populations (Servheen, 1999a). Both natural and anthropogenic factors can influence bear ecology and habitat use and it is important to identify accurately the most distinct and interactive influences on these dynamics. Generalisations from limited or biased information can damage both the species and the conservation mechanisms intended to protect it. For bears, forage, habitat character, landscape features, competition, security, habitat loss, and fragmentation are influential in varying degrees (Servheen *et al.*, 1999). Thus, the focus in this study was to identify and predict the most dominant influences affecting sun bear biogeographic ecology and, thereby, its persistence and evolutionary potential. The geometry of an organism interacting with its environment plays a major role in determining its optimal use of landscapes (MacArthur and Pianka, 1966).

Survival for most animals requires the ability to access suitable habitat, resources, mates, cover, security, and territory across the landscape. Natural biogeographic and environmental conditions can influence these needs, particularly where habitat and forage abundance, diversity and availability are affected. For the majority of bear species, food availability and diversity, habitat condition, and cover are frequently the most prominent ecological factors influencing habitat use. Individuals and populations are also vulnerable to both stochastic and anthropogenic perturbations, which can change continuous forests into a fragmented matrix of disturbed, lost, and unsuitable habitat. Recent studies and reports indicate that sun bears may be seriously affected by such influences (Santiapillai and Santiapillai, 1996; Servheen, 1999a; Whitten *et al*., 2000; Augeri, 2003 and Meijaard *et al*., 2005). For species like sun bears with coevolved adaptations to specific habitat types, natural and anthropogenic factors can influence access to, and the density and abundance of, food and other resources (Augeri, 2003 and Meijaard *et al*., 2005). Such loss or limited availability of otherwise suitable habitat for bears can lower habitat carrying-capacities, fragment and isolate populations (Merrill *et al*., 1999; Murrow, 2001; Maher *et al.*, 2003 and Larkin *et al.*, 2004), and limit demographic exchange among populations (Craighead and Vyse, 1996 and Waits *et al*., 1999). These influences can shift the bears' movement dynamics and affect their habitat use (Mattson *et al.*, 1987; McLellan and Shackleton, 1988; Mattson *et al.*, 1996; Merrill *et al.*, 1999; Boyce, 2000; Augeri, 1994, 2003 and Meijer *et al.*, 2005). Consequently, health, mating, recruitment, and population dynamics can be affected (Jonkel and Cowan, 1970; Rogers, 1976, 1987; Craighead *et al.*, 1995 and Powell *et al.*, 1997).

Loss of resources, and reduced access to, high-quality resources and habitat, whether from biogeographic or human-causes, can increase physiological stress (Frid and Dill, 2002 and Wasser *et al.*, 2004) reduce individual survival and reproductive rates (White *et al.*, 1999), create insular effects (Craighead and Vyse, 1996 and Larkin *et al.*, 2004), and affect bear fitness and persistence (Rodgers, 1976; Mattson *et al.*, 1987; Craighead *et al.*, 1995; Powell *et al.*, 1997; White *et al.*, 1999; Boyce *et al*., 2001 and Freedman *et al.*, 2003). It is clear that accurate scientific information will enable greater success for sun bear conservation plans (Santiapillai and Santiapillai, 1996; Augeri, 1998; Servheen, 1999a, 1999b and Peyton *et al.*, 1999). In addition to the paucity of information regarding many aspects of basic sun bear ecology until now, very little known about the impacts of biogeographic conditions, landscape structure, and human disturbances on sun bear habitat use, resources, ecological relationships, densities, distributions, isolation, behaviour and basic life-history (Servheen,1999a). Because the last remaining sun bear populations exist in increasingly human-dominated landscapes, the persistence of sun bears and tropical forests in general are inevitably linked to how ecosystems are managed (Meijaard *et al.*, 2005). Indeed, the persistence of local sun bear populations depends on our ability to predict how biogeographic conditions, changing landscape structures, environmental stochasticity, and anthropogenic disturbances affect bear movement, foraging patterns, and access to critical resources in increasingly patchy landscapes over the year.

1.9.1 Applied research

Study feeding ecology and behaviour under different logging regimes; develop survey techniques and compare densities in different habitat types with different levels of disturbance; study the effects of hunting pressure, study hunting in plantations.

1.9.2 Policy matters

Promote improved conservation of the species at national and international level; develop management guidelines for sun bears in plantations.

1.9.3 Education and awareness

Design a program that shows Arunachal Pradesh people the value of these wild animals; address the medicinal use of bears and bear parts; address the problem of hundreds of bears in captivity.

1.9.4 Training

Train conservation authorities to collect, store, and use data on bear distribution and other characteristics.

1.9.5 Bear holding facilities

Establish bear holding centres to help law enforcement and to provide a place to collect bears. Such centres could be used for educational purposes. Hundreds of sun bear live in captivity waiting to be slaughtered when they are too old to keep as pets. These animals will not be confiscated as long as there is no suitable follow-up

1.10 Justification of the study

i. Of the eight species of bears in the world, Malayan sun bear (*Helarctos malayanus*) is the least known species. The global population trend is still not known. Its global distribution is restricted to south-east Asian countries. Throughout its range, sun bears are facing continuous threat for survival and even extinction. Consequently, the conservation efforts for the sun bear, an endangered species, are adversely affected.

ii. It has been listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) since 1979. It is classed under the 'data deficient' in IUCN Red list of threatened species. In India, Malayan sun bear is an endangered species restricted to the north-eastern states only. Its occurrence was way back in 1970s and before. Thereafter, the population of sun bear in these states declined and till recent times, its distribution was even doubtful.

iii. As the sun bear population very sparsely distributed in the north-eastern region of India, very little is known about its ecology and behaviour. There is no information available on the status and distribution, sun bear habitat use, food habits, nature and extent of human-sun bear conflict and socio-economic impacts of bear menace which can help conservation and scientific management of its population.

iv. Basic research on sun bears is the highest priority for bear biologist. Research on the status, ecology, food habits, and distribution of the sun bear is needed everywhere in its range in South-east Asia. There are no readily available measures for management of sun bears in tropical habitats and there is a need for site-specific application of methods to assess distribution, density, and the impacts of forest harvest on sun bear populations in representative habitats throughout the range of the species.

v. The sun bear has globally-threatened status which requires timely proactive science and conservation. Given that most sun bears are limited to small isolated populations, environmentally-stochastic events, such as a seasonal fruiting or primary forage crop failures, can negatively affect the survival and persistence of isolated populations. Disturbance and fragmentation are also important influences throughout the range of sun bear and can act independently and synergistically at both local and landscape scales when coupled with stochastic events.

vi. This interaction will affect the sun bear, its ecological relationships, and its influences on tropical forest dynamics as a primary competitor, seed disperser and predator. In addition to international and intrinsic mandates for its conservation, the sun bear is an excellent species for tropical forest conservation.

vii. The costs of not conserving this species are extensive, but the benefits are immeasurable. Bear conservation helps conserve healthy watersheds, hydrologic and ecosystem processes, genetic diversity and evolutionary potential for numerous species beyond its own range, including for humans (Herrero, 1999 and Craighead, 2000).

viii. To mitigate human-bear conflicts in human-dominated landscapes in South-East Asia, accurate data on the use of sun bear and displacement from, specific habitats in various biogeographic and disturbance conditions are required for conservation plans, where conservation requirements may displace or limit human needs of the same landscapes (Diamond, 1986; Western *et al.*, 1989; Woodroffe and Ginsberg, 1998; Noss, 1991 and Servheen *et al.*, 1999).

ix. Through research identification of the primary factors that either aid or restrict sun bear habitat and landscape use, i.e. what biogeographic and anthropogenic parameters affect sun bear habitat use, ecology, and distributions across temporal and geographic extents is necessary. Sun bears have evolved under diverse biogeographic conditions and a key to their persistence has been access to suitable habitat. If bears are not able to access resources, this can create fragmented or isolated populations resulting in weakened metapopulation dynamics.

x. Systematic surveys to study the status and distribution of sun bear and human-sun bear conflict have been conducted in the Manipur, Mizoram, Nagaland and Arunachal Pradesh. This is the first detailed study conducted on sun bear in Namdapha tiger reserve, Arunachal Pradesh in India.

xi. This in-depth systematic scientific research on ecology, behavior and management of sun bear has been undertaken for the first time in and around Namdapha Tiger Reserve in Arunachal Pradesh. This will help develop an action plan for conservation and management of sun bear and also to mitigate the human-sun bear conflict effectively on long term basis.

xii. While the study is specific state the project outcome would have the potential of application to similar habitat situation elsewhere in north-eastern states of India.

xiii. The study will also help suggest ways to use the forest and other land resources in a sustainable way towards resolving the problem. Thus the knowledge gained on the ecology of sun bear and conflict aspect etc. will be highly beneficial for use by the wildlife managers and scientists.

1.11 Specific objectives

The objectives of my Ph.D. work are as follows:

1. To study the distribution of Malayan sun bear in Namdapha Tiger Reserve.

2. To assess the habitat use by Malayan sun bear in Namdapha Tiger Reserve.

3. To investigate food habits of sun bear in the study area.

4. To assess the nature and extent of human-sun bear conflict: human casualties and agricultural and horticultural crop damage by sun bear.

5. To suggest strategies for mitigation of human-sun bear conflict and conservation of sun bear population.

Chapter 2

Review of literature

2.1 Introduction

Bears belong to the order Carnivora. Around 57 million years ago, Carnivora evolved from small arboreal predators, miacids (Herrero, 1999). On the evolutionary tree of the order Carnivora, bears are close relative of dogs, racoons and weasels, from which, the bears split about 34 million years ago (Catton, 1990). Today the bear family comprises of three genera having eight living species. The six ursinae bears, namely, sun bear (*Helarctos malayanus*), American black bear (*Ursus americanus*), sloth bear (*Melursus ursinus*), Asiatic black bear (*Ursus thibetanus*), brown bear (*Ursus arctos*) and polar bear (*Ursus maritimus*) were found to have a nearly identical karyotype with 74 diploid chromosomes (Ewer, 1973 and Waits *et al*., 1999). These chromosomes consisted of 72 autosomes (60 acrocentric and 12 metacentric or sub-metacentric) and 2 sex chromosomes, a large metacentric X and small acrocentric Y (Pasitschniak-Arts, 1993). The sun bear is one of eight species of bears distributed South-East Asia, and one of six Ursinae member of the genus *Helarctos*.

2.2 Evolution and taxonomy

As member of the order Carnivora, the Ursidae family evolved from smaller, tree climbing predatory ancestors (Miacidae) about 25 million years ago (mya) (Herrero, 1999). All eight species of modern bears today found to share a common ancestor, *Ursavus*, which evolved in sub-tropical Europe during the Miocene period over 20 mya (Craighead, 2000). During the Miocene epoch, ursavine bears increased in size and their dentition shifted from a faunivorous diet to one more like present day bears with broad flat molar (Ward and Kynaston, 1995), indicating a more frugivorous and herbivorous diet. Three lines of modern bears emerged from *Ursavus*. The majority of molecular studies included the giant panda (*Ailuropoda melanoleuca*) within the

Ursidae family and the most current phylogenetic reconstructions among the eight Ursidae placed it as the oldest modern bear species (Gittleman, 1999 and Waits *et al*., 1999). Giant pandas splited from the main *Ursavus* line and evolved from *Agriarctos* approximately 20 mya (Ward and Kynaston, 1995). Molecular analyses concluded that the next modern bear to evolve was the spectacled (Andean) bear (*Tremarctos ornatus*) (Waits *et al*., 1999), which splited from *Ursavus elemensis* around 14 mya (Ward and Kynaston, 1995) and is the only South American bear today (Nowak, 1991; Stirling, 1993 and Craighead, 2000). The direct progenitor of the third bear line, which has been subfamily Ursinae or true ursine bears, was *Protursus*, having evolved from *U. elemensis* between 12-10 mya.

The first true Ursinae bear, *Ursus minimus*, evolved from *Protursus* and appeared about 5 mya (Ward and Kynaston, 1995). Mitochondrial DNA sequence analyses indicated that sloth bears were the first modern Ursinae lineage to emerge, but the branching order of the remaining species was uncertain (Waits *et al*., 1999 and Gittleman, 1999). Sun bears were likely evolved in South-East Asia from the main lineage of Ursinae bears (*U. minimus*) about one million years after the sloth bear line branched (Craighead, 2000), but the phylogenetic placement of sun bears among the Ursidae remained unclear. The mitochondrial DNA analyses by Zhang and Ryder (1994) indicated that sun bear and American black bear (*U. americanus*) species diverged as sister taxa after the sloth bear and the next to evolve was the Asiatic black bear (*U. thibetanus*). However, Waits (1996) reported that the branching order among the sun bear, American black bear and Asiatic black bear was not statistically resolved with a 95% confidence interval. The latter could be the result of a rapid radiation event among these three species (Waits *et al.*, 1999).

Opinions were different about keeping the sun bear in its own genus *Helarctos* or to include it in the genus *Ursus* (Meijaard, 2004 and Meijaard *et al.*, 2005), which already included of four species. It is currently listed by the IUCN Species Survival Commission, the IUCN/IBA Bear Specialist Group, the IUCN Red List, and by CITES as *Helarctos malayanus*. Based on cranial variation among a few of sun bear specimens from different parts of South-East Asia, Meijaard (2004) suggested that the Bornean race might be a distinct sub-species and proposed that it should be called *Ursus malayanus euryspilus*, but the quantity and gender of specimens from Borneo examined in that study were limited. Furthermore, cranial variation was not the only taxonomic consideration for sub-specific distinctions, particularly for Ursidae, which had a large degree of morphological and physiological variation and had inter-bred, producing reproductively viable offspring. Nevertheless, if this distinction was supported, then Meijaard (2004) proposed that other sun bear populations should be within *Ursus malayanus malayanus* (Meijaard, 2004 and Meijaard *et al.*, 2005). At the height of its distribution, it was assumed that the mainland sun bear populations were connected by contiguous habitat (Craighead, 2000). The sun bears were also found inhabit found to most of the islands west of Wallace's Line, which marked the edge of the continental shelf between Borneo and Sulawesi and a division between Asiatic and Australian fauna and flora (Wallace, 1880 and Craighead, 2000).

Throughout geologic evolution, ocean levels were never low to enable a land bridge between Borneo and Sulawesi, effectively limiting the abilities of most terrestrial animals to migrate further east or west (Wallace, 1880). It was assumed, therefore, that ancestral sun bear populations had become isolated on Sumatra and Borneo from the Malay Peninsula in periods of higher sea levels during the Pliocene epoch about 5 mya (Craighead, 2000). There were no fossil records of sun bears east of Wallace's Line and it was believed that if some sun bears did cross this deep ocean trench, they were never able to establish successful populations (Craighead, 2000). Although the sun bear persisted in isolated forest pockets from Myanmar to Borneo it could not exist on any islands other than Sumatra and Borneo. Today, the sun bear was reported to be the only bear species inhabiting Malaysia, Indonesia and Brunei and equatorial lowland rain forests anywhere on Earth (Servheen *et al*., 1999).

2.3 Bear phylogeny

The Ursidae originated as the dog like Cephalogale 20-30 million years ago (mya) from middle Oligocene and early Miocene of Europe (Kitchener, 1993). It gives rise to a lineage of early bears, the *Ursavas* species, in the Miocene which then spilt into i) Ailuropodinae which gave rise to (*Agriarctos* 20 mya and ultimately the only surviving member giant panda, *Ailuropoda melanoleuca*: ii) Termarctinae (the short-faced bears) whose sole surviving member, the Andean bear, *Tremorctos ursinus*, evolved from an earlier *Ursavus* ancestor 10-15 mya; and iii) Ursinae which gave rise to *Ursus minimus*, the first of the true bears five million years ago (Kitchener, 1993). The *Ursavus* species radiated in Europe and Asia and the *Tremarctos* ancestor entered the Americas via the Bering land bridge (Kitchener, 1993). Other phylogenies put the split of the ancestor of Andean bears and giant pandas at 12 mya, and the origin of true bears 4 mya (Waits *et al.*, 1999). Phylogenetic analyses by Talbot and Shields (1996) also suggested that the giant panda and the Andean bear were the basal taxa of the ursid radiation. Waits *et al.* (1999) proposed that a rapid radiation of the Ursinae occurred between 2-3.5 mya leading to four ancestral lineages: Asiatic black bear (*U. thibetanus),* American black bear (*U. americanus*), sun bear (*U. malayanus*) and the lineage that lead to both the brown bear (*U. arctos*) and polar bear (*U. martimus*).

Yu *et al.* (2004) in their analyses grouped the brown and polar bear together, and also found that the Asiatic and American black bears clustered as a sister and proposed sun and sloth bear are sister taxa. They confirmed the early divergence of sloth bears (Talbot and Shields, 1996 and Waits *et al.*, 1999), but the exact placement of the sun bear was unresolved (Yu *et al.*, 2004). A wild sun bear was documented to hybridize with an Asiatic black bear (Galbreath *et al.*, 2008) and a captive sun bear could hybridize with a sloth bear (Asakura, 1969). In a quantitative study of brain morphology in sun bear, giant panda and American black bear, there was a general contrast indicated between American and Asian bears (Kamiya and Pirlot, 1988).

2.4 Physical characteristics

The sun bear (*Helaractos malayanus*, Raffles, 1821) has short, typically black hairs with a characteristic, orange-yellow horseshoe-shaped chest marking and small round ears and whorls of hairs on the forehead and behind the ears (Pockock, 1932 and Lekagul and McNeely, 1977). The sun bear's chest marking is somewhat similar to that seen in Asiatic black bear and sloth bear. It may function as a social signal since it is best seen when the bear stands bipedally, such as during aggressive encounters, accentuating a threat posture (Fitzgerald and Krusman, 2002). They have a compact body and coat that is short and sleek but thick with under wool (Pocock, 1932). They have extremely loose skin that reputedly allows them to turn to bite at the back, and reputed to assist with predator, the escape (Domico, 1988). Besides men and large felines only other known predator of the sun bear is the reticulated python, *Python reticulates* (Fredriksson, 2005a). Sun bears, like other bears, go bipedal readily and have been known to even carry their young ones that way in captivity (Poglayen-Neuwal, 1986).

The sun bear, though largely terrestrial, is often an arboreal and has bare sloes on it's and highly developed claws to aid in climbing (Pocock, 1932). Their bowed legs and inward facing paws are well adapted for arboreal habits (Pocock, 1932 and Sasaki *et al*., 2005) such as feedings on figs and going after bees nests in tree cavities (Dathe, 1975 and Wong *et al.*, 2002) or sometimes using high branches as resting or bedding sites (Wong *et al.*, 2004). Though they may typically rest in a log or the forest floor (Fredriksson, 2005a), sun bear are considered skilful climber (Dathe, 1975). The feeding adaptations of sun bear include a light-coloured mobile snout (modified rhinarium and protractible lips) and long narrow tongue (Pockock, 1932 and Dathe, 1975). Like other bears, they are opportunistic omnivores consuming a wide variety of food items (Wong, 2002). Yet they rely heavily on termites and figs when they are available (Wong, 2002, 2004 and Fredriksson *et al.*, 2006a), and may be primarily frugivorous (Fredrikssion *et al.*, 2006a). It has been suggested by Fredrikssion *et al.* (2006a) that just as other bear species have developed dietary niche specializations, sun bears have evolved to fill a primate like niche relying heavily on fruits such as figs and may be able to gorge on these fruits when they are available and store fat.

Body colour: The short-haired fur is dense and deep black or brown-black in colour, and muzzle is light grey to orange. The crescent marking on the chest may form a complete circle under the throat, and sometimes, it is spotted, or lacking altogether. Some believe that the origin of the name of sun bear comes from the fact that the crescent looks like a rising sun. Both sexes are of the same colour.

Head and body length: Body length is 3.5-4.5 feet (1.1-1.4 m), tail is tiny about 2 inches (3-7 cm), and they stand up to about 28 inches (70 cm) at the shoulder. Males are typically about 10-20% larger than females.

Body weight: It ranges from 60 to 143 pounds (23-65 kg) in zoos - males on heavier end of range and wild bears show mid-range.

Other characteristics: Sun bear has a very long narrow tongue; long, sharp sickle-shaped claws on naked-soled feet; head is large in proportion to body; muzzle is short and ears are round; small eyes but keen eyesight; smell is the most important sense.

Life history

Breeding season and interval of sun bear is unknown. Oestrus may occur up to 3 times a year. Hugging, mock fighting and head bobbing have been observed during 2 to 7 day mating period. Number of offspring is 1 to 2. The gestation period is 96 days. Reported gestation periods of 174,228 and 240 days at Fort Worth Zoo suggest a delayed fertilization (embryonic diapause) is sun bears. Young are at birth weighs 10-15 ounces. Time of weaning is 18 months. Age of sexual mortality in females is about three years and in males, it is four years. The lifespan is unknown in wild condition. But in captivity, it is 25 to 35.9 years.

Little is known about the social life of these bears in the wild, but some evidences that suggest that they may be monogamous. Mating may occur at any time of the year. Mother bears, called sows, make ground nests and give birth to one or two blind young(s). Mothers have actually been observed cradling a cub in their arms while walking on their hind legs, a rare trait among bears. Cubs can move about after two months, but they remain with their mothers for two years or more, learning about feeding habits and fend for themselves (www.google.com/sunbear biology).

2.5 Bio-geographic ecology

Ecological biogeography includes the factors that define the spatial distribution of species in the present times.

2.5.1 Habitat structure

Forage, security cover, and suitable habitat have been frequently cited as the most important natural variables influencing bear ecology and habitat use (Jonkel and Cowan, 1970; Rodgers, 1976, 1987; McLellan and Shackleton, 1988; Nowak, 1991; Mattson *et al*., 1991, 1996; Stirling, 1993; Augeri, 1994; Craighead *et al*., 1995, 2001; Powell *et al*., 1997; Merrill *et al.*, 1999; Bader, 2000; Craighead, 2000 and Meijaard *et al*., 2005). Several studies reported that sun bears were mainly a primary forest-dwelling species (Fetherstonhauh, 1940; Wilson and Wilson, 1975; Wilson and Johns, 1982; Johns, 1983; Augeri, 2001 and Meijaard *et al.*, 2005), where the most dominant traits were mature and diverse forest structure with a high basal area of emergent and fruiting trees, full canopy cover, high escape cover, and diverse and abundant forage (Augeri, 2003 and Meijaard *et al.*, 2005). Wong *et al.* (2004) reported that the importance of primary forest for sun bears survival was uncertain. Topography was reported as generally insignificant for bears, but in many regions, slope, aspect and elevation were found significantly influencing the bear forage type and productivity.

In general, the highest abundances of bears throughout the world were correlated with undisturbed habitats of varying types that were in mature to late successional stages with heterogeneous biogeographic structure, moderate to high cover, and access to large ranges with considerable and diverse forage productivity (Servheen *et al*., 1999). Biogeographic conditions, environmentally-stochastic events and anthropogenic disturbance were found to affect these resources for sun bears in Indonesia, particularly cover and the availability, abundance and diversity of primary bear forage (Augeri, 2003; Meijaard *et al.*, 2005 and Fredriksson, 2005). Although sun bears were found to be principally associated with primary forests, escalating habitat and forage losses were increasingly influenced the sun bear ecology and habitat use (Augeri, 2003; Wong *et al.*, 2004; Meijaard *et al*., 2005 and Fredriksson, 2005).

2.5.2 Cover

For most bear species, access to cover and the spatial configuration of cover were reported to be vital for their persistence (Mattson and Knight, 1991; Stirling, 1993;

Augeri, 1994; Craighead *et al*., 1995, 2001; Powell *et al*., 1997; Mattson *et al*., 1987, 1996; Merrill *et al.*, 1999; Boitani *et al*., 1999; Servheen *et al.*, 1999; Bader, 2000 and Meijaard *et al.*, 2005). Female bears were generally to have a higher affinity for cover and secure habitat, but most studies showed that all bears were susceptible to human-induced mortality, especially in or near open or exposed habitats, roads, trails, and sites with moderate to high levels of human use (Servheen *et al.*, 1999). Recent studies in East Kalimantan and northern Sumatra indicated that sun bears were particularly prone to such mortalities in areas with increasing forage and habitat losses (Augeri, 2002, 2003; Meijaard *et al.*, 2005 and Fredriksson, 2005). For bears, habitat fragmentation was found to lowers the effectiveness of preferred habitat (Bader, 2000). Blanchard and Knight (1991) found that female grizzly bears (*Ursus arctos horribilis*) with yearlings chose security over more productive habitats in the Yellowstone Ecosystem. Human-caused or related mortality accounts for more than 85% of grizzly bear mortalities in this ecosystem (Bader, 2000) and secondary roads were five times higher in mortality risk for all bears than in inter areas without roads (Mattson and Knight, 1991). For sun bears, mature primary forests with extensive and high cover were found to be dominant influences (Meijaard *et al*., 2005) and perceived risk appeared to be an important variable in their habitat selection. Loss of suitable habitat, however, led to increased conflicts between people and sun bears in some parts of their range (Augeri, 2001, 2002 and Fredriksson, 2005).

2.6 Biology

2.6.1 Past research

Meijaard *et al*. (2005) compiled the full body of research conducted on wild sun bears. All the major studies in the wild began in 1997-1999. (Fredriksson, 2001 and 2005) studied on the effects of fire on sun bear foraging ecology in East Kalimantan. Wong (2002) conducted research on ecology of sun bear including ranging pattern within a 43,800 ha protected area surrounded by logging concessions in the Danum valley of Sabah, Malaysia. The study also included camera trapped of sun bears (Wong *et al*., 2004). Another study was conducted on the use of oil palm plantation by sun bear Sabah (Normua *et al.*, 2003, 2004). On the biogeographic ecology of the

Malayan sun bear study was conducted by (Augurai, 2005) in East Kalimantan, Borneo. In Thailand, a study on sun bear and Asiatic black bear ecology and sympatric habitat use was completed (Steinmetz and Garshelis, 2008). Fredriksson (2001, 2005) was conducted in Sungai Wain Protection Forest in East Kalimantan, research on sun bear rehabilitation and a study using telemetry on three habituated and three wild bears, faecal analyses and habitat traits related to sun bear diet was conducted. Effects of forest fires on termites and fruiting phenology were also evaluated. The seasonal movements of four radio-collared sun bears were studied in and around an oil palm plantation patches in Sabah, Malaysia (Normua *et al.*, 2003, 2004). Despite significant and high-quality efforts, sun bear capture success rates by Wong (2002) and Normua *et al.* (2003, 2004) were minimal and sample sizes were low. Although a total of 14 wild sun bears were captured for research purposes in all above studies; three bears in East Kalimantan, six bears in Sabah (Wong, 2002); four bears in Sabah (Normua *et al.*, 2004); and one bear in Thailand. These captures required extensive multi-year trapping efforts resulting in only a 42.8% success rate of full-time telemetry data of six bears for more than six months. The remaining eight bears in these studies were lost or died.

2.6.2 Inter- and intra-specific competition

Prior to work of Augeri (2005), there was no published information regarding intra-specific competition and density-dependent processes among sun bears. The most important competitive influences were probably related to the frugivorous and insectivorous diet of bear (Augeri, 2005). In this study more than 50 sympatric fruigivorous and insectivorous vertebrate competitors were recorded overlapping within 10 m of sun bear activity and the most dominant taxa comprised of forest ungulates, primates and birds. The author cited that a sun bear and orang-utan were observed foraging in the same fig tree near the Ketambe research station in Gunung Leuser national park by (Wich, S.A. pers.comm.). Fredriksson (pers. comm.) observed that some ground birds were found to trail sun bears during termite foraging. As an insect competitor, sun bears were found to affect the availability and distribution of live termite nests and ant colonies through significant predation, but they were conservative in their consumption (Augeri, 2002, 2003 and Fredriksson, 2001). Meijaard *et al.* (2005) cited that observed a 50:50 ratio of untouched *versus* foraged termite colonies in the Sungai Wain Protection Forest, East Kalimantan. About 300 live nests/ha of one termite species remained active while an average of 300 nests/ha were excavated by bears. It was certain that bears would influence and be affected by the distribution and/or foraging activities of rival insectivorous species like pangolin (*Manis javanica*).

2.6.3 Agonistic interactions

Sun bears evolved with large carnivorous Felidae like tigers (*Panthera tigris sumatrae*), clouded leopards (*Neofelis nebulosa*) and Asian leopards (*Panthera pardus*). The latter species was probably extinct in Indonesia, but it still found to exist in mainland Asia. The Asiatic golden cat (*Felis temminkii*) was found to be smaller than the other felids, but it was capable of preying on bear juveniles and cubs and antagonistic interactions probably occurred when encountering adult bears (Augeri, 2005). These predators might have influenced the evolution, behaviour, ecology, and time-energy budget of bears relative to predation-risk, including the arboreal foraging and nesting habits of bears. Augeri (2005) cited that a observed while conducting telemetry study a reticulated python was killed and eaten an adult female sun bear in the Sungai Wain Protection Forest in East Kalimantan, but there was no information on the frequency of such interactions. Other than humans, there were no other local predators of sun bears. Sometimes, tigers and leopards were presumed to be antagonistic when encountered with sun bears (Augeri, 2001) and might influence bear habitat use temporally and perhaps spatially. Kawanishi (2002) recorded one sun bear carcass presumably killed by tigers, and two tiger scats containing the remains of sun bear. The frequency of such antagonistic or predatory interactions was unknown. Geographic overlap within one metre was observed in this study sun bears and tigers, clouded leopards and Asiatic golden cats. Such overlapping of sun bears was also observed with marbled cats (*Pardofelis marmorata*), leopard cats (*Felis bengalensis)* and bay cats (*Felis bada*), but temporal overlap between bears and tigers was at least three days apart.

2.6.4 Ranging pattern

In the Danum valley, Sabah, recorded minimum convex pologyon (MCP) home ranges of four male sun bears of 6.2-20.6 km^2 with an average of 14.8 km^2 were recorded (Wong, 2002). Straight-line daily distances between telemetry coordinates were 141-5,660 m. Fredriksson and Wich (cited in Meijaard *et al.*, 2005) reported a daily range of 8 km of sun bears and a mean home range of 4-5 km^2 in Sungai Wain protection forest, East Kalimantan. Normua *et al.* (2004) reported minimum MCP home ranges for two male and two female sun bears which range from 1.2-5.1 km^2 near an oil palm estate in Sabah, but these telemetry survey efforts were limited to only about 1-2 km around the estate. The latter home ranges were mainly in the interior forest and were expected to be much larger (Normua *et al.*, 2004). Sun bears found to be non-migratory, but might alter their ranges across seasons and years according to food availability, such as during local and seasonal fruiting events and mast fruiting or when shifting to alternative food sources during low fruiting years (Augeri, 2003).

It was assumed that, like other Ursidae, many female sun bear ranges would overlap with their mothers while other females and most males dispersed to new ranges, although ranges of both genders could overlap with other bears. Wong (2002) estimated such overlaps among four telemetry surveyed male bears which varied from 0.54 km^2 to 3.45 km^2. Fredriksson cited in Wong, 2002 and Meijaard *et al.* (2005) reported females with cubs, siblings and occasional groupings at large food sources (e.g. large fruiting *Ficus* spp.). Although the frequency and extent of sun bear aggregations was unknown, it was likely minimal and parallel to other Ursidae, where the majority of adult bears without cubs followed relatively solitary behaviour patterns. The majority of sun bear activities were concentrated in lowland and hill dipterocarp forest below 750 m asl (Davies and Payne, 1982; Fredriksson, 2001; Augeri, 2002, 2003; Wong, 2002; Normua *et al.*, 2003, 2004 and Meijaard *et al.*, 2005), but signs and camera-trapping data from this study showed bears and bear activity in lower and upper montane forests as high as 2,143 m asl in North Sumatra and 1,450 m asl in East Kalimantan, Borneo. Payne *et al.* (1985) reported sun bear occurrence as high as 2,300 m asl, while Meijaard *et al.* (2005) noted an upper range of 2,700 m asl. Sun bear activity was rarely observed in recently logged or burned areas (Augeri, 2003; Fredriksson and Wich, cited in Meijaard *et al*., 2005) and the bear's activity patterns showed diurnal and nocturnal behaviour, tracked movements of four bears whiling tracking by telemetry in and around an oil palm plantation in Sabah, 100% of bear activity around the estate was nocturnal and the most of the bear activity (88%) was in primary forest at least one kilometre from the edge (Normua *et al.*, 2003). Griffiths and van Schaik (1993) found in northern Sumatra that sun bears shifted their activities to nocturnal behaviour in areas with higher human activity.

2.6.5 Activity pattern

The sun bear was regarded as nocturnal (Nowak, 1991; Lekagul and McNeely, 1977; Domico, 1988 and Stirling, 1993), but more recent work suggested variability in their activity patterns. They were found to be primarily diurnal in East Kalimantan (Fredriksson *et al.*, 2006a) and in Danum valley in Sabah (Wong *et al.*, 2002), but showed nocturnal activity in disturbed areas such as around oil palm plantations (Normua *et al.*, 2004). Wong *et al.* (2004) studied male sun bears that were primarily diurnal, but also included few individuals that were active at night for short periods. It was also observed that human traffic in the tropical rainforest could alter the activity pattern of sun bears (Wong *et al.*, 2004). This activity cycle flexibility in the face of human disturbance (such as hunting) was reported in other bear species (Brown, 1993).

2.6.6 Foraging ecology

Most bears were opportunistic omnivores, their diets comprised of fruits, other vegetative materials, and in lesser amounts, mammals, fishes and insects (Rathore, 2008). Evolutionary, brown bears have developed several adaptations for herbivory, including expansion of molar chewing surfaces and longer claws for digging. Nevertheless, they maintained an unspecialized digestive system capable of digesting protein with efficiency equal to that of obligate carnivores (Bunnell and Hamilton, 1983). Most commonly, sun bear feeding habits were quantified by analysis of scat contents. However, because of the differential digestibility of foods, contents of fecal residue were rarely equivalent to amounts of foods ingested by bears. The underestimation of highly digestible foods was found most pronounced for meat and fish diets (Hewitt and Robbins, 1996).

The feeding ecology of sun bears was found to omnivorous, with a principal diet as a fauni-frugivore largely consisting of fruits, termites, ants, bee honey, larvae, beetles, earthworms and occasionally small animals, and mushrooms, succulent plants and flowers (Lekagul and McNeely, 1977; Payne *et al*., 1985; McConkey and Galleti, 1999; Wong, 2002; Augeri, 2002, 2003 and Fredriksson, 2001). It was found that fruits comprised the primary food resource for sun bears. At least 37 species of fruits were recorded in the sun bear diet in the East Kalimontan and *Ficus* spp. were the most frequently occurring fruits in the diet of bears during inter-mast periods (Fredriksson unpubl. data as cited in Meijaard *et al.*, 2005). It appeared that fruits from the Fagaceae family (oak) could dominate the frugivorous diet of bears at higher elevations (Davies and Payne, 1982; Augeri, 2003 and Meijaard *et al.*, 2005). At least 48 species of termites and 60 ant species were documented in the diet of sun bears in Sungai Wain (Fredriksson *et al.*, 2006 and Meijaard *et al*., 2005). While Wong (2002) observed a variety of vertebrates in the scats of sun bears consisting of birds, eggs, reptiles, fish and several unidentified small vertebrates. Less than 1% of 1,297 scats collected between 1997-2003 in southern East Kalimantan and in northern East Kalimantan and northern Sumatra (this study were found to) (n=40) were found to contain hair or bone remains by G. Fredriksson (n=1,257) (as cited in Meijaard *et al.*, 2005). It was unknown as to how much time sun bears devoted to foraging, but several researchers had reported foraging activity as long as 20 hours/day of *U. arctos* and *U. americanus,* particularly in the periods prior to denning (Jonkel and Cowan, 1970; Rogers, 1976, 1987; Craighead *et al.*, 1995; Powell *et al.*, 1997 and Augeri, 2005). On a community level, sun bears were found to be a significant seed disperser, an important ecological component they were found dispersing seeds of for large-seeded trees (*Durio* spp. *Artocarpus integer* and *Dacryodes rugosa*) (McConkey and Galleti, 1999; Augeri, 2001, 2003; Fredriksson, 2001 and Wong, 2002). Sun bears were also found have an important lateral and hierarchical influence on community-wide dynamics through competition, insect and small vertebrate predation, soil turn-over and aeration, nutrient mixing and biomass decomposition.

Both spatial and temporal availabilities of food were found critical for sustaining healthy physiological and reproductive condition in bears. Mast fruiting, mass insect hatching, fish migrations and prey-calving were important for northern bears to build fat reserves to survive long hibernation (Jonkel and Cowan, 1970; Rodgers, 1976, 1977; McLellan and Shackleton, 1988; Stirling, 1993; Craighead *et al*., 1995 and Powell *et al*., 1997). Mast-fruiting was critical for tropical bears to survive long inter-mast periods or maternal denning (Meijaard *et al.*, 2005 and Fredriksson, 2005). Because all bear species could be highly susceptible to prolonged periods of primary forage loss, they needed unrestricted access to resources on a constant basis throughout the landscape to enhance their fitness (Rogers, 1976, 1987; Kasworm and Manly, 1988; Craighead *et al.*, 1995; Powell *et al.*, 1997 and Craighead, 2000). Sun bears were no exception. Wong (2002) observed 33-66% mortality of marked sun bears in Danum valley, Sabah, where the primary cause was suspected to be poor physiological condition from low food availability (Wong, 2002 and Wong *et al.*, 2004). Fredriksson (2005) reported similar forage deficiencies in the Sungai Wain Protection Forest, East Kalimantan.

Due to the highly-patchy nature of tropical food resources across variable geographic and temporal scales, especially of primary sun bear forage (fruits, termites, ants, bee hives), sun bears could depend on contiguous habitat and landscape features that facilitated unrestricted access to food resources. Sun bears were found to occur in areas where there were diverse productive and rich food sources. Poor habitat condition or habitat losses were found important and sometimes found influencing on the ecological dynamics of bears. Small habitat patches were most susceptible to stochastic and human disturbances, which could affect fruiting patterns, productivity and distribution, as well as access to those resources (Lovejoy *et al.*, 1986 and Laurance *et al.*, 2001, 2002). In East Kalimantan, 60% loss of suitable habitat by fires and human encroachment induced sun bears to forage outside the Sungai Wain Protection Forest, particularly in agricultural areas along forest edges (Fredriksson, 2005). Alternating drought and rain were found to have notable influences on fruit productivity in the tropics, particularly on dioecious and other figs, which were important resources for sun bears throughout year (Fredriksson, 2001; Augeri, 2002 and Wong, 2002). Such pressures turned species like sun bears with a predominantly frugivorous diet highly dependent on alternative resources, especially the areas outside these areas. In contrast, large tracts of contiguous undisturbed forests were found to support less disturbed and more stable micro-climatic conditions (Lovejoy *et al.*, 1986; Bierregaard *et al.*, 2001 and Laurance *et al.*, 200, 2002). This stability in undisturbed forests was found to increase the availability of fruit-bearing trees across a more accessible and diverse landscape, including the availability during stochastic episodes like fires and El Niño southern oscillation events that could affect mast-fruiting in the tropics (Ross *et al*., 2002; Condit *et al*., 2004; Bebber *et al.*, 2004 and Fredriksson, 2005). These episodes would not create as significant effect in large continuous forests as in smaller forests subject to disturbance and edge effects (Lovejoy *et al.*, 1986; Bierregaard *et al.*, 2001; Laurance *et al.*, 2001, 2002; Augeri, 1995, 2003 and Meijaard *et al*., 2005).

Access to forage cover and suitable habitat were important for all bears and these factors appeared to cause significant influences on sun bear habitat use (Augeri, 2003 and Meijaard *et al*., 2005). For the majority of bear species, environmentally-stochastic events like resource and habitat losses could influence bear health, movement, mating, recruitment and population dynamics (Jonkel and Cowan, 1970; Rogers, 1976, 1987; Craighead *et al.*, 1995; Powell *et al.*, 1997 and Wong, 2002). The effects of such stochastic events on bears, however, could be exacerbated by logging, habitat loss and other disturbances (Mattson *et al.*, 1996; Merrill *et al.*, 1999; Augeri, 2001, 2003; Fredriksson, 2005 and Meijaard *et al*., 2005). The net result of forest loss and degradation in Indonesia was increased fragmentation of habitats with corresponding effects of insularity isolation and stress on remaining sun bear populations (MacKinnon *et al*., 1996; Santiapillai and Santiapillai, 1996; Whitten *et al.*, 2000; Laidlaw, 2000; Augeri, 2003; WRI, 2004 and Meijaard *et al.*, 2005).

2.6.7 Reproduction

There are no quantitative data regarding sun bear reproduction in the wild. Based on captive bears, oestrus was found to start at three years of age, but first parturition could be at about five years (Meijaard *et al.*, 2005). Stirling (1993) reported that cubs were born throughout the year in captivity, which was also verified in Indonesia (Fredriksson, 2005). Dathe (1970) reported two successful births to a single female in one year, all indicating possible a seasonal breeding. According to Dathe (1970), females were found capable of having pregnancy soon after they lose cubs. Gestation periods for captive sun bears were recorded to range from 90 to 240 days, of which the upper time length suggested delayed implantation as seen in with other bear species (Stirling, 1993). Local people in Indonesia reported that sun bears gave birth and/or reared young cubs in hollow logs or other secure natural cavities at the base of large trees (Meijaard *et al.*, 2005). The majority of such evidences was found in primary forests and was rare in secondary forests younger than 30 years. There were also observations by locals that an adult sun bears fled from inside a hollow log in Sungai Wain Protection Forest, East Kalimantan, found presence of a young or new-born cub in the log (Fredriksson, 1998). There was no evidence of the mother or return of the cub and it was assumed that the mother likely abandoned the log due to human disturbance. Like other Ursidae, sun bear mothers were found most likely waiting until the cubs were weaned and large enough or died before having another (Nowak, 1999). Captive litters consisted of one or two cubs weighing an average of 325 grams each (Nowak, 1991) and either one or two cubs were observed with adult females in the wild (Fredriksson, 2005; Nowak, 1999 and Meijaard *et al.*, 2005). Camera-trapping in this study captured one instance of a female with two yearling cubs in Kayan Mentarang National Park, whereas other photo captures of females accompanied by were of one cub.

2.6. 8 Social aspects of reproduction

Most bears are considered to be primarily solitary, except for mothers with cubs. There was almost no information about social system of sun bears in the wild (Stirling, 1993). They were reported as often traveling in pairs (Lekagul and McNeely, 1977 and Domico, 1988), however, an adult female with similar sized cub could a likely explanation. Females with young and siblings were reported, and even groupings of several bears could be possible at large food sources (Meijarrd, 2005). The limited field data of Normua *et al.* (2004) supported the solitary lifestyle of sun bear.

The home range of a male sun bear's was reported to be more than three times larger than that of a female. American black bear males also showed much larger than females and home range of a male's might overlap with that of several females (Stirling, 1993). Whether or not this overlapping existed in sun bears remained. Nomura *et al.* (2004) tracked a radio collared male and female sun bear that stayed separate except for a few days in October during 1999 and 2000; it was assumed that they mated during these periods. Mating in sun bears was reported to occur between one and four days (Schwarzenberger *et al.*, 2004).

Behavioral oestrus was reported to last up to 5-7 days, but it might often be shorter lasting only 1-2 days (Domico, 1988 and Johnston *et al.*, 1994). Further it was found that the combined 4-days period on either side of peak estrogen reflected the majority of physiological and behavioral changes associated with oestrous. Sexual behavior found to be greater in the four days following peak estrogen. This finding was different than the result of Schwarzenberger *et al*. (2004), which indicated estrogen precursors coinciding with peak mating. The period of courtship or male visitation prior to breeding appeared to be shorter in sun bears than in some other bear species where it might span for weeks, i.e. American black bears (Barber and Lindzey, 1983 and Ward and Kynaston, 1995). Endocrine data on reproductive cycles from 13 captive female sun bears did not support sun bears being copulation-induced ovulators. It remained unclear whether or not olfactory cues were as important to sun bears as they were to giant pandas (Knauf *et al.*, 2002; Swaisgood *et al.*, 2002 and White *et al.*, 2003). Male sun bear sniffing the urine or feces of females increased markedly in frequency, time and intensity as oestrous approached. This pattern was also observed to a lesser extent in sun bear females. But when unpaired females were presented with male urine or feces, it did not result in any discernable changes to the cycle (Frederick, 2005). Behavioral interactions, however, did seem to play a role in stimulating (male) or suppressing (female) the oestrous cycle depending on the positive-negative nature of the interactions. Contrary to what was reported in some other bears (Boone *et al.*, 2004), sun bears appeared to be primarily spontaneous ovulators like the giant panda (Durrant *et al.*, 2002).

2.6.9 Seasonality

The sun bear, unlike the other seven bear species reported to be reproductively a seasonal (Spadey *et al.*, 2007). Estrus and births were found to occur in nearly every month (Dathe, 1975; Schwarzenberger *et al.*, 2004 and Spadey *et al.*, 2007). Only Onuma *et al.* (2001) considered sun bears as seasonal in Borneo, but their less frequent sampling regime might result in missed cycles (Schwarzenberger *et al.*, 2004). Captive male testosterone patterns also did not appear to be seasonal and instead these were corresponding to the fluctuations observed in the females with whom they were socially housed. Similarly it was found that captive sun bear male testosterone concentrations did not vary seasonally, but did seem to increase after 3-4 month intervals corresponding to peak reproductive activity (Hesterman *et al.*, 2005). In giant pandas male androgen elevations were also found to correspond with peak female receptivity (Bonney *et al.*, 1982). There was, however, a tendency for captive births in the United States to occur more often in fall or winter. This tendency suggested either a similarity with temperate bears or that spring and summer estrous cycles were more likely to be conceptive.

Anecdotally, spring cycles were often observed to be behaviorally stronger than those occurred at other times, particularly during the winter months. In a sun bear female that was monitored for six consecutive years of reproductive cycling, the spring estrus was the only one to never be skipped whereas the winter cycles were least frequent. There could be minor influences such as stress from cold weather that sometimes inhibited cycling. Dathe (1966) stated that estrus could be induced in the winter months simply by keeping this tropical bear warm. In East Kalimantan, although there was not a significant difference, more wild cubs in the sample were born during the wet season (n=11) from November to April than during the dry season (n=7) from May to October (Schwarzenberger *et al.*, 2004). Onuma *et al.* (2001) also speculated that, based on the timing of estrus in the captive females in Sarawak, Malaysia, delivery was during the wet season between December and February. The tropical Andean bear were also found to give birth during the rainy season from November to February. However, Schwarzenberger *et al.* (2004) concluded that since wild sun bears were born in 15 out of 25 months, they were not seasonal breeders.

Temperate bears were typically found to live where there were distinct seasonal changes in food abundance and reflecting that these species had seasonally changing home ranges, a phenomenon not seen in the sun bear (Wong *et al.*, 2004). Scat analyses performed across seasons did not indicate shifts in diet (Wong *et al.*, 2002). Unlike the hibernating temperate bears, sun bears were found active year round (Wong *et al.*, 2002). Within individual female sun bears studied, there appeared to be fidelity to particular months or regularity in the cycling pattern. In non-conceptive cycles this resulted primarily from an inter-estrus interval that remained relatively constant. Thus up to three cycles per annum might be seen (Smith, 1979 and Spadey *et al.*, 2007).

2.6.10 Nesting ecology

Malayan sun bears were found to use several kinds of bedding sites. The use of tree nests by sun bears was reported by Fetherstonehaugh (1940), Lekagul and McNeely (1977), Piether (in Santiapillai and Santiapillai, 1996) and McConkey and Galetti (1999) Pieters (in Santiapillai and Santiapillai, 1996) suggested that sticks nests were used mostly in secondary forest. (Chauhan and Sethy, 2011) observed 50 nests in north-east, India forest area and Similarly (Meijaard, 1999) observed 14 nests in plantations and gardens and none in the forest area. McConkey and Galetti (1999) found three sun bear nests in the tree canopy in a 430 hectare forest located in Central Kalimanatan, Indonesia, where orang-utans were absent. Although there was no information about human disturbance in the forest, but the small forest size implied potential disturbance from the surrounding environment. Nest building might be more common in areas with significant human disturbance and safe resting places were rare (Meijarrrd, 1999). In addition, the presence of big cats such as tigers and leopards in Sumatra and the Asia mainland might cause sun bears to seek safer beds.

In contrast to the reports of sun bears using tree nests as beds, the use of tree cavities by sun bears was never reported. Other bear species such as Asiatic black bears (Lekagul and McNeely, 1977; Wang, 1988 and Li *et al.*, 1994), American black bears (Hayes and Pelton, 1994; Weaver and Pelton, 1994 and White *et al*., 2001), and giant panda (Schaller *et al*., 1989) also utilized hollow tree cavities, not as beds, but as denning sites.

2.6.11 Denning ecology

Denning ecology is important to bear survival and reproduction. American black bears were often found to select specific den types, presumably to reduce energy expenditure and increase cub survival (Johnson and Pelton, 1979, 1981; Lentz *et al*., 1983 and Alt, 1984). Specific den types also might be important for predator avoidance, especially for females with cubs (Lindzey and Meslow, 1976; Rogers and Mech, 1981; Ross *et al.*, 1988 and Pikunov *et al*., 1991). Asiatic black bears used a greater variety of den types than did brown bear, sloth bear and sun bear, and use of ground dens by Asiatic black bears was documented in many areas (Abramov, 1972 and Reid *et al*., 1991). During denning, bears did not eat, urinate or defecate and relied on fat reserves attained during the non-denning period (Hellgren, 1998). Dens were constructed or selected to provide thermal insulation (Vroom *et al*., 1980) and security cover for denning bears and birth sites for pregnant females (Swenson *et al*., 1997). There was general agreement that denning behaviour might be triggered by a reduction in availability of forage items (Servheen and Klaver, 1983; Schoen *et al.*, 1987 and Haroldson *et al.,* 2002) and reproductive status of individuals (Van Daele *et al*., 1990 and Mace and Waller, 1997).

Bears were found to excavate dens into the sides of slopes, and dens excavated by grizzly bears were reported often (Vroom *et al*., 1980; Servheen and Klaver, 1983; Van Daele *et al.*, 1990; Seryodkin *et al*., 2003 and Ciarniello *et al*., 2005). Numerous authors investigated the denning ecology of black bears using a variety of den types, such as excavated ground cavities (Johnson and Pelton, 1981), elevated tree cavities (Johnson and Pelton, 1981; Weaver and Pelton, 1994 and White *et al*., 2001), ground level tree cavities (Jonkel and Cowan, 1971; Johnson and Pelton, 1981 and Beecham *et al.*, 1983), rock crevices (Johnson and Pelton, 1981 and LeCount, 1983), brush piles i.e. logging slash, felled tree tops (Hellgren and Vaughan, 1989; Weaver and Pelton, 1994 and White *et al*., 2001) and other den types where bears were enclosed in a cavity (Jonkel and Cowan, 1971). Weaver and Pelton (1994) and White *et al.* (2001) observed that bears preferred tree and excavated ground dens over nest or brush dens.

2.6.12 Human-bears conflict

Most species of bears are opportunistic omnivores. Bears may be considered pests when attracted to human-related foods. North American bears (grizzly bears *U. arctos* and American black bears *U. americanus*) were known to use apiaries, crops, orchard fruits, garbage and livestock for food (Ambrose and Sanders, 1978; Knight and Judd, 1983 and Garshelis *et al.*, 1999). They also might afflict considerable damage to timber stands (Stewart *et al.*, 1999). In Japan, Asiatic black bears (*U. thibetanus*) were found to raid crops, orchards and fish farms (Huygens and Hayashi, 1999). Sloth bears (*M. ursinus*) were found to damage sugarcane and groundnut plantations (Iswariah, 1984). Andean bears (*T. ornatus*) in South America were found to predate on livestock (Goldstein, 2002).

Until a few decades ago, bounties were commonly used as a means of reducing or eliminating bears to protect crops or livestock (Azuma and Torii, 1980; Swenson *et al.*, 1994 and Mattson and Merrill, 2002). Bears were found to cause extensive damage to agricultural crops, apiaries, orchard fruits and livestock (Bargali *et al*., 2005; Chauhan and Sethy, 2011; Peyton, 1980; Jorgensen, 1978, 1983; Vaughan *et al*., 1989; Servheen, 1990; Conover and Decker, 1991; Reid *et al*., 1991, Stowell and Willing, 1992; Ambrose and Sanders, 1978; Azuma and Torii, 1980; Will, 1980; Watanabe, 1980; Singer and Bratton, 1980; Horstman and Gunson, 1982; Knight and Judd, 1983; Maehr, 1982; Elowe, 1984; Hygnstrom and Craven, 1986; Calvert *et al.*, 1992; Swenson *et al*., 1994; Huzumi, 1994 and 1999; Garcia-Gaona, 1997; Jonker *et al*., 1998; Garshelis *et al*., 1999; Huygens and Hayashi, 1999; Angeli, 2000; Iswariah, 1984; Chauhan, 2003; Huygens *et al*., 2004; Fredriksson, 2005 and Chauhan and Sethy, 2011b).

In Southeast Asia, sun bears (*H. malayanus*) probably started crop-raiding when attractive foods were first planted close to forest habitat. Early reports from colonialists in Indonesia described ways of deterring or killing marauding bears in fruit plantations (O-Viri, 1925). Human-sun bear interactions included attacks on people, crop depredation and hunting for consumption, sale of bear parts and effects of human resource extraction activities on bears (Mills and Servheen, 1991; Sethy and Chauhan 2011; Chauhan and Sethy, 2011 and Sethy and Chuhan, 2012b). Meijaard (1997) reported more and more sale of bear parts such as gall bladders with an influx of foreign users in Kalimantan, Indonesia.

2.6.13 Bear mortality

Bears deaths were found to be primarily human related. Natural mortality could result from old age, intra and inter-specific strife, starvation, rock or snow avalanche, den collapse or unknown reason. Natural mortality constituted a greater proportion of total mortality for dependent young ones (Nagy *et al*., 1983). Most bears were found to die during the non-denning season. Although an occasional mortality was documented during winter (McLellan *et al*., 1999) but most deaths occurred when bears were active. Aune and Kasworm (1989) and Mace and Waller (1998) reported that occasionally bear succumbed to ailments, but documenting cause of death was difficult, particularly under natural conditions.

Chapter 3

Study area

3.1 Background

The Eastern Himalayas and the hills of north-east India are recognized as a global biodiversity hotspot. While north-east region occupies 8% of the country's area, it harbours 56% of its faunal diversity. Within this region, arguably the most biodiversity rich state (the largest among the seven in north-east India, covering 83743 km^2) is the state of Arunachal Pradesh (26° 28'-29° 30'N and 91° 30'-97° 30'E). Arunachal is considered among the least developed and most remote state. Lying in the Eastern Himalayan region, Arunachal Pradesh has remained isolated from the rest of India by virtue of its geographical position and inaccessible terrain. It is situated in the north eastern most part of India and is surrounded by international boundaries of Bhutan to the west, Tibet to the north and Myanmar to the east. About 82% of the geographical area is actually forested compared to the national average of 21%, albeit the recorded forest area is 62% of the total area reported (Forest Survey of India, 2009). The state harbours the northern most tropical rainforests of the world and an estimated 7000-8000 species of flowering plants occur here (nearly 50% of the total flowering plants in India). The wide altitudinal range (100 to 6000 m) has resulted in a great diversity of forest types. Of the recorded forest area, 9722 km^2 (12%) is classified as reserve forest. Protected forests, Anchal reserve forests, village reserve forests and unclassed state forests constitute the remaining forests. The later, where tribal people have customary rights, comprise the largest area of 30965 km^2 (37% of the geographical area). Ten wildlife sanctuaries (7114 km^2) and two national parks (2468 km^2) (of which two are Tiger Reserves) covering an area of 9582 km^2 (11.44 % of the geographical area of Arunachal Pradesh) have been established.

Namdapha Tiger Reserve is situated in the Changlang district of Arunachal Pradesh and has common boundary with Kamlang wildlife sanctuary in the north, Miao reserve forest (RF), Nampong RF, Diyun RF etc. in the west, forest areas of Kachin

Province of Myanmar in the south and unclassed state forest areas of Gandhigram in the east. The total landscape with the RFs and USFs surrounding the Namdapha (i.e forest areas in Myanmar) makes a continuous patch of approximately 20,000 km^2 forest areas, which becomes wide and large home range and ideal for the conservation of animals.

3.2 Name and location

The name Namdapha Tiger Reserve is based on the name of Namdapha national park. Namdapha infect is the name of a river which originates from Dapha Bum (Dapha is the name of hill and Bum means peak of a hill). This river flows right across in an east-west direction of the national park and meets the Noadihing river. In local Singpho language, 'Nam' means water or river and 'Dapha' is the name of Singpho tribes. The local information reveals that the Singphos fought with British during mid nineteenth century but lost the battle and they left the river bank some of them fled away to the interior areas of the present national park and settled in the foot hills near the present farm base at the confluence of Namdapha and Noa-Dihing.

The reserve is located in the Changlang district of Arunachal Pradesh in the north eastern part of India, between 27° 15' N and 27° 39' N Latitude and 96° 15' E and 96° 58' E longitude (**Map 1)**.

3.3 Legal provisions

The administration and management of the Namdapha Tiger Reserve is guided by the provisions of the Wildlife (Protection) Act of 1972 (as amended up to 2006), Indian Penal Code, Criminal Procedure Code, Arunachal Pradesh Wildlife Rules of 1976, Indian Forest Act (1927), Assam Forest Regulation of 1891 etc, being followed in vogue while dealing with the protection and anti-poaching activities in the protected area and surrounding areas.

3.4 Delineation of the reservation

The Tiger Reserve has been delineated in to the core zone, encompassing over whole area having status of national park (1808 km^2) and the buffer zone (177 km^2), added to the Tiger Reserve subsequently but still having the status of reserve forest. Both the areas are completely protected and can be treated as same for protection and conservation purpose. A proposal to add ten kilometre radius on north-western boundary of the present reserve comprising of 245 km^2 as true buffer to act as protective cushion to park was submitted to the government under provision of section 38V(4) (ii) of Wildlife (Protection) Amendment Act, 2006. Five hundred meters all around the protected area boundary considered as the zone of impact, and has been proposed for notification of eco-fragile zone in view of implementation of Wildlife Conservation Strategy 2002, decision taken as per the proceedings of the XXI meeting of Indian Board of Wildlife and also as per the directive Ministry of Environment and Forest.

The proposal submitted to the Government for creating true buffer area of 10 km wide around north-western boundary of the protected area would function as Miao buffer, covering an area of 245 km^2 including Miao reserve forest lying in the ordinates 96° 08’48.5” E to 96° 25’ 02.5” E longitude and 27°39’15” N to 27°24’51.5” N latitude comprising 17 villages located on southern and northern bank of Noadihing river. These villages are Pisi, Khamuk, Lewang, Phup, Khagam Singpho, Khagam Mossang, M’Pen, Bodhisatta, Anandapuri - I, Ananadapuri - II, Kamalpuri, Nandan Kanan, Punyabhumi, Pakhand, Deban village, Lama Camp and Khatan villages (**Map 2)**.

3.5 Constitution

Prior to the constitution of Arunachal Pradesh, the entire union territory was known as North East Frontier Agency (NEFA). Past history reveals that scheme for the constitution of a national park in NEFA was prepared by Sri W. Meiklijohn, the then forest adviser to the governor of Assam in the year 1947. The area chosen for the purpose fell in the valley of the Diyun or Noa-Dihing river and its catchments areas have elevation above mean sea level varying between 200 msl at the then Miao village to 4571msl on Daphabum offering a great diversity of flora and fauna. The scheme aimed at the establishment of a national park for public recreation, research and study of wildlife in natural surrounding over an area of 802.9 square miles. The notification was issued by the Governor of Assam as Namdapha reserve forest in the year 1970.

As the area of the proposed reserve forest extending up to Patkai range and Daphabum is situated just on the inter district boundary between Tirap and Lohit, it can be suitably named as Namdapha reserve forest instead of Daphabum reserve forest as the river Namdapha flows through the area. Subsequently the whole reserve was declared as a wildlife sanctuary in the year 1972 under the Assam Forest Regulation 1891 and in June, 1983 only, the whole area of the sanctuary was declared as a national park under the Wildlife (Protection Act 1972).

3.6 Area statement and legal status

The total area of the reserve is 1985.25 km^2 (1807.82 km^2 core and 177.43 km^2 reserve forest area as buffer), delineated on the north south and south east by the international boundary between Myanmar and India, on the north and west the reserve area is surrounded by contiguous patch of reserve forests of Lohit and Changlang district with the exception of Deban, M'Pen and Gandhigram settlement areas, there is no other village in the periphery of the reserve. The entire notified national park area was neither having revenue nor forest village, however five encroachments developed subsequently within notified core area only.

The total area of the is 2200.25 km^2.The core area of 1807.82 km^2 is having the status of national park, but the present buffer of 177.425 km^2 area has been added during 1986 and still having the status of reserve forests. The surrounding area can be categorized as reserve forests, unclassed state forest and international boundary. The reserve forests in Changlang district were formerly managed by Arunachal Pradesh Forest Corporation for all purposes, but ownership vested with the government. Now the Corporation is defunct and these reserve forests are with the forest department, where local people have the right of way and collection of non timber forest product for household use and their other rights have been ceased. The forestry operation in the unclassed state forests are regulated by the state forest department, but the land of unclassed area is dealt with by the administration of the state government. New areas from unclassed state forest are classed every year for various purposes. The Tiger Reserve is facing problems of movement of the lease holders or contractors of various forest produce from the unclassed forests through the national park or within its boundary in the absence of any alternative road to Miao, because while passing through the national park, it is apprehended that the contractors may resort to some illegal activity. This is the most important handicap for the management of the reserve. Similar is the case with the other forestry operations in Deban area, for which one is required to pass through the protected area.

3.7 Biological values

3.7.1 Flora

The flora of is unique, rich, dense and diverse in species composition. It supports several endemic species that have evolved locally or have survived only because of protective natural barriers against the invaders. In the phyto-geographical relationships and affinities, the flora of shows greater affinities with Indo-Malayan flora, although it also harbours the plants of other parts of India, neighbouring as well as far off places along with its own flora.

On the basis of survey carried out by the Botanical Survey of India in two third parts of this protected area, it is observed that there are 73 species of lichens, 59 species of Bryophytes, 112 species of Pteridophytes, 5 species of Gymnosperms and 801 species of Angiosperms by (Sharma *et al.*, 1990). All these species have been listed in the (**Table 1)**

Table 1: Group of plants identified in Namdapha Tiger Reserve.

Group of plants	No. of families	Genera	No. of species
Lichens	18	35	73
Bryophys	21	34	59
Pteridops	35	53	112
Gymnosps	3	4	5
Angiospem	41	277	801

This survey does not include the floral elements of temperate and alpine regions as the same has not been explored due to inaccessibility and lack of infrastructure. Recently during February and March 2009, survey on expedition mode conducted by the park officials up to 1871m altitude revealed that the tree species found were of the tropical rain forest region and also the presence of *Rhododendron* species, but no conifer was recorded.

According to the estimates of the Hooker (1904), the Indian subcontinent showed the proportion of monocots to dicots as 1:0.3 and genera to species as 1:7, whereas Namdapha protected area showed these ratios as 1:3 and 1:6.6 respectively. Sharma *et al.* (1990) revealed the uniqueness and richness of the vegetation in Namdapha. As per the Botanical Survey of India report of 1990, many taxa reported as rare and endemic in other parts of the north-east region were found in this protected area, and some of them growing profusely in this area, are *Achyranthes superba*, *Angiopeteris erecta*, *Bruinsmia polysperma*, *Cheirestylis pusilla*, *Cyathea giganteum*, *Arundina graminifolia*, *Gnetum ula*, *Glyeosmis cymosa*, *Lycopodium phegmaria*, *Magnolia griffithii*. Apart from these, many primitive species of the Annonaceae, Lawraceae, Myrsinaceae and Piperaceae etc. are found in this protected area. However, many taxa of nearby region i.e. Sino-Himalayan, Bhutan, Myanmar, Malaysia and to some extent, taxa of peninsular Indian affinity have been found in this protected area, exhibiting the richness and genetic diversity of the floral elements of this area. In view of number of rare, endangered and threatened taxa, two new genera, four new species, three new records for India and fourteen new distributional records have been reported so far (Sharma *et al.*, 1990).

Many plants having medicinal properties are widely used by the indigenous tribes for treatment of different ailments. Each of the tribe has its own way of treatment. These medicinal plants have lot of scope for inventorisation and confirmation by proper tests for the benefit of mankind. Out of 186 ethno-botanical plants in use, 81 plants have some medicinal values. Some of these plants are *Abroma angusta*, *Achyrarthes aspera*, *Aquillaria spp.*, *Barleria cristata*, *Canabis Centella*, *Citrus spp.*, *Clerodendron spp.*, *Cyathea spp.*, *Dillenia spp.*, *Dioscorea spp.*, *Elaeocarpus spp.*, *Equisetum spp.*, *Musa spp.*, *Piper spp.*, *Schima spp.*, *Solanum spp.*, *Syzigium* and *Terminalia spp.*

3.7.2 Fauna

Tiger Reserve is located at the junction of the Indian sub-continent biogeographic region and the Indo-China biogeographic region (Dinerstein *et al.*, 1997) and hence faunal diversity exists. Moreover according to Kurup (1974), this belt acted as a faunal gateway through which the Indo-Chinese elements of the Oriental as well as Palaearctic fauna could spread to India and colonized when the Indian Peninsula and Asiatic mass were linked through land bridge. Most of the faunal dispersal took place through this gateway due to the natural barriers of the Thar desert in the west, the great oceans in the south and the high Himalayas in the north because of which extensive diversity of fauna resulted. Due to this fact, in every group along the evolutionary pathway, large and diverse species complexes existed in the protected area and its surrounding areas. The comprised of diverse pattern in vegetation and it was found rich in autotrophic components which led to a richness of heterotrophic organisms. The faunal group inhabiting forests, soil, ground, litter, under stone, decaying woods and grasslands comprised 1285 species, and they are listed below as per checklist prepared during 1999-2000 **(Table 2)**.

Namdapha is known for its diverse faunal assemblage. Carnivores present are tiger, leopard, snow leopard and clouded leopard. It is also the habitat of the endangered mammalian species like slow loris and hollock gibbon, the only ape species of India. A variety of other threatened mammals recorded here include golden cat, marbled cat, dhole, Asiatic black bear, red panda, musk deer, takin, gaur, wild Asiatic water buffalo, flying squirrel and various reptiles viz. cobra, viper, krait, python etc. The rare and most endangered leaf deer (*Muntiacus putaoensis*) and black barking deer (*Muntiacus crinifron*) found only in China and Myanmar has been discovered in Namdapha. Birds are indicative of the unique faunal diversity of Namdapha. Notable species of birds include lesser fishing eagle, mountain hawk eagle, grey peacock pheasant, imperial pigeon, pin-tailed green pigeon, oriental bay owl, rufous-necked hornbill, great Indian hornbill, red-headed trogon, Hodgson's frogmouth, lesser shortwing, scarlet-backed flower pecker, rufous-necked and crimson-winged laughing thrush, white-hooded shrike babbler, sultan tit, beautiful nuthatch and Temminck's tragopan. Namdapha Tiger Reserve having different forest type i.e. mixed forest, Tropical wet-ever green forest, Tropical semi-ever green forest, Semi-ever green forest, Temperate forest and Bamboo forest.

Table 2: Faunal group and number of species in Namdapha Tiger Reserve.

Faunal group	**No. of species**
Earthworm	10
Leeches	5
Insects except Lepidopteron	430
Butterflies and Moths	300
Fishes	76
Amphibian	25
Reptiles	50
Birds	453
Mammals	97

Out of the total 135 genera of land mammals available in India, 75 genera are represented in Namdapha protected area, whereas among 9 orders, Carnivora is richest with 22 genera, as mentioned in the following table including tiger, leopard, clouded leopard and snow leopard existing in the same area in different niches **(Table 3).**

Table 3: Order, genera and specie of animal in Namdapha Tiger Reserve.

Order	**Genera**		**Species**
	Total in India	**Total in Namdapha**	
Insectivora	11	5	11
Chiroptera	28	10	6
Primata	5	4	1
Pholidota	1	1	1
Carnivora	26	22	29
Proboscidea	1	1	1
Pterissodactyla	1	-	-
Artiodactyla	21	11	13
Logomorpha	3	1	1
Rodentia	38	20	30

Besides, 14 species of beetles, 4 species of land mollusc, 5 species of fishes, 3 species of amphibians including the only Indian salamander (*Tylolototriton verrucosa*), rare turtle (*Cycloms mouhati*) and 3 species of snakes belonging to the genus *Natrix* have been reported. New species of flying squirrel, namely, Namdapha flying squirrel (*Biswamoyeeptarus biswasi*), leaf deer (*Muntiacus putaoensis*) black barking deer and Chinese goral are noteworthy reports from Namdapha. During recent survey of butterflies conducted during 2008 to 2009, 242 and 300 + species were recorded from Deban and surrounding areas alone respectively. Peculiar feature of the survey was variation of species found during post monsoon and spring season.

3.8 Park values

3.8.1 Functional values

The exhibits lush green landscape which is acting as carbon sink for the industrial areas of Kharsang coal mines and petroleum wells. Though large sized mother trees are almost nil in surrounding area due to commercial extraction but Namdapha is the only refuge of these tree species and seed stand for future.

3.8.2 Physical attributes

The topographical and geological variation in the Tiger Reserve provides a scenic beauty; with gentle rocky hills to steep rocky cliffs on roadside and Chiriapoong area. In addition, other lakes are source of aesthetic values to the people.

3.8.3 Conceptual values

Harbours a number of endemic and interesting flora and fauna due to which the reserve is considered as complete ecological unit. The endemism nature has the following features:

i. Amongst the animals of higher groups, five species of fishes are new to science and endemic to Namdapha. They are *Danio horai* and *Barilius jayarami* of the family Ciprinidae; *Aborichthys tikadari* and *Neomacheilus arunachalensis* representing family Cobitidae and *Kryptopterus indicus* belongs to the family Siluridae.

ii. Out of the 25 species of amphibian recorded from Namdapha, three species belonging to family Rhacophoridae (*Rhacophorus namdaphaensis*, *Philautus namdaphaensis* and *Philautus shyamarupus*) are new to science. The only salamander found in India *Tylototriton verrucossus* (*Pleurodeles verrucossus*) has been recorded by Zoological survey of India.

iii. The bird, Namdapha shortwing (*Brachyopteryx criptica*) has been recorded by Zoological survey of India.

iv. Presence of Leaf deer (*Muntiacus putaoensis*) and black barking deer (*Muntiacus crinifrons*) was reported by the Nature Conservation Foundation, Mysore. Besides these, four species of land Mollusc, rare turtle (*Cycloms mouhati*), three species of snakes belonging to the genus *Natrix*, new species of flying squirrel, namely, Namdapha flying squirrel (*Biswomoyeepterus biswasi*) and 14 new species of beetle are noteworthy from Namdapha. Probably many more species of plants and animals may be present in this Tiger Reserve.

3.8.4 Recreational values

The Tiger Reserve has a great richness of flora and fauna and thus has a great scope for the people to enjoy the aesthetic values of its wilderness. Bird watching on existing trails and water bodies, viewing wildlife such as butterflies and moths in different seasons and habitats is the source of recreation. In recent survey of butterflies, more than 300 species were recorded, out of which, three were are very rare and the first record in India and one species is yet to be identified. In addition, Namdapha has an immense potential for nature camp, hitch hiking, adventure tourism etc. Moreover the waterfalls and lakes inside the reserve add beauty to the protected area.

3.8.5 Scientific values

The provides ample scope for the scientists to study in different disciplines right from geology for the variety of rocks and other geological formations, for chemistry of the water of Bulbulia lake and its chemical nature having an immense value to the local tribes as they believe that sprinkling of water of this lake acts as disease controller and thus requiring study of the chemicals present there in the water. Botanists can study the varieties of plant species at least of high hills not explored yet and zoologists as well as wildlife's can study the different groups of animals.

The park management is carrying out research on the regeneration of major tree species and its impact on the regeneration of some species of plants, rhizome formation and flowering in bamboos, regeneration pattern and availability of animals in grassland areas by dung count methods. The protected area also provides scope for studies in taxonomy of rare and endangered plants and animals, insects, fishes, amphibians etc.

There is a great scope in this Tiger Reserve to study the alternate prey potential for tiger in view of low density of ungulates presumed to be inadequate to support large number of tiger population. The archaeologists need to study the old temples and monuments to find the history of these constructions as their age is totally unknown. The palaeontologists have immense scope of studies of the fossils generally found in the stratified rocks.

3.8.6 Educational values

The Tiger Reserve provides a great scope for nature education, conservation education etc. The diverse plant and animal kingdom provides ample scope for the study of botany, zoology, ecology, entomology, geology and almost all spectrums of life sciences to compare the situations in protected area and nearby reserve forests.

3.8.7 Ethological values

The temples in the fringe areas of and wisdom stones have got an immense mythological value to the local people. Even the Bulbulia lake is regarded as a holy place, and people believe that the water of the lake has got a disease immunity power in the human and animal bodies. The hollow stone situated on the uphill side at 13th mile is regarded as holy place by the Tibetan buddhists for paying offerings during festivals. Many people visit the place on specific occasions.

3.8.8 Historical values

The Tiger Reserve has got a very important role to play in the history of the state especially with regard to the old ruined temples and the old stone pillars at 13th mile which are being worshipped by the Tibetan refugees. The stone idols now kept at Parbateswar temple on the side of the road towards Deban and also the beautiful old forest rest house are worth preserving from religious point of view. These stone idols were found in the debris of landslides.

3.8.9 Real or economic values

In view of ban on exploitation of timber and non-timber forest produce which are not permitted under the provisions of Wildlife (Protection) Act of 1972, the protected area has got notional value of excellent stocking of valuable timber like hollong, mekai, hollock etc, and other non-timber forest produce like varieties of bamboo, cane, and other produces like agar, dhuna (resin) and honey produced by the honey bees of high quality. Besides, there are plenty of mineral resources in the protected area such as coal, lime stone etc. which are not allowed to be removed.

Therefore, it is a very significant conservation unit whose statements of significance are as follows:

i. Diverse geological formations, diverse habitats supporting biodiversity of plants and animals.

ii. The acts as catchment of important rivers, viz. Namdapha, Karwai Hka, M'Pen etc. whereas its forests act as carbon sink for industrial pollutants and effluents.

iii. Namdapha Tiger Reserve is a beautiful landscape with high hills, meadows, lakes, riparian zones etc. is an excellent physical attribute for public.

iv. It provides ample scope for the visitors to experience wilderness besides trekking, bird watching and wildlife viewing.

v. This provides ample scope for scientific studies and research for scientists such as botanists, zoologists, geologists, palaeontologists, archaeologists, entomologists, orchidologists, soil scientists, chemists etc.

vi. The protected area provides scope for education in nature and conservation also.

vii. This has large significance related to religious, cultural, historical and ethological aspects.

viii. Lastly the conservation unit can be considered as forest wealth or green gold for future generations which would be used as carbon credit.

3.9 Geology and soil

3.9.1 Geology

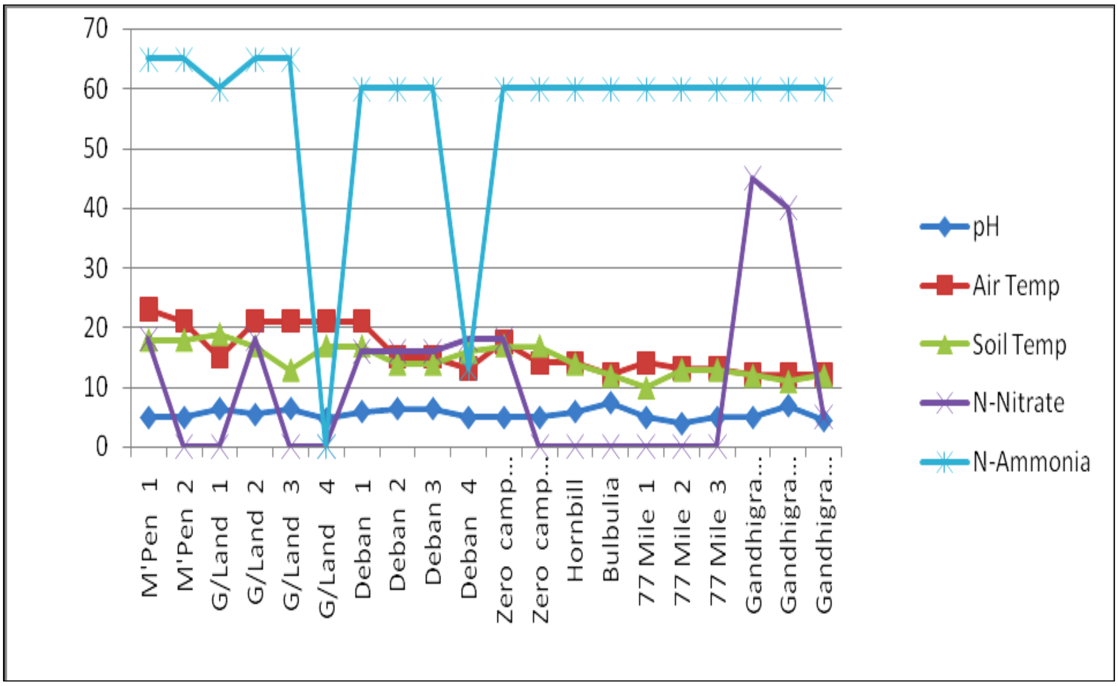
During the period from late fifties to early eighties, Geological Survey of India had conducted surveys in the and collected various geological information which so far could lead to the deciphering of geological aspects structural, tectonic and geomorphic in broad patterns and confined to some extent in establishing the mineral resources of the park. The Area is bounded on the north by Daphabum range and in the south by Patkai range. Noa-Dihing river forms the main drainage system in the area.

Geological formation includes tertiary and quaternary sequence which is the extension from Nagaland and upper Assam. Geologically the area is bounded tectonic lineaments which remained active in various geological periods between upper cretaceous and pleistocene times. They were The ENE-WSU trending mega Patkai range which constitutes imbricate thrust, and the NW-SE trending mishmi thrust along the Lohit foot hills.

3.9.2 Soil

The soil is characterized by a surface layer of considerable depth and loamy texture with colour varying from yellowish to reddish. It is acidic in nature. Deep layer of sandy loam soil rich in vegetative matter is also found in the lower gentle slopes of the hills which support the best fully stocked dipterocarps forests. On the river banks and precipitous slopes, the soil depth becomes shallow while on the areas near the river banks liable to be frequent inundation, the soil tends to be sandy on the sloping grounds and loamy on the plains. Zoological survey of India had carried out a detailed analysis of the soil and water in various sites inside the protected areas as well as in the surrounding areas during 1981 to1987. The findings are shown graphically below **(Figure 1).**

Figure 1: Soil characteristics in various sites in Namdapha Tiger Reserve.



3.9.3 Climate

The area falls within the geographical sub-tropical region and has sub-tropical climate with a distinct short cold weather from November to February in the lower reaches. This is most pleasant period when humidity in the air is least, cold season is for longer period at higher altitudes as on other Himalayan mountains. With the onset of south west monsoon, the humidity rises in the month of May. This along with the rise of temperature makes the weather oppressive especially during the month of June, July and August. The tract is highly malariacious.

Because of the altitudinal variation from 200 m to 4500 m and area under zone of heavy rainfall, the climate varies at different heights. Since the interior high altitudinal areas have not been explored much, climatologically classification for these zones is not possible at the moment. On the other hand, there is no meteorological observatory in the areas. However, on the basis of experience and available information, seasons can be classified as the cold season i.e. from December to February, the pre-monsoon season of thunder storms i.e. March to May, the south west monsoon mainly till September, and the post monsoon season and is a period of transition i.e. from October to December. The varied topography has a profound influence on the climate which varies according to elevation and locations. The mountainous parts of the territory have mountain types of climate while the low lying narrow peripheral plains and the valleys experience tropical climate.

The mountain type of climate is characterized by the unique influence of mountainous terrain on air temperature and its variation, which in turn cause other weather phenomena like occurrence of fog, thunderstorm etc. There is large diurnal variation of temperature particularly in the valley.

3.9.4 Rainfall

High rainfall during the monsoon is an important feature of this state. The territory receives winter rainfall particularly in the northern parts from western disturbances. Narrow peripheral strip of land below the elevation of 1000 m surrounding the

Brahmaputra valley is the rainiest part of the territory receiving more than 250 cm of rain annually. In this region, the rainfall increases to 400 cm towards east. The number of rainy days i.e. days with more than 2.5 mm of rains averages from 125 to 150 cm annually. The variations in the amount of precipitation received from year to year are not significant. This territory rarely suffers from droughts but floods on the other hand are frequent in some parts.

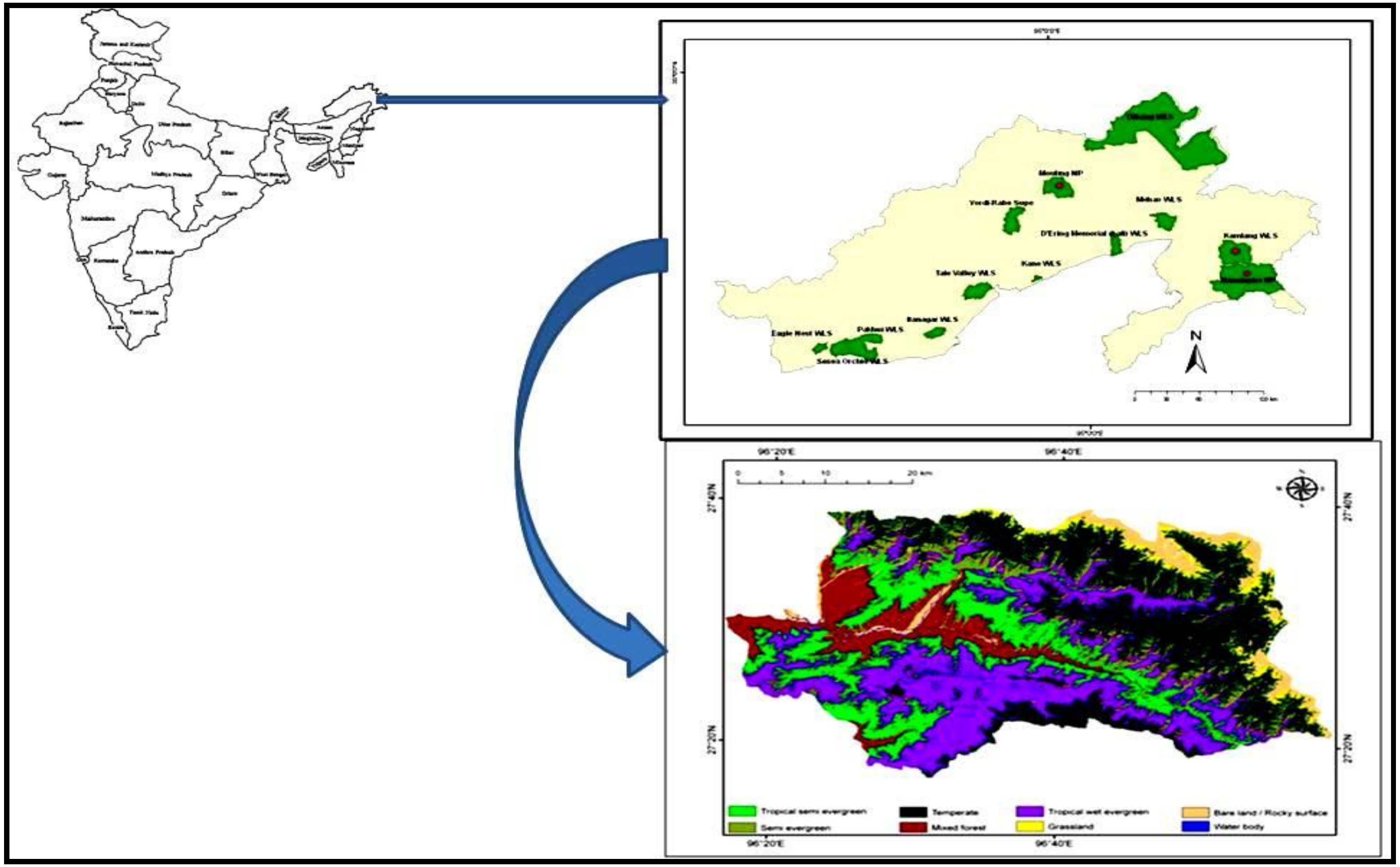
3.9.5 Temperature

In December and January are generally the coldest months when the mean maximum temperature in the plains (below 900 m) is of the order of 200° C and the mean minimum temperature is about 50° - 200° C respectively. Much lower temperature is experienced at higher elevations above 3000 m. The mean daily temperature is below freezing point. Temperature begins to rise in March and continues to rise till July and August which are normally the warmest months when the mean daily temperature of 27° C prevails at place below 900 m. At 3000 m elevation, the mean daily temperature is about 25° C.

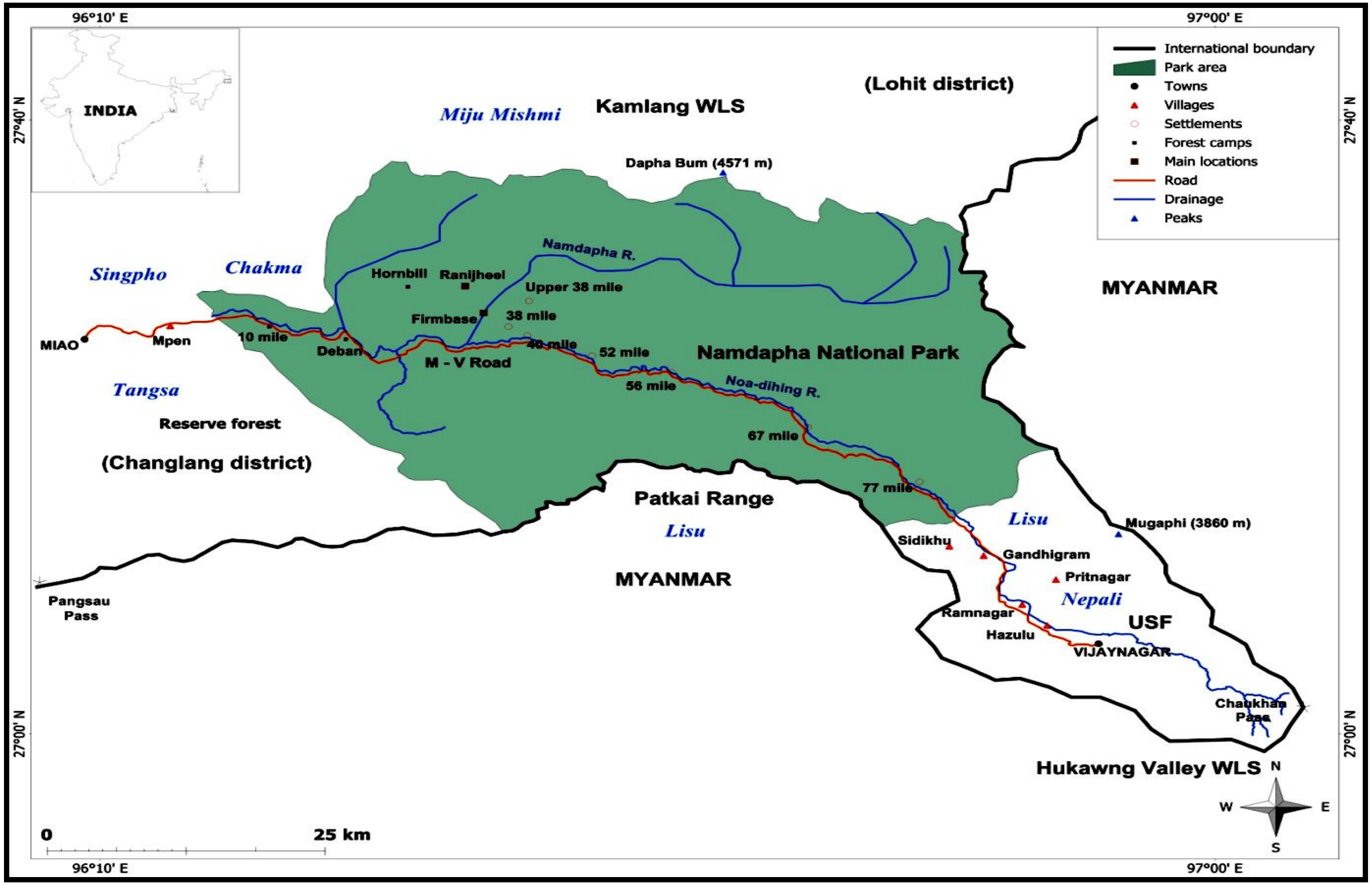
3.9.6 Relative humidity

Relative humidity is always high except in the winter months. Clear or lightly clouded skies are common during the post monsoon season. During the winter season, sky becomes obscure in the morning owing to fog, which generally clears with the advancement of the day. During the southwest monsoon, the skies remain heavily clouded.

Map 1: Namdapha Tiger Reserve, the study area.



Map 2: Village locations in Namdapha Tiger Reserve.



Chapter 4

To study the distribution of Malayan sun bear in Namdapha Tiger Reserve.

4.1 Introduction

Sun bear (*Helarctos malayanus*) remains the least known bear species in the world. The historic distribution of sun bears in India was in the tropical rainforest habitats of Manipur and Assam states south of the Brahmaputra River (Higgins, 1932), although there were reports of its occurrence in the north-eastern hilly region during the 1960s and 1970s. During the 1980s and 1990s, sun bear population apparently declined, and its occurrence became doubtful in the north-eastern hilly region. The reasons for the dwindling sun bear population are probably increased human population with its attendant activities. Rapid deforestation resulting in habitat destruction and fragmentation coupled with indiscriminate hunting has threatened sun bears with extirpation in India**.** Servheen *et al*. (1999) stated that sun bears no longer exist in Arunachal Pradesh, Manipur, Mizoram, Nagaland and Assam and their map of current distribution did not include India. This is likely because very little information is available on its status, distribution, and habitats in these states and adjoining Indian states.

Due to increase in human populations, loss, degradation and fragmentation of forests, sun bear populations have sharply declined to low levels in most of its range. They are found in the forest of Laos, Thailand, Myanmar, Bangladesh, Kampuchea, Southern China, Vietnam, Peninsular Malaysia and the Islands of Sumatra and Borneo (Servheen, 1993). There were also reports of occurrence of sun bears on the Island of Java (Greve, 1892; Cuvier, 1834 and Fishcher, 1829). In India, the historic distribution of sun bear was in the tropical rain forest habitats in the north-eastern region (Cowan, 1972; Gee, 1967; Higgins, 1932; Blanford, 1888, 1891; Pocock, 1941; Choudhry, 1983, 1989, 1992; Hinton and Lindsay, 1926 and Prater, 1980). In most of these areas, the species was reported to be extinct. According to the report of Servheen (1999), there were no sun bears in India in the 1990s.

Meijaard (1997) has compiled an excellent summary of the historic distribution records for the sun bear. Of interest are the historic records for sun bears in places like eastern Tibet and Sichuan, China (Lydekker, 1906), Manipur state and Assam (Higgins, 1932) and the upper Chitwan district in India (Wroughton, 1916), the places where the species is now extinct. There were old published reports of sun bears on the Island of Java (Greve, 1894; Cuvier, 1834 and Fischer, 1829), but there was apparently never any evidence to document the species from this Island in historical time, only fossil evidence was from the Pleistocene (Erdbrink, 1953). Sun bears were also reported in mangrove forest, although their occurrence in this forest type was probably dependent on proximity to other, more favoured habitats. Sun bears were found to use selectively logged areas (Wong *et al.*, 2004 and Meijaard *et al*., 2005), and oil palm plantations near forest edges (Nomura *et al.*, 2004). Sun bears were found to occur from near sea level to over 2,100 m elevation, but appeared to be most common in lower elevation forests. In Indonesia and western Thailand, for example, sun bears occurred primarily below 1,200 m (Augeri, 2005 and Vinitpornsawan *et al.*, 2006). Sun bears were observed up to 2,100 m in Myanmar (Saw Htun, 2006), 1,600 m in Lao PDR (Steinmetz *et al.*, 1999), and 2,143 m in Sumatra (Augeri, 2005).

Malaysian Islands of Borneo (sub-species *H. m. euryspilus*) and Sumatra; hence the common name of Malayan sun bears was assigned (Fredriksson *et al*., 2008). Black bear populations are also classed as 'Vulnerable' by the IUCN. Black bears range from south-eastern Iran east to Myanmar, with scattered populations in southern and north-eastern China, southern Russia Far East, North Korea, South Korea, Japan, Taiwan and Hainan (Garshelis and Steinmetz, 2008).

Recently sun bears were reported to occur in mainland South-East Asia as far west as Bangladesh and north-eastern India. Occurrence of sun bear was reported in Manipur, Mizoram, Nagaland, Arunachal Pradesh and Assam (Chuahan and Singh, 2005a; Chuahan and Singh, 2005b; Chauhan and Singh, 2006; Chauhan and Lalthanpuia, 2008; Chauhan and Sethy, 2011a; Chauhan and Sethy, 2011b; Sethy and Chauhan, 2011; Sethy and Chauhan, 2012a; Sethy and Chauhan, 2012b; Chauhan *et al.*, 2012a, 2012b; Sethy and Chauhan, 2012c; Choudhury, 2011**;** Borah *et al*., 2012 and Karanth and Nicols, 2000). During 1996-97, a sun bear was photographed in a camera trap in Namdapha by Karanth and Nichols (2000). Again in 2005, sun bears were captured in camera trap in Namdapha National Park (Dutta unpublished).

On the contrary, other bear species, brown bear and black bear, show wide range of distribution in Asian region. The Asian range of brown bear extends from Turkey, Iran, and Afghanistan to Pakistan and along the Himalayas of India, Nepal, and Bhutan, then north and east through the mountains of central Asia, Tibet, northern China, and Mongolia to Russia. The Himalayan brown bear is largely confined to the rolling uplands and alpine meadows above timberline, ecologically separated from forest dwelling black bear (Schaller, 1977). But in the north-western Himalayas, the Himalayan brown bear is reported to occur in the subalpine forests. In India, the Asiatic black bear inhabits forested hills ranging from 1,200 m to 3,300 m (Prater 1980). Its range overlaps with that of the sloth bear below 1,200 m and the Himalayan brown bear above 3,000 m. The Asiatic black bear is distributed throughout the Himalayan ranges in the northwest (Jammu and Kashmir, Himachal Pradesh), west (Himachal Pradesh and Uttaranchal), central (Sikkim and northern West Bengal) and east (Arunachal Pradesh). The species is also present in some hills of other north-eastern states of India. Asiatic black bear distribution in the Indian subcontinent is contiguous with Nepal (eastward from Uttaranchal to Sikkim) and Bhutan (eastward from Sikkim to Arunachal Pradesh). At present, the Asiatic black bear is continuously distributed in North India, all along the Himalayas and hills of north-eastern India between 1,200 m and 3,300 m. This is largely due to the black bear's use of plantations, orchards, cultivated areas, scrublands, and even villages to move between forested areas. There are few estimates of Asiatic black bear populations or densities in India.

In India, there is no information on the population status, distribution and ecology of sun bear. Estimation of sun bear (*Helarctos malayanus*) populations and distribution becomes more important in areas where a species is highly threatened due to continuous habitat degradation and loss of habitat with the increasing human population. Reliable estimation of sun bear population and knowledge about its status and distribution pattern are very important for the field managers to develop management plan of sun bear populations and also for mitigation of human-bear conflicts on long term basis. This is the first study of its kind in India to study the status and distribution of sun bear based on direct and indirect evidences in Namdapha Tiger Reserve, Arunachal Pradesh.

4.2 Methodology

The status and distribution of sun bear was studied based on questionnaire surveys by conducting interview of local people in different villages located in the vicinity of Namdapha Tiger Reserve, and also by using line transects and recording indirect evidences of sun bears. To find the distribution of sun bear, different forest types available in the Tiger Reserve were categorised **(Appendix 1)**. They were broadly Mix forest, Tropical wet-ever green forest, Tropical semi-ever green forest, Semi-ever green forest, Temperate forest and Bamboo forest.

4.2.1 Questionnaire survey

A basic premise was that the survey should cover the entire population of sun bears in Namdapha Tiger Reserve. A questionnaire format to carry out field investigations was used, and this was based on the assumption that people who were engaged in outdoor activities had some idea of the sun bear, black bear and sloth bear distribution and abundance in their areas. Questionnaire formats was therefore distributed in different villages. Following this, questionnaire surveys with photographs of sun bear, Asiatic black bear and sloth bear were carried out in different villages located in and around the protected area and information on the distribution of sun bear was collected during 2008 to 2010. Village houses were also surveyed to look for bear trophies or body parts.
Interviewees were selected by considering their knowledge of the local region into account, in particular their knowledge of the forest and wildlife **(Map 1)**.

4.2.2 Use of line transects

Extensive field surveys were carried out in the Tiger Reserve and then 43 line transects were laid in different parts to collect information on distribution of sun bear based on direct sightings of bears and their indirect evidences (tracks, scats, claw marks, nests and others). Locations of these line transects are shown in (**Map 2)**. The layout details of each transect for sign surveys and vegetation analysis are given in the **Appendix 2 and 3.** The starting points of transects were chosen randomly in different forest types within a range. Forest types often changed along transects so the extent of each forest type surveyed was recorded. Each line transect was walked by a team of 4-5 people. A direction (north, south, east or west) was chosen randomly in advance and one person (temporary local staff) acted as navigator, leading the way by using a compass. One person walked along the midline, measured the length of transect with a measuring rope, and recorded the information. Two to three people searched for bear signs along five meter strips on either side of the mid-line, and recorded the data. To avoid any basis the team members held the same role for all transects although, they alternated on sides of the midline. Field equipment comprised of a compass, map and GPS unit (Garmin) were used for navigation and 10 meter and 5 meter lengths of rope for measuring the widths and length of transects. A flexible measuring tape was used to measure the circumference of tree trunks at breast height. Templates of very fresh, fresh, old and very old claw marks were recorded in a ring-bound note pad. All transects were covered at least 2-3 times in a season with 15-20 days of interval. On every 100 m along transect, sun bear scats were collected and other indirect signs were recorded. All instances of bear signs within transect boundaries were recorded in the data sheet. Elevations were also recorded at the start, middle and end points of each transect. Fruit trees, ant nests and termite nests were counted along transects to obtain a measure of food abundance. The distribution of sun bear was mapped in different forest types in the Tiger Reserve.

4.2.2.1 Survey of nests and dens

Through intensive surveys and transect study, sun bear nesting and den sites were located and identified as active sites and temporary ones. Villagers were contacted to find location of den sites in their areas during the field work. Besides questionnaire survey and line transects, forest and village interface areas were also surveyed to look for indirect evidences and collect hairs snagged on trees, fences etc. The hair samples were identified through the morphology characters.

4.2.2.2 Crop raiding locations

In addition to direct sightings and indirect evidences, information on occurrence of crop raids in different jhuming areas i.e. crop field was also collected to know the distribution of sun bear in the Tiger Reserve.

4.2.3 Description of signs

All claw marks, bear nests, broken bee’s nests, digging sites, scats, tracks and trails were recorded as signs. Claw marks on climbed trees were also recorded as one sign. In case where claw marks of different age categories were observed on one tree, the most recent sign was recorded. Signs were allocated into broad age categories; very fresh (1-3 days), fresh (3-15 days), old (3-16 weeks) and very old (>16 weeks).The age of sign was decided through a combination of expertise and protocol. Steinmetz and Garshelis (2010) found that claw marks from climbing events could be placed in broad age categories and that wood hardness and seasonal effect had little consequence on aging rates. But in this study, signs were assigned the age categories using aging characteristics adopted.

4.2.3.1 Age categories

Very fresh - Sign estimated to be aged 1-3 days. Claw marks were void of woody grit, becoming smooth and hard with new bark growth spreading across the inside of the gouge. Edges were faded and less distinct than very fresh marks. Digging sites were have hardened dirt clumps and were often covered with fallen leaves, sticks and other vegetation.

Fresh - Sign estimated to be aged less than 3-15 days. Claw marks had fine woody grit within gouge and distinct sharp edges. Foot prints and faces always classed as fresh due to short life span of these signs. Dig sites usually had clearly disturbed, fresh soft dirt scattered around. Live insects and eggs could be seen in particularly fresh diggings. According to (Steinmetz and Garshelis, 2010) 1 to 3 months old signs considered as fresh signs.

Old - Sign estimated to be aged between 3-16 weeks. Claw marks were filled by wood re-growth or bark which developed around the edges. Edges were often raised out from the tree trunk. According to (Steinmetz and Garshelis, 2010) 1to 2 years old signs considered as fresh signs.

Very old - Sign estimated to be aged more than 16 weeks. Claw marks were stretched and distorted considerably due to tree growth. Bark re-growth often resulted in claw marks being pushed out from tree trunk. According to (Steinmetz and Garshelis, 2010) more than 2 years old signs considered as fresh signs.

4.2.3.2 Distinguishing claw marks

The field reference to classify Asiatic black bears and sun bears from the measurements of hind foot claw marks on climbed trees is given in **Table 1**. If either 4 or 5 claw in a set is detected, the reference is followed from step 1. Progressing to step 2 and 3 is required only if earlier steps result in an indeterminate classification. If the most complete claw mark set on a tree has only 3 marks, classification begins at step 3. These are small puncture marks in the bark of trees, including diagonal marks (front paw) and horizontal marks (back foot), produced by bears when they climb a tree. All trees (>5 cm DBH) within the belt transect should be investigated for signs of bear climbing.

Representation of bear claw mark set typically found on climbed trees shows the arc of 5-claw imprints and measurements used to distinguish Asiatic black bears from sun bears. The claw set axis from hind foot marks is horizontal with respect to the trunk. The innermost toe (digit 1) is usually lowest, revealing which foot made the mark (right in this figure).

Step 1 Recognizing claw marks of the hind foot: Claw marks of only the hind foot were used for measurements. Usually, the claw set axis from hind foot marks is horizontal with respect to the tree trunk while the front foot marks are oriented diagonally.

Step 2 Making a template of the claw mark set: A template of the claw marks was prepared by placing a piece of paper over the claw mark set following the curvature of the tree trunk. Holes were then punched at the bottom centre of each claw mark (**Plate 1**) and the outline of each claw mark drawn above the holes.

Step 3 Measuring the claw marks: After preparing the template, straight-line measurements were taken. a) the middle 3 claws, b) the outer 5 claws and c) the shortest distance between 4 claws as shown in **Figure 1**.

Step 4 Comparing with reference table: Then measurements obtained from the template were compared with the reference **Table 1**.

4.2.4 Camera-trapping surveys

Karanth (1995), Karanth and Nichols (1998), Carbone *et al.* (2001), and O'Brien *et al.* (2003) demonstrated methods with theoretical foundations in capture-recapture sampling studies that estimate the densities of cryptic animals like tigers using cameras and the software programme CAPTURE. Carbone *et al.* (2001) examined the camera-trapping capture rates from 19 tiger studies across the species' range and found the number of camera days for each tiger photograph possibly correlates with independent estimates of tiger density. O'Brien *et al.* (2003) and Kawanishi (2002) used capture rate indices in their respective studies for relative abundance estimates. The three latter studies suggest that estimates do not require individual animal identity.

In Namdapha Tiger Reserve, a grid size of 4 km^2 was selected as followed in other camera-trapping surveys in south-east Asia (Grassman, 2003; O'Brien *et al*., 2003; Kawanishi and Sunquist, 2004 and Johnson *et al*., 2006). Of the 40 grids covering the study area, a random selection of 20 grids was made in the Tiger Reserve. All field work was carried out on foot. Given logistic difficulties in the hilly terrain, limitations of time, manpower and equipment, sampling was carried out from August 2008 to November 2010. For this study 10 passive infra-red camera trap units (DEERCAM) and 20 Digital (Wild view) camera traps were deployed for 320 days and 390 nights. Traps were deployed along animal trails, streambeds, and ridgelines, in locations with evidences of animal movement. The GPS locations, altitude and other habitat parameters at each trap site were recorded. A group of highly skilled *Lisu* trackers assisted in identifying suitable locations for deploying camera traps. At every location, one passive infra-red camera trap was placed perpendicular to the expected direction of animal movement at a height of 25-35 cm from the ground. A minimum distance of 1 km between trap locations was maintained. However, the traps were operational for 24 hours a day, and were removed after a period of 7 days. The number of camera trap days was calculated from the date of deployment till the date of retrieval (if film was not used up) or till the date of the final photo. A potential bias of our survey was that all camera traps were located on the ground; therefore certain species that were more reported to be more arboreal might not be captured as frequently.

4.3 Results

The occurrence and distribution of sun bear population based on the village interviews, transects by observing indirect evidences: claw marks, nests, scats and digging of termite mounds along, and camera trapping in the Namdapha Tiger Reserve is presented as under:

4.3.1 Distribution based on questionnaire survey

During the study period from 2008 to 2010, questionnaire surveys were conducted in 18 fringe villages, namely, Gandhigram, Vijoy Nagar, Sidhikhu, 52 Mile, 56 mile, 77 Mile, Ram Nagar, Hazulu, 40 mile, 38 Mile, Upper 38 Mile, Deban, Lama Camp, Chhemile, Tera Mile, Tuhat, Phaparbari and Miltary camp to know the occurrence and distribution of sun bears. The locations of these villages are shown in (**Map1)**.

4.3.2 Sighting of sun bear

In total 785 respondents were interviewed in different villages located in and around Namdapha Tiger Reserve. Out of these respondents, 265 respondents (33.6%) confirmed the presence of sun bear based on direct sightings **(Table 2)**, and they had also observed the indirect evidences in the forest area adjacent to their villages during the study period. Highest number of respondents confirming presence of sun bear was from Gandhigram (n=108), followed by Vijoynagar (n=27), 52 Mile (n=22), 77 Mile and Sidikha (n=21 each), 38 Mile (n=19), Hazulu (n=11) and so on. According to 21 respondents there was probability of occurrence of sun bear in these villages as (2.7%). Rest of the respondents (63.7%) did not respond about the occurrence of sun bear. Among these, the status of sun bear occurrence was low in three villages (Tuhat, 40 mile and Miltary camp) and medium in five villages (Vijoy Nagar, Sidhikhu, Ram Nagar, Hazulu and Phaparbari). In Chhemile village and Tera Mile, there were no reports of sun bear occurrence although most of the respondents reported that they used to ramble around these areas long time back.

Sun bear were reported to use different forest types in Namdapha Tiger Reserve **(Figure 2)**. The respondents observed sun bears them maximum times in the Tropical wet-ever green forest (30.5%), followed by Semi-ever green forest (26.7%), Mix forest (19.6%), Tropical semi-ever green forest (17.2%) and Bamboo forest (6.0%). Number of sightings of sun bear was more in the Tropical wet-ever green forest and Semi-ever green forest because there was plenty of food available in these areas and low disturbance**.**

During the questionnaire surveys, the respondents also sighted indirect evidences of sun bear such as claw marks, nests, scats, foot prints and dens. They sighted highest number of claw marks (n=289), followed by nests (n=73), scats (n=95), footprint (n=73) and dens (n=12) in the Namdapha Tiger Reserve**.** Respondents also sighted of sun bear performing different activities; they were found resting on the tree branches (n=90), moving (n=75), feeding (n=43) in forest and a few times in cultivated area**.** Generally sun bear were reported to be active during morning, evening, noon and night time. According to respondents, sun bear were found to be the active during the day time. Sun bear were observed 47 times in the morning, 48 times in the evening and 86 times in the noon times **(Table 3)**. They were reported to be the least active during night time; the respondents observed sun bears only 7 times in the night**.**

In addition to direct sightings and indirect evidences, information on occurrence of crop raiding in different cultivation ('jhum') areas was also collected to know the distribution of sun bear in the Tiger Reserve **(Map 1)**.

4.3.3 Distribution based on surveys and transects

During the survey period, 43 transects laid in Namdapha, Deban and Gandhinagar ranges**.** These transects were located in Tropical wet-ever green forest, Temperate forest, Semi ever green forest, Tropical semi ever-green forest, Bare land and Bamboo forest **(Map 2)**. Through intensive surveys and transect study, all these forest types were covered during plot sampling and their availability and locations of active and inactive nesting and den sites of sun bear were found out in Namdapha Tiger Reserve. Besides, villagers were also contacted during the field work and the the locations of den sites informed by them were indicated in the (**Map 3**).

4.3.3.1 Availability of forest types

The availability of forest types varied in the Namdapha Tiger Reserve **(Figure 3)**. The area of Tropical wet-ever green forest was highest (618.61 km^2), followed by Temperate forest (510.60 km^2), Semi ever-green forest (316.05 km^2), Tropical semi-ever green forest (280.40 km^2), Mix forest (166.05 km^2), Bare land (135.70 km^2), Bamboo forest (44.17 km^2) and Water body (6.07 km^2). Similarly the percentage availability of Tropical wet-ever green was highest (29.8%), followed by Temperate forest (24.6%), semi ever-green forest (15.2%), Tropical semi-ever green forest (13.5%), Mix forest (8.0%), Bare land (6.5%), Bamboo forest (2.1%) and water body (0.3%). These habitat types were more or less evenly distributed in the whole area **(Appendix 1)**. All these land cover and land use categories fell into 500 to 4000 m elevations range and occurred in flat to undulation terrain facing different directions.

4.3.3.2 Extent of forest types

While doing plot sampling along the transects, 3.768 ha of Tropical semi-ever green forest, 3.454 ha of Tropical wet-ever green forest, 2.198 ha of Semi-ever green forest, 1.571 ha of Mix forest, 1.256 ha of Temperate forest and 1.256 ha of Bamboo forest were covered in the study areas **(Figure 4)**.

4.3.3.3 Occurrence of bear signs

In Namdapha Tiger Reserve, different types of sun bear signs were recorded along the 43 transects **(Table 4).** Altogether 379 bear signs were identified in the study area **(Map 4)**. Number of claw marks was found to be the highest (n=224) as compared to number of scats (n=85), nests (n=45), diggings (n=10), dens (n=8) and footprints (n=7) (**Plate 1, 2 and 3)**. In terms of percentage, occurrence of claw marks was highest (59.1%) as compared to scats (22.4%), nests (11.9%), diggings (2.6%), dens (2.1%) and footprints (1.8%).

4.3.3.4 Range-wise bear signs distribution

Based on sign survey along the transects, distribution of sun bear was found quite widespread in Gandhigram range as compared to Namdapha (n=58) and Deban (n=45) ranges **(Table 5).** In Gandhigram range, number of claw marks was highest (n=148) as compared to number of scats (n=78), nests (n=33), diggings (n=7) and footprints and dens (n=5 each). In Namdapha range, number of sun bear claw marks was highest (n=41) as compared to number of nests (n=7), scats (n=5), diggings and dens (n=2 each) and footprint (n=1). Similarly in Deban range, number of sun bear claw marks was highest (n=35) as compared to number of nests (n=5), scats (n=2) and footprints, diggings and dens (n=1 each) in the study area. **Map 5, 6, 7 and 8** shows that the distributions map of different signs in Namdapha Tiger Reserve.

4.3.3.5 Age of bear signs

During the transect study, bear signs observed were of different age groups **(Figure 5)**. Many of them were very fresh (36.7%) as compared to fresh signs (25.6%) and old signs (23.5%). Very old bear signs were only (14.2%)**.**

4.3.3.6 Bear signs and reasons

Sun bear signs recorded along the transects included claw marks on trees for fruit consumption, claw marks for unknown uses, tree-tear for beehives, tree-tear for termites, log-tear for insects in addition to nests, scats, diggings, dens and footprints **(Figure 6).** The percentage of claw marks was highest (59.1%). Sun bear left different types of claw marks on trees for different proposes. They climbed trees to eat fruits and left claw marks on them, they were 35.6%. Similarly, they left claw marks and tree tear for feeding on beehives (9.2%), tree tear for feeding on termites (7.7%), log tear for feeding insects (1.3%) and claw marks on trees for unknown reason (5.3%) **(Plate 4, 5 and 6)**.

Other signs recorded in the study areas were scats (22.4%)**,** nests (11.9%)**,** dens (2.6%), diggings (2.1%) and footprints (1.8%) during the study period (**Plate 7 and 8)**. Claw marks were found on trees were 12.4-86 cm in diameter at breast height (DBH). The mean DBH was calculated 39 cm (SD=16.5), and the mean height of trees was 26 m (SD = 11.3).

4.3.3.7 Season wise occurrence of bear signs

All these bear signs were recorded in summer, monsoon and winter months. The percentage occurrence of bear signs was highest in winter (43.8%), followed by monsoon (32.7%) and summer (23.5%) season **(Figure 7)**. Similarly the mean signs were highest during the winter months (41.5±5.80), followed by monsoon months (31.0±6.25) and summer (22.25±3.83) months during the study period.

4.3.3.8 Seasonal occurrence of signs in forest types

As mentioned above, distribution of sun bear signs showed seasonal variation in different forest types in Namdapha Tiger Reserve **(Figure 8).** During winter season, sun bear signs were highest in Tropical wet-ever green forest (17.2%), followed by

Tropical semi-ever green forest (15.6%), Semi-ever green forest (11.3%), Mix forest (7.1%), Temperate forest (3.7%) and Bamboo forest (1.3%). In summer season, bear signs were highest in Temperate forest (6.3%), followed by Tropical semi-ever green forest (6.1%), Tropical wet-ever green forest (5.5%), Semi-ever green forest (5.0%), Mix forest (4.5%) and Bamboo forest (0.8%). Whereas in monsoon season, sun bear signs were highest in Tropical semi-ever green forest (4.2%), followed by Tropical wet-ever green forest (3.4%), Mix forest (2.9%), Semi-ever green forest (2.6%), Temperate forest (1.6%) and Bamboo forest (0.8%).

4.3.3.9 Density of bear signs

The transect study revealed that the number of signs per unit area varied in different forest types in the Tiger Reserve. The mean occurrence of bear signs was 63.17±13.82 **(Figure 9).** The density of signs was highest in Mix forest (140.1/ha) and Temperate forest (140.1/ha), followed by Semi ever-green forest (131.0/ha), Tropical wet-ever green forest (113.5/ha), Tropical semi-ever green forest (105.1/ha) and Bamboo forest (35.0/ha) recorded during the study period.

4.3.3.10 Occurrence of signs along elevations

The occurrence of bears signs also varied along transects laid along different altitudinal gradients **(Figure 10).** The percentage of bear signs was highest at an elevation of 1001-1500 msl (50.9%), followed by 501-1000 msl (26.4%) and 0-500 msl (20.1%). The percentage of bear signs was lowest at an elevation of 1500 and above (2.6%). There was distinct relationship between the season, elevation and density of bear signs per unit area (R^2 Linear = 0.81488). The density of bear signs showed an increasing trend with the increasing elevation in the Tiger Reserve **(Figure 11)**. But from 1500 msl or above, the density of bear signs decreased drastically.

4.3.3.11 Bear signs in disturbed and undisturbed areas

There was marked difference in occurrence of bear signs in disturbed and undisturbed areas along the transects in Namdapha Tiger Reserve **(Figure 12).** The percentage of bear signs was much more in undisturbed area (74.1%) than in disturbed area (25.9%). At a landscape scale, bears in the study area showed clumped distribution. Chi-square test of sign distribution at the micro-habitat level indicated distribution of sun bear in clustered pattern in disturbed areas, whereas signs were randomly distributed within undisturbed area.

4.3.3.12 Distribution based on camera trapping

By using 30 camera traps (20 Digital and 10 infra-red Deer cam), distribution of sun bear was found out in Namdapha Tiger Reserve **(Plate 9, 10, 11 and 12)**. Initial two surveys were conducted in diverse habitats in Deban and Namdapha ranges from August 2008 to January 2009. Later three sites were selected in the Gandhigram range based on surveys conducted from August 2009 to November 2010.

Based on camera trapping efforts, the animal capture in 560 days/nights was highest (n=32) in Gandhigram range as compared to capture in 100 days/nights in Deban range (n=7), and capture in 76 trap days/nights in Namdapha range (n=4) **(Table 6).** Out of total 32 animal captures, only three sun bear captures were from within Gandhigram range. There were no sun bear capture in other two ranges because of high human interference and disturbance due to road network.

4.4 Discussion

Very little information is available on the status and distribution of Malayan sun bear (*Helarctos malayanus*), the least known bear species in north-eastern states of India. The historic distribution of sun bear in India was in the tropical rainforest habitats of Manipur and Assam states south of the Brahmaputra river (Higgins, 1932), although there were reports of its occurrence in the North-Eastern hilly region during the 1960s and 1970s. Servheen *et al*. (1999) reported that sun bear no longer exists in Arunachal Pradesh, Manipur, Mizoram, Nagaland and Assam.

In 2006, the WCS/IUCN-BSG Range Wide Assessment of Asian Bears Workshop used expert opinion to map the extant range of sun bear throughout South-East Asia. In changing environment, population distribution of animal species is essentially required not only to know the trend but also to effectively manage decline or increasing problematic species populations. Since human-black bear and sun bear conflicts are on the little bit rise in Namdapha Tiger Reserve, hence it requires to know the population abundance of bears and their distribution so that future course of action to deal with the conflicts can be developed.

The knowledge of the distribution and status of sun bears and black bear in Laos is also limited due to a lack of scientific research. Deuve (1972) reported that sun bear distribution was widespread throughout every province in Laos. A report included in the action plan for bears worldwide, compiled by the IUCN bear specialist group, stated that sun bear were probably widely distributed throughout the country with an exception of the heavily settled and cultivated areas of the Mekong plain (Salter, 1991). A joint report from TRAFFIC and WWF, speculated that Laos could represent a global stronghold for both species (Mills and Servheen, 1991).

Bear population distribution and size is extremely difficult to find out. In the Namdapha Tiger Reserve, the status and distribution of sun bear population is based on the village interviews transect surveys by recording indirect evidences: claw marks, nests, scats and digging of termite mounds along, and camera trapping. The findings of this study are presented and discussed in this chapter. The findings of the present study showed the status and distribution of sun bear in Namdapha Tiger Reserve, Arunachal Pradesh.

The questionnaire surveys conducted in 18 fringe villages, namely, Gandhigram, Vijoy Nagar, Sidhikhu, 52 Mile, 56 mile, 77 Mile, Ram Nagar, Hazulu, 40 mile, 38 Mile, Upper 38 Mile, Deban, Lama Camp, Chhemile, Tera Mile, Tuhat, Phaparbari and Miltary camp during 2008 to 2010 showed distribution of sun bear in forest areas in the vicinity of these villages except Chhemile and Tera Mile. In total, 785 respondents were interviewed in different villages located in and around Namdapha Tiger Reserve. Out of these respondents, 265 respondents confirmed the presence of sun bear based on direct sightings and indirect evidences in the forest areas adjacent to their villages.

Highest number of respondents confirming the presence of sun bear was from Gandhigram, followed by Vijoynagar, 52 Mile, 77 Mile, Sidikha, 38 Mile, Hazulu and so on. Amongst these villages, the status of sun bear occurrence was low in three villages and medium in five villages. In Chhemile village and Tera Mile, there were no reports of sun bear occurrence although most of the respondents reported that they used to ramble around in these areas long time back.

According to the respondents, sun bear were reported to use different forest types in Namdapha Tiger Reserve. The respondents observed them maximum times in the Tropical wet-ever green forest, followed by Semi-ever green forest, Mix forest, Tropical semi-ever green forest and Bamboo forest. Number of sightings of sun bear was high in the Tropical wet-ever green forest and Semi-ever green forest because there was plenty of food available in these areas and low disturbance.

The respondents sighted indirect evidences of sun bear such as claw marks, nests, scats, foot prints and dens. Sighting of claw marks was highest, followed by nests, scats, footprint and dens in the Tiger Reserve. The respondents sighted sun bear directly also. They were found either resting on the tree branches or moving or feeding in forest area and a few times in cultivated area. Sun bear distribution in and around the Tiger Reserve was also evident based on location of crop raiding incidences in different cultivation areas.

Namdapha Tiger Reserve has high density of sun bear signs as compared to other ranges of its distribution in north-east India, when using sign index as a measure of its percentage and mean (Chuahan and Sethy, 2011b). This could be largely attributed to the long term management and conservation initiatives which turned Namdapha Tiger Reserve into a model for conservation, sustainable use, ecotourism, education, culture and scientific research.

Arunachal Pradesh has rich resources in comparison to neighbouring countries with bears likely to be far more abundant. Bears and bear parts are reported to be sold at lower prices in Gandhigram than other villages and the proximity to Tiger Reserve an attractive source for local traders. The level of human-caused animal mortalities is unknown, as is the annual volume of crop damage.

In Namdapha Tiger Reserve, sun bear were reported to be active during morning, evening, noon and night time. According to respondents, sun bear were most active during the day time. Sun bear were observed 47 times in the morning hours, 48 times in the evening and 86 times in the noon. They were reported to be the least active during night time, the respondents observed sun bear only 7 times in the night**.**

In general, activity patterns of animals are considered an adaptation to seasonal and diurnal variation in environmental factors (Cloudsley-Thompson, 1961 and Nielsen, 1983). Aschoff (1964) stated that the daily activity pattern of animal result from a complex compromise between optimal foraging time, social activities, and environmental constraints. In a study, movements and activity patterns of female sun bears in East Kalimantan, Indonesian Borneo was reported to have implications for conservation. Male sun bear exhibited a definite diurnal pattern of activity (Wong *et al*., 2004).

Sun bear were primarily diurnal animals. Sun bear were distinctly more active during daylight hours than at night (a-z-animals.com/animals/sun-bear/). They spent the daytime foraging for food and resting high in their tree-top nests at night. They tended to become active about 0.5 h before sunrise and ceased activity about 2.5 h after sunset. Peaks of activity generally occurred during 0700-0900h and 1600-1800 h, with diminished activity during 1000-1400 h. But in areas that were increasingly affected by growing levels of human activity, sun bear were known to adopt a more nocturnal way of life to avoid confrontation (a-z-animals.com/animals/sun-bear/). The human-habituated individuals were found to be frequently slept for brief periods during the hottest time of day on fallen log or on the forest floor. When these bears were cubs (< 1 year), they spent large parts of the day resting alone in trees (Fredriksson, 2012).

Daily activity rhythms and time budgets in bears have been related to seasonal changes in sunrise and sunset, weather conditions, food type and abundance, human disturbance, presence of other bear species and the sex, age and family associations of bears (e.g. Amstrup and Beecham, 1976; Garshelis and Pelton, 1980; Ayers *et al*., 1986; Roth and Huber, 1986; Clevenger *et al*., 1990; Reid *et al*., 1991; Lariviere *et al*., 1994; MacHutchon *et al*., 1998; Holm *et al*., 1999; MacHutchon, 2001; Wagner *et al*., 2001; Paisley and Garshelis, 2006 and Hwang and Garshelis, 2007). There was minimal seasonal variation in day length and the sun bears showed only short-term changes in activity patterns related to rainfall (Fredriksson, 2012). In Sumatra, Indonesia, sun bear photographs were taken by camera traps between 1200h and 1500 h, indicating movement of bears in this area during at mid day (in Meijaard, 1999). Van Schaik and Griffiths (1996) showed that the Malayan sun bear were active both during day and night.

During the survey period, transects were laid in Tropical wet-ever green forest, Temperate forest, Semi ever green forest, Tropical semi ever-green forest, Bare land and Bamboo forest in Namdapha, Deban and Gandhinagar ranges. Through intensive surveys, transect study and by talking to villagers, the availability of forest types, location of sun bear nesting and occurrence of active and inactive den sites were found out.

The availability of forest types varied in different parts of Namdapha Tiger Reserve. The area of Tropical wet-ever green forest was highest, followed by Temperate forest, Semi ever-green forest, Tropical semi-ever green forest, Mix forest, Bare land, Bamboo forest and Water body. Similarly, the percentage availability of Tropical wet-ever green was highest, followed by Temperate forest, Semi ever-green forest, Tropical semi-ever green forest, Mix forest, Bare land, Bamboo forest and Water body. They were more or less evenly distributed in the whole area. In the Tiger Reserve, 1.256 to 3.768 ha of area was covered under the Tropical semi-ever green forest, Tropical wet-ever green forest, Semi-ever green forest, Mix forest, Temperate and Bamboo forest. All these land cover and land use categories fell into 500 to 4000 m range and flat to undulation terrain facing different directions.

In reality, most organisms, mammals in particular, found to have natural irregular distributions due to differences in forage distribution and habitats or effects from population pressures (e.g. density dependence), competition, predation, or climate (MacArthur, 1972 and Thrall *et al.*, 2000). Results were consistent with this supposition and demonstrated that the distribution of sun bear habitat use between undisturbed forest areas is patchy. This begs an important question for conservation biology. If an organism has a naturally patchy distribution, why would habitat fragmentation be a problem? Many species, particularly mammals, focus their activity in certain locations or core areas due to very specific micro-habitat characteristics that provide suitable or preferred foods, denning and nesting sites, mates, and interspecific dynamics. Radio telemetry, signs, and field observations indicated many species, including large carnivores (e.g. Ursidae, Felidae, Canidae, among others), moved throughout their home ranges and territories, but all show that a high proportion of their activities are focused in specific core areas, at least on a seasonal or annual basis.

From management point of view, identification of sun bear distribution sites and density indices based on bear evidences such as scats and digging of termite mounds is very important. Bears usually rest in dens or nests during day time. They rarely come out of dens and move in search of food at the time when people remain active and cattle are around in the day time. There is a conception that the distribution and abundance of bears can be found out on the basis of line transects. In Namdapha Tiger

Reserve, line transects were walked during day time, mostly in morning and evening time. Many nest sites fell along the transects, but bear movement was not observed despite the presence of indirect evidences along the belt.

In Namdapha Tiger Reserve, 379 different bear signs were identified along 43 transects**.** Number of claw marks was found to be highest as compared to number of scats, nests, diggings, dens and footprints. Distribution of sun bear was found to quite widespread in Gandhigram range as compared to Namdapha and Deban ranges**.** In Gandhigram range, number of claw marks was highest as compared to number of scats, nests, diggings and footprints and dens each.

Sun bear signs recorded along the transects included claw marks for fruit consumption, claw marks for unknown uses, tree-tear for beehives, tree-tear for termites, log-tear for insect, nests, scats, diggings, dens, footprints**.** Among these, the percentage of claw marks was highest. Sun bear left different impression of claw marks on trees used for various proposes. They climbed trees to eat on fruits and left claw marks on trunk. They also left claw marks and tree tear for feeding on beehives, tree tear for feeding on termites, log tear for feeding on insects. All these bear signs observed were of different age groups. Many of them were recent as compared to fresh signs and old signs.

Occurrence of scratch marks on trees confirmed the presence of sun bear in different parts of the Tiger Reserve. But as such low numbers of sun bear in the reserve could be due to natural population gradient which decreased into the northern parts of their range. Sun bear are more vulnerable to poachers as they venture closer to villages than black bear, and exhibit bolder behaviour towards humans. Poachers may also favour sun bear as their bile has a higher market value. Bear population in the Tiger Reserve is threatened by habitat disturbance (shifting cultivation, livestock grazing, logging, collection of NTFP and other illegal forest activities). However, hunting for the international wildlife trade poses an even bigger threat.

All these bear signs were observed in summer, monsoon and winter months in different forest types in Namdapha Tiger Reserve. The percentage occurrence of bear signs was highest in winter (43.8%), followed by monsoon (32.7%) and summer (23.5%) season. But the mean signs were highest during the winter months (41.5±5.80), followed by monsoon months (31.0±6.25) and summer months (22.25±3.83) during the study period. This seasonal variation could be related to fruiting of trees and availability of fruit biomass during winter season than other season.

During winter season, sun bear signs were highest in Tropical wet-ever green forest (17.2%), followed by Tropical semi-ever green forest (15.6%), Semi-ever green forest (11.3%), Mix forest (7.1%), Temperate forest (3.7%) and Bamboo forest (1.3%), In summer season, bear signs were highest in Temperate forest (6.3%), followed by Tropical semi-ever green forest (6.1%), Tropical wet-ever green forest (5.5%), Semi-ever green forest (5.0%), Mix forest (4.5%) and Bamboo forest (0.8%). Whereas in monsoon season, sun bear signs were highest in Tropical semi-ever green forest (4.2%), followed by Tropical wet-ever green forest (3.4%), Mix forest (2.9%), Semi-ever green forest (2.6%), Temperate forest (1.6%) and Bamboo forest (0.8%). This variation in bear signs was mainly due to availability food resources in different forest types during winter, monsoon and summer month.

The percentage of bears signs also varied along the transects laid along different altitudinal gradients**.** The percentage of bear signs was highest at an elevation of 1001-1500 msl (50.9%), followed by 501-1000 msl (26.4%) and 0-500 msl (20.1%). The percentage of bear signs was lowest at an elevation of 1500 and above (2.6%). There was distinct relationship between season, elevation and density of bear signs per unit area (R^2 Linear = 0.81488). The density of bear signs showed an increasing trend with the increasing elevation in the tiger reserve. But from, 1500 msl or above, the density of bear signs decreased drastically. Altitudinal variation in occurrence of sun bear might be and to habitat presence shelter, availability of food resources, and disturbance factor.

There was marked difference in occurrence of bear signs in disturbed and undisturbed area along transect in Namdapha Tiger Reserve**.** The percentage of bear signs was much more in undisturbed area (74.1%) than in disturbed area (25.9%). At a landscape scale, bears in these study areas have clumped distribution. Chi-square test of sign distribution at the micro-habitat level indicated distribution of sun bear in clustered pattern in disturbed areas, while signs were randomly distributed within undisturbed area. Sun bear distribution could be directly related human disturbance factor. They preferred undisturbed areas much more than disturbed areas just to avoid any interaction on threat from people.

By using camera traps, distribution of sun bear was conducted at Namdapha Tiger Reserve from August 2008 to November 2010. Based on camera trapping efforts, the animal capture in 560 days/nights was highest in Gandhigram range as compared to capture in 100 days/nights in Deban range, and capture in 76 trap days/nights in Namdapha range**.** Out of total 32 animal captures, only three sun bear capture were from within Gandhigram range. There were no sun bear capture in other two ranges because of high human interference and disturbance due to road network. Though sun bear were captured in camera traps in Gandhigram range, not in Deban and Namdapha ranges, there were more chances of their movement pattern which could not enable photo capture in camera traps in later two ranges.

Bears have patchy distributions, often with concentrated seasonal or annual activities in specific locations, that can change in their life-time (Jonkel and Cowan, 1970, Bunnell and Tait, 1981; Rogers, 1977, 1987; Mattson *et al.*, 1987; McLellan and Shacklton, 1988; Beak, 1989; Craighead *et al*., 1995; Mattson *et al.*, 1996; Noss *et al.*, 1996; Craighead and Vyse, 1996; Powell *et al.*, 1997; Craighead WWI, 2000; Craighead *et al.*, 2001; Merrill *et al.*, 1999; Waits *et al.*, 1999; Boyce *et al.*, 2001; Augeri, 1994, 2003, and Meijaard *et al*., 2005). For sun bear in undisturbed areas, patchy distribution is associated with microhabitat traits, such as tree stand structure, diversity, and maturity level, dead biomass or elevation gradient. Such habitat features will concentrate termite colonies, ant colonies, and beehives, optimise fruit productivity, or will provide suitable ground cover, canopy cover, security, and topography.

Although occupied bear habitat in contiguous undisturbed forest is relatively ‘patchy’, but this secure continuous forest facilitates the capacity and behavioral choices of bears to move between good micro-habitat sites and access valuable resources across a continuous forested landscape over seasons and years. This ability to move between high-quality microhabitats, in turn provides a higher probability for reproductive success and fitness. In contrast, forest fragmentation from developments, road network, clear-cuts, fencing, and plantations blocks access to necessary resources and reduce bear movements through the landscape (Noss *et al.*, 1996; Anderson, 1997; Beausoleil, 1999; Merrill *et al.*, 1999; Bader, 2000; Murrow, 2001; Augeri, 1994, 2003; Larkin *et al.*, 2004 and Meijaard *et al*., 2005). These situations can also create population 'sinks', such as **(a)** local gardens, garbage areas, etc. that may attract bears and provide other resources where human-bear interactions result in bear mortality or **(b)** an area with diminished resources where a bear may be 'forced' or compressed into the area due to disturbance, social, or forage needs, but access to other areas may be blocked, resulting in health decline or mortality. Both of these scenarios and others have been observed in numerous areas with bears and other large carnivores (Mattson *et al.*, 1996; Noss *et al.*, 1996; Powell *et al.*, 1997; Craighead *et al.*, 2001; Merrill *et al.*, 1999; Servheen *et al*., 1999; Bader, 2000; Boyce *et al.*, 2001; Augeri, 1994, 2003 and Meijaard *et al*., 2005). Thus, the difference between a naturally patchy distribution and the one that is caused by fragmentation is that in a contiguous undisturbed landscape, bears can still move between suitable habitat to access resources and mates despite lack of preferred resources between good sites.

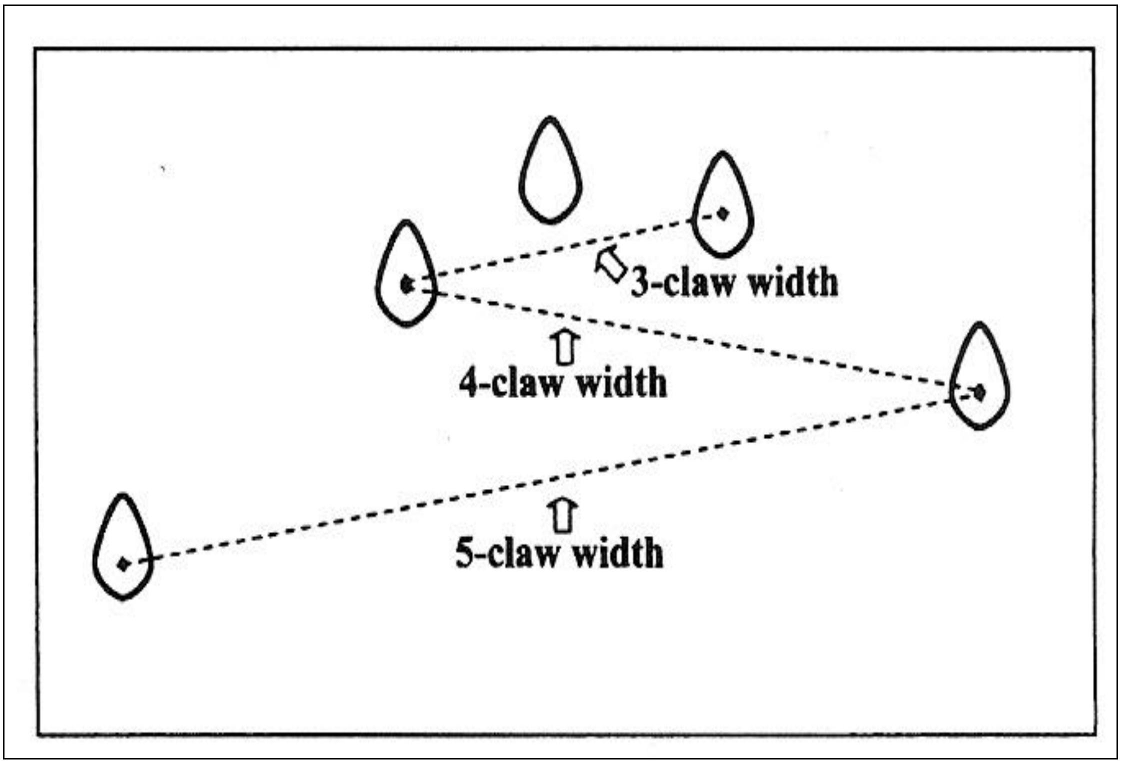
In a fragmented landscape the capacity for bears to access resources and suitable habitats might be limited or blocked beyond the borders of a truly isolated 'Island' patch surrounded by disturbance, inhospitable terrain, or intensive human activity (Craighead *et al.*, 2001). If an isolated patch is small, it could lead to compression or insular effects. Deteriorated bear health and survival can result along with increased mortality, diminished reproductive capacity, inbreeding depression, and conflicts with humans, among other deleterious effects. Such fragmentation problems led to reduced recruitment into bear population and, in the long-term, possible extinction of that sub-population (Craighead and Vyse, 1996; Craighead *et al.*, 1998; Waits *et al.*, 1999 and Servheen *et al.*, 1999). In either case, the loss of bears could cause wider population impacts on a regional level (Boyce *et al.*, 2001). This could also result in ecological impacts on the community, such as reduced seed dispersal and nutrient cycling, along with altered competitive and predatory dynamics (Augeri, 1994 and Terborgh *et al.*, 1999, 2001). It could be concluded from these analyses that the sun bear use of disturbed and non forested areas, young secondary forests, edges, agricultural areas, clear-cuts, and so forth by sun bears was insignificant relative to the overall population and landscape use. At a landscape scale, habitat loss will obviously produce clumped distribution of bears between suitable and unsuitable areas. Essentially, sun bear distributions in this area were too patchy and fragmented across the landscape matrix.

This study marked the first of its kind in this country and provided valuable and encouraging information on the distribution of sun bears in Namdapha Tiger Reserve.

Table 1: Claw mark reference table adopted by Steinmetz and Garshelis (2008).

Species	Step 1	Step 2	Step 3
	4-claw width (cm)	**5 claw-width (cm)**	**3 claw-width (cm)**
Black bear	> 6.6	> 9.0	> 4.1
Sun bear	< 6.0	< 6.2	< 4.0
Indeterminate	6.0-6.6	6.2-9.0	4.0-4.1

Figure 1: Measurement of claw marks for identification of bear species.



Appendix 1: Forest types in Namdapha Tiger Reserve.

Forest types	**Description**
Mixed forest	This forest type is dominant in Namdapha Tiger Reserve which is characterised by a mixture of evergreen and deciduous tree species
Tropical wet-ever green forest	The tropical evergreen forests usually occur in areas receiving more than 200 cm of rainfall and having a temperature of 15 to 30 degrees Celsius. The trees are evergreen as there is no period of drought. They are mostly tall and hardwood type.
Tropical semi-ever green forest	Such forests have a mixture of the wet evergreen trees and the moist deciduous tress. The forest is dense and is filled with a large variety of trees of both types.
Semi-ever green forest	semi-ever green forest of a plant that is incompletely evergreen; "it was evergreen where the weather was mild but deciduous in the rigorous parts of the range"
Temperate forest	Temperate forests correspond to forest concentrations formed in the northern and southern hemisphere. Main characteristics include: wide leaves, big and tall trees and non seasonal vegetation. Temperate forests can be further distinguished by weather patterns and geographical features that favour the predominance of certain kinds of trees.
Bamboo forest	Bamboo. Large areas of dense bamboo are usually discernible due to their pink and orange colour and typical texture. It was decided to map all visible bamboo into one class.

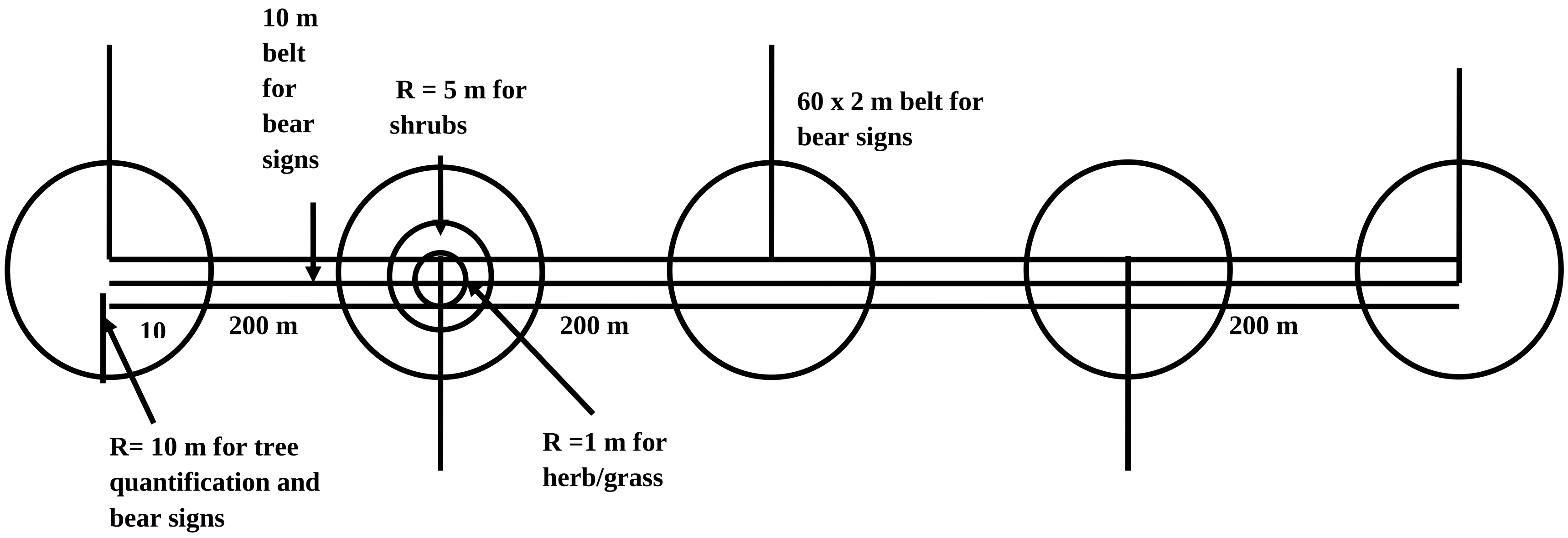
Appendix 2: Sun bear sign survey data sheet used in Namdapha Tiger Reserve during 2008-2010.

Date…………………………………… **Time: Start……………………. End……………………..**

Range/Locality: ………………………..

Transect no.	Sign type	GPS coordinate	Tree species	GBH	Aspect	Sign age	Habitat type	Disturbance	Distance from water source	Phenology

Appendix 3: Plot sampling for sign and vegetation survey in Namdapha Tiger Reserve during 2008-2010.



Map 1: Location of villages in and around the Namdapha Tiger Reserve where interviews were conducted.

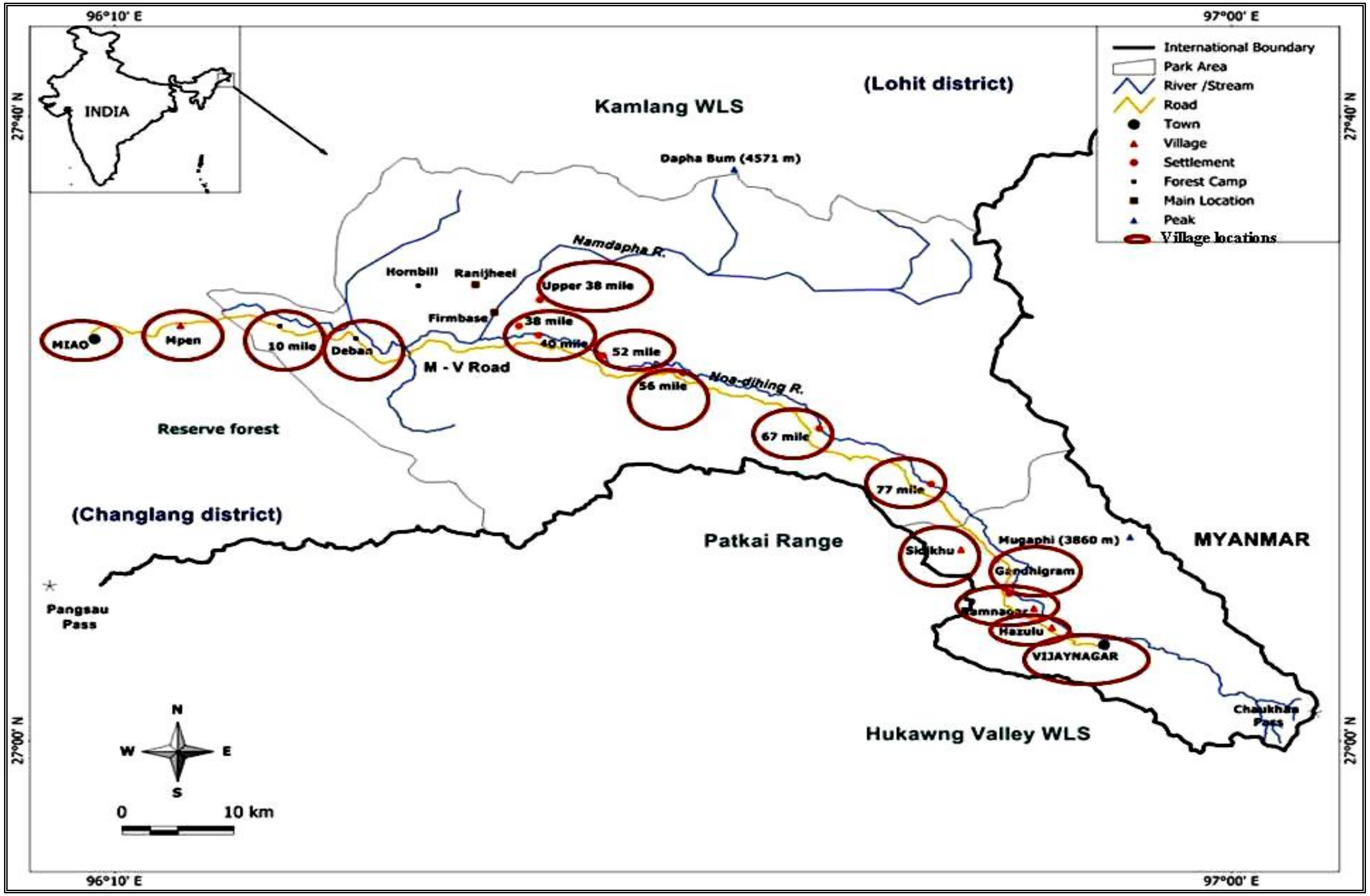


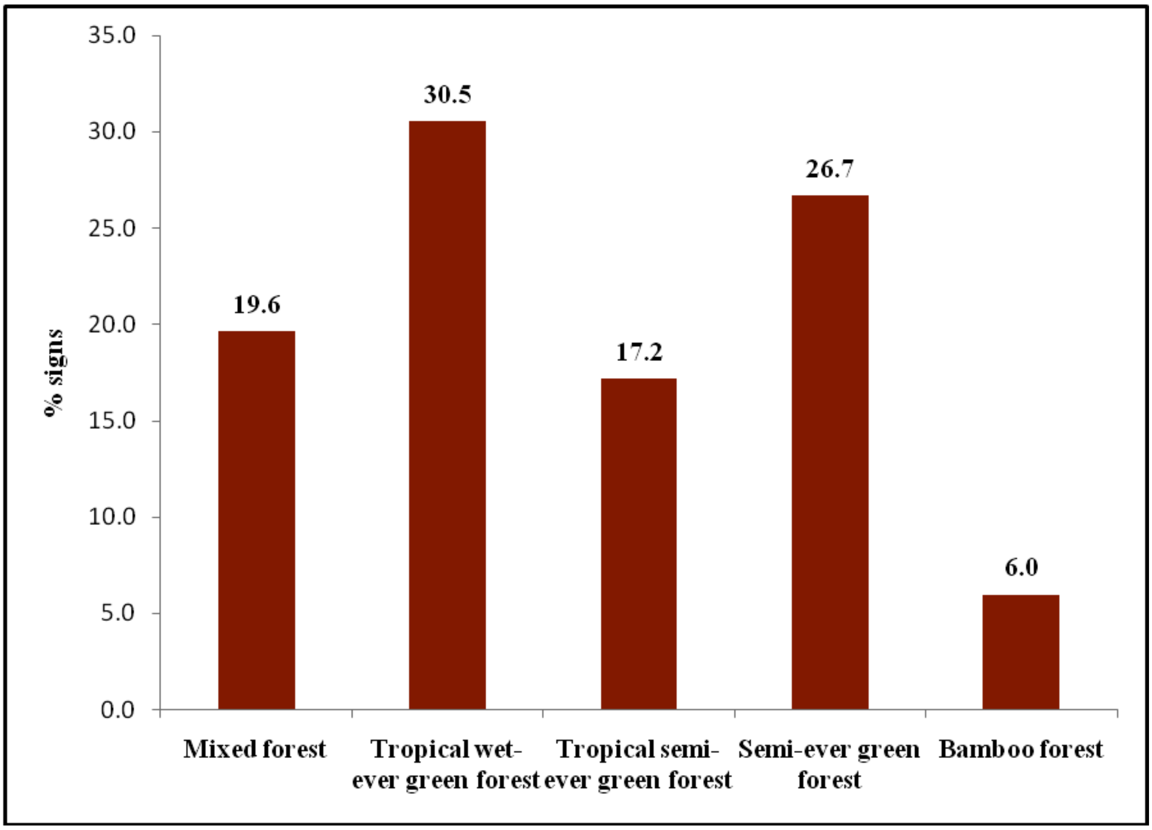
Table 2: Number of respondents in different villages who sighted sun bear in various forest types in and around Namdapha Tiger Reserve.

Name of villages	No. of respondents	Occurrence in forest types
Gandhigram	108	Tropical wet-evergreen, Tropical semi-ever green forest and Bamboo forest.
77 mile	21	Tropical wet-evergreen tropical semi-ever green forest and bamboo forest
52 mile	22	Tropical semi-ever green and Mixed forest
56 mile	2	Tropical wet-evergreen and semi-ever green forest
40mile	2	Mixed forest and semi-ever green forest
38 mile	19	Mixed forest and semi-ever green forest
Upper 38 mile	3	Mixed forest and semi-ever green forest
Sidikha	21	Tropical wet-evergreen tropical semi-ever green forest and bamboo forest
Ramnagar	5	Tropical wet-evergreen and tropical semi-ever green forest
Vijoynagar	27	Tropical wet-evergreen and tropical semi-ever green forest
Hazulu	11	Tropical wet-evergreen and tropical semi-ever green forest
Phaparbari	3	Tropical wet-evergreen and tropical semi-ever green forest
Chhemile	0	-
Theramile	0	-
Deban	3	Mixed forest and semi-ever green forest
Lama camp	7	Mixed forest and semi-ever green forest
Tuhat	5	Tropical wet-evergreen and tropical semi-ever green forest
Military camp	4	Mixed forest

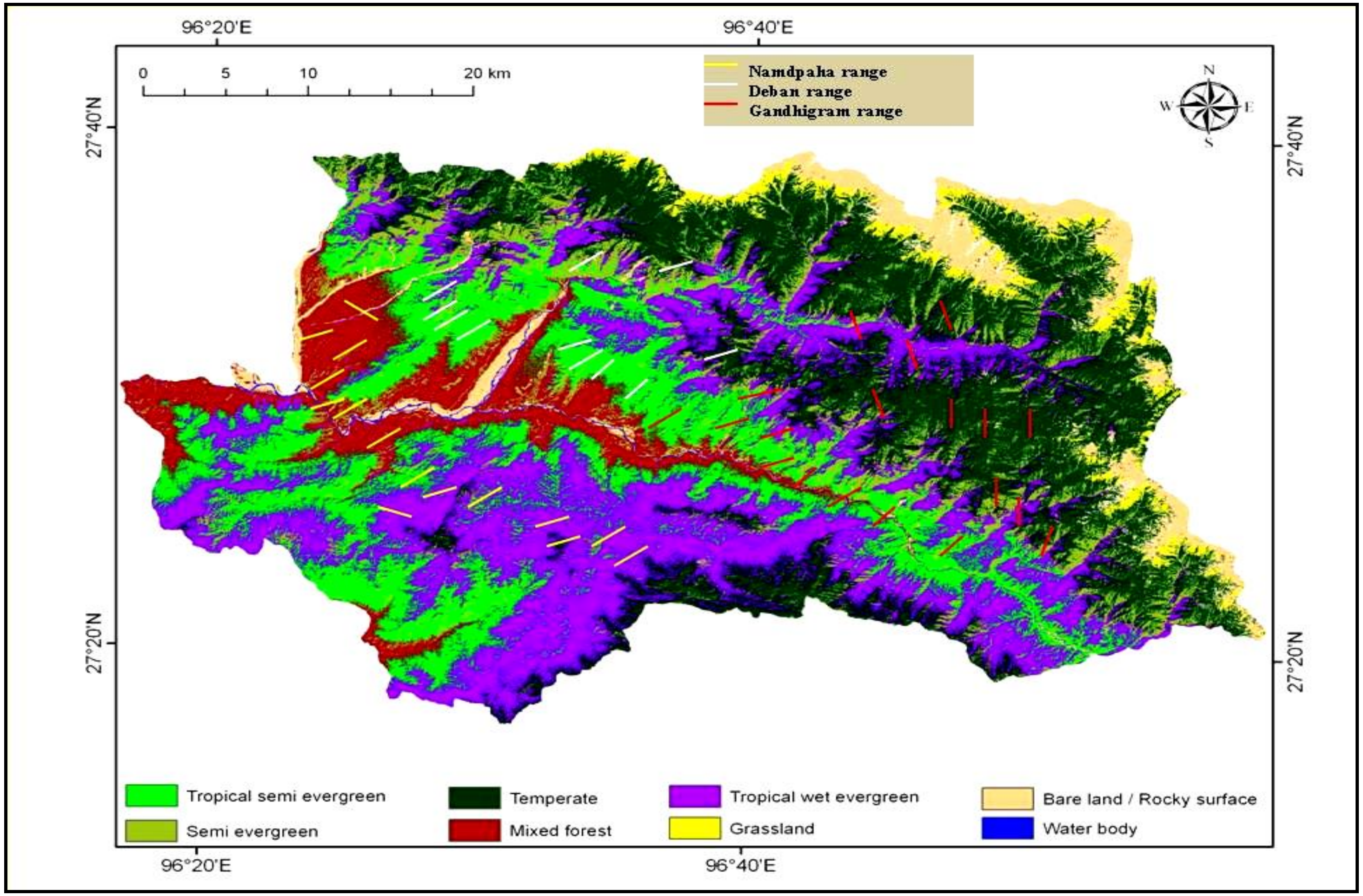
Table 3: Interview survey results on time of movement of sun bear.

No. of respondents	No. of bear in morning time	No. of bears in evening time	No. of bears in noon time	No. of bears in night time
265	47	48	86	7

Figure 2: Occurrence of signs in different forest habitat based on respondent.



Map 2: Location of transects in three ranges of Namdapha Tiger Reserve to know bear distribution based on their signs.



Map 3: Location of den site in Namdapha Tiger Reserve.

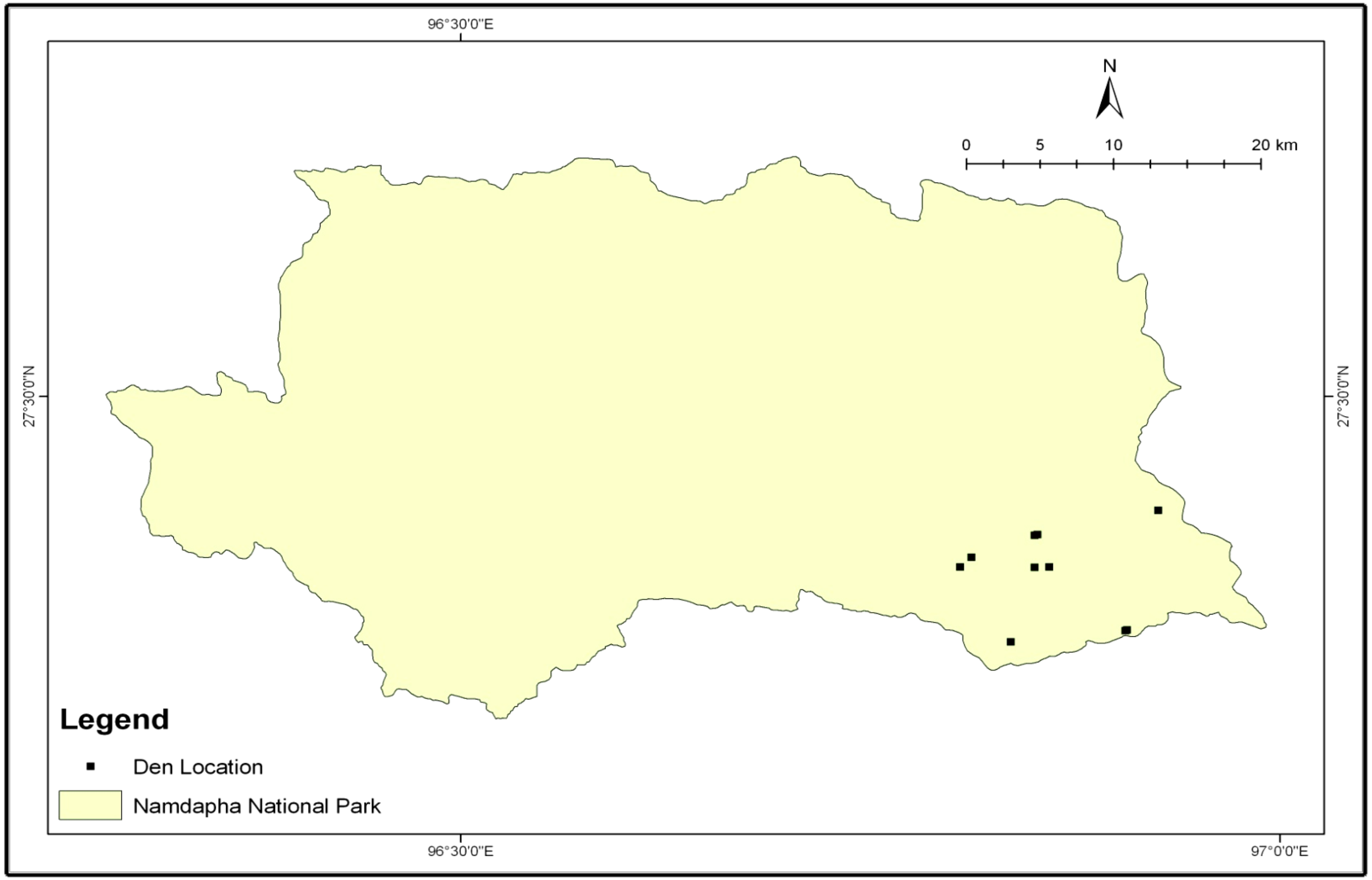


Figure 3: Availability of forest types in Namdapha Tiger Reserve.

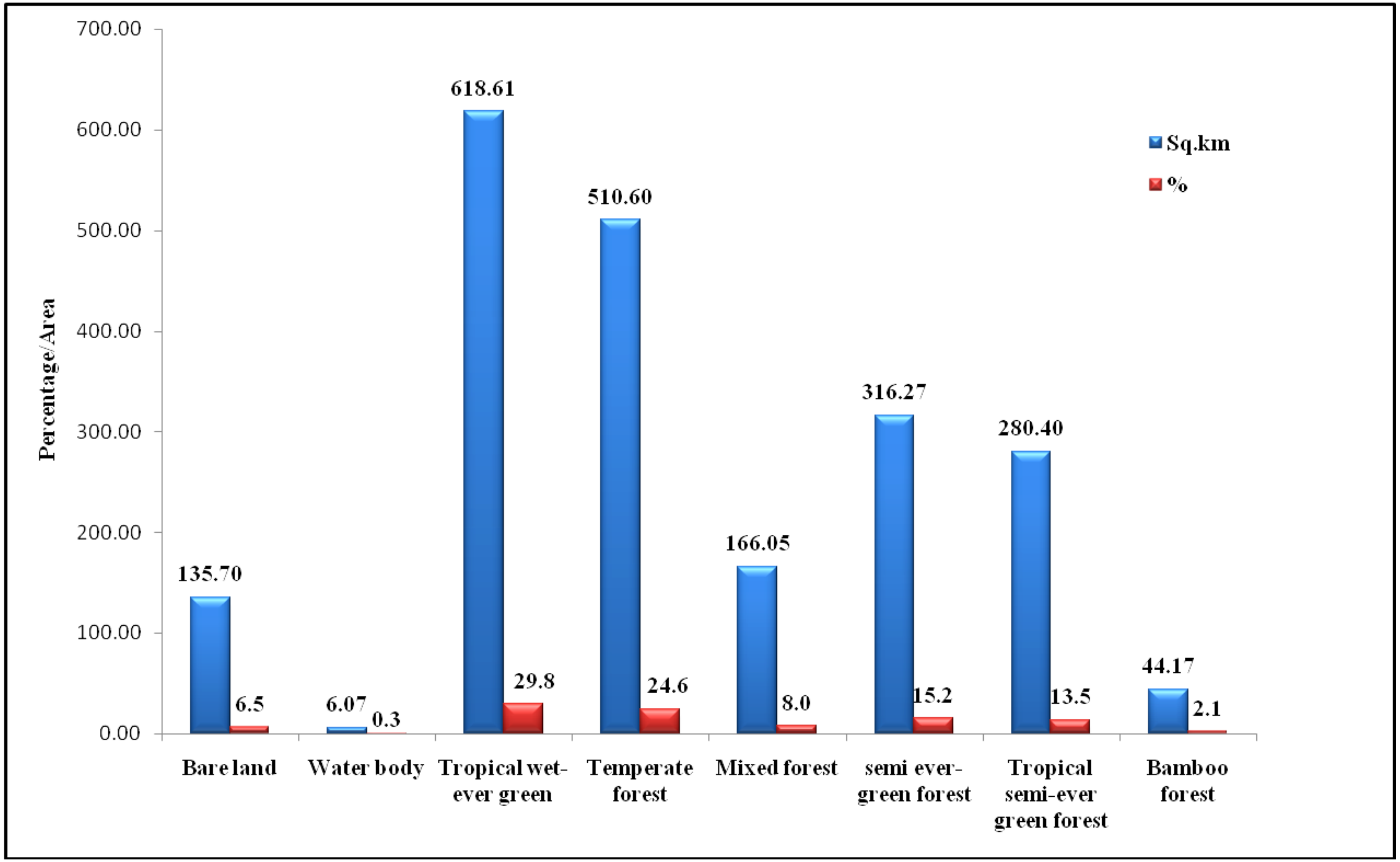


Figure 4: Area of forest types covered during plot sampling along transects in Namdapha Tiger Reserve.

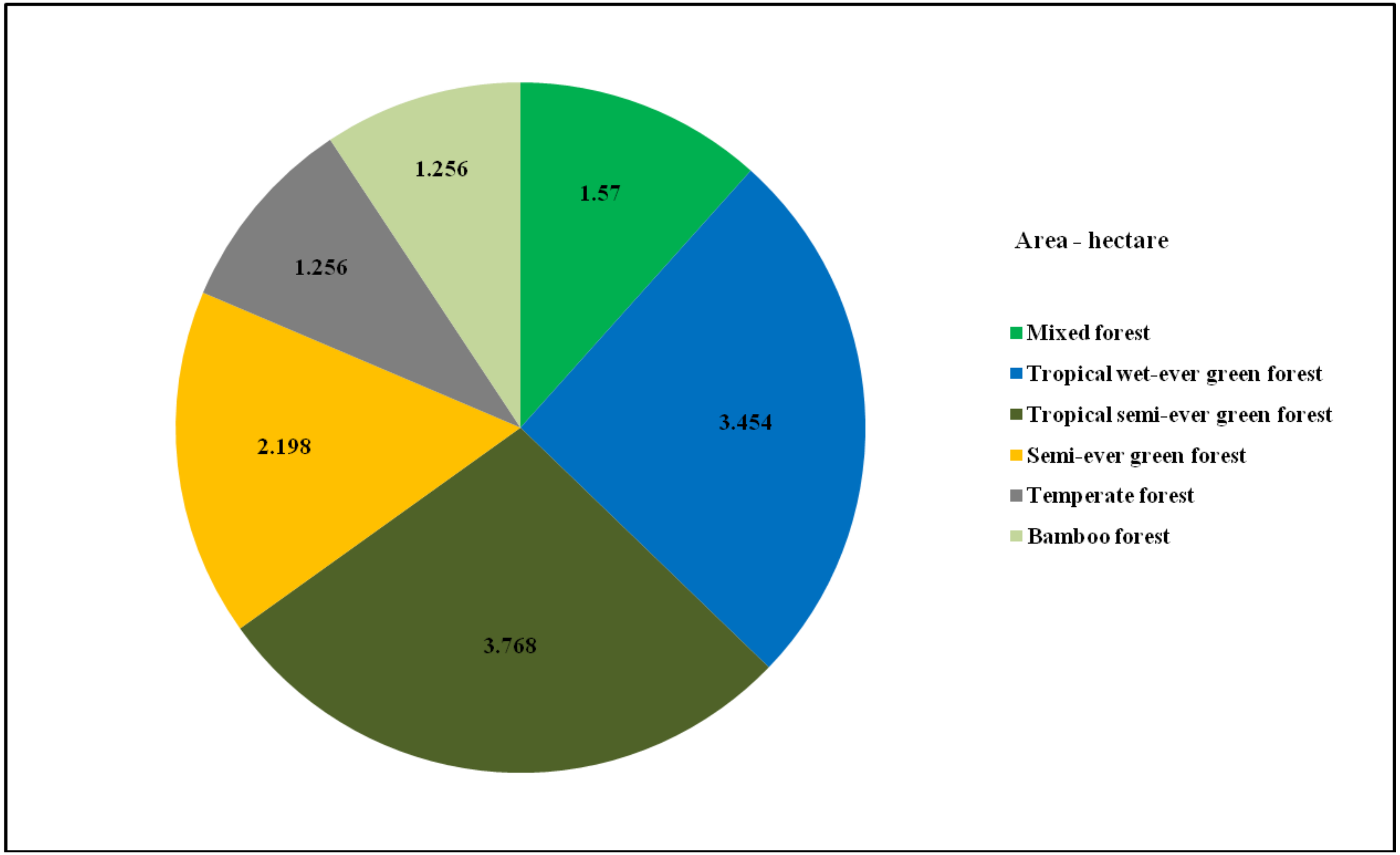


Table 4: Bear signs and their number and percentage along transect in Namdapha Tiger Reserve.

Sign type	No. of signs	% of signs
Claw marks	224	59.1
Nests	45	11.9
Scats	85	22.4
Diggings	10	2.6
Dens	8	2.1
Foot prints	7	1.8

Table 5: Number of bear signs recorded along transects in different ranges of Namdapha Tigre Reserve.

Range	Claw marks	Scats	Foot prints	Diggings	Dens	Nest	Total
Namdapha	41	5	1	2	2	7	58
Deban	35	2	1	1	1	5	45
Gandhigram	148	78	5	7	5	33	276

Figure 5: Age categories of bear signs observed along transects in Namdapha Tiger Reserve.

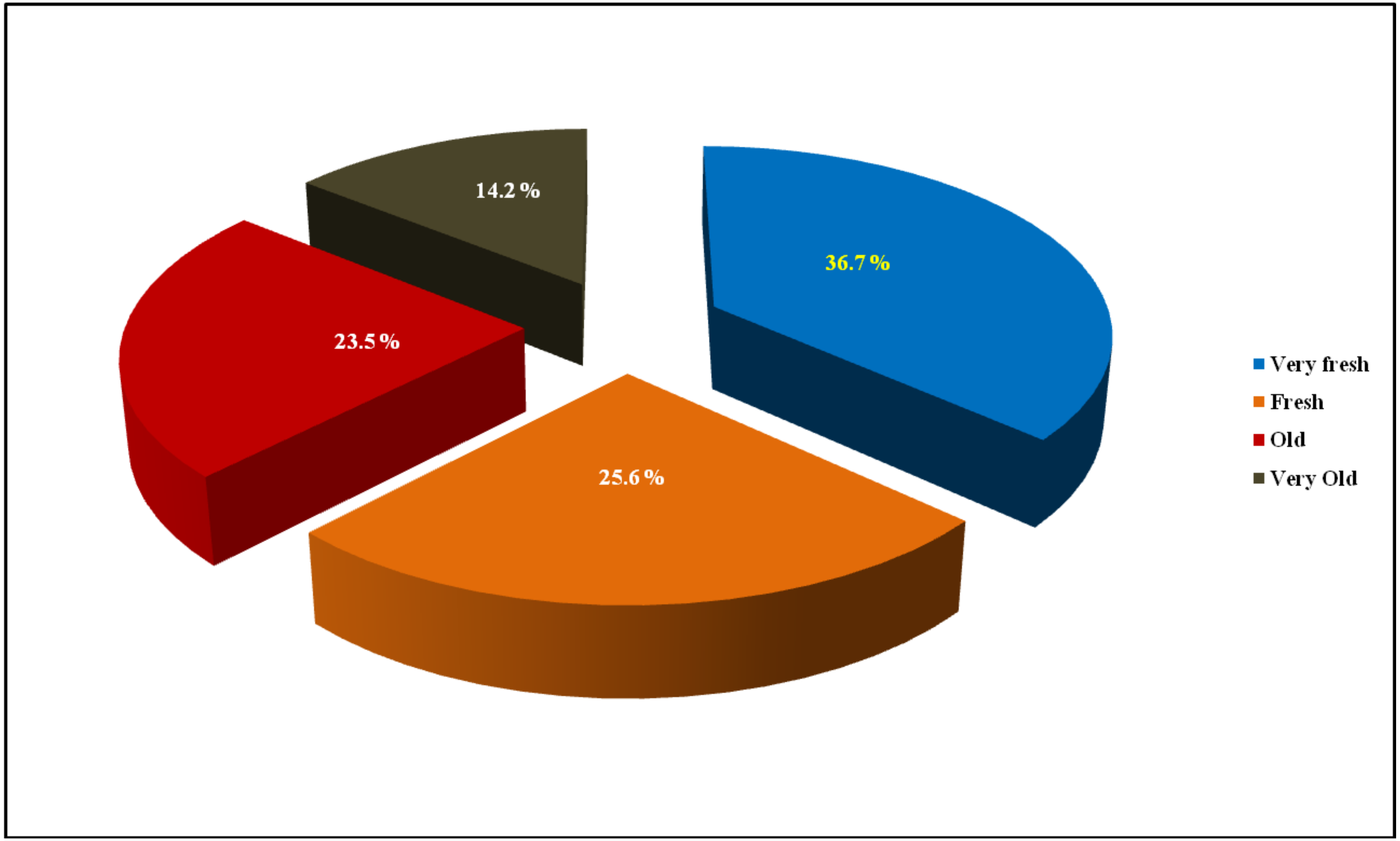


Figure 6: Type of bear signs and their percentage recorded along transects in Namdapha Tiger Reserve.

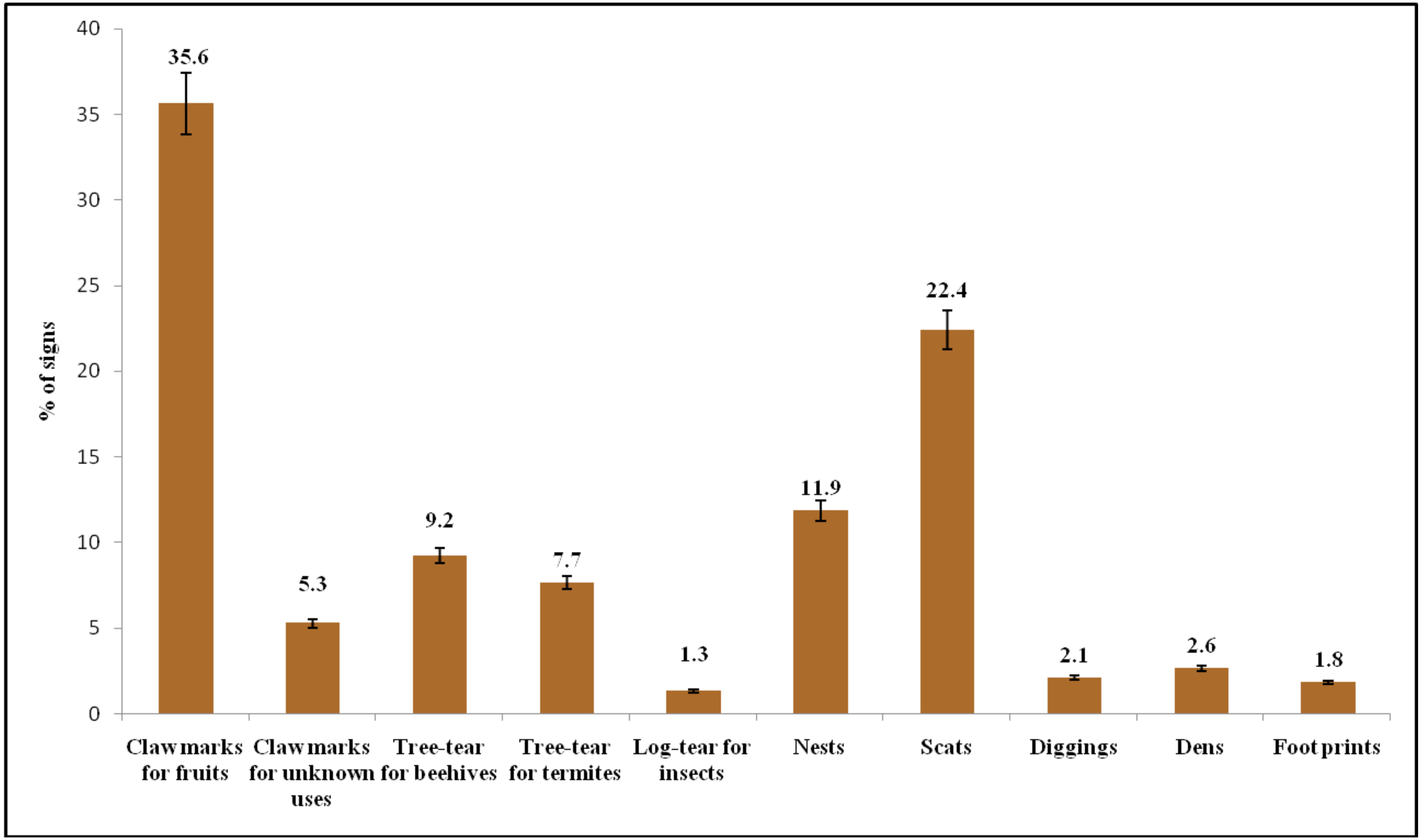


Figure 7: Percentage of signs in different seasons in Namdapha Tiger Reserve.

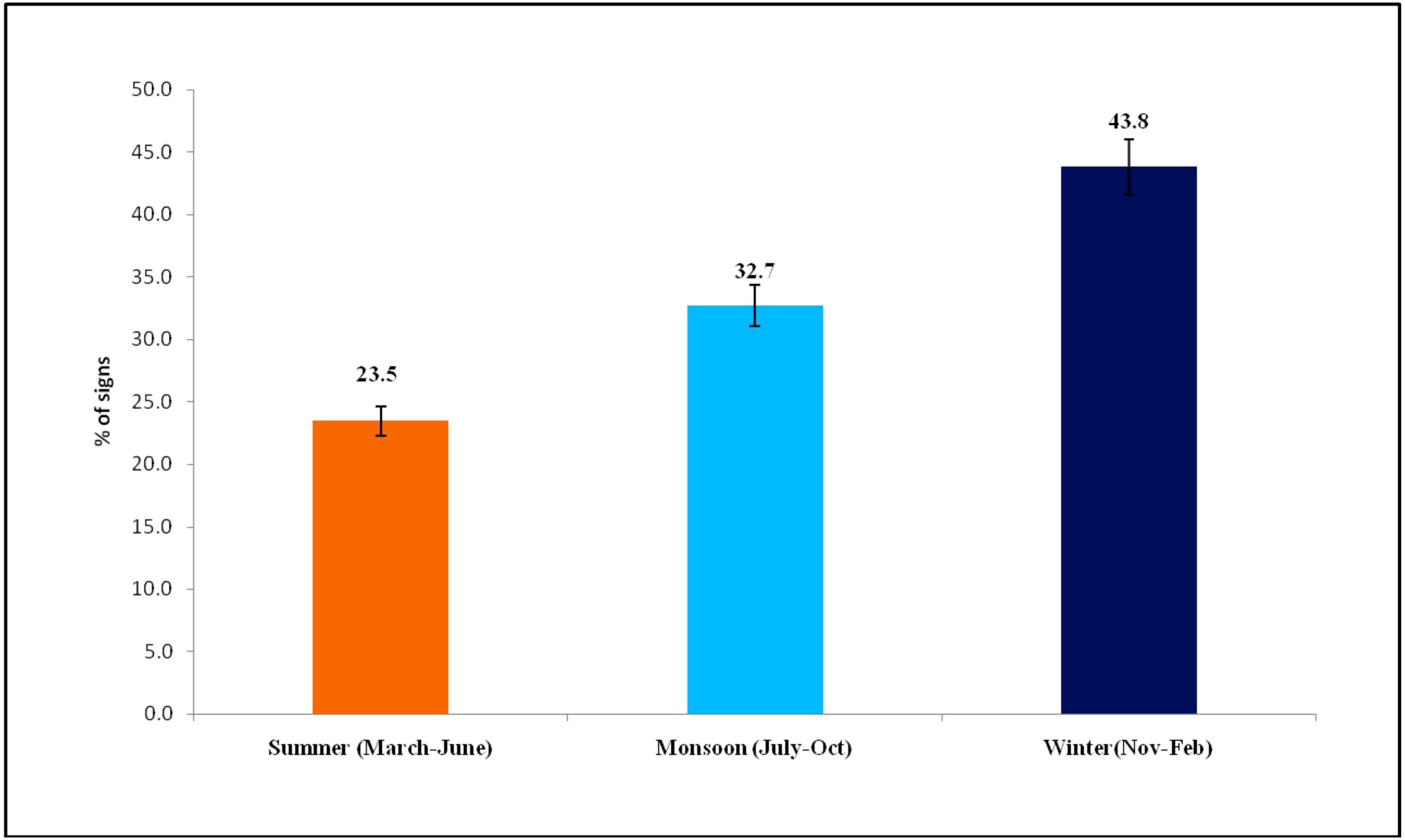


Figure 8: Seasonal variation in sign distribution in different forest types in Namdapha Tiger Reserve.

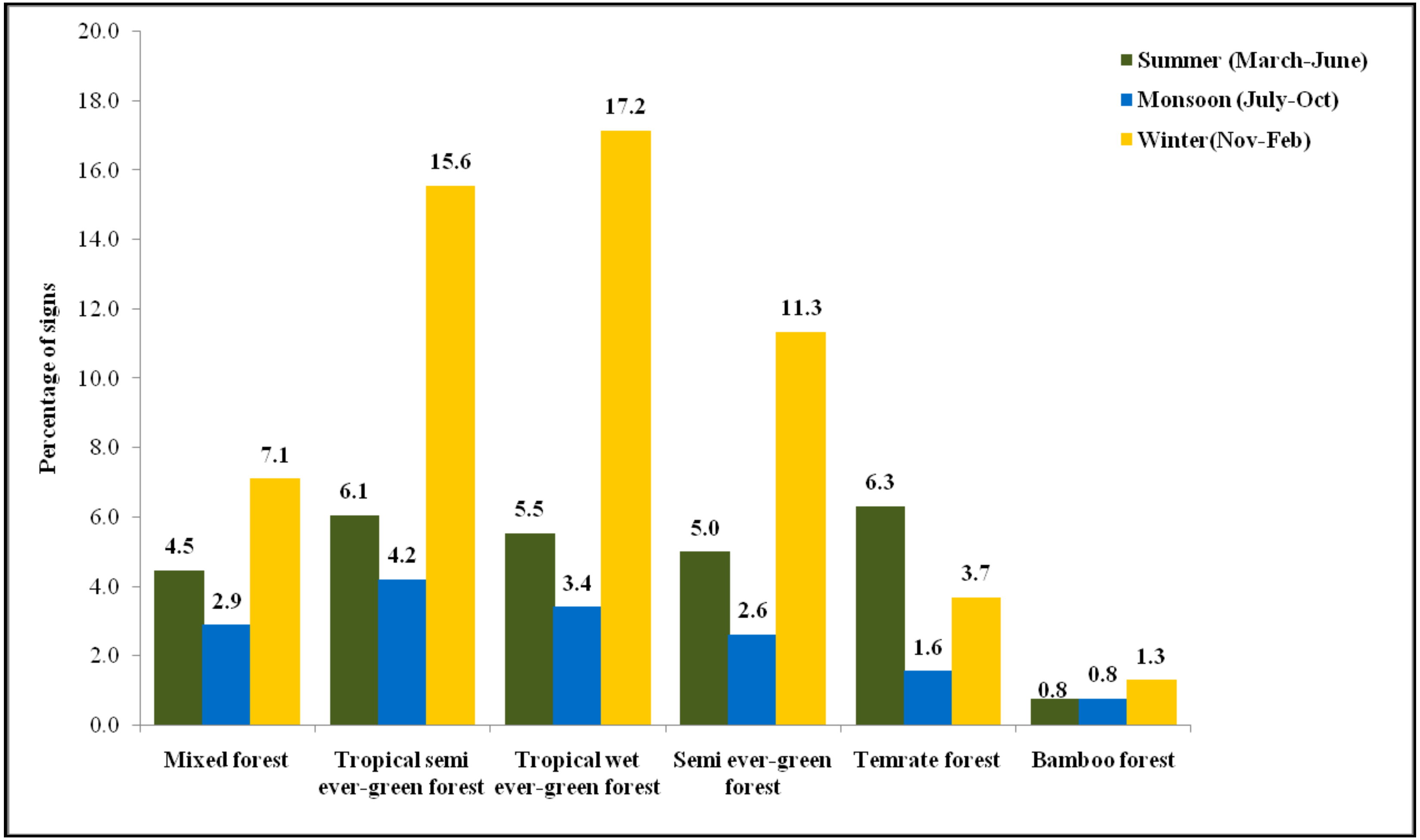


Figure 9: Number of signs per hectare in different forest types along transects in Namdapha Tiger Reserve.

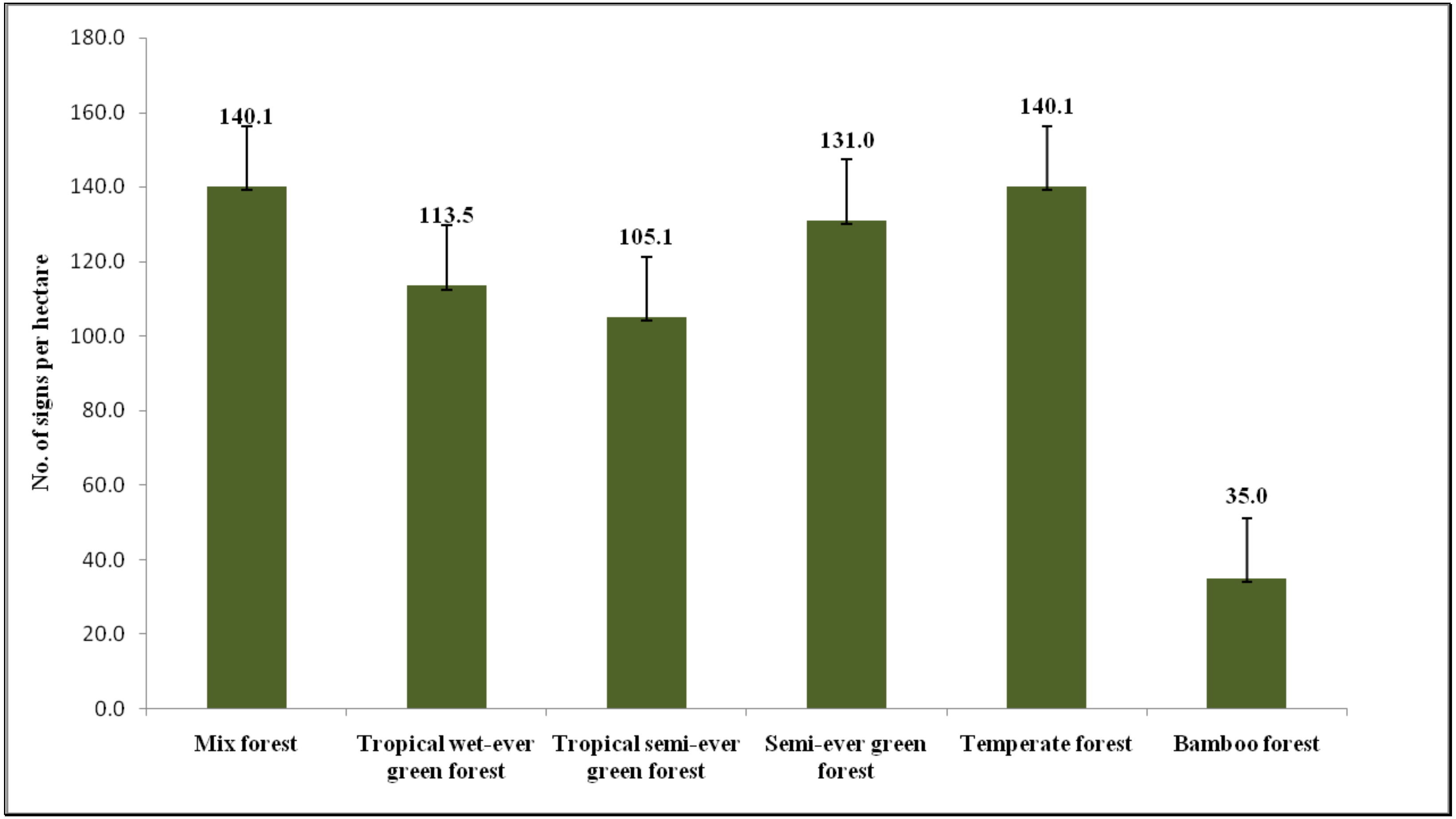


Figure 10: Percentage of signs along transect in different elevations in Namdapha Tiger Reserve.

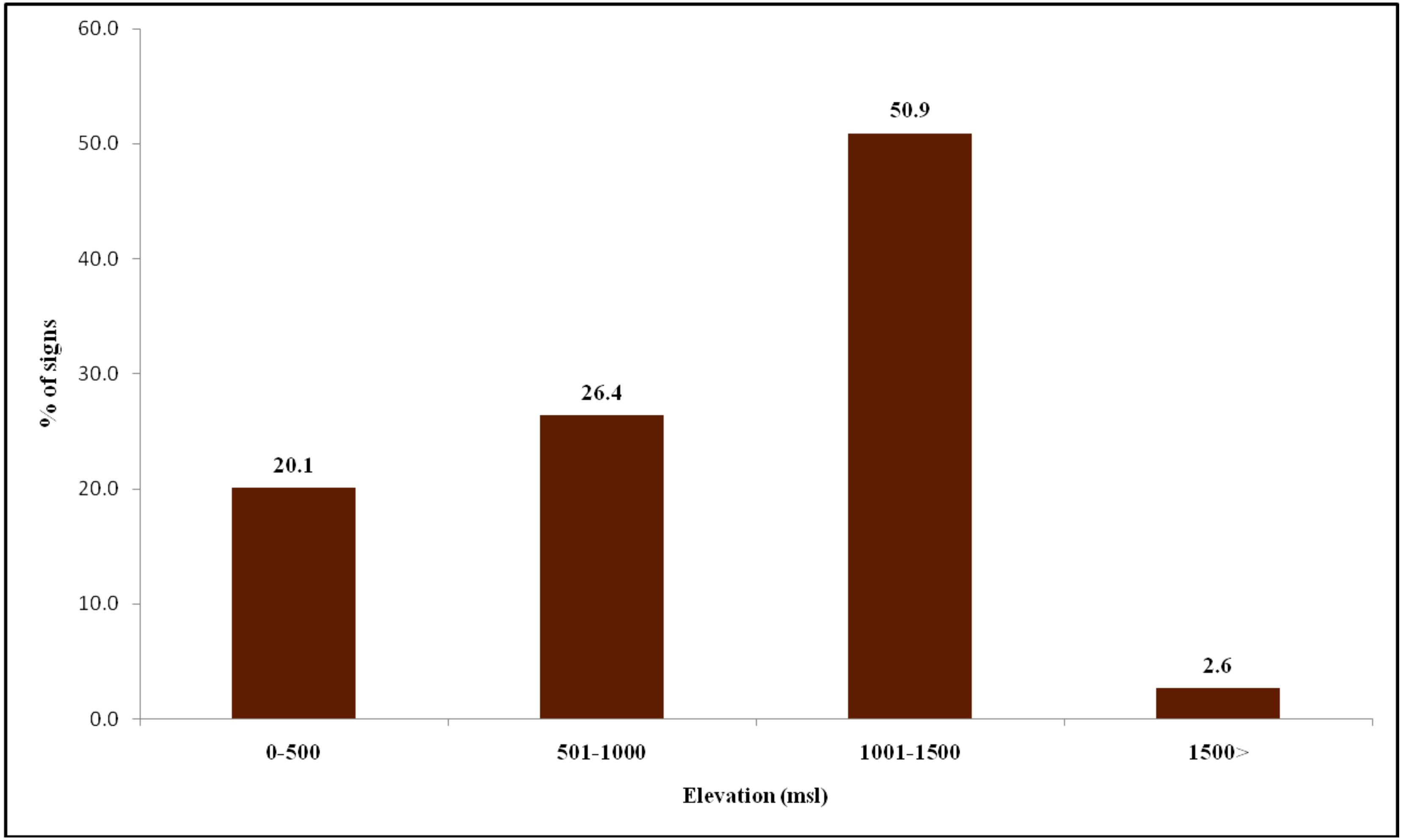


Figure 11: Relationship between mean elevation and the density of signs per hectare (R^2 Linear = 0.81488).

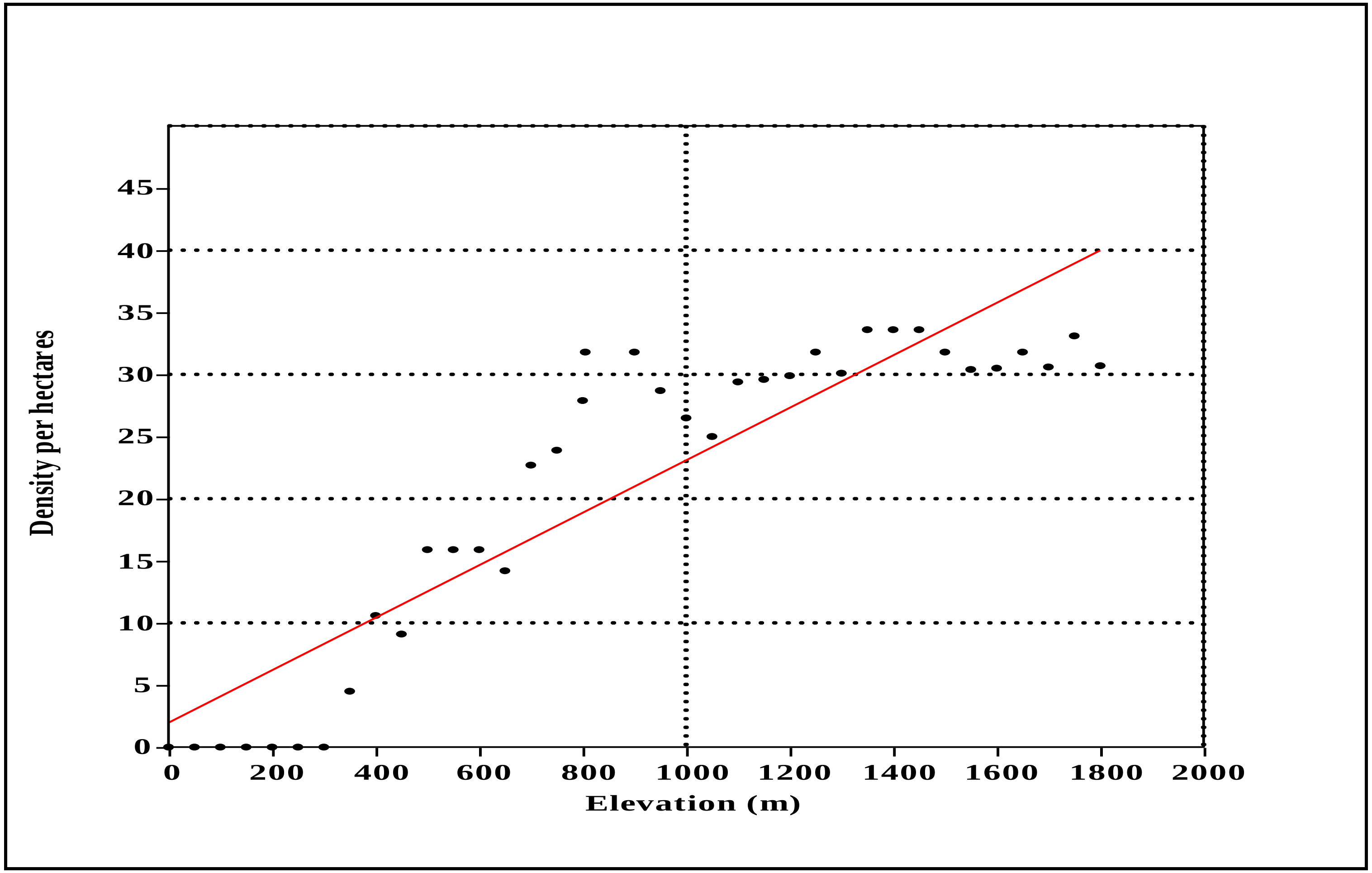


Figure 12: Percentage of signs along transects in disturbed and undisturbed areas in Namdapha Tiger Reserve.

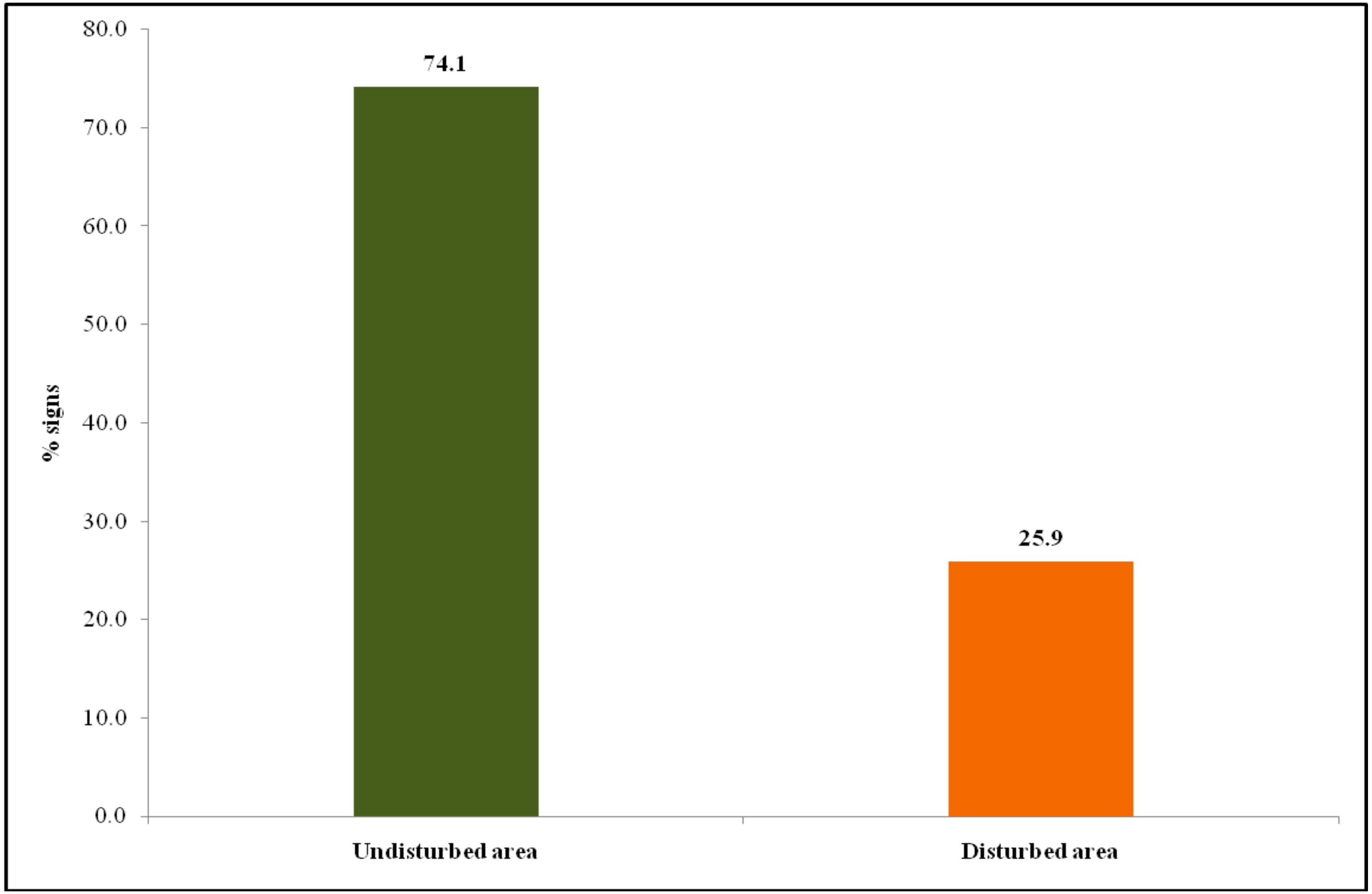
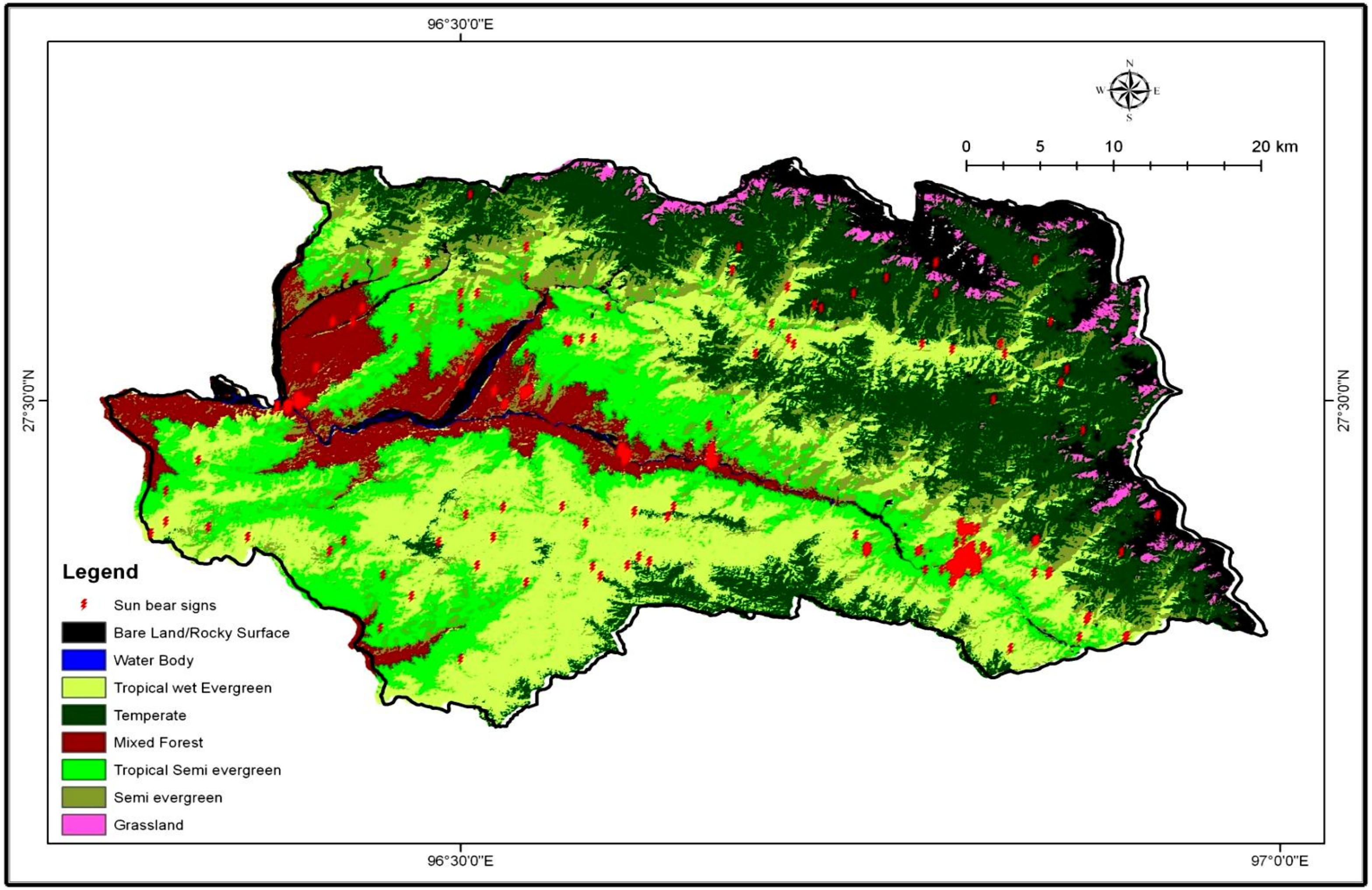


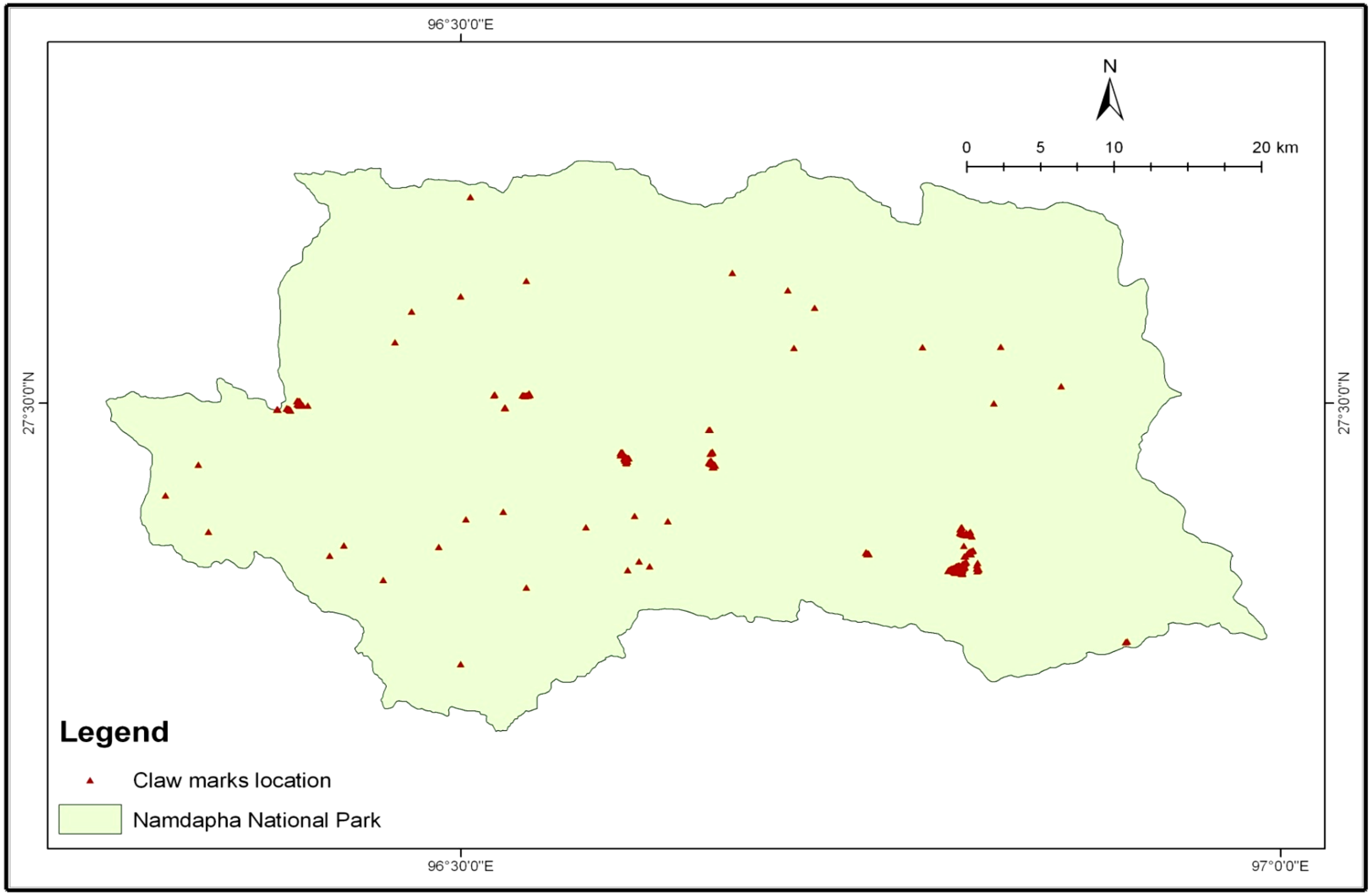
Table 6: Camera-trapping efforts in different ranges of Namdapha Tiger Reserve during 2008 to 2010.

Range	Elevation (msl)	Survey period	No. of camera stations	Trap days and nights	Total photos	Animal photos	Bear photos
Gandhigram	500-1500	12^{th} Aug. 09 to 20^{th} Nov. 10	125	560	380	32	3
Deban	300-790	23^{rd} Aug. 08 to 9^{th} Jan. 09	25	100	120	7	0
Namdapha	300-700	23^{rd} Aug. 08 to 9^{th} Jan. 09	25	50	76	4	0
	Total		175	710	576	43	3

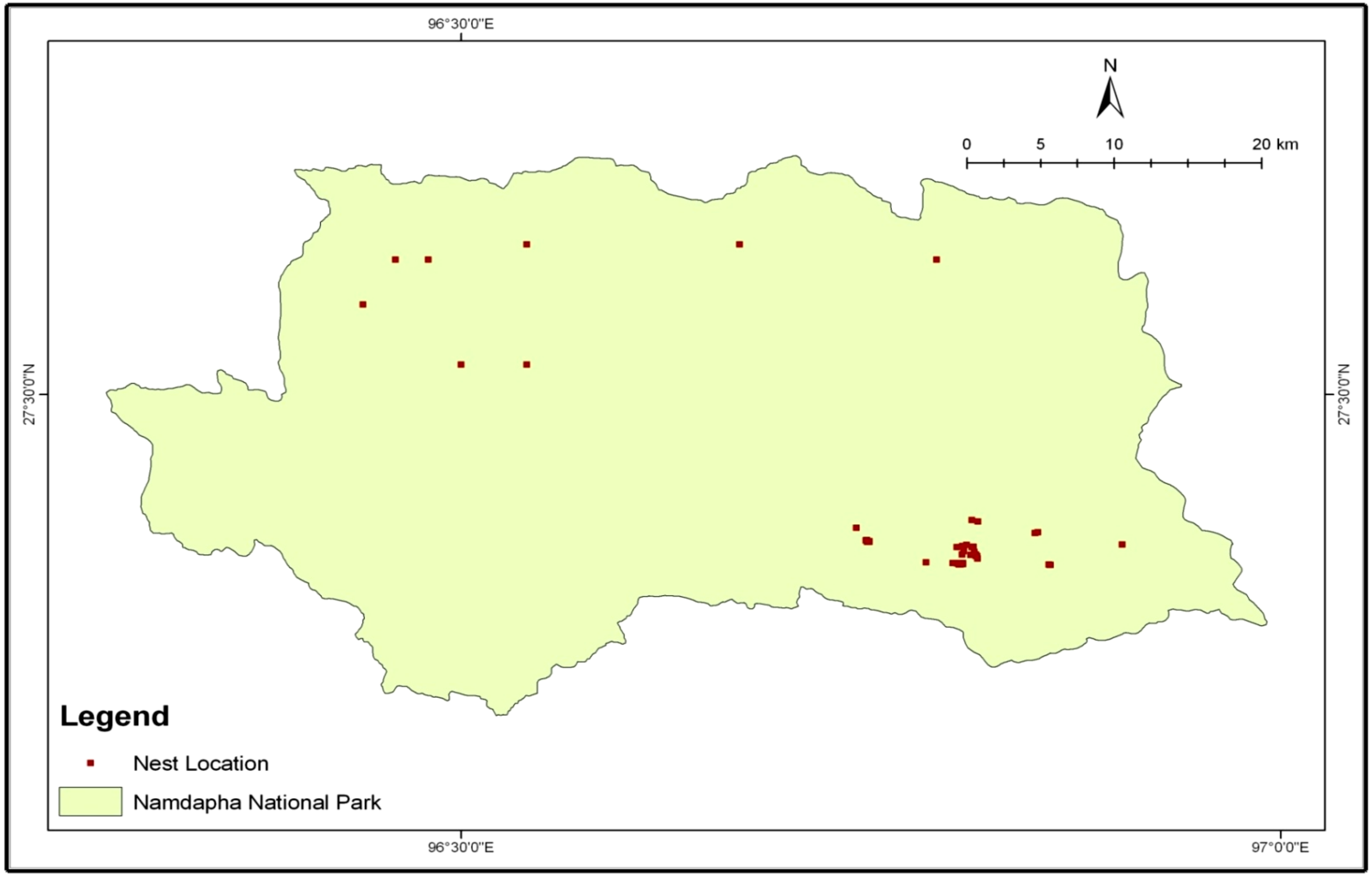
Map 4: Signs distribution of sun bear recorded in Namdapha Tiger Reserve.



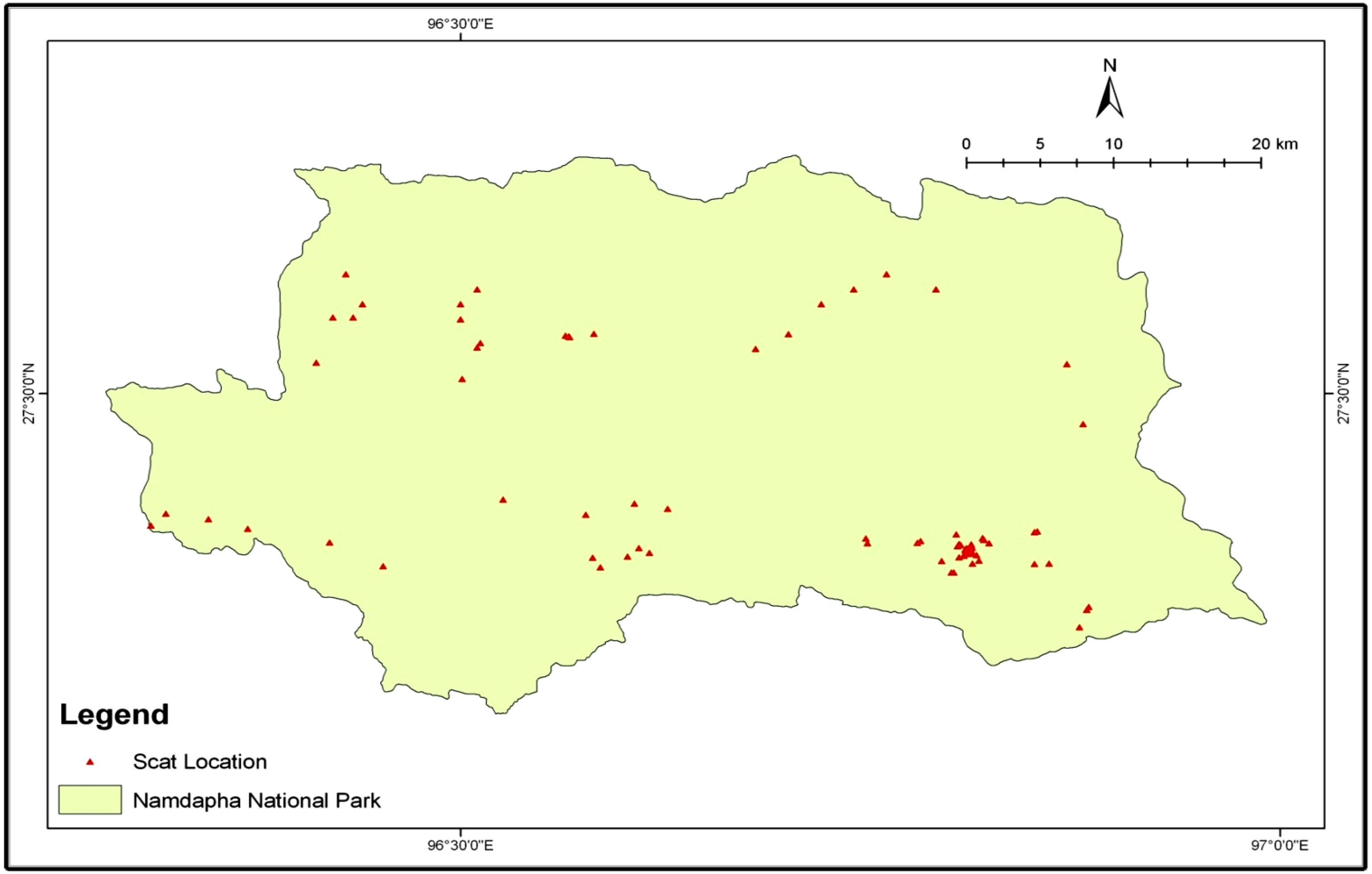
Map 5: Claw marks distribution sun bear recorded in Namdapha Tiger Reserve.



Map 6: Nests distribution of sun bear observed in Namdapha Tiger Reserve during 2008 to 2010.



Map 7: Scats distribution sun bears observed in Namdapha Tiger Reserve during 2008 to 2010.



Map 8: Location of crop raids by sun bear in and around Namdapha Tiger Reserve.

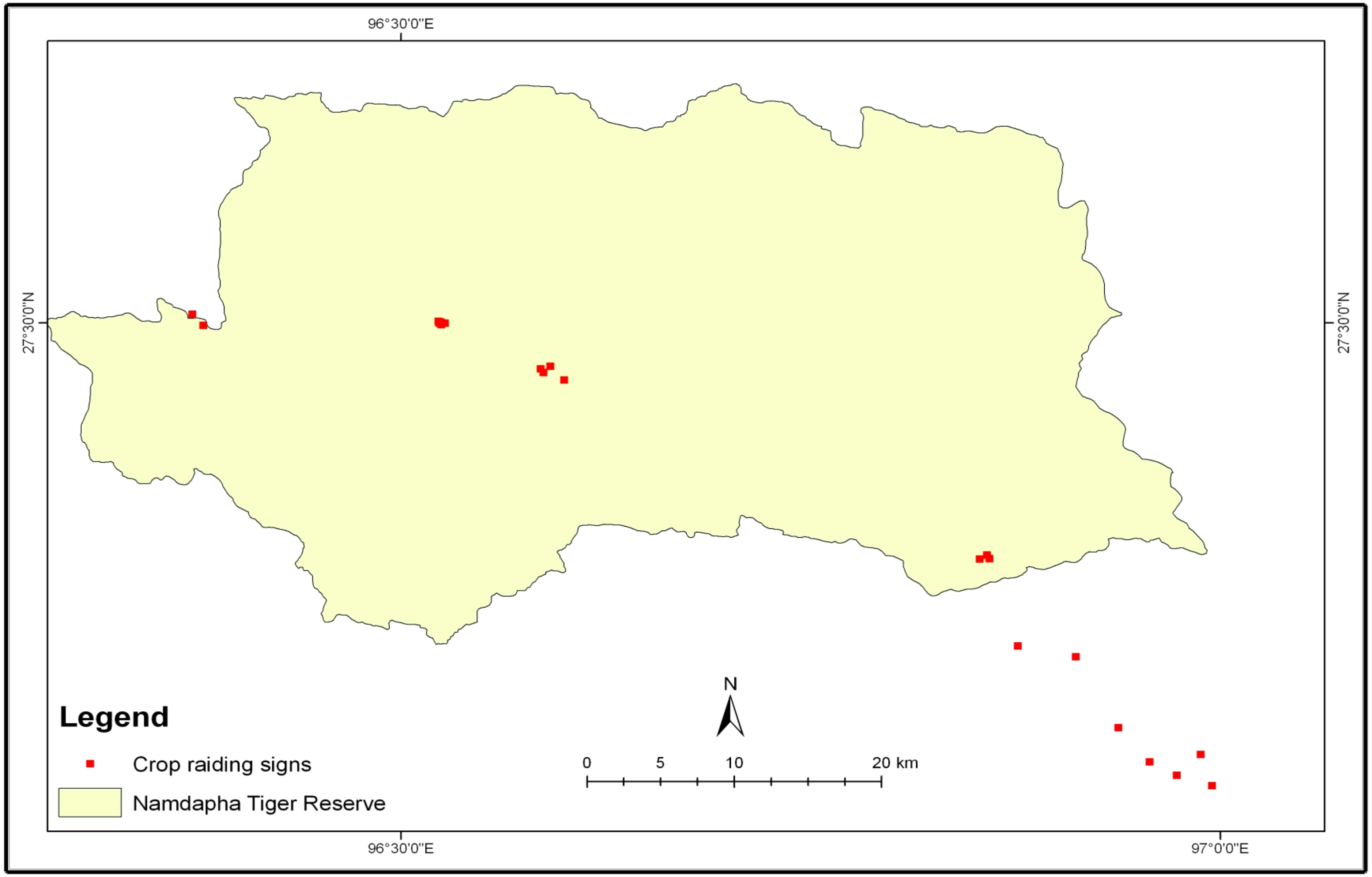


Plate 1: Sun bear claw marks on a tree.

Plate 2: Scat of sun bear.

Plate 3: Nest of sun bear.

Plate 4: Tearing sign in a tree by sun bear.

Plate 5: Tree tears for termites.

Plate 6: Tree tears for unknown region.

Plate 7: Sun bear digging signs.

Plate 8: Foot print of sun bear.

Plate 9: Deploying Deer Cam on a tree.

Plate 10: Deploying Digital Camera.

Plate 11: Deploying Digital Cam.

Plate 12: Deploying Digital Cam.

Table 1: Availability of food plants of sun bear in different habitats in Namdapha Tiger Reserve during 2008-2010.

S. No.	Mix forest	Tropical wet-ever green forest	Tropical semi-ever green forest	Semi-ever green forest	Temperate forest	Bamboo forest
1	*Spondias axillaris* .	*Horsefieldia mygdalina*	*Symplocos spp.*	*Medinilla erythrophylla*	*Ostodes paniculata*	*Flosrajnae*
2	*Ardisia spp.*	*Micromelum pubescens*	*Actinodaphre obovata*	*Ostodes paniculata*	*Knema angustifolia*	*Amara walichai*
3	*Quercus pachyphylla* .	*Natsiatum nerpeticum*	*Gnetum montanum*	*Knema angustifolia*	*Symplocos javanica*	*Ficus*
4	*Balanophora nvolucrata*	*Turpiria pomifera*	*Eulophia* spp.	*Symplocos javanica*	*Acer hookari*	*Symplocos javanica*
5	*Alangium chinense* .	*Polyalthia simiarum*	*Streptous simplex*	*Acer hookari*	*Polyalthia simiarum*	-
6	*Terminalia chibula*	*Calamus* spp. .	*Phoebe spp.*	*Terminalia chibula*	*Calamus* spp.	-

Continued

S. No.	Mix forest	Tropical wet-ever green forest	Tropical semi-ever green forest	Semi-ever green forest	Temperate forest	Bamboo forest
7	*Terminalia belerica*	*Elaeocarpus phaericus*	*Gnetum montanum*	*Terminalia belerica*	-	-
8	***Embilica offcianlisis*** **.**	*Ficus* spp.	*Dimocarpus longana*	*Ficus* spp.	-	-
9	*Ficus* spp.	- .	*Biscofia zapanica*	*Biscofia zapanica*	-	-
10	-	- .	*Phibi coporina*	*Phibi coporina*	-	-
11	-	- .	*Flosrajnae*	*Flosrajnae*	-	-

Table 2: Variables selected to determine sun bear habitat availability in Namdapha Tiger Reserve.

Variable (Unit of measure)	**Range**	**Data source**
Elevation (m)	0-4000	Transect survey
Slope (degree)	0-76	Transect survey
Vegetation cover	-	Vegetation characterization by Champion and Seth (1968)
Distance to water (m)	0-4000	Transect survey
Human disturbance (%)	0-45.9	Questionnaire survey and transect survey
Terrain shape index	_22.4–25.4	Calculated from elevation based on McNab (1989)

Table 3: Habitat use by sun bear in Namdapha Tiger Reserve.

S. No.	Habitat category	No. of plots (n=430)	No. of bear signs in sample plots (n=379)	No. of plots with bear signs (n=339)	Density of signs (signs/ha)
1	Mix forest	50	55	47	140.1
2	Tropical wet-ever green forest	110	98	87	113.5
3	Tropical semi-ever green forest	120	99	92	105.1
4	Semi-ever green forest	70	72	66	131.0
5	Temperate forest	40	44	38	140.1
6	Bamboo forest	40	11	9	35.0

Table 4: Frequency occurrence of food plants in plots used by sun bear in Namdapha Tiger Reserve.

No. of food plants	No. of plots sampled (n=430)	Plots with or without food plants (%)	No. of plots used by bears (n=339)	Proportional utilization of plots (%)
0	10	2.3	6	60.0
1	51	11.9	35	68.6
2	56	13.0	43	76.8
3	79	18.4	72	91.1
4	88	20.5	78	88.6
5	40	9.3	31	77.5
6	38	8.8	27	71.1
7	34	7.9	25	73.5
8	20	4.7	12	60.0
9	14	3.3	10	71.4

Table 5: Habitat availability vs. habitat use by sun bear in Namdapha Tiger Reserve (Based on the Bonferroni confidence intervals).

Habitat type	No. of plots (n=430)	Relative index	Utility (n=339)	Relative Index (p)	Lower confidence limit	Upper confidence limit	Utilization
Mix forest	50	0.116	47	0.139	0.089	0.188	**
Tropical wet-ever green forest	110	0.256	87	0.257	0.194	0.319	**
Tropical semi-ever green forest	120	0.279	92	0.271	0.208	0.335	**
Semi-ever green forest	70	0.163	66	0.195	0.138	0.251	**
Temperate forest	40	0.093	38	0.112	0.067	0.157	**
Bamboo forest	40	0.093	9	0.027	0.004	0.050	**

**** Calculated according to Neu *et al.* (1974). The asterisk denotes the habitat use in proportion to its availability.**

Table 6: Seasonal variation of habitat use by sun bear based on indirect signs in Namdapha Tiger Reserve.

Habitat type	No. of sample plots (n=430)	No. of bear signs	No. of signs (%)		
			Summer	Monsoon	Winter
Mix forest	50	55	7 (12.7)	16 (29.1)	32 (58.2)
Tropical wet-ever green forest	110	98	23 (23.5)	33 (33.7)	42 (42.8)
Tropical semi-ever green forest	120	99	25 (25.2)	36 (36.4)	38 (38.4)
Semi-ever green forest	70	72	19 (26.4)	24 (33.3)	29 (40.3)
Temperate forest	40	44	11 (25.0)	13 (29.5)	20 (45.5)
Bamboo forest	40	11	4 (36.4)	2 (18.2)	5 (45.4)

Summer: March, April, May, June; **Monsoon:** July, August, September, October; **Winter:** November, December, January, February.

Table 7: Use of terrain in different habitats by sun bear based on indirect signs in Namdapha Tiger Reserve during 2008-2010.

Habitat type	No. of plots	No. of signs (%)				Total no. of bear signs
		Flat terrain	Undulating terrain	Gentle slope terrain	Steep slope terrain	
Mix forest	50	2 (3.6)	35 (63.6)	7 (12.7)	11 (20.1)	55
Tropical wet-ever green forest	110	4 (4.1)	54 (55.1)	9 (9.2)	31 (31.6)	98
Tropical semi-ever green forest	120	5 (5.1)	59 (59.6)	5 (5.1)	30 (30.2)	99
Semi-ever green forest	70	3 (4.2)	33 (45.8)	7 (9.7)	29 (40.3)	72
Temperate forest	40	7 (15.9)	16 (36.4)	3 (6.8)	18 (40.9)	44
Bamboo forest	40	2 (18.1)	3 (27.3)	2 (18.1)	4 (36.5)	11

Table 8: Proportional availability and expected use of terrain by sun bear in Namdapha Tiger Reserve. (Based on the Bonferroni confidence interval).

Terrain type	Availability of terrain (n)	Relative index	Utility of terrain (n)	Relative index (p)	Lower confidence limit	Upper confidence limit	Utilization of terrain
Flat	46	0.107	24	0.089	0.043	0.135	**
Undulating	188	0.437	121	0.450	0.370	0.530	**
Gentle slope	124	0.288	87	0.323	0.248	0.399	++
Steep slope	72	0.167	37	0.138	0.082	0.193	++

**** Asterisk denotes the use of terrain in proportion to availability, and ++ Plus sign denotes the use of terrain more than availability.**

Table 9: Analysis of variance using Kruskal-Wallis non-parametric test for habitat use by sun bear.

Habitat variable	No. of trees	No. of shrubs	No. of herbs	No. of tree felled	No. of tree lopped	Cattle dung	Distance from habitation	Distance from road	Nearest water source	Herb cover	Shrub cover
Chi-sq.	84.103	109.146	140.754	21.140	162.367	90.938	413.590	413.408	416.081	135.193	107.351
df	5	5	5	5	5	5	5	5	5	5	5
Asymp.	.000	.000	.000	.001	.000	.000	.000	.000	.000	.000	.000

a. Kruskal Wallis Test

b. Grouping variable: Habitat type

Figure 1: Annual veriation of bear signs in different habitat in Namdapha Tiger Reserve.

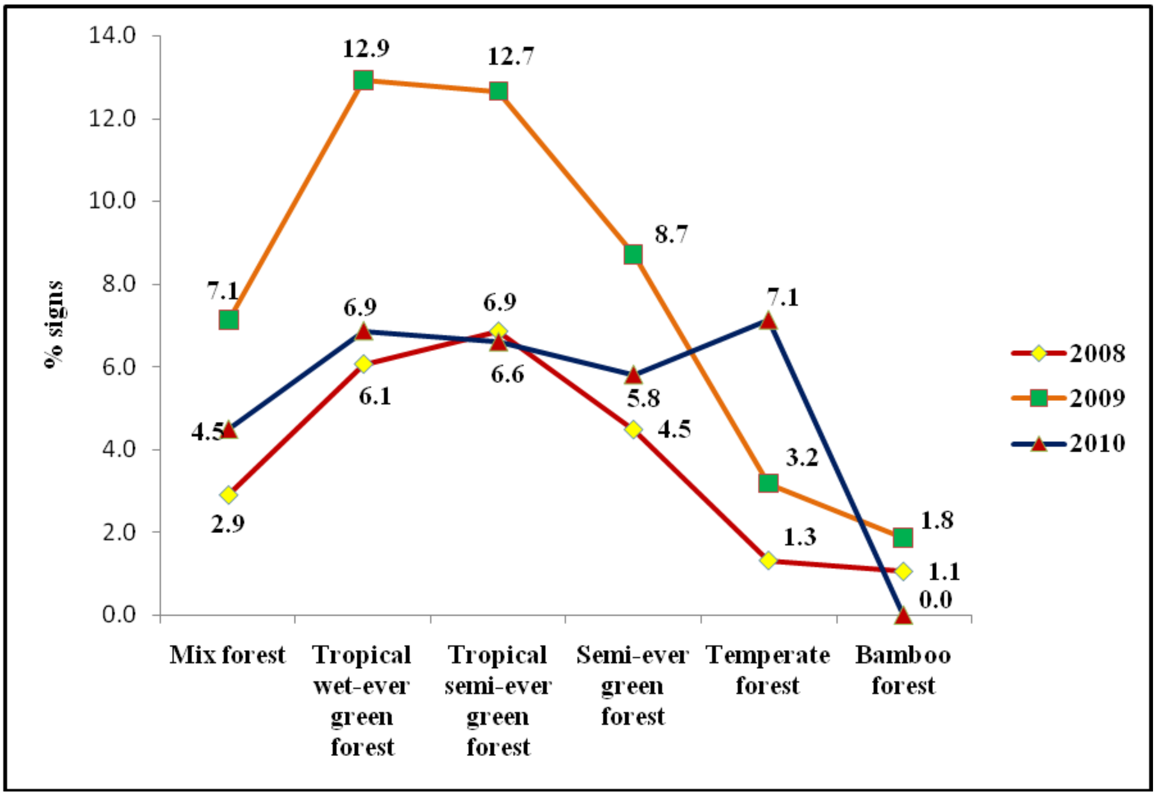


Figure 2: Presence of signs in different terrain types in Namdapha Tiger Reserve.

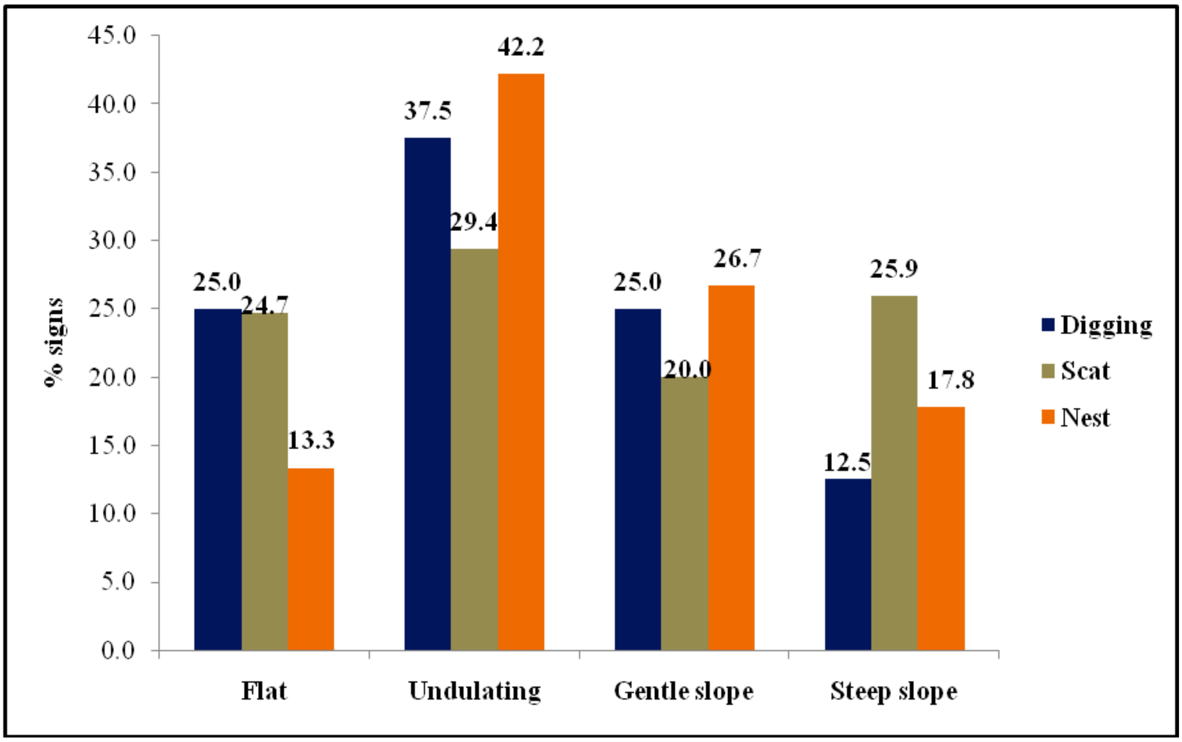


Figure 3: Comparison of total observed signs in primary undisturbed forest *versus* disturbed areas.

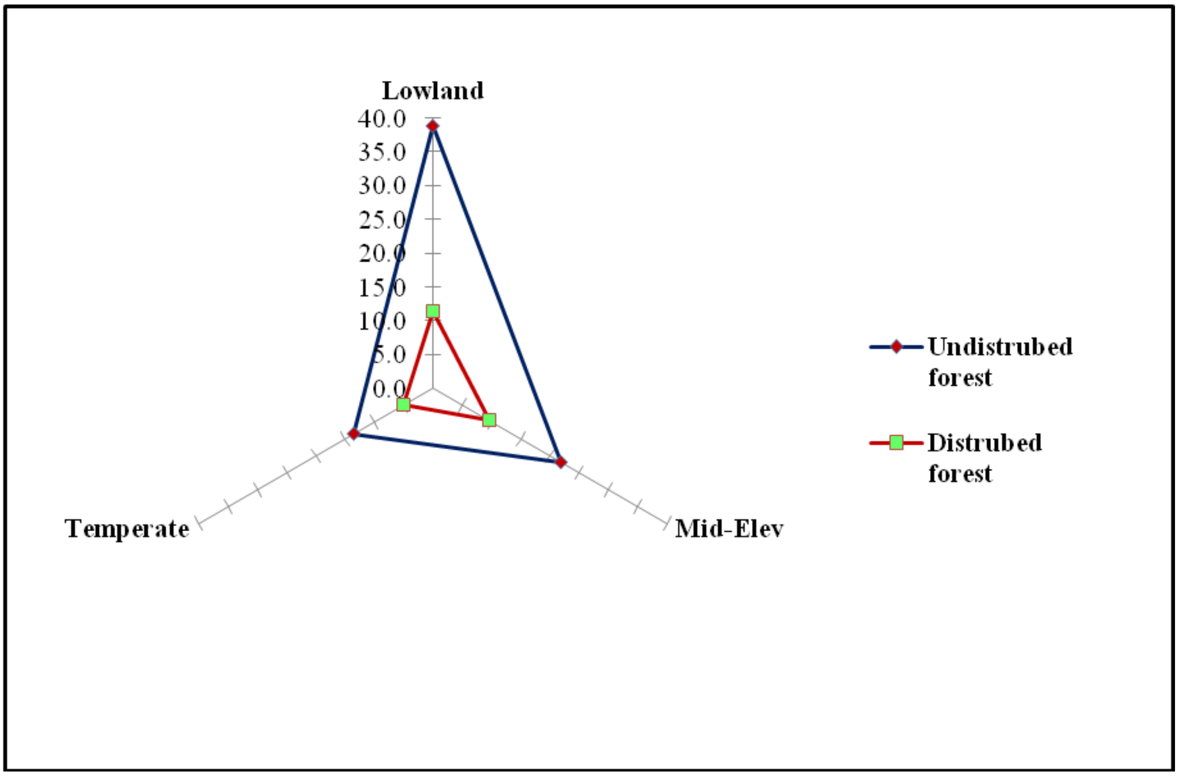
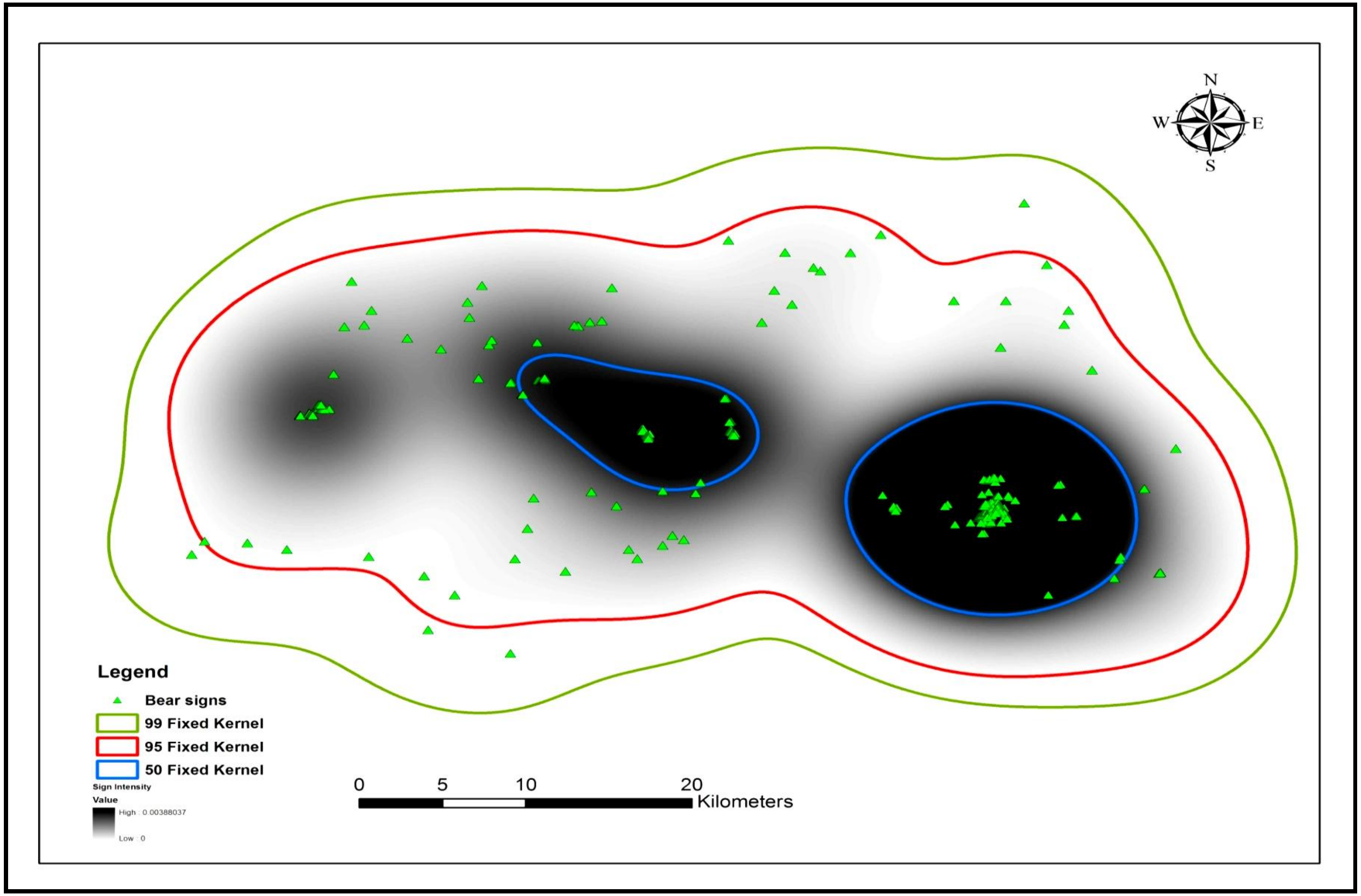
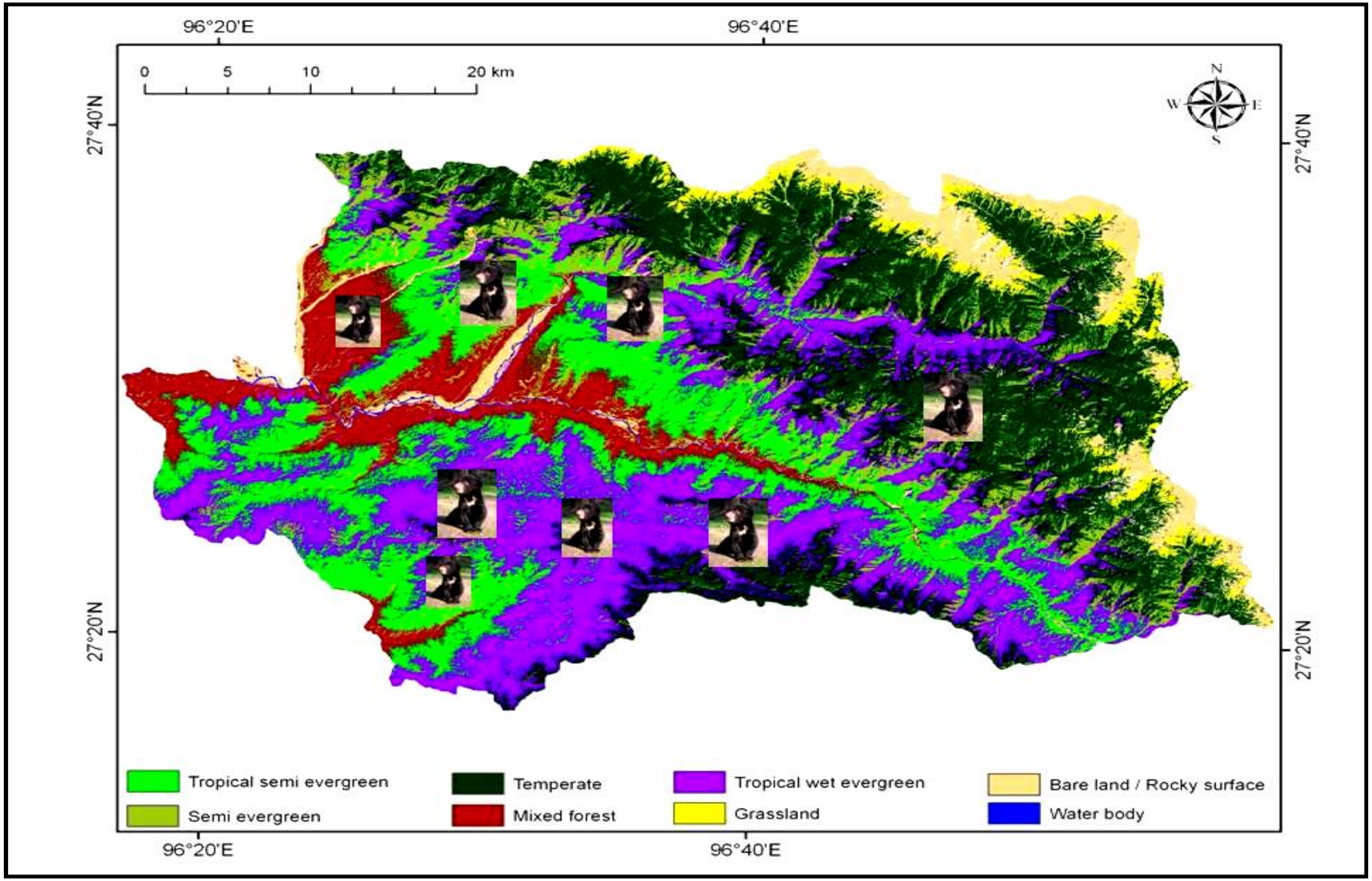


Figure 4: Fixed Kernel (99%, 95% and 50%) based habitats of sun bear in Namdapha Tiger Reserve.



Map 1: Habitat use by sun bear in different forest types in Namdapha Tiger Reserve.



Appendix 1: Sampling layout for vegetation quantification and collection of bear evidences.

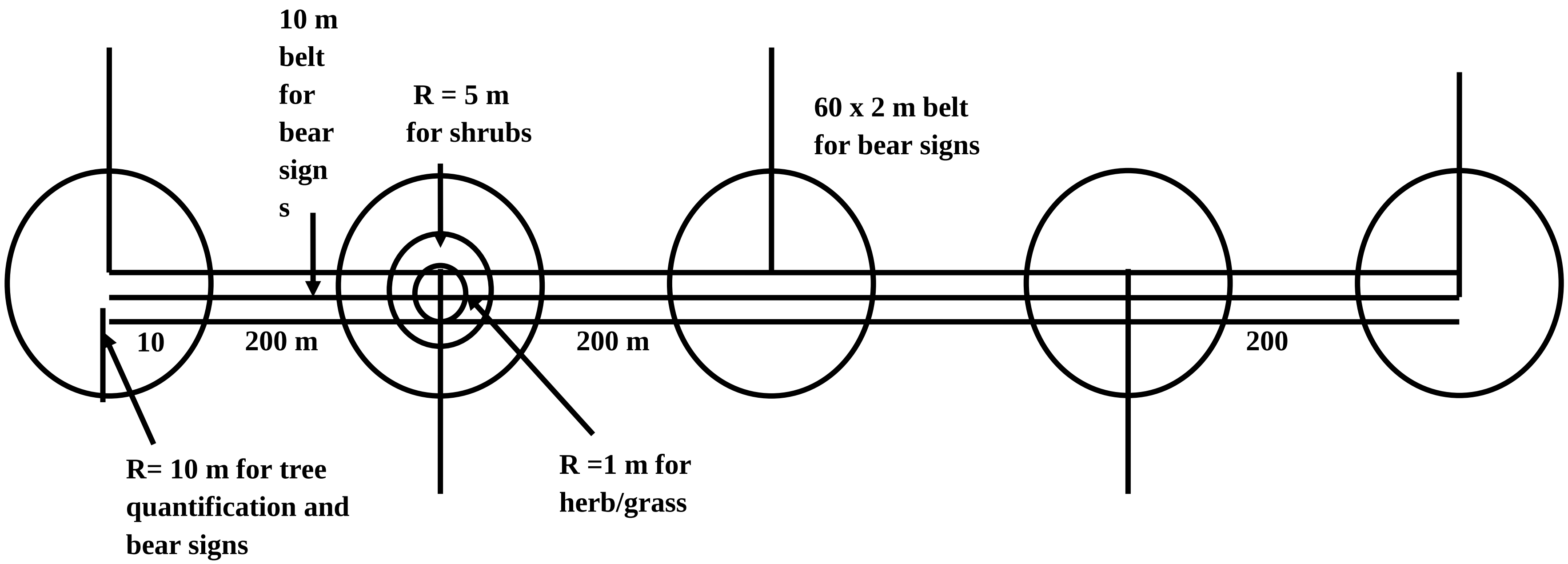


Plate 1: Mix forest

Plate 2: Tropical wet-ever green forest

Plate 3: Tropical semi-ever green forest

Plate 4: Semi-ever green forest

Plate 5: Temperate forest

Plate 6: Bamboo forest

Chapter 5

To asses the habitat use by sun bears in Namdapha Tiger Reserve.

5.1 Introduction

In India, the increase in human and livestock population has created pressures on all natural resources. Most of the protected areas are fragmented, degraded, and disturbed from anthropogenic activities. Forests, pastures and wastelands were brought under cultivation to sustain increased demand of cereals and other food products (Chauhan and Sawarkar, 1989). The unsustainable land-use patterns in rural areas have further altered landscapes. This habitat modification has caused wildlife species to become ecologically dislocated. For the management of wildlife and its habitat, information on food, water and shelter and conditions suited to a particular animal species have to be known accurately. The quality of habitat is generally reflected in the status of vegetation cover and its seasonal variation. The site characteristics like fruiting trees and shrub availability, location of dens, water availability and presence of termite mounds and ant nests are directly related to the habitat use. The necessity of assessing preference or avoidance of a given habitat or plant species in terms of its availability has long been recognized (Neu *et al.*, 1974).

The habitat utilization by bear species showed varied patterns in different places. Sun bears rely mainly on tropical forest habitat. Two ecologically distinct categories of tropical forest occur within its range, distinguished by differences in climate, phenology, and floristic composition (IUCN Red list, 2006). Tropical evergreen rainforest is the main habitat of sun bear in Borneo, Sumatra, and peninsular Malaysia. This seasonal habitat receives high annual rainfall that is relatively evenly distributed throughout the year. Tropical evergreen rainforest includes a wide diversity of forest types used by sun bears, including lowland dipterocarp, peat swamp, freshwater swamp, limestone/karst hills, hill dipterocarp, and lower montane forest.

In contrast, sun bears in mainland Southeast Asia inhabit seasonal ecosystems with a long dry season (3-7 months), during which rainfall is <100 mm per month (IUCN Red list, 2006). Seasonal forest types are usually interspersed in a mosaic that includes semi-evergreen, mixed deciduous, dry dipterocarp (<1,000 m elevation), and montane evergreen forest (>1,000 m). The range of sun bears overlaps with that of Asiatic black bears (*Ursus thibetanus*) in this seasonal forest mosaic.

Some observations have been reported of sun bear occurrence in secondary forests or disturbed areas (Wong, 2002; Wong *et al.*, 2004 and Fredriksson, 2005), but the ages of these forests, as well as the scale and frequency of use by these bears relative to their overall populations, are important factors when analysing population-level patterns. Results concur with those of several other studies (Wilson and Wilson, 1975; Wilson and Johns, 1982; Johns, 1983 and Normua *et al.*, 2003, 2004) that indicated sun bears predominantly occur in primary forest. Wong *et al*. (2004) extrapolated across the sun bear's global range, concluding that the importance of primary forests for sun bear survival is uncertain and that bears clearly occur in logged forests.

Sun bears also have been reported in mangrove forest, although their occurrence in this forest type probably depends on proximity to other more favoured habitats. Sun bears use selectively logged areas (Wong *et al.*, 2004 and Meijaard *et al.*, 2005), and oil palm plantations near forest edges (Nomura *et al.*, 2004). However, there is no evidence that sun bears can survive in deforested or agricultural areas in the absence of nearby forest (Augeri, 2005). This can alter a bear's movement dynamics through the landscape and prohibit critical habitat use (McLellan and Shacklton, 1988; Augeri, 1994, 2000; Mattson *et al.*, 1996; Merrill *et al.*, 1999; Boyce, 2000 and Augeri, 2002b)

Sun bears occur from near sea level to over 2,100 m elevation, but appear to be the most common in lower elevation forests. In Indonesia and western Thailand, for example, sun bears occur primarily below 1,200 m (Augeri, 2005 and Vinitpornsawan *et al.*, 2006). Sun bears have been observed up to 2,100 m in Myanmar (Saw Htun, 2006), 1,600 m in Lao PDR (Steinmetz *et al.*, 1999), and 2,143 m in Sumatra (Augeri, 2005).

Sun bears are omnivores, and use habitats where they feed primarily on termites, ants, beetle larvae, bee larvae and honey, and a large variety of fruit species, especially figs (Ficus spp.), when available (McConkey and Galetti, 1999; Wong *et al.*, 2002; Augeri, 2005 and Fredriksson *et al.*, 2006a). Occasionally, growth shoots of certain palms and some species of flowers are consumed in these habitats (Fredriksson *et al.*, 2006a), but otherwise vegetative matter rarely occurs in the diet. In Bornean forests, fruits of the families Moraceae, Burseraceae and Myrtaceae make up more than 50% of the fruit diet (Fredriksson *et al.*, 2006a), whereas in western Thailand fruits of Lauraceae and Fagaceae are the most commonly consumed (Vinitpornsawan *et al.*, 2006). In Thailand sun bears and Asiatic black bears use many of the same habitats and have extensive overlap in diet. However, in montane forests >1,200 m elevation (where ground cover is sparse) Asiatic black bears are more abundant than sun bears (Vinitpornsawan *et al.*, 2006).

Nair and Jayson (1988) studied the habitat utilization by large mammals in teak plantation and natural forest, and focused their study on abundance of animals, fodder consumption by animals and damage to plantation by animals. Nams *et al.* (2001) studied the scale dependent habitat selection by grizzly bear in the central Selkirk Mountains and found that grizzly bears were patchy in abundance at all spatial scales. The bears selected about six kilometres areas at higher elevations and fewer trees within the radius of 15 km areas. In the Mission mountains of Montana, food habits, movement pattern and habitat selection were studied by Servheen (1983), and the habitat use was ascertained from 381 radiolocations of six bears during 1977-1979. Habitat component elevations and aspects were recorded for each radio locations, and only one location was used per bear per 24 hours period.

Habitat loss and fragmentation are two of the main challenges in the conservation and management of large carnivores in the world (Peyton *et al.*, 1999 and Tirira *et al.*, 2001). Habitat fragmentation can result in small, isolated populations that become increasingly vulnerable to extinction (Diamond, 1986 and Wilcove, 1987). The sun bear presents a clear example of how habitat fragmentation and illegal hunting have caused severe population reductions; consequently, this species is now considered threatened at a global scale (Hilton-Taylor, 2000) and in danger of extinction in Southeast Asia IUCN 2009. The sun bear is a key species in the conservation and management of habitats due to its large spatial requirements, its ecological role (e.g., potential seed disperser), and its profound charisma (Yerena and Torres, 1994; Young, 1999 and Cuesta, 2000). The sun bear's wide ecological requirements and its seasonal use of different habitats, such as extensive paramour and tropical forest areas, make this species an appropriate subject on which to base conservation planning to preserve the high biodiversity of these ecosystems (Peyton, 1999). The seasonal variability in food availability in habitats used by sun bears triggers wide-ranging movements of the animals within their home ranges, as has been documented for other bear species (Schoen, 1990). Those movements, however, often are impeded by the loss of cloud forest and paramour because of advancing agricultural frontiers and expanding infrastructure (e.g. roads).

Most habitat use studies of large mammals rely on direct observations or radio-telemetry. Wild bears in Southeast Asia are rarely observed and difficult to capture, however, so used incidence of bear signs to examine habitat use. Bear signs have been used to describe habitat use by brown bears (Clevenger *et al.*, 1997 and Poscillico *et al.*, 2004), Asiatic black bears (Carr *et al.*, 2002), and Andean bears (Cuesta *et al.*, 2003 and Rios-Uzeda *et al.*, 2006). Bears in Southeast Asia leave abundant signs in the forest which are conspicuous, long-lasting, and related mostly to feeding. Signs most commonly encountered are diggings and logs torn apart for invertebrates, and claw marks on trees climbed for fruits, resting, or refuge. Such signs result from behavioral decisions related to feeding or security, and thus are a good currency for quantifying habitat use and selection because they are linked directly to individual fitness. Bear signs are discrete ‘event sites’ places where animals have invested time and energy to accomplish important life functions (Buskirk and Millspaugh, 2006).

No systematic information is available on the habitat use, its seasonal variation and nesting activities of sun bear in Namdapha Tiger Reserve. How the increasing biotic pressure is affecting sun bear habitat and its population in this area is also not known? The study therefore envisages assessing the habitat use pattern of sun bear in Namdapha Tiger Reserve.

5.2 Methods

To study the habitat use pattern of sun bear, the following methods have been used in Namdapha Tiger Reserve.

5.2.1 Transect sampling

Monitoring of wildlife populations through sign records has been used in many studies to determine population abundance and to quantify habitat use and availability (Nams, 1989 and Clevenger *et al.*, 1997). Bear sign information was gathered along 43 transects with a length of 2-3 km each. Placement of transects within the study areas was stratified according to the area represented by each vegetation type in the study area (Kendall *et al.*, 1992). Given the poor accessibility within the study area, starting locations for most transects were placed near the Gandhigram villages to Namdapha and Dehing River or near the unpaved road that connects different village with portions of the study area. Once we located the start of each transect, we followed an upslope direction for those transects starting near the Namdapha and Dehing River and a random direction for high-elevation transects.

In the study area, vegetation showed high degree of heterogeneity and variable degree of biotic pressure. After the reconnaissance survey, 43 linear transects were laid at random encompassing in six different habitat categories viz. Mix forest, Tropical semi-ever green forest, Tropical wet-ever green forest, Semi-ever green forest, Temperate forest and Bamboo forest in Namdapha Tiger Reserve. Along each transect of 2 km length, ten sampling plots of 10 m radius with 200 m interval were laid. **Appendix 1** shows the sampling layout for vegetation quantification and collection of bear evidences. Indirect evidences such as digging signs, presence of scats and claw marks, were recorded from within 430 plots marked along the transects. In addition, information on habitat variables like terrain, vegetation type, tree and shrub species, number of cut and lopped trees, stand height, canopy cover, nearest water source, cattle dung and distance from the habitation was recorded from within these sample plots as per the formats. The data of each sampling plot was pooled as per habitat type for analysis. Bear sighting on both sides of transects and habitat types of bear locations were recorded.

The 43 transects were surveyed once every 1 months. For each site with bear sign, field personnel collected (1) global positioning system (GPS) coordinates of the location, (2) the type of sign, and (3) additional field measurements to characterize the site. The GPS co-ordinates were used in combination with GIS to measure topographic, ecological, and anthropogenic variables selected to assess bear habitat use within the study area.

To generate a habitat map of the study area, 430 permanent vegetation plots were marked along 43 transects at an interval of 200 m. Within each sampling plot, a 10 m circular plot was laid to quantify tree density, 5 m circular plots for shrub density, and four 1 x 1 m quadrates for ground cover (herb, grass, bare ground, rock and litter) estimation. Habitat parameters such as altitude, slope and aspect were also recorded by using GPS and ocular estimation for each sampling plot. Aspect was measured on four point scale of North, South, East and West using a compass. For the habitat characterization and community classification, TWINSPAN analysis (Hill, 1979) was used.

5.2.2. Availability of food plants

From the vegetation data of different sample plots, assessment of food plants and their abundance in each habitat type was calculated. The food plants were counted within circular plot of 10 m radius and shrub species were counted within plot of 5 m radius for their density estimation. Certain species with ≥ 30 cm GBH were considered as tree and other species with ≤ 30 cm GBH were considered as shrub. Identification of food plants of bear diet was ascertained on the basis of analysis of scats, collected from the study area.

To assess the habitat use by sun bear in Namdapha Tiger Reserve, availability and utilization approach of Neu *et al.* (1974) was adopted here and analysis was done in the '*PREFER*' software package developed at the Wildlife Institute of India. During this exercise, following hypothesis was tested using Chi square test: bear utilized each habitat category in exact proportion to its occurrence within the study area. To know the difference between the habitat variables in the plots where bear signs were present or absent, Kruskal-Wallis non-parametric test was used (Zar, 1984). Multi-dimensional scaling, regression analysis, and non-parametric analysis were performed in SPSS software (Norussis, 1994).

5.3 Results

The habitat use by sun bear was assessed based on direct sightings and indirect evidences such as claw marks, scats, nests, dens, digging sign and foot prints etc. in Namdapha Tiger Reserve, Arunachal Pradesh. The Namdapha Tiger Reserve encompasses an area of 2200.25 km^2, and has six distinct habitat types viz. Tropical semi-ever green forest, Tropical wet-ever green forest, Semi-ever green forest, Mix forest, Temperate forest and Bamboo forest. In Exposed rock with slope grasses and Tropical semi-evergreen forest and Tropical wet-evergreen forest, trees were dominated by *Ficus, Alglinium chinense, Spondias axillaris* and *Horsefieldia amygdalina* species. **Plate 1 to 6** show the Eastern Himalayan, Mix forest, Tropical wet-ever green forest, Tropical semi-ever green forest, Semi-ever green forest, Temperate forest and Bamboo forest habitats in the Tiger Reserve.

5.3.1 Availability of food plants

In Namdapha Tiger Reserve, the habitat use by sun bear was found to be largely dependent on the availability of food resources, variety of food plants and shelter in different habitat types. There were 11 species of food plants found in Tropical semi-ever green forest and Semi-ever green forest, followed by 8 species in Mix forest, 7 species in Tropical-wet ever green forest, 6 species in Temperate forest and 4 species in Bamboo forest. Since the habitat use by bears was largely dependent on the availability of food resources and shelter, number of fruiting tree and shrub species were recorded in various habitat types. Fruiting tree species recorded in these forest types were *Spondias axillaris*, *Horsefieldia amygdalina*, *Micromelum pubescens, Natsiatum herpeticum, Turpinia pomifera*, *Ardisia* spp., *Lithocarpus pachyphyllus, Balanophora involucrate*, *Symplocos* sp., *Actinodaphne obovate*, *Gnetum montanum, Eulophia* spp., *Alangium chinense*, *Streptopus simplex*, *Phoebe* spp., *Dimocarpus longan*, *Polyalthia simiarum*, *Calamus* spp., *Elaeocarpus serrata*, *Medinilla rubicunda, Ostodes paniculate*, *Knema angustifolia*, *Symplocos cochinchirensis*, *Acer sikkimense*, *Terminalia chebula*, *Terminalia belerica*, *Emblica officinalis*, *Bischofia javanica*, *Phoebe cooperina*, *Flosrajnae* spp., *Amara wallichii and Ficus* spp **(Table**

1). These fruiting trees and other food items including insects and ants were available in different habitat types in the Tiger Reserve and in the vicinity of villages.

5.3.2 Habitat variables

Habitat variables based on GIS technology are suitable tools to predict the presence and relative use of bear habitat across large landscapes (Clark and van Manen, 1992), particularly because such models are appropriate for generalist species (Donovan *et al.*, 1987). Six variables, namely elevation, slope, vegetation cover, distance to water, human disturbance and terrain type were used to measure habitat conditions for the bear sign locations sampled during the field surveys **(Table 2)**.

5.3.3 Habitat use by sun bears

In Namdapha Tiger Reserve, the data on habitat use by sun bears collected from the 430 sample plots along the 43 transects showed maximum number of plots with bear signs in Tropical semi-ever green forest (n=99), followed by Tropical wet-ever green forest (n=98), Semi ever green forest (n=72), Mix forest (n=55), Dry Mix forest (n=44) and Bamboo forest (n=11) **(Table 3)**. Although sun bears showed some preference for Tropical semi-ever green forest and Tropical wet-ever green forest habitat categories, but as such there was no preference or avoidance by bears for rest of the habitat types. Out of 430 plots along the transects, bear evidences were found in 339 plots. Maximum number of plots (n=92) with bear signs fell in Tropical semi-ever green forest, followed by Tropical wet-ever green forest (n=87), Semi ever green forest (n=66), Mix forest (n=47), Temperate forest (n=38) and Bamboo forest (n=9). Density of bear signs per hectare was found highest in Mix forest and Temperate forest (140.1/ha each), followed by Semi ever-green forest with (131.0/ha), Tropical wet-ever green forest (113.5/ha), Tropical semi-ever green forest (105.1/ha) and Bamboo forest (35.0/ha) **(Table 3).**

The frequency occurrence of food plants in plots used by bears varied considerably in Namdapha Tiger Reserve **(Table 4)**. Plots with presence of 1, 2, 3 and 4 food plant species were 11.9%, 13.0 %, 18.4% and 20.5% respectively. Further as the number of food plant species increased, the percentage of these plots decreased. Plots with presence of 6, 7, 8 and 9 food plant species were 9.3%, 8.8%, 7.9% and 4.7% respectively. Irrespective of this variation, the proportional utilization of these plots with variable number of food plant species was very high, except the plots without any food plants. The proportional utilization of these plots ranged from 60% to 91.1%. The Chi square test comparison showed that expected high proportional utilization in each habitat category differed significantly from the occurrence of habitat categories within the study area (χ^2=2.951, df=9 p=0.967). Indirect bear evidences were mainly recorded from the forests, located far from villages, hillocks and water bodies. Perhaps bears did not spent much time in villages, and in search of food and shelter.

5.3.4 Habitat availability vs. utilization

In Namdapha Tiger Reserve, the data on habitat use by sun bears collected from the 430 sample plots along the transects showed maximum number of plots in Tropical semi-ever green forest (n=120), followed by Tropical wet-ever green forest (n=110), Semi-ever green forest (n=70) Mix forest (n=50) and there were 40 plots in each of Temperate and Bamboo forest **(Table 5)**. The Tropical semi-ever green forest near water bodies, river and streams and Tropical wet-ever green forest were characterized by the presence of *Actinodaphre obovata* species. The habitat category: Mix forest characterized by *Spondias axillaris and Ardisia* spp. and Exposed rocks with slope grasses and Tropical wet-ever green characterized by *Horsefieldia amygdalina* and *Calamus* species were found to have 5 plots in each. So among various habitat categories, the proportional availability of Tropical semi-ever green forest was found to be highest (0.279), followed by Tropical wet-ever green forest (0.256), Semi-ever green forest (0.163), Mix forest (0.116) and the proportional availability was 0.093 in each of Temperate forest and Bamboo forest. In comparison to the availability of various habitat types, the expected use of these habitat categories was found in proportion.

The habitat use based on density of bear signs per hectare was highest in Tropical semi-ever green forest (0.271), followed by Tropical wet-ever green forest(0.257), Semi-ever green forest (0.195) Mix forest (0.139), Temperate forest (0.112) and Bamboo forest (0.027) **(Table 5)**. The use of Tropical semi-ever green forest Tropical wet-ever green forest habitats was high, and the expected use was highest. So the habitat use by sun bears was also found to be in proportion to the availability and the expected use of these habitat categories.

The Kruskal-Wallis test comparison showed that there was no significant difference between the expected utilization of each habitat category and the use of these habitat categories within the study area (χ^2=15.709, df=5, p=0.0077). The null hypothesis was therefore accepted, implying that observed bear evidences were distributed proportionally to the occurrence of habitat categories.The availability and the utilization patterns of different habitat types by sun bear used the Tropical-wet ever green habitat more than its availability.

5.3.5 Seasonal variation in habitat use

The habitat use pattern of sun bears showed marked seasonal variation in Namdapha Tiger Reserve **(Table 6)**. Except Mix forest, Temperate with conifers and Bamboo forest, although the overall extent of habitat use was considerably high for most of the habitat categories as indicated in **Table 5**, but there was considerable seasonal variation in the use of each of these habitat categories.

Based on number of signs and presence of scats, use of different habitats was highest during winter in Namdapha Tiger Reserve **(Table 6)**. During summer season, use of Bamboo forest characterized by *Flosrajnae* spp. and *Ficus spp.* (36.4%) by bears was highest, followed by Semi-ever green forest characterized by *Medinilla erythrophylla* (26.4%), Tropical semi-ever green forest characterized by *Actinodaphre obovata* species (25.2%), Temperate forest characterized by *Calamus* spp. and *Ostodes paniculata* (25.0%), Tropical wet-ever green characterized by *Horsefieldia amygdalina* species habitat (23.5%), Mix forest characterized by *Spondias axillaris* and *Ficus* spp. (12.7%) with the mean value 14.83±3.56. During monsoon season, habitat use by sun bear in Tropical semi-ever green forest was highest (36.4%), followed by Tropical wet-ever green forest (33.7%), Semi-ever green forest (33.3%), Temperate forest (29.5%), Mix forest (29.1%) and Bamboo forest (18.2%) with the mean value 20.66±5.25. Whereas during winter season, the use of Mix forest by bears was highest (58.2%), followed by Temperate forest (45.5%), Bamboo forest (45.4%), Tropical wet-ever green forest (42.8%), Semi-ever green forest (40.3%) and Tropical semi-ever green forest (38.4%) with the mean value 27.66±5.49.

5.3.6 Habitat use overview

By surveying a total of 43 transects covering six different habitats, 379 bear signs were collected from 1500 trees. All these bear signs were recorded in Tropical semi-ever green forest, Tropical wet-ever green forest, Semi-ever green forest, Temperate forest, Mix forest and Bamboo forest. The highest percentage (46.4% with 29.33±7.19) of bear signs were recorded during 2009, followed by (30.9% with 14.33±3.75) during 2010 and (22.7% with 19.5±4.16) during 2008 **(Figure 1).** During 2008, sun bear signs were highest in Tropical semi-ever green forest (6.9%) followed by Tropical wet-ever green forest (6.1%), Semi-ever green forest (4.5%), Mix forest (2.9%), Temperate forest (1.3%) and Bamboo forest (1.1%). In 2009, bear signs were highest recorded in Tropical wet-ever green forest (12.9%) followed by Tropical semi-ever green forest (12.7%), Semi-ever green forest (8.7%), Mix forest (7.1%), Temperate forest (3.2%), and Bamboo forest (0.8%). Whereas in 2010, sun bear signs were highest in Temperate forest (7.1%), followed by Tropical wet-ever green forest (6.9%), Tropical semi-ever green forest (6.6%), Semi-ever green forest (5.8%), Mix forest (4.5%). There were no signs were found in Bamboo forest in 2010 during the study periods.

5.3.7 Use of terrain types

Based on sign surveys and presence of scats and nests, various terrain types viz. flat, undulating, gentle slope and steep slope were found to be differentially used by sun bears in the study area **(Table 7)**. The use of flat terrain by sun bear was maximum (52.8%), followed by steep slope (32.4%), gentle slope (8.4%) and flat terrain (6.1%) in different forest types. Sun bears were found to use flat terrain maximum in Bamboo forest (18.1%), followed by Temperate forest (15.9%), Tropical semi-ever green forest (5.1%), Semi-ever green forest (4.2%), Tropical wet-ever green (4.1%) and Mix forest (3.6%) with mean value of 3.83±0.79. Sun bears were found to use undulating terrain maximum in Mix forest (63.6%), followed by Tropical semi-ever green forest (59.6%), Tropical wet-ever green forest (55.1%), Semi-ever green forest (45.8%), Temperate forest (36.4%) and Bamboo forest (27.3%) with mean value of 33.33±8.77. Whereas they were found to use gentle slope maximum in Bamboo forest (18.1%), followed by Mix forest (12.7%), Semi-ever green forest (9.7%), Tropical wet-ever green forest (9.2%), Temperate forest (6.8%) and Tropical semi-ever green forest was (5.1%) with mean value of 5.50±1.08. The steep slope terrain was used maximum in Temperate forest (40.9%) by sun bear, followed by Semi-ever green forest (40.3%), Bamboo forest (36.5%), Tropical wet-ever green forest (31.6%), Tropical semi-ever green forest (30.2%) and Mix forest was (20.1%) with mean value of 20.5±4.62.

The data on proportional availability and utilization of various terrain types: flat, undulating, gentle slope and steep slope has been compared with the expected use of these terrains by sun bears **(Table 8)**. The proportional availability of undulating terrain was found to be the highest (0.437), followed by gentle slope (0.288), steep slope (0.167) and flat terrain (0.107). The expected use of these terrain types was found to be directly proportional to the availability of these terrains. The expected use of undulating terrain was found to be highest (0.450), followed by gentle slope terrain (0.323), steep slope terrain (0.138) and flat terrain (0.089).

Following hypothesis was tested using the Chi square test: sun bear used each type of terrain category in exact proportion to its occurrence within the study area (null hypothesis). The observed utilization of each terrain category was compared with expected utilization of terrain. Goodness fit of comparison showed that the expected utilization of each terrain category was not significantly different (χ^2=2.202, df=3, p=0.531) from the observed utilization. The null hypothesis was therefore accepted, implying that the observed utilization of each terrain category was in proportion to its occurrence. There was neither any preference nor avoidance by bears for any type of terrain. Bear used certain category of terrains for specific purpose.

During the study period, indirect evidences: nests, scats and digging signs were recorded in different terrain as sun bears were feeding and resting in various terrain types (**Figure 2)**. The digging sings were highest in undulating terrain (37.5%), followed by flat and gentle terrain (25.0% each) and steep slope (12.5%). Scat signs were highest in undulating terrain (29.4%), followed by steep slope (25.9%), flat terrain (24.7%) and gentle slope (20.0%). Similarly nests were highest in undulating terrain (42.2%), followed by (26.7%) gentle slope, (17.8%) steep slope and (13.3%) flat terrain.

5.3.8 Use of disturbed and undisturbed habitats

Sun bear were found to use disturbed and undisturbed habitats to varying extent along different elevations. There were three categorise of elevations i.e. Lowland ranged from 0 to 500 msl, Mid-elevation was 501 msl to 1500 msl and Temperate was 1500 msl and above. The majority of bear signs (74.1%) were observed in undisturbed forest regardless of sites ($r2=0.8291$, $F=4.851$, $df=3$, $P<0.2713$). In areas with higher intensities and extents of disturbance, fewer bear signs (25.9%) were observed **(Figure 3)**.

5.3.9. Analysis for variance among the variables (Kruskal-Wallis test)

Two hypotheses were assessed; first was that all the habitat variables viz. number of trees, lopped trees, fell trees, number of shrubs, number of herbs, cattle dung, distance from habitation, distance from water and distance from road were evenly distributed in the used and unused areas of sun bears i.e. null hypothesis (H_0), and second was that all the habitat variables were not evenly distributed in the areas where bear signs were present and absent i.e. Alternative hypothesis (H_A).

The Chi-square values clearly showed that when habitat variables within the sampled plots were correlated with the bear presence as a fixed variable, then the number of shrubs (109.146), distance from human habitation (413.590), distance from road (413.408) distance from water sources (416.081), and cattle dung (90.938) had highly significant correlation with bear presence. This has proved that these variables were not the same in areas where bear signs were present or absent. This rejects the null hypothesis (H_0) and accepts the Alternative hypothesis (H_A). Whereas, for the number of trees (84.103), lopped trees (162.367), fell trees (21.140), number of herbs (140.754) and distance from road (413.408), Chi-square values were not significant. This showed that these habitat variables were almost the same in the areas where bear signs were present or absent **(Table 9)**. Therefore null hypothesis was not rejected.

5.3.10. Analysis of Fixed Kernel

The Fixed Kernel showed that, which was more than suitable for habitat use in the three different Fixed Kernel analyses. The estimated habitat use (99%, 95% and 50% Fixed Kernel) of all was given in **(Figure 4).** The core activity (50% Fixed Kernel) area of sun bear habitat as determined, followed by 95% Fixed Kernel and less activity in (99% Fixed Kernel).

5.4 Discussion

In Namdapha Tiger Reserve, six distinct habitat types, namely, Tropical semi-ever green forest, Tropical wet-ever green forest, Semi-ever green forest, Mix forest, Temperate forest and Bamboo forest. Sun bears have been found to use all these habitat categories. Due to increasing human population, expansion of agricultural land, continuous encroachment on forest land, livestock grazing and biotic pressure, sun bear population seems to be adversely impacted in this Reserve, and so it is threatened. These factors together might have also adversely impacted the habitats and their use in the study area.

The Malayan sun bear occurs in low densities in these habitats. Survival of sun bear is found to be largely dependent on availability of suitable habitats, and food resources, variety of food plants, water and shelter within these habitats. There were 11 species of food plants available in the Tropical semi-ever green forest and Semi-ever green forest, followed by 8 species in Mix forest, 7 species in Tropical-wet ever green forest, 6 species in Temperate forest and 4 species in Bamboo forest. Since the habitat use by bears was largely dependent on the availability of food resources and shelter, number of fruiting trees and shrub species were recorded in various habitat types. These fruiting trees and other food items including insects and ants were available in different habitat types in the Tiger Reserve and in the vicinity of villages.

The frequency occurrence of food plants in plots used by bears varied considerably in Namdapha Tiger Reserve. Plots with presence of 1, 2, 3 and 4 food plant species were 11.9%, 13.0 %, 18.4% and 20.5% respectively. As the number of food plant species increased, the percentage of these plots decreased. Irrespective of this variation, the proportional utilization of these plots with variable number of food plant species was very high, except the plots without any food plants.

It is important to consider the frequencies of individual bears among different habitat types relative to forest age and the overall population. Some observations have been reported of sun bear occurrence in secondary forests or disturbed areas (Wong, 2002; Wong *et al*., 2004 and Fredriksson, 2005), but the ages of these forests, as well as the scale and frequency of use by these bears relative to their overall populations, are important factors when analysing population-level patterns. Habitat models based on GIS technology are suitable tools to predict the presence and relative use of bear habitat across large landscapes (Clark and van Manen, 1992), particularly because such models are appropriate for generalist species (Donovan *et al.*, 1987). Six variables, namely elevation, slope, vegetation cover, distance to water, human disturbance and terrain type were used to measure habitat conditions for the bear sign locations sampled during the field surveys.

The habitat use by sun bear was assessed based on direct sightings and indirect evidences such as claw marks, scats, nests, dens, digging sign and foot prints etc. in Namdapha Tiger Reserve. Results from the present study showed that the significant majority of sun bear activity in undisturbed areas was predominantly in older heterogeneous forests that retained some primary forest traits and had substantial time to regenerate and evolve through older succession stages that provide mature forest structure. The overwhelming majority of bear signs, photographs, and hair snags were observed in undisturbed primary forest regardless of habitat, ecosystem, site, or region.

In Namdapha Tiger Reserve, the data on habitat use by sun bears collected from the 430 sample plots along the 43 transects showed maximum number of plots with bear signs in Tropical semi-ever green forest, followed by Tropical wet-ever green forest, Semi ever green forest, Mix forest, Dry Mix forest and Bamboo forest. Although sun bears showed some preference for Tropical semi-ever green forest and Tropical wet-ever green forest habitat categories, but as such there was no preference or avoidance by bears for rest of the habitat types. Out of 430 plots, bear evidences were found in 339 plots. Maximum number of plots with bear signs fell in Tropical semi-ever green forest. Density of bear signs per hectare was found highest in Mix forest and Temperate forest. However there was a specific pattern of habitat use in the study area. In Namdapha Tiger Reserve, habitat use pattern of sun bears showed marked seasonal variation. Although the overall extent of habitat use was considerably high for most of the habitat categories, but there was considerable seasonal variation in the use of each of these habitat categories. Based on number of signs and presence of scats, use of different habitats was highest during winter.

Although sun bears showed some preference for Tropical semi-ever green forest and Tropical wet-ever green forest habitat categories, but as such there was no preference or avoidance by bears for rest of the habitats in Namdapha Tiger Reserve. Since maximum bear signs were from Tropical wet-ever green forest located far away from the Gandhigram village, perhaps bears did spent much time in this habitat for feeding on fruits and other food items. More bear signs in these habitats might be due to intensive use of these habitats by bears and more availability of preferred food items and shelter to bears. Several studies documented habitat use and movement patterns of sun bears (Wong, 2002; Augeri, 2005 and Steinmtz, 2009). Sun bears in South East Asia ranged widely during the season.

Presence of bear signs in different habitats varied with availability of food items in different seasons. Black bear feeding signs in decaying stumps and ground cavities on sand ridges to feed on insects were seen frequently during spring and summer. Black bears need large areas with a variety of habitat types in coastal plains of North Carolina to meet their food and cover requirement (Landers *et al.*, 1979*)*. In Denali National Park, Alaska, habitat use and activities of bears were found to be influenced by the phenological development of cowberry (*Empetrum nigrum*), peavine (*Hedysarum alpinum*), horsetail (*Equisetum arvense*), polar grass (*Arctagrostis latifolia*), soapberry (*Shepherdia canadensis*) and availability of animal food items (Stelmock and Dean, 1986).

In Namdapha Tiger Reserve, the proportional availability of Tropical semi-ever green forest was found to be highest, followed by Tropical wet-ever green forest, Semi-ever green forest, Mix forest, Temperate forest and Bamboo forest. In comparison to the availability of various habitat types, the expected use of these habitat categories was found in proportion. Likewise the habitat use based on density of bear signs per hectare was highest in Tropical semi-ever green forest, followed by Tropical wet-ever green forest, Semi-ever green forest, Mix forest, Temperate forest and Bamboo forest. The use of Tropical semi-ever green forest Tropical wet-ever green forest habitats was high, and the expected use was highest. So the habitat use by sun bears was also found to be in proportion to the availability and the expected use of these habitat categories.
In comparison to the availability of various habitats, the expected use of these habitat categories was found in proportion. So the habitat use by sun bears was also found to

be in proportion to the availability and the expected use of these habitat categories. Thus, habitat use in proportion to its availability could be correlated with availability of food items and also shelter. The relation between utilization and availability of sun bear habitat features using ten variables was compared by testing the hypothesis i.e. bears used habitats in proportion to their availability. The null hypothesis was not rejected.

Ultimately, compression can create insular effects, possibly increase stress levels in individual bears, and exert notable pressure on the population. Reduced food density, availability or access can influence bear health, movements, mating, recruitment, and population dynamics (Jonkel and Cowan, 1970; Rogers 1976, 1987; Craighead *et al.*, 1995; Powell *et al.*, 1997 and Wasser *et al.*, 2004) and can increase physiological stresses on the bears (Cattet *et al.*, 2003; van der Ohe *et al.*, 2004; Owen *et al.*, 2004 and Wasser *et al.*, 2004). The habitat used by grizzly bear more than expected were riparian zones and wet seeps in spring, wet seeps and alpine slab rock in summer and reparian zones and, wet seeps, in spring, wet seeps and alpine slab rock in summer and riparian zones, wet seeps, wet meadows, and alpine slab rock (Servheen, 1983). In Arctic National Wildlife Refuge, northeast Alaska, tussock tundra and tall shrub land were used slightly more frequently by grizzly bears during spring than expected based on availability, whereas low shrub land was used much more frequently than expected and bears were observed in tall and low shrub land usually digging hedysarum roots (Phillips, 1987). In North Bilaspur forest division, sloth bear population used different habitat types, and the expected utilization in each habitat category differed significantly from the occurrence of habitat categories within the study area (Akhtar *et al*., 2002). Reynold and Beecham (1980) also recorded the movements of black bears in response to the phenological stages of food plants in different areas. Amstrup and Beecham (1976) indicated that bears associated mostly with particular plant species during its peak fruit availability. Manjrekar (1989) in Dachigam National Park found that black bears were mainly dependent on fruits of *Prunus avium, Morus alba, Quercus robur and Juglans regia* by extensively utilizing forest habitats.

The habitat use pattern by sun bears in Namdapha Tiger Reserve revealed that they differentially used available habitat types. The habitat use pattern by sun bears showed marked seasonal variation. Except Mix forest, temperate with conifers and Bamboo forest, although the overall extent of habitat use was considerably high for most of the habitat categories but there was considerable seasonal variation in the use of each the habitat category.

Augeri (2005) compared natural patterns of Malayan sun bear (*Helarctos malayanus*) habitat selection, ecology and landscape use with the effects of disturbance. Augeri (2005) conducted two phases of field work at 16 study sites grouped among three focal areas in the Leuser Ecosystem in northern Sumatra and three focal areas in the Kayan Mentarang Bulungan ecosystems in East Kalimantan, Borneo. Sloth bear population also showed no avoidance or preference for any habitat type in North Bilaspur forest division, Madhya Pradesh (Akhtar *et al*., 2002). Sloth bears were found to use different habitat types covering smaller areas and showed distinct seasonal shifts between different habitat types. Presence of bear signs in different habitats was found mainly dependent on availability of food items in different seasons. In Mudumalai wildlife sanctuary, maximum scats were found in Dry deciduous tall grass forest, followed by Dry deciduous short grass, Thorn forest and Moist deciduous forest (Desai *et al*., 1997). In North Carolina, black bears need large areas with a variety of habitat types in coastal areas to meet food and cover requirement (Landers *et al*., 1979).

In Namdapha Tiger Reserve, flat, undulating, gentle slope and steep slope terrains were found to be differentially used by sun bears based on sign surveys and presence of scats and nests, in the study area. The use of flat terrain by sun bear was maximum, followed by steep slope, gentle slope and flat terrain in different forest types. Sun bears were found to use flat terrain maximum in Bamboo forest, and they were found to use undulating terrain maximum in Mix forest. The proportional availability of undulating terrain was found to be the highest, followed by gentle slope, steep slope and flat terrain. The expected use of these terrain types was found to be directly proportional to the availability of these terrains. The expected use of undulating terrain was found to be highest, followed by gentle slope terrain, steep slope terrain and flat terrain. In Namdapha Tiger Reserve, the differential use of terrains in various habitat types could be related to factors like availability food, resting, seeking shelter, escape cover and biotic disturbance.

The indirect evidences in different available habitats revealed that sun bears were generalist as far the habitat use was concerned. In northern Sumatra and in East Kalimantan, Borneo, another study on the habitat use by sun bear indicated that differences in family age, seasons, and years contribute to differences in overall habitat use patterns (Augeri, 2005). In spring, bears were generally on low slopes and in valley bottoms, whereas in summer they were found on upper and middle hillsides. They moved back down to lower hillsides and valleys in fall but were less concentrated in valley bottoms than in spring.

Sun bear were found to use disturbed and undisturbed habitats to varying extent along different elevations in Namdapha Tiger Reserve. Sun bears preferred forested habitats and the phenomenon may explain the tight home range patterns of sun bears in small forest reserves such as Sungai Wain Protection Forest, East Kalimantan (Meijaard *et al*., 2005), where the bears have also been observed in edge areas and local gardens (Fredriksson, 2005). In the current study, sun bears avoided the use of or movement through such disturbed areas, but in smaller patches, forage and habitat losses could force bears into marginal edge habitats and human-cultivated areas for food. Changing contiguous primary forests into a discontinuous patch-work of disturbed and undisturbed areas bordered by abrupt, sharply contrasting edges can induce geographic and density dependent compression. This can alter a bear’s movement dynamics through the landscape and prohibit critical habitat use (McLellan and Shacklton 1988; Augeri, 1994, 2000; Mattson *et al.*, 1996; Merrill *et al.*, 1999; Boyce 2000 and Augeri, 2002).

Chapter 6

Food habits of Malayan sun bear in Namdapha Tiger Reserve.

6.1 Introduction

The Namdapha Tiger Reserve of Changlang district, Arunachal Pradesh seems to harbour sizeable population of Malayansun bears. Inside Namdapha Tiger Reserve, there are only five villages, upper and lower Namdapha and agricultural lands are located away from the village and close to Tropical semi-ever green forests. People invade forests and share natural resources, which results in increasing competition and confrontation with wild animals. Malayan sun bear were seen active during the early morning hours in Tropical semi-ever green forest and Mix forest, where there are fewer disturbances. Sun bears raid agricultural crops, fruiting trees in the vicinity of villages and use Tropical semi-ever green forest and Mix forest areas in search of food and shelter while people collect non-timber forest produce and fuel wood from forests and take their livestock especially in forests for grazing. This common dependency and resource sharing by people and bears results into conflicts in form of livestock depredation and crop raiding by bears and developing antagonism by people for conservation of bears inside the Tiger Reserve.

The survival of bears and their physiological activities are governed by the availability of food items and dietary components in their habitat. Most bears are opportunistic omnivores and their diet varies from fruits, other vegetative material, insects, fishes and mammals. Information on composition and seasonal variation in bear diet can be studied either by making direct observations on feeding activities and signs in these areas or indirectly through scat analysis. Scats are required to be analyzed both qualitatively and quantitatively. Dietary composition through scat analysis has been widely studied in different bear species. In few studies on black bear, both scats and stomach contents were used and in many other studies, only scats were used to study the feeding ecology of bears (Tisch, 1961; Schaller, 1967; Laurie and Sedensticker, 1977; Landers *et al.*, 1979; Mealey, 1980; Kendall, 1983; Bunnell and Hamilton, 1983; Nagy *et al.*, 1983a; Graber and White, 1983; Hechtel, 1985; Maehr and Brady, 1984; Mace and Jonkel, 1986; Phillips, 1987; Hamer and Herrero, 1987; Ohdachi and Aoi, 1987; Cicnjak *et al.*, 1987; Clevenger *et al.*, 1992; Mattson *et al.*, 1991a; Aune, 1994; McLellan and Hovey, 1995; Dahle *et al.*, 1998; MacHutchon and Wellwood, 2003; Kobayashi *et al.*, 2006; Minamiyama *et al.*, 2006 and Xu *et al.*, 2006).

In most bear species including Asiatic black bear, sloth bear, American black bear, grizzly bear and brown bear, it has been found that in addition to the animal matter, plant matter constituted a major parts of diet (Cicnjak *et al.*, 1987; Schaller, 1969; Landers *et al.*, 1979; Nozaki *et al.*, 1983; Maehr and Brady, 1984; Mace and Jonkel, 1986; Odhachi and Aoi, 1987 and Manjrekar, 1989). All species of bears, except polar bear (*Ursus maritimus*) were found to feed on insects, especially ants.

Sun bear remains the least known bear species in the world. Even basic biology such as food habits, activity and ranging pattern and reproductive biology is unknown. Until recently, very little research has been done on ecology of sun bear, and there have been no organized surveys of its distribution and population densities (Meijaard, 1997). The lack of biological information on the sun bear seriously limits conservation efforts (Servheen, 1999). Basic research on sun bears should be of high priority for bear biologists. Food habits of Malayan sun bear are poorly documented, but have been briefly described by many authors (Shelford, 1916; Bank, 1931; Lekagul and McNeely, 1977; Medway, 1978; Tweedie, 1978; Davies and Payne, 1982; Payne *et al*., 1985; Domico, 1988; Nowak, 1991; Servheen, 1993; MacKinnon *et al*., 1996; Kanchanasakha *et al*., 1998; Lim, 1998; Sheng *et al.*, 1998; Yasuma and Andau, 2000; Fredriksson, 2001 and Wong *et al.*, 2002). Their diet is described as bee nests, termites, earthworms, small rodents, small birds, lizards, animal carcasses, fruits and coconut palms. Documentation of sun bears as seed dispersers by Leighton (1990) and McConkey and Galetti (1999) were the only two scientific reports published so far.

In this chapter, the results of food habits and seasonal variation of Malayan sun bears in Namdapha Tiger Reserve are presented.

6.2 Methods

While some plant matter and seeds were not altered to any notable degree when passing through the digestive tract of bear, animal flesh in scat was substantially reduced (Hatler, 1972). Scat analyses of habituated free-ranging wild sun bears in Sungai Wain protection forest indicated that sun bears concentrated on plants, fruits and insect biomass, much of which was sustained through the digestive process (Fredriksson, 1998). The food habits of Malayan sun bear were determined by analysing scat samples. Diet composition and seasonal variation were studied during the year 2008 to 2010. Dietary composition was estimated in terms of frequency occurrence of food items in the scats, and percent dry weight of each of the items was calculated. Variation in dietary composition in different seasons viz. summer (March-June), monsoon (July-October) and winter (November-February) was estimated.

6.2.1 Scat collection

During the sampling period, scats were collected from different parts of Namdapha Tiger Reserve. Though systematic collection technique was not feasible in the mountainous and rugged terrain, bear scat samples were collected based on sign survey of sun bear along the transects (n=43) as well as opportunistically. Scat collection was easy during November (n=45), moderately successful during September and December, and least successful during the rest of the time. Scat searching effort was the same each month except from August 2008 to August 2010 when there no rain. Scat samples were collected in plastic bags and weighed wet. They were later air-dried either in trays or on newspaper in the sun and stored.

6.2.2 Sample size for determining food habits

It is necessary to know whether the numbers of scats analyzed are adequate to reflect an accurate picture of the diet of the Malayan sun bear. Following the methods of Odum and Keunzler (1995), minimum number of scats required to study the dietary composition was calculated. An observation area curve for the percent frequency of occurrence of major food items represented in the diet was calculated at an interval of every five scats (Mukherjee *et al.*, 1994 and Edgaonkar and Chellam, 1998)**.** So on the basis of number of food items and scats, items/species area curve was plotted to find the minimum number of scats required. For this purpose, 85 scats were analyzed and observation area curve was plotted **(Figure 1).** It was observed that a minimum of 28 scats in summer, 15 scats in monsoon and 42 in fall (winter) were required to know the dietary composition of sun bear.

6.2.3 Analysis

Scats were analysed both qualitatively and quantitatively. In the laboratory, scats were oven dried for 24 hours at 70º C and reweighed. Dried scats were then soaked in water for 1-3 hours, washed thoroughly in 0.7 and 0.3 mm mesh sieves, and dried again. The contents were manually separated and examined. Dried materials from scat samples were sorted by using either hand lens or a binocular dissecting scope (2x~8x). Whenever insect parts particularly termites and beetles were observed, their body parts were sorted by using a hand lens. Occasionally scats containing bee hive remains were found, containing no other items. Other items such as hairs in the scats were collected with sterilised tweezers and stored for analysis in clean envelopes. Envelopes with hairs were then stored inside plastic bags with silica beads.

Taxonomic classes of organisms (e.g. termites, ants, beetles) were sorted and grouped for further identification. Many scats were contaminated with items such as live ants, live dung beetles, dead leaves and twigs (sometimes attached to scats when collected from the forest floor). These materials were removed from the scat samples during analysis. Other items such as bear hairs were not included in the analysis. On the basis of number of food items and scats, items/species area curve was plotted to find the minimum number of scats required for the study.

In this chapter, the results of scat analysis are presented as frequency of occurrence of an item in different samples. Frequency of occurrence is defined as the total number of times a specific food item appeared in a scat sample. Percent frequency of occurrence can be calculated as the total number of times a specific food item appeared in hundred scats of the samples divided by total number of scats collected. Analyses were focussed on patterns of sun bear resource use relative to biogeography, general habitat, disturbance, and interactive variables. Chi-square test was used to determine any seasonal variation in the dietary composition.

6.2.4 Assumptions

Only information from the feeding sites assumed with high confidence to be of a sun bear was recorded. But without actual observation on the feeding activities of the bear, bear signs were only the indirect evidences of their feeding behaviour. It was certain that other mammals like pangolin (*Manis javanica*), pigs (*Sus* spp.), civets (Viveridae spp.), Malay badger (*Mydaus javanensis*), porcupine (*Hystrix* spp.) and other species showed similar feeding evidences. To improve the probability for the assumption that feeding signs were made by sun bears, the data was recorded only from scats most certain to be from bears, based on all known indicators of bear scat size, shape, contents and associated signs such as tracks and markings most probably associated with the scat deposit, and only from feeding sites where bear claw marks, tracks, or other definite sun bear signs were present. In addition, uneaten food items from verified sites for identification and comparisons with samples from other sites were collected.

Usually, bear scats did not remain in the field for a long period due to their moist condition and soft texture, and the efficiency of dung beetles (Order Coleoptera, Family Scarabaeidae) utilizing faces in a short time. Thus the collected scats were usually very fresh (< 24 hours old). A possible exception was that the scats containing mostly figs (*Ficus* spp.) were not commonly attractive to dung beetles. They were also washed in the frequent heavy rain. Only eighty five scat samples could be collected from August 2008 and October 2010. After the bear left the feeding site, the site was examined for the availability of possible foods, and uneaten food items were collected. A sample unit was considered a feeding episode, which could be defined as a site where a bear was feeding (i.e. decayed wood in a log, where termite nest(s) could be seen or below a fruiting tree). Only confirmed feeding sites known to be of a sun bear were recorded. Other mammals such as bearded pig (*Sus barbatus*), pangolin

(*Manis javanica*) and Malay badger (*Mydaus javanensis*) were also known to create similar feeding evidence when they fed on termites, earthworms and other invertebrates from soil or decayed wood (Payne *et al*., 1985 and Yasuma and Andau, 2000). To ensure that feeding sites were indeed the feeding sites of sun bear, only very fresh feeding sites having bear claw marks and sun bear tracks were recorded. Sun bears have been known for their arboreal behaviour. They were found to climb trees in order to harvest ripe fruits and bee nests or to seek shelter or to escape danger (Payne *et al*., 1985; Lim, 1998 and Yasuma and Andau, 2000). On such trees, bears were found to leave distinct claw marks. This tree-climbing behaviour provided indirect evidence of sun bear feeding behaviour. These tree species were identified and fruiting condition of the tree and tree height and size were recorded.

6.3 Results

Based on claw marks on trees, direct feeding signs, scat analysis and indirect signs, the dietary composition of sun bears and seasonal difference in their food habits was studied in Namdapha Tiger Reserve. Eighty five scats were collected from August 2008 to November 2010 during the field survey. The average scat weight was 329g, the scat weight ranged from 73 to 1,119 g.

6.3.1 Trees with bear claw marks

Sun bear were found to use 33 tree species, namely, *Spondias axillaris*, *Horsefieldia amygdalina*, *Micromelum pubescens*, *Natsiatum herpeticum*, *Turpinia pomifera*, *Ardisia* sp., *Lithocarpus pachyphyllus*, *Balanophora involucrate*, *Symplocos* sp., *Actinodaphne obovate*, *Gnetum montanum*, *Eulophia* sp., *Alangium chinense*, *Streptopus simplex*, *Phoebe* sp., *Dimocarpus longan*, *Polyalthia simiarum*, *Calamus* sp., *Elaeocarpus serrata*, *Medinilla rubicunda*, *Ostodes paniculate*, *Knema angustifolia*, *Symplocos cochinchirensis*, *Acer sikkimense*, *Terminalia chebula*, *Terminalia belerica*, *Emblica officinalis*, *Bischofia javanica*, *Phoebe cooperina*, *Flosrajnae* sp., *Amara wallichii and Ficus* sp. **(Table 1)**.

During the study period, we found 155 trees with sun bear claw marks, 69 trees were climbed repeatedly, as indicated by healed scars and overlapping of claw marks on tree bark. This showed affinity of sun bears for these trees for certain resources such as fruits, bee nests or nesting or bedding sites.

From all 155 trees, *Ficus* spp. were used maximum (9%), followed by the use of 13 trees of *Alangium chinense* (8.4%), *Spondias axillaris* (7.1%), *Horsefieldia amygdalina* (6.5%), *Polyalthia simiarum* (5.8%) and *Micromelum pubescens* (5.2%) (**Table 1**). These tree species were most frequently used by sun bears. Fruits of *Ficus* spp., *Spondias axillaris*, *Horsefieldia amygdalina*, *Micromelum pubescens*, *Natsiatum herpeticum*, *Turpinia pomifera* and *Ardisia* sp. acted as the important food for sun bears, especially acorns and figs produced by *Ficus* spp. and *Alangium chinense* respectively. We also recorded 11 trees of *Spondias axillaris* with bear claw marks and tree cavities with a shattered entrance, which probably had bee nests. Large dipterocarps such as *Horsefieldia amygdalina* were found to provide comfortable and safe bedding sites for sun bears, rather than offering fruits. *Actinodaphne obovata* had 4.5% claw marks, *Gnetum montanum and Calamus* spp. had 3.9% claw marks, and *Elaeocarpus serrata* and *Symplocos cochinchirensis* had 3.2% claw marks. Rest of the tree species had 0.6% to 1.9% claw marks.

6.3.2 Analysis of feeding sites

We found 10 confirmed sun bear feeding sites in the study area from August 2008 to November 2010. All feeding sites were very fresh, which we estimated within a few hours to a day old. Seven types of sun bear feeding sites were found in the study area: i. decayed standing tree stumps (usually with broken tops), ii. decayed wood or decayed log on forest floor, iii. fruiting trees, iv. underground termite nests, v. many different types of termite mounds, vi. tree cavities with bee nests, and vii. tree root cavity. Decayed wood or log was the most common feeding site recorded.

6.3.3 Species-area curve

The items/species area curve was developed to find minimum number of scats required to study the dietary composition. For this purpose, all the 85 scats were analyzed, and observation area curve for the percent frequency of occurrence of major food items represented in the diet of sun bear was calculated at an interval of every five scats **(Figure 1).** The analysis of total 85 scats revealed that the curve flattened out for most of the food items as well as other food items to greater extent, and all the food items were represented within 40 scats. The scats collected during summer (n=28), monsoon (n=15) and fall (n=42) were analysed, and the proportion of food items and inseparable mixture was calculated.

6.3.4 Food items in scats

Analysis of 85 scats of sun bear showed presence of animal food items belonging to different classes, orders and families **(Table 2)**. Food of animal origin comprised of Arachnida, Insecta, Mammalia and Osteichtyes classes. Insects consumed by sun bear were mainly from order Coleoptera, Hymenoptera and Isoptera. Presence of rodents and scorpions in food of sun bear was also recorded. There were some unidentified items in the scats.

There were 15 families of insects viz. Carabidae, Chelonariidae, Chrysomelidae, Dytiscidae, Histeridae, Passalidae, Scarabaeidae, Tenebrionidae, Blattidae, Apidae, Apoidae, Formicidae, Vespidae, Termitidae and Gryllotalpidae used by sun bear. Among these, 8 families of beetles (Coleoptera), one family of stingless bee (Apidae), one family of ants (Formicidae) and one wasp (Vespidae) could be identified. Other three animal food items, belonging to order Scorpionidae, Rodentia and Cyprinidae, found in the sun bear scats could not be identified at the family level**.** Among 15 families, 14 insects were identified as food items of sun bear. They were *Aceraius* sp., *Chalcosoma* sp., *Panesthia* sp., *Trigona collina*, *Trigona* sp., *Camponotus gigas*, *Camponotus* sp., *Gnamptogenys menadensis*, *Polistine* sp., *Globitermes globosus*, *Hypotermes xenotermitis*, *Macrotermes* sp., *Odontotermes* sp. and *Bulbitermes* sp. found in sun bear scats **(Table 2).**

Scat analysis revealed that the food items of plant origin belonged to family Anacardiaceae, Myristicaceae, Moraceae, Cornaceae, Annonaceae, Acoraceae, Elaeocarpaceae, Melastomataceae, Lauraceae and Rutaceae **(Table 3)**. Plants consumed by sun bear were of 10 different species, plant remains of *Spondias axillaris*, *Horsefieldia amygdalina*, *Ficus* sp., *Alangium chinense*, *Polyalthia simiarum*, *Acorus calamus*, *Elaeocarpus serrata*, *Medinilla rubicunda*, *Actinodaphne obovata*, and *Micromelum pubescens* were found in scats of sun bear.

6.3.5 Dietary composition

Sun bears were found to be omnivorous, consuming both animal and plant items. An analysis of total 85 scats, comprising of 28 scats of summer season, 15 scats of monsoon and 42 scats of fall, showed both plant and animal matter in the diet of sun bear in all seasons. When only plant and animal matters were considered to know their contribution to the diet annually, it was found that the frequency of occurrence of plant matter was higher (55.3%) than the animal matter (44.7%) in the scats of sun bear **(Figure 2)**.

The annual frequency of occurrence of invertebrates and vertebrates was 43.1% and 1.5% respectively in the scats of sun bear **(Table 4, Figure 3)**. Beetles and termites were the most common food items in the scats. Beetles constituted 13.7% and termites 10.2%. Among other animal matter, ants were 6.1%, cockroach 4.1%, wasps 3.6%, orthoptera 3.0% and bees were 2.5%. The unidentified food items were 0.5% in the scats of sun bear. Whereas, the annual frequency of occurrence of plants species in the scats of sun bear was 54.9%. *Ficus* spp. contributed highest (13.7%) in the diet of sun bear, followed by *Calamus* spp. (7.1%), *Alangium chinense* (6.6%), *Horsefieldia amygdalina* (5.6%), *Elaeocarpus phaericus* (5.1%), *Medinilla erythrophylla* (4.6%), Spondias *axillaris* (4.1%), *Polyalthia simiarum* (3.6%) and Micromelum *pubescens* (3.0%). *Actinodaphre obovata* constituted the least (1.5%) in the scats of sun bear. **Appendix 1** summarizes the taxonomy of fruit species consumed by Malayan sun bear as reported by different authors.

6.3.6 Seasonal dietary pattern

Out of total 85 scats, 28 scats were collected during summer season, 15 scats in monsoon and 42 scats were collected during fall. All these scats showed presence of both plant and animal matter in the diet of sun bear in all seasons. When plant and animal matters were considered to know their contribution to the diet annually, it was found that the frequency of occurrence of plant matter was higher than the animal matter in the scats in all the seasons.

The frequency occurrence of animal matter was highest in summer (53.2%), followed by 49.1% in fall and 32.2% in monsoon **(Figure 4).** The annual frequency occurrence of animal matter was 45.2%. Among the plant matter, the frequency occurrence of plant matter was found highest in the scats in monsoon (67.8%), followed by fall (50.5%) and summer (46.8%)**.** The annual frequency occurrence of plant matter was 54.8%. Error bars showed 95% confidence level in this figure. Similarly the percent composition of animal matter in scats of sun bear was highest in summer (42.9%), followed by 40.5% in fall and 40.0% in monsoon **(Figure 5).** The annual percent composition of animal matter was 38.8%. The percent composition of plant matter was highest in monsoon season (60.0%), followed by 59.5% in fall and 57.1% in summer. The annual percent composition of plant matter was 49.4%. Error bars also showed 95% confidence level.

Amongst the overall annual frequency occurrence, there were 9 animal food items and 10 plant species in different seasons in the diet of sun bear**.** The annual frequency occurrence of animal items was 44.2% and plant matter was 55.8% **(Table 5)**. The annual frequency occurrence of beetles was highest (13.7%), followed by termites (10.2%), ants (6.1%), cockroaches (4.1%) and wasps (3.6%). There were some unidentified animal food items.

The animal matter was found to be comprised of beetles, termites, ants, cockroach, wasps, orthoptera and bees, and unknown items including hairs and bones in the bear diet **(Table 5).** The plant matter eaten by sun bear were comprised of 10 plant species, namely, *Spondias axillaris*, *Horsefieldia amygdalina*, *Ficus* sp., *Alangium chinense*, *Polyalthia simiarum*, *Acorus calamus*, *Elaeocarpus serrata*, *Medinilla rubicunda* and *Actinodaphne obovate* as confirmed through scat analysis. The plant matter diet included 10 different parts of plants of 7 species during the summer season, 10 plant matters of 8 species during the monsoon season and 10 plant matter of 9 species during the fall season.

During summer, fall and monsoon seasons, the frequency occurrence of animal matter was 53.2%, 49.5% and 32.2% respectively, and the frequency occurrence of plant matter was 46.8%, 50.5% and 67.8% respectively **(Table 5)**. During summer, the frequency occurrence of beetles was highest (19.1%), followed by termites (10.6%), ants (6.4%), and cockroaches, orthoptera and wasps constituted 4.3% each. Similarly the frequency occurrence of beetles was highest (13.7%) during monsoon. Whereas the frequency occurrence of termites and ants was 5.1% each, cockroaches was 3.4% and bees, orthoptera and vertebrates was 1.7% each in this season. On the contrary, the frequency occurrence of termites was highest (13.2%) during fall. This was followed by beetles (12.1%), ants (6.6%), wasps (5.5%) and cockroaches (4.4%).

During summer, the frequency occurrence of *Ficus* spp. was highest (14.9%), followed by *Horsefieldia amygdalina* (10.6%), *Alangium chinense* and *Medinilla rubicunda* (6.4% each) and *Calamus* spp. (4.3%) **(Table 5)**. Whereas the frequency of occurrence of *Spondias axillaris* and *Actinodaphne obovata* was 2.1% each. During summer, *Elaeocarpus serrata, Micrommelum pubescens* and *Polyalthia simiarum* were not found in the scats of sun bear. Whereas in monsoon season, the frequency ocuurrence of *Ficus* spp. was highest (15.3%), followed by *Elaeocarpus serrata* (13.6%), *Medinilla rubicunda* (10.2%), *Alangium chinense* (8.5%), *Horsefieldia amygdalina* (6.8%), *Calamus* spp. (5.1%) and *Spondias axillaris* (3.4%). The frequency of occurrence of *Micrommelum pubescens, Polyalthia simiarum* and *Actinodaphne obovata* was 1.7% each. During fall season, the frequency of occurrence of *Ficus* spp. was highest (12.1%), followed by *Calamus* spp. (9.9%), *Polyalthia simiarum* (6.6%), *Alangium chinense* and *Micrommelum pubescens* (5.5% each), *Spondias axillaris* (5.1%), *Horsefieldia amygdalina* and *Elaeocarpus serrata* (2.2% each) and *Actinodaphne obovata* (1.1%). *Medinilla rubicunda* was not present in the scats in the fall season

The estimated volume of animal and plant matter varied from small, medium and large scales in different seasons **(Table 5)**. The annual estimated volume bees was large, followed by medium volume of beetles, orthoptera and unidentified food items. The annual estimated volume of termites, ants, wasps and cockroaches was small. Similarly the estimated volume of bees was large in summer season, followed by medium volume of beetles and orthoptera. The annual estimated volume of termites, ants, wasps and cockroaches was small. During monsoon, the estimated volume of beetles, bees, orthoptera and unidentified food items was medium. Whereas the estimated volume of termites, ants, wasps and cockroaches was small. During fall, the estimated volume of beetles and bees was medium, and it was small for rest of the food items. **Plate 1** shows the old scat of sun bear containing beetles. **Plate 2** shows presence of honey bees in the scat. **Plate 3 and 4** show the fresh scats of sun bear containing seeds. **Plate 5** shows the presence of insect matter, termites and ants. **Plate 6 and 7** show the diggings by sun bear with insects and termites. **Plate 8, 9 and 10** show the presence of fruit items, *Alangium chinense* and *Ficus* spp. All these food items were preferred by sun bear.

6.3.7 Percent dry weight

The percent dry weight of plant matter was higher than animal matter in the scats of sun bear; there was distinct variation in animal and plant food items **(Table 6)**. Among animal matter, the percent dry weight of vertebrates was highest (6%), followed by unidentified items (3.4%), bees (2.5%), ants (1.9%), termites and beetles was (1.8% each), orthoptera (1.6%), cockroaches (1%) and wasps (0.6%). The percent dry weight of plant matter was highest in *Micrommelum pubescens* (10.6%), followed by *Alangium chinense* (9.8%), *Spondis axillaris* (9.5%), *Calamus* spp. (9.1%), *Polyalthia simiarum* (8.2%), *Horsefieldia amygdalina* (7.3%), *Medinilla rubicunda* (6.6%), *Actinodaphne obovata* (6.5%), *Elaeocarpus serrata* (6.3%) and *Ficus* spp. (5.3%). Overall the annual percent dry weight of plant matter was higher (78.4%) than the animal matter (21.6%).

During summer season, the percent dry weight of plant matter was more (77.3%) than the animal matter (22.7%) **(Table 6)**. Among the animal matter, the dry weight of vertebrates was highest (6.5%), followed by unidentified items (4.1%), ants (3.7%), bees (2.4%), termites (2%), orthoptera (1.6%), beetles (1.2%), cockroaches (0.8%), and wasps (0.4%). Whereas among plant matter, the dry weight *Micrommelum pubescens* was highest (12.6%), followed by *Spondis axillaris* (12.2%), *Alangium chinense* (10.2%), *Calamus* spp. (9.3%), *Horsefieldia amygdalina* (8.1%) and *Ficus* spp. (6.1%). The dry weight of *Polyalthia simiarum*, *Elaeocarpus serrata* and *Actinodaphne obovata* was 4.9% each and *Medinilla rubicunda* was 4.1%. During monsoon, the percent weight of plant mater was more (88.7%) than the animal matter (11.3%). Among the animal matter, the percent dry weight of bees and vertebrates was 2.1% each, followed by beetles, cockroach and orthoptera (1.4% each). The dry weight of termites, ants and wasps was 0.7% each. Whereas among the plant matter, the dry weight of *Micrommelum pubescens* was highest (14.3%), followed by *Actinodaphne obovata* (11.3%) and *Calamus* spp. (10.6%). Dry weight of *Polyalthia simiarum* and *Medinilla rubicunda* was 9.2% each, and the dry weight of *Spondis axillaris* and *Ficus* spp. was 7.8% each. The dry weight of *Elaeocarpus serrata, Alangium chinense* and *Horsefieldia amygdalina* was 7.1%, 6.4% and 5.0% respectively. Likewise during winter, the percent dry weight of the plant matter was higher (76.9%) than the animal matter (23.1%).

Among the animal matter, the percent dry weight of vertebrates was 7.5%, followed by unidentified food items (4.1%), bees (2.7%), beetles (2.4%), termites (2.0%), orthoptera (1.7%), cockroaches and ants (1% each) and wasps (0.7%). Whereas among the plant matter, dry weight of *Alangium chinense* was 11.5%, followed by *Polyalthia simiarum* (10.5%), *Calamus* spp. and *Spondis axillaris* (8.1% each), *Horsefieldia amygdalina* (7.8%), *Micrommelum pubescens* and *Medinilla rubicunda* (7.5% each), *Elaeocarpus serrata* (7.1%) and *Actinodaphne obovata* (5.4%). Thus all these dietary compositions showed that the frequency of occurrence of plant matter was more than the animal matter during all the seasons. In case of the percent dry weight, plant matter was always more than the animal matter in all seasons **(Table 6).** Using two way ANOVA without replication, it was found that there was no difference in the diet of sun bear between monsoon and fall seasons (F_{crit} = 1.798, df = 18, p = 0.018807).

6.3.8 Composition of major food categories

Important food plant and animal items were grouped together for calculation of their frequency of occurrence in the scats of sun bear diet in different seasons **(Figure 6)**. The major categories were insects, other animals, *Ficus* spp. and other plants. The annual frequency of occurrence of insects was highest (42.7%), followed by other plants (37.5%), *Ficus* spp. (13.6%) and other animal matter (6.0%). During summer, the frequency occurrence was highest again for insects (47.0%), followed by other plants (31.4%), *Ficus* spp. (13.7 %) and other animal matter (7.9%).

During monsoon, the frequency of occurrence of other plant matter was highest (48.2%), followed by insects (29.3%), *Ficus* spp. (15.5%) and other animal matter (6.8%). During fall, the frequency of occurrence of insects was highest (48.8%), followed by other plants (34.5%), *Ficus* spp. (12.2 %) and other animal matter (4.4%). Thus the frequency occurrence of insects was high in summer and fall except monsoon season **(Figure 6)**. The *Ficus* spp. dominated in all the seasons and it was important food component of the sun bear diet. Using two way ANOVA without replication, it was found that there was no difference in the diet of sun bear between summer, monsoon and fall ($F_{crit} = 1.798$, df = 18, p = 3.14E-10).

6.3.9 Month-wise presence of food items

Presence of food items in the scat of sun bear showed marked monthly variation (**Figure 7)**. The animal matter, namely, bees, termites and beetles occurred in the scats during most of the months. Wasps were found in the scats for four months in a year. Ants and orthropods were found present in the scats almost for three months. Plant matter was found to be present in the scats collected during different months. *Ficus* spp. and *Actinodaphre obovata* occurred in the scats almost for 6-7 months. *Ficus* spp. was present during January, February, May, June, July, November and December. Whereas *Actinodaphre obovate* was present in the scats collected during January, February and September to December. *Elaeocarpus serrata* was found in the scats from August to December. *Alangium chinense* and *Horsefieldia amygdalina* occurred from September to December. *Polyalthia simiarum* was present in the scats during January to March and November and December. *Calamus* spp. and *Spondis axillaris* were present during January, February and November and December. Remaining plant matter occurred for 2-3 months. Presence of remnants of different food items in the scats of sun bear was found to be directly correlated with the availability of food items in different months in the scats of sun bear**. Plate 3 and 5** show the presence of seeds of *Actinodaphre obovata* in the scats of sun bear.

Food items of sun bear were available in the study area in most of the months except in April **(Figure 8)**. *Ficus* spp. was available during January, February, May, June, July, November and December. *Alangium chinense* and *Horsefieldia amygdalina* were available in the study area from September to December. *Elaeocarpus serrata* was available in the fields from August to December. *Polyalthia simiarum* was available during January to March and November and December. Whereas *Calamus* spp. and *Spondis axillaris* were available during January, February, November and December months. Presence of food items in the scats of sun bear and availability are directly correlated with each other.

6.4 Discussion

We attempted to study food habits of Malayan sun bears in Namdapha Tiger Reserve. Sun bear were found to use 33 tree species for different purposes including feeding activities. There were 155 trees with sun bear claw marks, and 69 trees were climbed repeatedly. This showed affinity of sun bears for these trees for certain resources such as fruits, bee nests or nesting or bedding sites. From all 155 trees, *Ficus* spp. were used maximum, followed by the use of 13 trees of *Alangium chinense*, *Spondias axillaris*, *Horsefieldia amygdalina*, *Polyalthia simiarum* and *Micromelum pubescens*. These tree species were most frequently used by sun bears. Fruits of most of these trees acted as the important food for sun bears, especially acorns and figs produced by *Ficus* spp. and *Alangium chinense* respectively. We also recorded 11 trees of *Spondias axillaris* with bear claw marks and tree cavities with a shattered entrance, which probably had bee nests. Large dipterocarps such as *Horsefieldia amygdalina* were found to provide comfortable and safe bedding sites for sun bears, rather than offering fruits.

Fredriksson (2001) reported that Malayan sun bears have been recorded to feed on more than 50 plant species and more than 100 species of insects in the Sugai Wain Protection Forest, East Kalimantan, Indonesian, and Borneo. Wong (2002) reported that sun bear have been recorded to feed plant food items mainly consisted of figs, 4 known species of fruits, and at least 14 species of unknown fruits in lowland tropical rainforest of Sabah, Malaysian and Borneo.

Seven types of sun bear feeding sites were found in the study area in Namdapha Tiger Reserve. Decayed wood or log was the most common feeding site recorded. Decayed standing tree stumps, decayed wood or decayed log on forest floor, fruiting trees, underground termite nests, different types of termite mounds, tree cavities with bee nests and tree root cavity were found as feeding sites.

Food habits of Malayan sun bear have been studied in many places through direct feeding observations and scat analysis. The methods have been used on a wide range of bear species to infer dietary composition (Schaller, 1967; Hamer and Herrero, 1987; Mattson *et al.*, 1991a; McLellan and Hovey, 1995 and Bargali *et al.*, 2004).

Although the method of faecal matter analysis has some shortcomings but it has the advantage of yielding substantial data without locating or disturbing free-ranging animals (McLellen and Hovey, 1995). It has been realized by making feeding observations on bears that it was not possible to precisely measure dietary intake and composition. Some studies were conducted on the basis of frequency occurrence and percent weight of different food items in the scats (Mealey, 1980; Nozaki *et al.*, 1983; Servheen, 1983; Graber and White, 1983; Maehr and Brady, 1984; Mace and Jonkel, 1986; Ohdachi and Aoi, 1987; Cicnjak *et al.*, 1987; Hamer and Herrero, 1987b; Mattson *et al.*, 1991a; Aune, 1994; Mclellen and Hovey, 1995; Noyce *et al.*, 1997; Frackowiak, 1997; Dahle *et al.*, 1998; Swenson *et al.*, 1999; MacHutchon and Wellwood, 2003; Huygens *et al.*, 2003 and Xu *et al*., 2006). One could find the frequency of feeding on certain food items or presence of food items in the scats, but not the quantity of food item(s) consumed. Frequency of feeding was found dependent on availability of varied types of food material in a particular area. When the method of percent occurrence of a food items used, it would not indicate the quantity consumed, and frequent consumption of small quantities would show frequent occurrence of the species in the scats and therefore it would indicate high percent occurrence of food items in the diet (Desai *et al.*, 1997).

Scat analysis method was used to study the feeding ecology of Malayan sun bears in the study area. This method has perhaps provided the reliable estimates of food items consumed by the sun bear. In Namdapha Tiger Reserve, the frequency of occurrence of plant matter was higher (55.3%) than the animal matter (44.7%) in the scats of sun bear. The annual frequency of occurrence of invertebrates and vertebrates was 43.1% and 1.5% respectively. Beetles and termites were the most common food items in the scats.

Food items of animal origin comprised of Arachnida, Insecta, Mammalia and Osteichtyes classes in the study area. Insects consumed by sun bear were mainly from order Coleoptera, Hymenoptera and Isoptera. Presence of rodents and scorpions in food of sun bear was also recorded. There were some unidentified items in the scats. Among 15 families, 14 insects were used as food items of sun bear. Among these, 8 families of beetles, one family of stingless bees, one family of ants and one wasp could be identified. Other animal matter included ants, cockroach, wasps, orthoptera and bees. Three animal food items were from the order Scorpionidae, Rodentia and Cyprinidae. Scat analysis revealed that the plants consumed by sun bear were of 10 different species. Plant remains of *Spondias axillaris*, *Horsefieldia amygdalina*, *Ficus* sp., *Alangium chinense*, *Polyalthia simiarum*, *Acorus calamus*, *Elaeocarpus serrata*, *Medinilla rubicunda*, *Actinodaphne obovata*, and *Micromelum pubescens* were found in scats of sun bear. *Ficus* spp. contributed highest in the diet of sun bear.

Food items of Malayan sun bear found in this study were limited and represented a small proportion of the total diet eaten by sun bears. Low numbers of food items found here might be due to the small sample size of bear scats collected and limited number of feeding observations in the Namdapaha Tiger Reserve. Also low numbers of fruit items in sun bear diets might be probably due to the lack of a normal mass fruiting season during the study period. On the contrary, Fredriksson (2001) reported that Malayan sun bears have been recorded to feed on more than 50 plant species and more than 100 species of insects.

Ficus spp. is a keystone resource for tropical frugivorous species, especially birds, primates, and bats (Janzen, 1979; Leighton and Leighton, 1983; Kalko *et al*., 1996 and Kinnaird *et al*., 1999). This indicated that bears were able to consume termites in large amounts. Additional evidence that sun bears could consume termites in large amounts at one time came from the amount of scat with termites collected (wet weight=350gm) in this study. Although hard shells of acorns from the Fagaceae family only occurred once in the scat analysis, Davies and Payne (1982) stated that the sun bears feed on large quantities of the hard seeds of the Fagaceae family. The low encounter rate of Fagaceae's shells in our study was likely due to extremely low fruit production during the study period. Other species of bears, such as Asiatic black bear (*Ursus thibetanus*) and brown bear (*Ursus arctos*) are also known to consume acorns (Nozaki *et al*., 1983; Schaller *et al.*, 1989 and Clevenger *et al*., 1992).

In our study conducted in Namdapha Tiger Reserve, the major categories were insects, other animals, *Ficus* spp. and other plants. Among the overall annual frequency occurrence, there were 9 animal food items and 10 plant species in different seasons in the diet of sun bear**.** The animal matter was found to be comprised of beetles, termites, ants, cockroach, wasps, orthoptera and bees, and unknown items including hairs and bones in the bear diet. The frequency occurrence of animal matter was highest in summer, followed by fall and monsoon**.** Among the plant matter, the frequency occurrence of plant matter was found highest in the scats in monsoon, followed by fall and summer**.** Likewise the percent composition of animal matter in scats of sun bear was highest in summer, followed by fall and monsoon**.** The percent composition of plant matter was highest in monsoon season.

The estimated volume of animal and plant matter varied from small, medium and large scales in different seasons. The annual estimated volume bees was large, followed by medium volume of beetles, orthoptera and unidentified food items. The annual estimated volume of termites, ants, wasps and cockroaches was small. During monsoon, the estimated volume of beetles, bees, orthoptera and unidentified food items was medium. During fall, the estimated volume of beetles and bees was medium, and it was small for rest of the food items. The percent dry weight of plant matter was higher than animal matter in the scats of sun bear; there was distinct variation in animal and plant food items. Among animal matter, the percent dry weight of vertebrates was highest. Thus all these dietary compositions showed that the frequency of occurrence of plant matter was more than the animal matter during all the seasons. In case of the percent dry weight, plant matter was always more than the animal matter in all seasons. Like typical omnivorous food habits of sun bears, both animal and plant materials were found to be consumed by bears. Differential feeding on food plants by sun bear could be related with the food preference and availability of these plants in

The Malayan sun bear is also known as "honey bear" which refers to its voracious appetite for honeycombs and honey. Thus, bees, beehives, and honey, are another important food item (Lekagul and McNeely, 1977; Medway, 1978 and Payne *et al*., 1985). We found sun bears occasionally feed on wild bees, especially the stingless bee (*Trigona* spp.). Sun bears are known to tear open trees with their long, sharp claws and teeth in search of wild bees **(***Trigona collina* and *Trigona spp.***)** and leave behind shattered tree trunks (MacKinnon *et al*., 1996; Lim, 1998; Fredriksson and Meijaard, 1999 and Meijaard, 1999). During the study, 17 similar foraging sites with shattered tree trunks in tropical were observed. Meijaard (1999) suggested this feeding habit explained why older sun bears have damaged teeth, such as the canines being broken off. Malayan sun bears are typical omnivores and opportunist feeders that utilize a broad range of resources in the ecological niche they occupy. Bank (1931) stated that almost anything served as bear food. Besides fruits and invertebrates, Malayan sun bears also are reported to feed on variety of vertebrates, animal carcasses, small animals, rodents, small birds, and reptiles (Shelford, 1916; Bank, 1931; Medway, 1978; Tweedie, 1978; Davies and Payne, 1982; Payne *et al*., 1985; Domico, 1988; MacKinnon *et al*., 1996; Lim, 1998; Kanchanasakha *et al*., 1998; Sheng *et al*., 1998 and Yasuma and Andau 2000). Lim (1998) reported only a desperately hungry bear would prey on vertebrates, such as pheasants, civets, cats, and rodents. However, fragments of bones, claws, scales, feathers and egg shells found in scat analysis suggest sun bears opportunistically prey upon small vertebrates in the study area.

6.4.1 Availability of food items

Presence of food items in the scat of sun bear showed marked monthly variation in Namdapha Tiger Reserve. The animal matter, namely, bees, termites and beetles occurred in the scats during most of the months. Presence of remnants of different food items in the scats of sun bear was found to be directly correlated with the availability of food items in different months in the scats of sun bear**.** Food items of sun bear were available in the study area in most of the months except in April. Presence of food items in the scats of sun bear and their availability in forest are directly correlated with each other.

Unlike fruit production that fluctuated throughout the year, numbers of invertebrates were available year round with little fluctuation (Burghouts *et al*., 1992). Due to the fact that most invertebrates were small, sun bears had to spend more effort in search of invertebrate food items to meet their energy requirement. This is in contrast to consumption of fruits where bears can consume a large quantity with minimal effort. Presence of many termite wings and termite eggs, and beetle larvae in scat samples indicated that sun bears did eat individual invertebrates that contained high levels of nutrients. For example, ant alate, termite alate, and large beetle larva were found to contain more body fat, than adult ant worker, termite worker, and adult beetles

(Phelps *et al*., 1975; Redford and Dorea, 1984 and Rawlins, 1997). The sun bear feeding sites with termite eggs were found near the feeding sites, where mostly termite eggs, larvae, and alates with higher body fat and discard termite solders and workers were available (Lubin and Montgomery, 1981 and Redford and Dorea, 1984). Earthworms were important food item of sun bears (Shelford, 1916; Lekagul and McNeely, 1977; Tweedie, 1978; Davies and Payne, 1982; Domico, 1988; Lim, 1998 and Sheng *et al*., 1998).

Many reports stated that sun bears were found to consume the heart of coconut palm (*Cocos nucifera*), and could do serious damage to coconut plantations (Lekagul and McNeely, 1977; Domico, 1988; Payne *et al*., 1985; Servheen, 1993 and Yasuma and Andau, 2000). Rapid conversion of lowland tropical rainforest into large scale oil palm plantations in Sabah and other parts of Southeast Asia had caused many bears to access plantations to become pests and nuisance animals. This could be expected from an opportunistic omnivore when food diversity is reduced as forests are converted to monoculture plantation agriculture. Wilson and Wilson (1975) and Wilson and Johns (1982) suggested that sun bears existed only in primary forest. Malayan sun bears did exist in logged forest. The proportion of beetles, termites, and bees was higher in the logged forest than the primary forest (Burghouts *et al*., 1992). However, the complexities of food webs capable of supporting sun bears in tropical forests dominated by Dipterocaraceae are more complex than just whether the habitat is logged, unlogged or a plantation (Curran *et al*., 1999).

Figure 1: Observation-area curve to determine the adequacy of sample size of scats for quantifying frequency of food items. (n= 85)

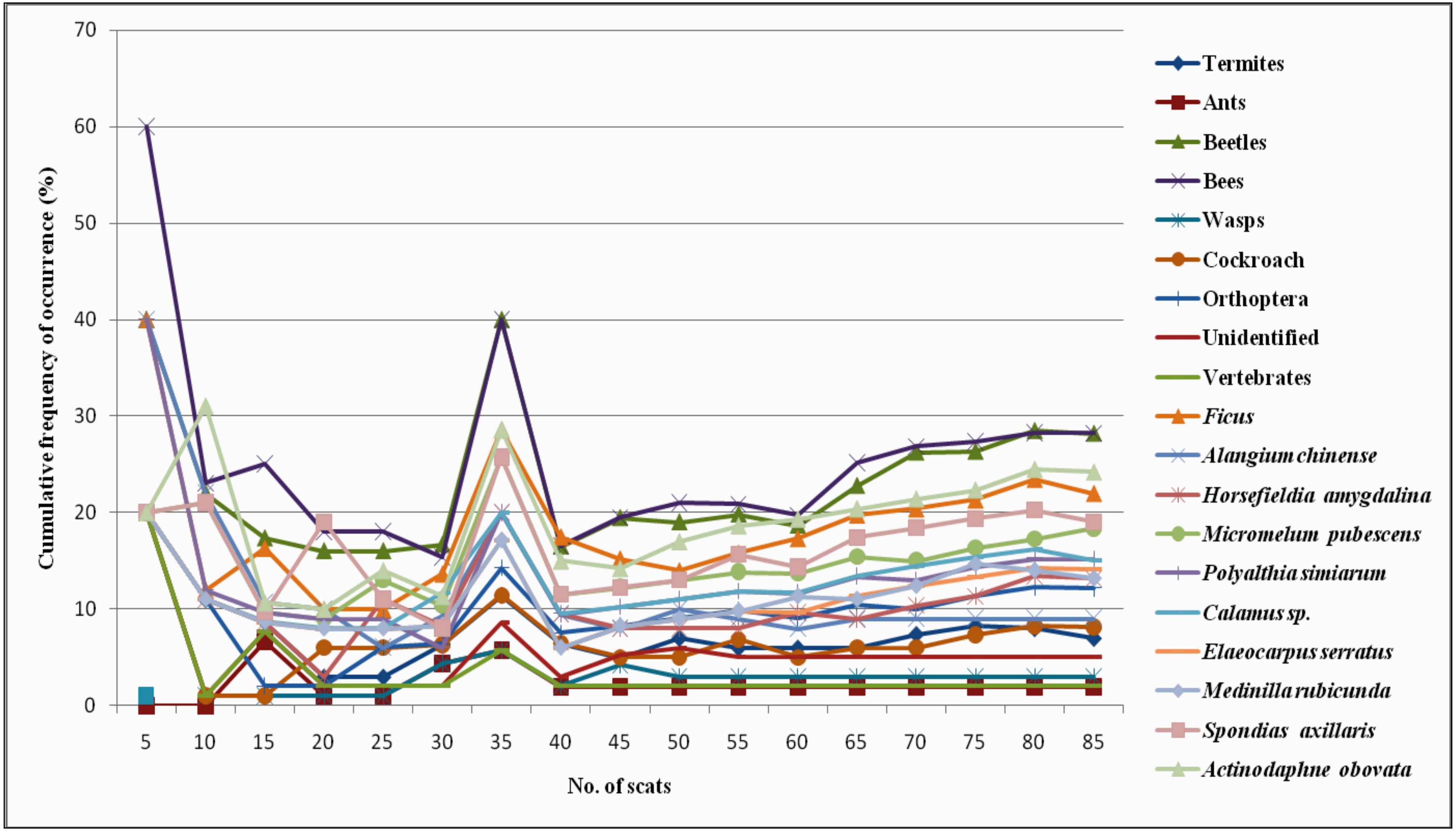


Figure 2: Percentage of animal and plant matter diet in the scats of sun bear in Namdapha Tiger Reserve.

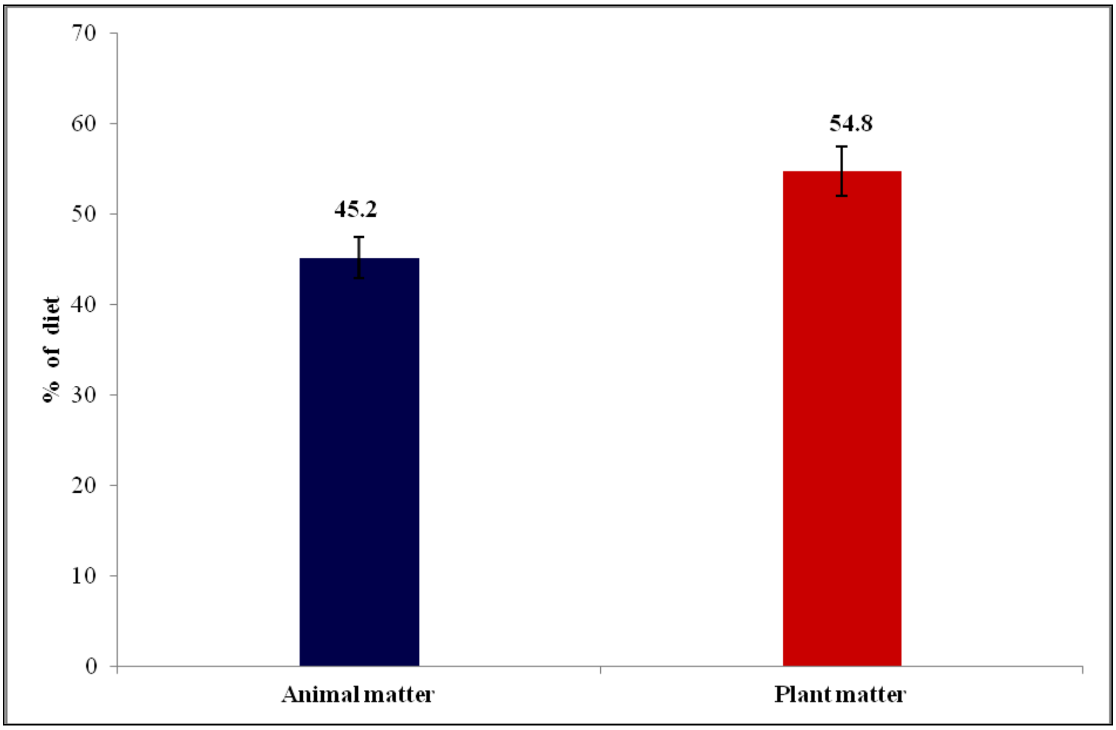


Table 1: Percent tree species with sun bear claw marks in Namdapha Tiger Reserve. (n = 155)

Tree species	Number of trees with claw marks	% of tree species with claw marks
Unknown tree species	2	1.3
Spondias axillaris	11	7.1
Horsefieldia amygdalina	10	6.5
Micromelum pubescens	8	5.2
Natsiatum herpeticum	3	1.9
Turpinia pomifera	3	1.9
Ardisia sp.	3	1.9
Lithocarpus pachyphyllus	3	1.9
Balanophora involucrata	3	1.9
Symplocos sp.	3	1.9
Actinodaphne obovata	7	4.5
Gnetum montanum	6	3.9
Eulophia sp.	3	1.9
Alangium chinense	13	8.4
Streptopus simplex	3	1.9
Phoebe sp.	3	1.9
Dimocarpus longan	2	1.3
Polyalthia simiarum	9	5.8
Calamus spp	6	3.9
Elaeocarpus serrata	5	3.2
Medinilla rubicunda	2	1.3

Continued

Tree species	**Number of trees with claw marks**	**% of tree species with claw marks**
Ostodes paniculata	3	1.9
Knema angustifolia	3	1.9
Symplocos cochinchirensis	5	3.2
Acer sikkimense	1	0.6
Terminalia chebula	2	1.3
Terminalia belerica	4	2.6
Emblica officinalis	3	1.9
Bischofia javanica	1	0.6
Phoebe cooperina	5	3.2
Flosrajnae	3	1.9
Amara wallichii	3	1.9
Ficus sp.	14	9.0

Table 2: List of animal food items of sun bears in Namdapha Tiger Reserve.

Class	**Order**	**Family**	**Species**
Arachnida	Scorpionida		
Insecta	Coleoptera	Carabidae	
Insecta	Coleoptera	Chelonariidae	
Insecta	Coleoptera	Chrysomelidae	
Insecta	Coleoptera	Dytiscidae	
Insecta	Coleoptera	Histeridae	
Insecta	Coleoptera	Passalidae	*Aceraius* spp.
Insecta	Coleoptera	Scarabaeidae	*Chalcosoma* spp.
Insecta	Coleoptera	Tenebrionidae	
Insecta	Dictyoptera	Blattidae	*Panesthia spp.*
Insecta	Hymenoptera	Apidae	*Trigona collina*
Insecta	Hymenoptera	Apidae	*Trigona* sp.
Insecta	Hymenoptera	Apoidea	
Insecta	Hymenoptera	Formicidae	*Camponotus gigas*
Insecta	Hymenoptera	Formicidae	*Camponotus* sp.
Insecta	Hymenoptera	Formicidae	*Gnamptogenys menadensis*
Insecta	Hymenoptera	Vespidae	*Polistine spp.*
Insecta	Isoptera	Termitidae	*Globitermes globosus*
Insecta	Isoptera	Termitidae	*Hypotermes xenotermitis*
Insecta	Isoptera	Termitidae	*Macrotermes*
Insecta	Isoptera	Termitidae	*Odontotermes* sp.
Insecta	Isoptera	Termitidae	*Bulbitermes* sp.
Insecta	Orthoptera	Gryllotalpidae	
Insecta	Orthoptera		
Mammalia	Rodentia		
Osteichtyes	Cyprinidae		

Table 3: List of plant food items found in the of sun bears in Namdapha Tiger Reserve.

Family	**Species**
Anacardiaceae	*Spondias axillaris*
Myristicaceae	*Horsefieldia amygdalina*
Moraceae	*Ficus*
Cornaceae	*Alangium chinese*
Annonaceae	*Polyalthia simiarum*
Acoraceae	*Acorus calamus*
Elaeocarpaceae	*Elaeocarpus serratus*
Melastomataceae	*Medinilla rubicunda*
Lauraceae	*Actinodaphne obovata*
Rutaceae	*Micromelum pubescens*

Table 4: Frequency occurrence of food items in the scats of Malayan sun bear in Namdapha Tiger Reserve during 2008-2010. (n= 85)

Food items	**Frequency of occurrence**	**% frequency of occurrence**
Termites	20	10.2
Ants	12	6.1
Beetles	27	13.7
Bees	5	2.5
Wasps	7	3.6
Cockroach	8	4.1
Orthoptera	6	3.0
Vertebrates	3	1.5
Unidentified	1	0.5
Ficus spp.	27	13.7
Alangium chinense	13	6.6
Horsefieldia amygdalina	11	5.6
Micromelum pubescens	6	3.0
Polyalthia simiarum	7	3.6
Calamus spp.	14	7.1
Elaeocarpus phaericus	10	5.1
Medinilla erythrophylla	9	4.6
Spondias axillaris	8	4.1
Actinodaphre obovata	3	1.5

Figure 3: Frequency occurrence of food items in the scats of sun bear in Namdapha Tiger Reserve.

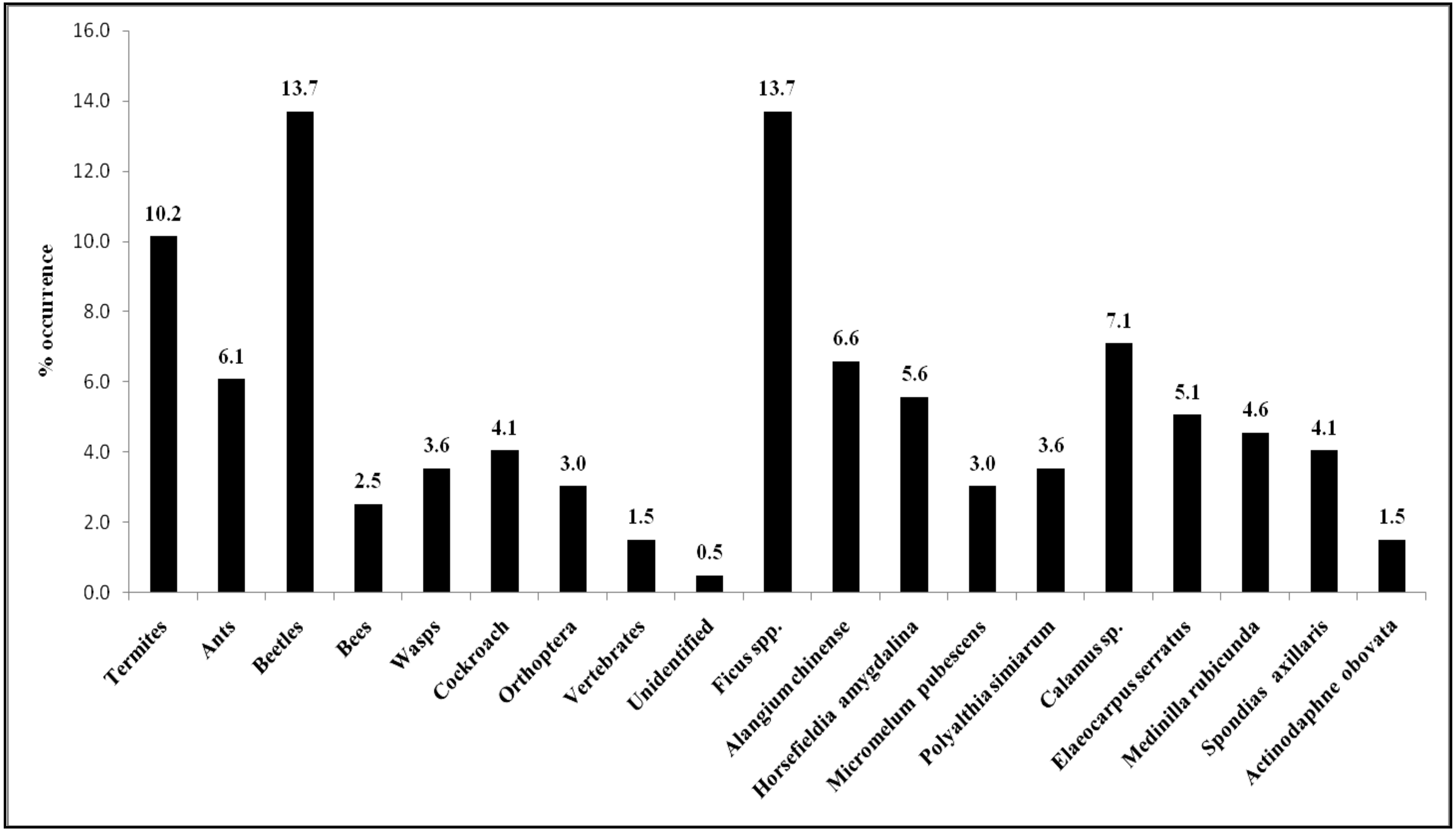


Table 5: Frequency occurrence and estimated volume of food items in the scats of sun bear in different seasons in Namdapha Tiger Reserve.

Food item	Summer, n=28			Monsoon, n=15			Fall, n=42			Annual, n=85		
	Occurrence	Frequency of occurrence (%)	Estimated volume (v)	Occurrence	Frequency of occurrence (%)	Estimated volume (v)	Occurrence	Frequency of occurrence (%)	Estimated volume (v)	Occurrence	Frequency of occurrence (%)	Estimated volume (v)
Termites	5	10.6	S	3	5.1	S	12	13.2	S	20	10.2	S
Ants	3	6.4	S	3	5.1	S	6	6.6	S	12	6.1	S
Beetles	9	19.1	M	7	11.9	M	11	12.1	M	27	13.7	M
Bees	1	2.1	L	1	1.7	M	3	3.3	M	5	2.5	L
Wasps	2	4.3	S	0	0.0	S	5	5.5	S	7	3.6	S
Cockroach	2	4.3	S	2	3.4	S	4	4.4	S	8	4.1	S
Orthoptera	2	4.3	M	1	1.7	M	3	3.3	S	6	3.0	M
Unidentified	0	0.0	-	1	1.7	M	0	0.0	S	1	0.5	M
Vertebrates	1	2.1	M	1	1.7	M	1	1.1	S	3	1.5	M

Ficus	7	14.9	L	9	15.3	L	11	12.1	L	27	13.7	L
Alangium chinense	3	6.4	L	5	8.5	L	5	5.5	L	13	6.6	L
Horsefieldia amygdalina	5	10.6	L	4	6.8	L	2	2.2	L	11	5.6	L
Micromelum pubescens	0	0.0	L	1	1.7	L	5	5.5	L	6	3.0	L
Polyalthia simiarum	0	0.0	L	1	1.7	L	6	6.6	L	7	3.6	L
Calamus sp.	2	4.3	L	3	5.1	L	9	9.9	L	14	7.1	L
Elaeocarpus serratus	0	0.0	L	8	13.6	L	2	2.2	L	10	5.1	L
Medinilla rubicunda	3	6.4	L	6	10.2	L	0	0.0	L	9	4.6	L
Spondias axillaris	1	2.1	L	2	3.4	L	5	5.1	L	8	4.1	L
Actinodaphne obovata	1	2.1	L	1	1.7	L	1	1.1	L	3	1.5	L

Summer: Bootstrap sampling using 28 sampling with 28 observations (Seed=28)

Monsoon: Bootstrap sampling using 15 sampling with 15 observation (Seed=15)

Winter: Bootstrap sampling using 42 sampling with 42 observation (Seed=42)

Annual: Bootstrap sampling using 85 sampling with 85 observation (Seed=85) **S=Small, L= Large, M=Medium**

Table 6: Percent dry weight of food items in the scats of sun bear in different seasons in Namdapha Tiger Reserve.

Food items	Summer (n= 28)		Monsoon (n=15)		Winter (n=42)		Annual (n=85)	
	% dry weight	± SE	% dry weight	± SE	% dry weight	± SE	% dry weight	± SE
Termites	2.0	0.2	0.7	1.5	2.0	0.2	1.8	0.1
Ants	3.7	0.2	0.7	0.5	1.0	0.2	1.9	0.1
Beetles	1.2	0.3	1.4	0.4	2.4	0.2	1.8	0.1
Bees	2.4	0.2	2.1	0.4	2.7	0.2	2.5	0.1
Wasps	0.4	0.5	0.7	0.4	0.7	0.2	0.6	0.1
Cockroach	0.8	0.3	1.4	0.4	1.0	0.3	1.0	0.1
Orthoptera	1.6	0.3	1.4	0.7	1.7	0.2	1.6	0.1
Unidentified	4.1	1.5	0.7	0.9	4.1	0.5	3.4	0.1
Vertebrates	6.5	0.6	2.1	0.5	7.5	0.3	6.0	0.1
Ficus	6.1	0.5	7.8	0.6	3.4	0.2	5.3	0.1
Alangium chinense	10.2	0.5	6.4	0.6	11.5	0.2	9.8	0.1
Horsefieldia amygdalina	8.1	0.3	5.0	0.5	7.8	0.1	7.3	0.0

Continued

Micromelum pubescens	12.6	0.3	14.3	0.4	7.5	0.2	10.6	0.1
Polyalthia simiarum	4.9	0.2	9.2	0.6	10.5	0.2	8.2	0.0
Calamus sp.	9.3	0.3	10.6	0.4	8.1	0.1	9.1	0.1
Elaeocarpus serratus	4.9	0.3	7.1	0.2	7.1	0.2	6.3	0.1
Medinilla rubicund	4.1	0.2	9.2	0.6	7.5	0.2	6.6	0.1
Spondias axillaris	12.2	0.2	7.8	0.4	8.1	0.2	9.5	0.0
Actinodaphne obovata	4.9	0.3	11.3	0.3	5.4	0.1	6.5	0.1

Figure 4: Frequency occurrence of animal and plant matter in the scats of sun bear in different seasons in Namdapha Tiger Reserve. Error bars showing confidence levels.

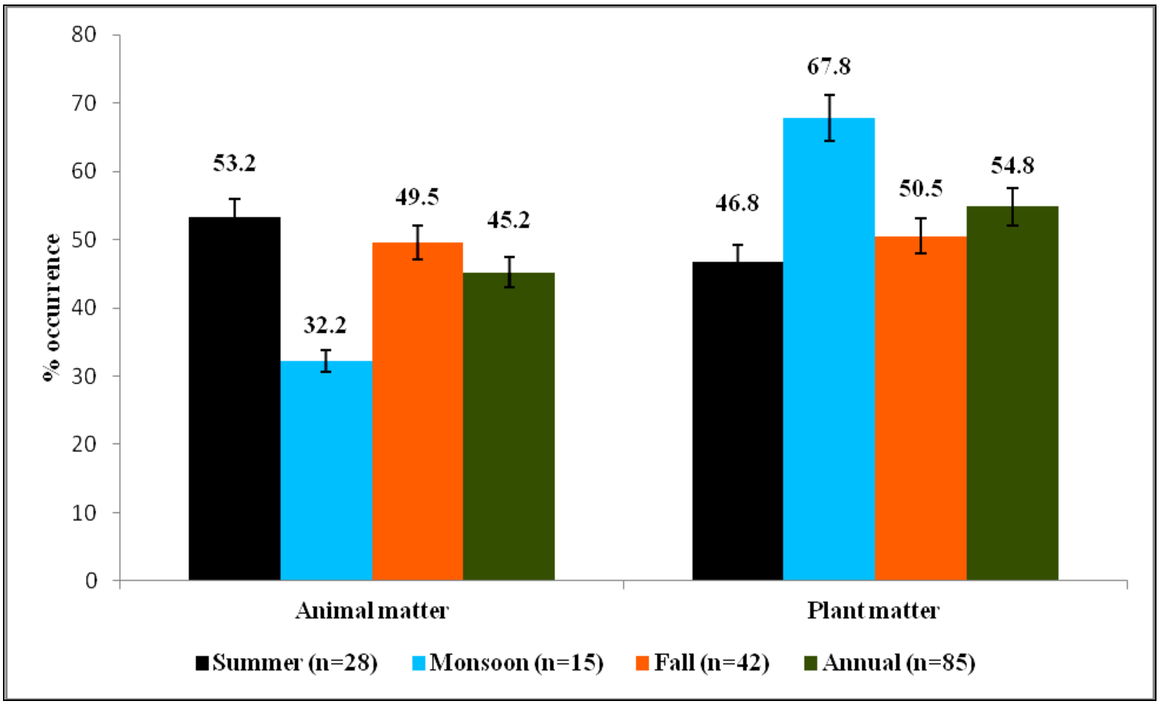


Figure 5: Percent composition of animal and plant matter in the scats of sun bear in different seasons in Namdapha Tiger Reserve. Error bars showing confidence levels.

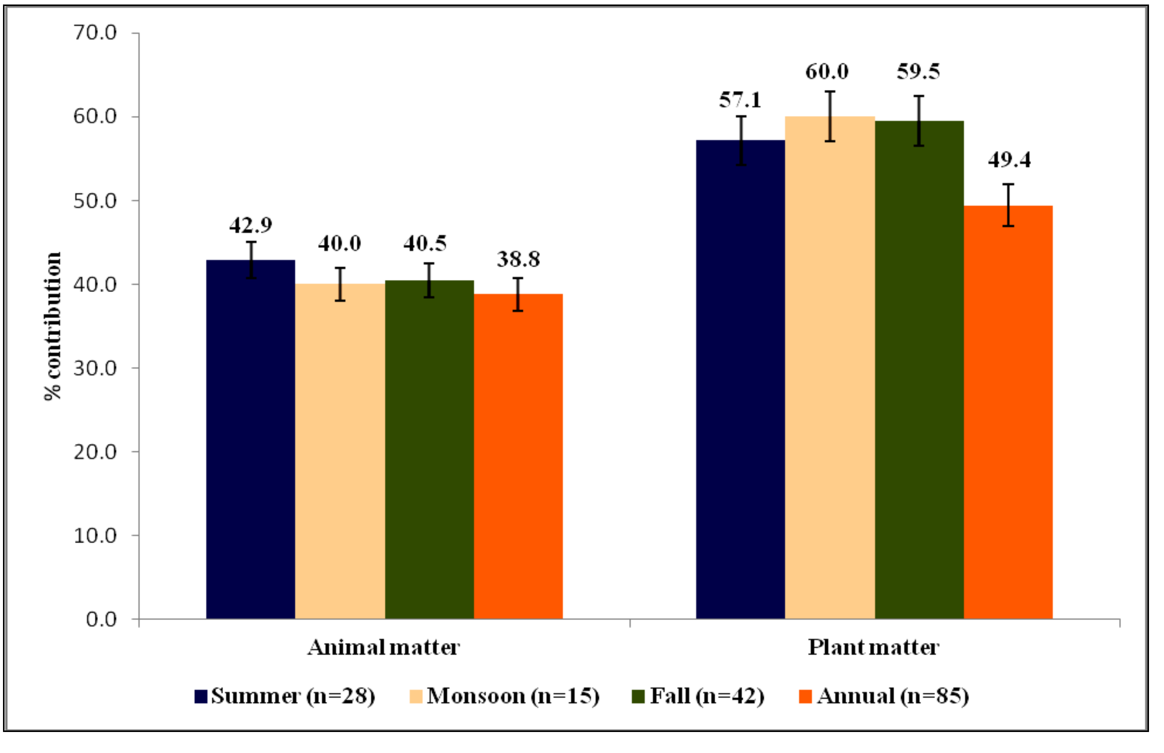


Figure 6: Contribution of food items in different seasons.

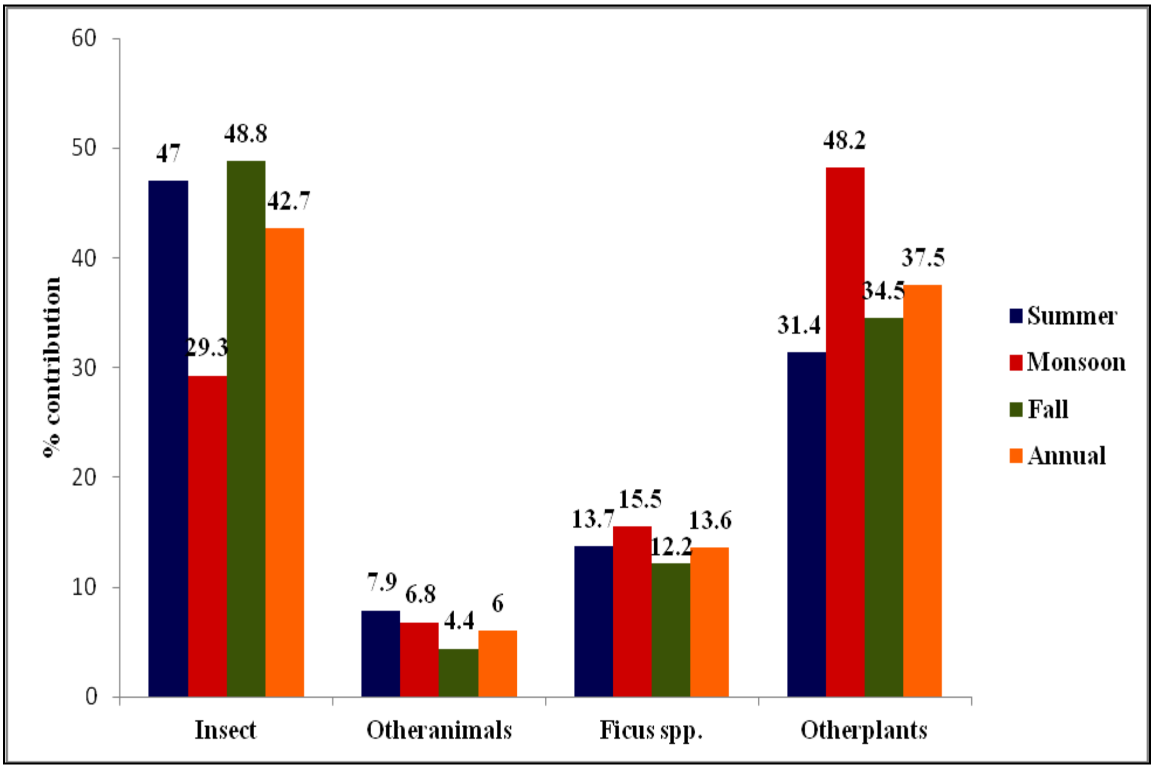


Figure 7: Presence of food items in the scats of sun bear in different months in Namdapha Tiger Reserve.

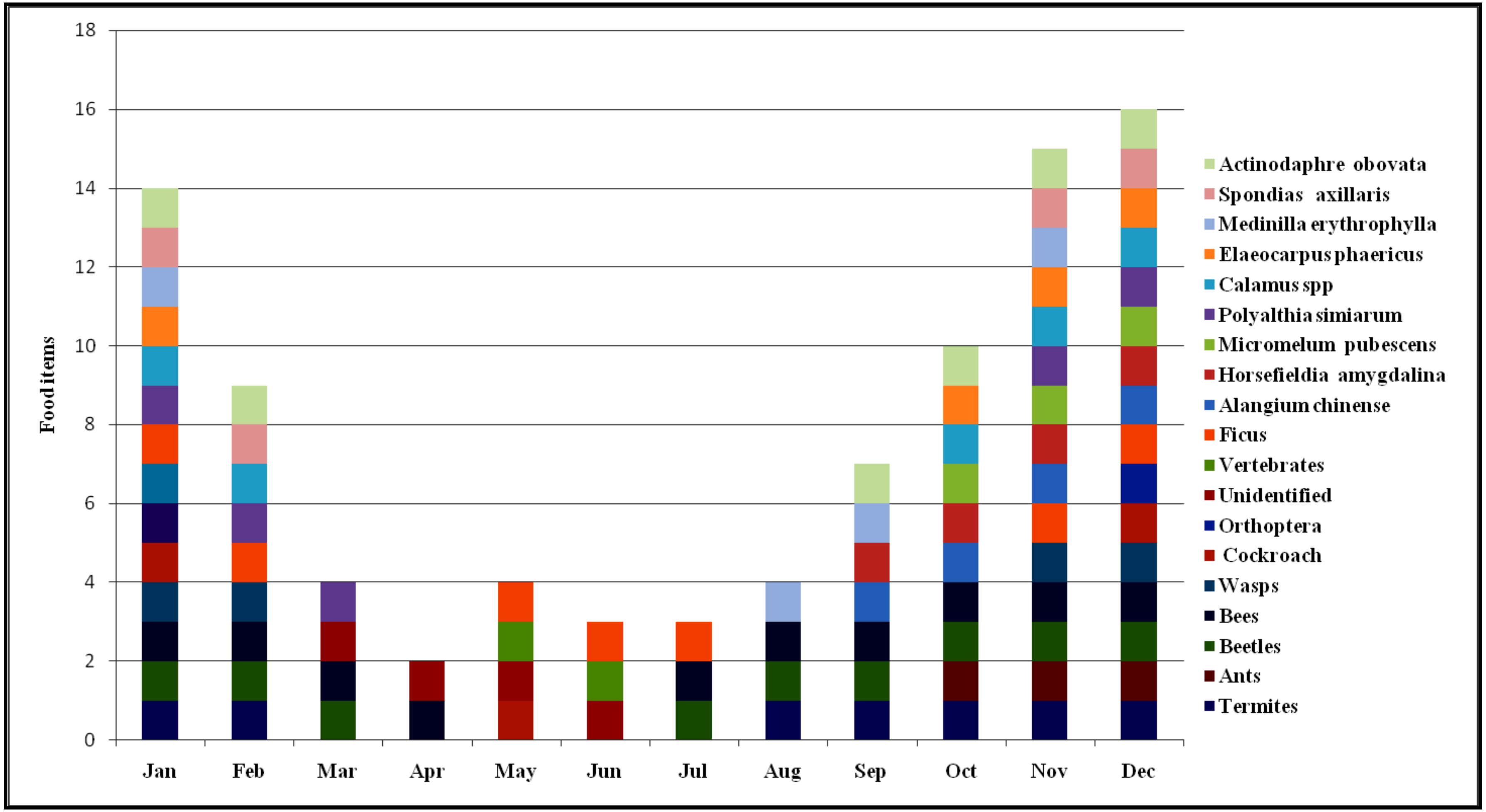


Table 7: Availability of plant food items in different months in Namdapha Tiger Reserve.

Food item	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ficus	+	+	-	-	+	+	+	-	-	-	+	+
Alangium chinense	-	-	-	-	-	-	-	-	+	+	+	+
Horsefieldia amygdalina	-	-	-	-	-	-	-	-	+	+	+	+
Micromelum pubescens	-	-	-	-	-	-	-	-	-	+	+	+
Polyalthia simiarum	+	+	+	-	-	-	-	-	-	-	+	+
Calamus sp.	+	+						-	-	+	+	+
Elaeocarpus serratus	+	-	-	-	-	-	-	+	+	+	+	+
Medinilla rubicund	+	-	-	-	-	-	-	+	+	-	+	-
Spondias axillaris	+	+	-	-	-	-	-	-	-	-	+	+
Actinodaphne obovata	+	+	-	-	-	-	-	-	+	+	+	+

Appendix 1: Fruit items in the diet of Malayan sun bear diets as reported in the literature.

Family	**Genus**	**Species**	**Source(s)**
Bombacaceae	*Durio*	*zibethinus*	Ridley (1930)
Burseraceae	*Canarium*	*pilosum*	McConkey and Galetti (1999)
Burseraceae	*Santiria*	*spp.*	Leighton (1990)
Convolvulaceae	*Erycibe*	*maingayi*	McConkey and Galetti (1999)
Fagaceae	*Lithocarpus*	*spp.*	Davis and Payne (1982)
Lauraceae	*Litsea*	*spp.*	Leighton (1990)
Moraceae	*Ficus*	*consociate*	McConkey and Galetti (1999)
Moraceae	*Ficus*	*stupenda*	S. Harrison in McConkey and Galetti (1999)
Moraceae	*Ficus*	*dubia*	Leighton (1990)
Palmae	*Cocos*	*nucifera*	Domico (1988); Lekagul and McNeely(1977); Payne *at el*. (1985); Servheen (1993); Yasuma and Andau (2000)
Palmae	*Elaeis*	*guineensis*	F. Nomura (Hokkaido University, Japan, personal communication, 1999)
Rhizophoraceae	*Carallia*	*spp.*	Leighton (1990)
Sapindaceae	*Nephelium*	*spp.*	Leighton (1990)

Plate 1: Old scat of sun bear in Namdapha Tiger Reserve.

Plate 2: Fresh scat of sun bear containing honey bees.

Plate 3: Fresh scat of sun bears containing seeds.

Plate 4: Sun bear scat with honey bee and termites.

Plate 5: Sun bear scat with termites and ants in Namdapha Tiger Reserve.

Plate 6: Sun bear digging site with termites.

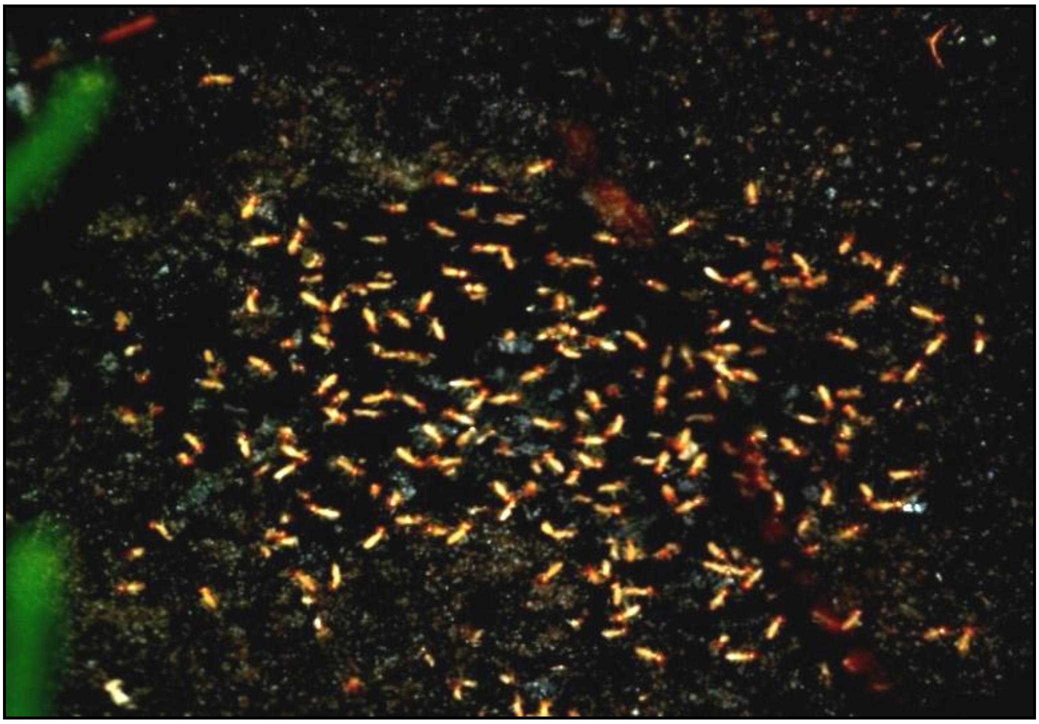


Plate 7: Sun bear digging site with insects and termites.

Plate 8: Sun bear food item, *Alangium chinense*.

Plate 9: Sun bear food item, *Ficus spp*. in Namdapha Tiger Reserve.

Plate 10: Sun bear food items.

Chapter 7

To assess the nature and extent of human-sun bear conflicts: human casualties and agricultural crop damage by sun bear in Namdapha Tiger Reserve.

7.1 Introduction

In India, exponential increase in human and livestock populations has caused tremendous pressure on almost all the natural resources including forests and wildlife. Most of the protected areas are fragmented, degraded and disturbed from human activities, livestock grazing and over-exploitation of resources. Vast areas of forests, marginal lands, pastures and wastelands were brought under cultivation in order to sustain increased demand of cereals and other food products. The irrational and unsustainable land-use patterns in rural areas have further added to this problem. Due to these factors, most wildlife species have become ecological dislocates over the period of time. Some species have become locally overabundant and adapted to the man-altered habitat successfully, while a few others stray out of protected areas. Consequently these species cause damage of varying degree to human life and property.

Most species of bears are opportunistic omnivores that may be considered pests when attracted to human-related foods. North American bears (grizzly bears, *Ursus arctos* and American black bears, *Ursus americanus*) are known to use apiaries, crops, orchard fruits, garbage, and livestock for food (Ambrose and Sanders, 1978; Knight and Judd, 1983 and Garshelis *et al.*, 1999). They also may afflict considerable damage to timber stands (Stewart *et al.*, 1999). In Japan, Asiatic black bears (*Ursus thibetanus*) raid crops, orchards, and fish farms (Huygens and Hayashi, 1999). Sloth bears (*Melursus ursinus*) have been reported to damage sugarcane and groundnut plantations (Iswariah, 1984). Andean bears (*Tremarctos ornatus*) in South America have been reported to predate on livestock (Goldstein, 2002). Until a few decades ago bounties were commonly used as a means of reducing or eliminating bears to protect crops or livestock (Azuma and Torii, 1980; Swenson *et al.*, 1994 and Mattson and Merrill, 2002). In Southeast Asia, sun bears (*Helarctos malayanus*) probably commenced crop raiding when attractive foods were first planted close to forest habitat. Early reports from colonialists in Indonesia described ways of deterring or killing marauding bears in fruit plantations (O Viri, 1925), even when adjacent forest habitat was still extensive. In recent years, the combined effects of timber harvesting and forest fires have significantly reduced forest coverage in Kalimantan (Curran *et al*., 2004 and Fuller *et al*., 2004). Increased human encroachment on Indone-sian forests has led to increased human-wildlife conflicts (Meijaard, 1999 and Rijksen and Meijaard, 1999), although little information is available on conflicts specifically with sun bears.

Bears, as to their association with man, they have been exterminated or driven out by man from many parts of their former domains. Contact with man has naturally affected the habits of bears. Where subjected to constant menace from man, they become much more alert, shyer, and more rigidly nocturnal in habit. Contact with man also gives bears the opportunity to raid his fields and orchards. Individuals developing this habit may become notorious pests (Prater, 2005). In Southeast Asia, sun bears (*Helarctos malayanus*) probably commenced crop-raiding when attractive foods were first planted close to forest habitat (Fredriksson, 2005).

Ordinarily, bears fear and avoid human, except when defending their young, or when wounded. Attacks on man are usually sudden and unprovoked. Short of sight and hard of hearing, the bear is likely to be surprised at close quarters. Taken unawares, it rushes to furious attack in self defense. Many people are attacked mostly as a result of these sudden meetings. Naturally, this is more frequent with species which take readily to living near human settlements (Prater, 2005). Here we (i) provide the information on the nature and extent of human sun bear conflict in the state of Namdapha Tiger Reserve (ii) suggest mitigation strategies to minimize the conflict so as to provide knowledge for sustaining both human and sun bear in these areas.

Human-sun bear interactions include attacks on people, crop depredation and hunting for consumption and sale of bear parts and effects of human resource extraction activities on bears (Mills and Servheen, 1991). Meijaard (1997) reported more and more sale of bear parts such as gall bladders with an influx of foreign users in Kalimantan, Indonesia. Meijaard (1997) stated that the sun bear was the most of tropical forest animals in its range and would attack humans and inflict serious wounds if surprised. In Ukhrul and Chandel districts of Manipur, Malayan sun bear (*Helarctos malayanus*) attack on people due to mere confrontation and invade remote human habitation and cultivation areas in search of food and cause damage to agricultural and horticultural crops.

Scattered information is available in India on status of bear species and human casualties, livestock predation and agricultural crop damage by them. In Jammu and Kashmir, Himachal Pradesh, Uttaranchal and a few North-eastern states, human casualties and livestock killing by leopard and bears is a serious problem (Akhtar and Chauhan, 2006, 2007). In Great Himalayan National Park, Himachal Pradesh, black bear and brown bear were found to increasingly venture into human settlement and cultivation areas in search of food and cause extensive damage to the agricultural and horticultural crops or injure or kill livestock and people (Chauhan, 2003). Sloth bear are known for their aggressiveness both towards human and large mammals. Human casualties and crop depredation by sloth bear are common in many states. Sloth bears are known to raid agricultural crops: agricultural crops: maize, sweet potato, sugarcane and peanut on occasions (Laurie and Seidensticker, 1977 and Prater, 1980). They scavenge meat occasionally. The resources available in the vicinity of the villages are minor forest produces: flowers of mahua (*Madhuca indica*); which perhaps attract bears to live in these areas and thus has resulted in increasing man-bear conflicts. In Melghat Tiger Reserve, there were 22 cases of bear attacks on human beings during 1986-1992 (Pillarisett, 1993). Another study by Khaire *et al.* (1994) revealed 16 incidences of human casualties by sloth bear during 1988-1993 over a period of five years in the same area.

In North Bilaspur forest division, sloth bear have developed aberrant behaviour and are causing lot of nuisance; incidences of human mauling and killing are quite frequent and now it has become beyond tolerable levels. Three hundred seventy cases of human mauling and 25 cases of human killing occurred during the years 1978 to 1998 (Chauhan *et al.*, 1999; Bargali *et al.*, 1999; Naim Akhtar *et al.*, 2000 and Sankar and Murthy, 1995). Information on sloth bear-human conflicts from 23 forest divisions and protected areas of Madhya Pradesh shows that 607 human casualties have occurred in the state during 1989-94 (Rajpurohit and Chauhan, 1996 and Rajpurohit and Krausman, 2000). In Andhra Pradesh, there were 20-30 mauling cases by sloth bears in different years (Krishna Raju *et al.*, 1987).

Bears are known to attack on people and cause damage to agricultural and horticultural crops in countries of their occurrence. In Japan, Canada, Mexico and United States, black bears caused damage to agricultural crops, apiaries, fish farms, livestock and human casualties (Michael *et al.*, 1999; Toshihiro, 1999 and Tsutomu and Joseph, 1999). In Japan, black bears caused significant damage to coniferous plantations, agricultural crops, apiaries, fish farms, livestock and human casualties. Inappropriate disposal of trash, agricultural and marine refuse act as major attractants for brown bears and cause human bear conflicts (Yamanaka, 1986 and Mano, 1990a, b). In Scandinavia, the brown bear population is increasing and dispersing, resulting in more interaction with humans (Swenson *et al.*, 1999).

The human-wildlife damage problems have adversely affected the local rural economy and thus have resulted in serious conflicts at the interface of wildlife habitats and human use dominated landscape. Further as the conflicts are increasing, acceptance of conservation ideals by the local people is also greatly affected. So mitigation of human-sun bear conflict in the affected areas of Namdapha Tiger Reserve is important, and therefore there is an urgent need to study the human casualties, nature and extent of damage to agricultural and horticultural crops, cropping pattern, time of depredation and circumstances in order to minimise or reduce the conflicts to tolerable level.

In this chapter, the nature and extent of human casualties and damage to agricultural and horticultural crops by sun bear in Namdapha Tiger Reserve is presented and mitigation strategies to reduce the conflicts have been suggested.

7.2 Methods

During the study period from 2008 to 2010, information was collected from the records of the forest department, survey of affected villages and by direct interview of the victims or their family members and by analysis of human attack cases in Namdapha Tiger Reserve.

7.2.1 Questionnaire survey

To know the nature and extent of the human-sun bear conflict, questionnaire survey of affected villages in the study area was carried out. During the study period, we conducted informal meetings in public places and made personal visits to 18 villages in Namdapha Tiger Reserve. We focused on the Gandhigram range and Deban range, with an established conflict history, but damage data were also collected at the province level. The representative of the villages and few more villagers were interviewed to record information about the occurrence of human casualties in different years, age and sex of victims, activity of victims, time and place of attacks, seasonal variation, mode of attack and nature of injuries and compensation paid was collected in the specially designed questionnaire formats **(Appendix 1)**. People were interviewed to know their dependency on forest and collection of timbers and NTFP such as fuel wood, food plants, fodder plants, medicinal plants, bamboos and canes, thatches etc. and hunting activities by them. Two-Sample T Test (Zar, 1984) was applied to find out the significant seasonal difference in conflict data.

Information was also collected on cropping pattern, crop damage pattern, time of damage and control methods etc. We also posed questions regarding farming practices, variety of crops cultivated and location of the crop field in relation to the forest edge **(Plate 1)**. The information collected from the villages was cross-checked every time with the records maintained in the forest range offices at Deban and Namdapha. Discussions were also held with the forest officials and staff in this regard. Based on this information, the conflict problem has been evaluated.

The status of human-sun bear conflict and the people's attitudes towards wildlife were also assessed. All above interviews were carried out with the help of the local trackers who acted translators of language, and information thus collected was cross checked with the data of the forest department.

Open-ended questions have a distinct advantage over closed format questions when the primary goal is to learn behaviour and attitudes of respondents (White *et al.*, 2005). During 2008 to 2010, we conducted informal meetings in public places and made personal visits to 18 villages in Namdapha Tiger Reserve. We had recorded people's complaints about wildlife damage, especially damage by sun bears.

A total of 785 house hold were interviews in and around Namdapha Tiger Reserve. It was not possible to obtain a random sample; rather, interviews were held with person (s) willing to interact during the visits. Similarly, previous research in less developed countries had to rely on a non-random set of subjects for such interviews rather than using a fully randomized sampling scheme (Fredriksson, 2005; Jorgenson and Sandoval, 2005 and Chauhan and Singh, 2006).

7.3 Results

Information on human-sun bear conflict: human casualties, cropping pattern, nature and extent of damage to agriculture and horticultural crops etc. was collected from different villages situated in and around the Namdapha Tigre Reserve during 2008 to 2010. During the study period, a total of 18 villages were surveyed. The human casualties were caused by black bear and sun bear in the vicinity of Gandhigram, Vijoynagar, Kuanal basti, 52 mile, 77 mile, Ram Nagar, Hazulu, 38 mile, Upper 38 mile, Deban, Lama camp, Chhemile, Tera mile, Tuhat, Phapar bari, Miao and Dayung villages and Military base camp **(Map 1)**. Informal interviews were conducted in 18 villages and 785 households in and around the Tiger Reserve. The number of households interviewed in each community was proportional to the number of inhabitants in that community.

Majority of the family interviewed in above mentioned villages were engaged in agriculture. Out of 785 households, 265 respondents (33.6%) confirmed the presence of sun bear based on direct sightings. Probable occurrence of sun bear was reported by 21 respondents (2.7%), and there were no responses from 499 respondents (63.7%) in these villages. Among all the respondents who had direct sightings of sun bear, 222 respondents had come across different body parts of sun bear; they saw their dead bodies or skin, bones, gall bladder, nails and jaws. **Plate 2 to 6 and 7** show the evidences of sun bear poaching.

The livelihood of the people largely depends on forest resources which result in extensive exploitation of the forest as well as sun bear habitat. The main forest produces which they used to collect were firewood, timber, fodder, medicinal plants, food plants, bamboos and canes for construction and handicrafts and thatches for roofing materials. All the 265 respondents reported that they used fuel wood for cooking purposes which are collected from the forest area. Any activity inside the forest area often leads to exploitation of sun bear habitat also. Therefore, encounter of sun bear is very likely to happen. Apart from exploitation of forest resources, illegal hunting is also still at large. Hunting and killing of wild animals still attached to their lifestyle.

7.3.1 Human casualties

A total of 31 human casualties were caused by Malayan sun bear in and around Namdapha Tiger Reserve, Arunachal Pradesh during 2002 to 2010.

7.3.1.1 Year-wise human casualties

Human casualties occurred almost every year in Namdapha Tiger Reserve during 2002 to 2010. But there was marked annual variation in human casualties by sun bear **(Figure 1)**. Maximum casualties (25.8%) were recorded in 2008, followed by 19.4% cases in 2003, 12.9% cases each in 2005 and 2006 and 9.7% casualties in 2002. There were 6.5% human injury cases each in 2004 and 2007 and 3.2% casualties each in 2009 and 2010. As such there was no pattern of human casualties in these years. In Namdapha Tiger Reserve during 2002 to 2010, majority of attacks were on males (n=22, 71.0%) and there were 11 attacks on females (29.0%) **(Figure 2)**.

7.3.1.2 Sex of victims

From the year 2002 to 2010, 31 human mauling and killing cases were reported in and around Namdapha Tiger Reserve **(Table 1).** Incidences of male mauling (58.1%) and killing (12.9%) were higher than female mauling (22.6%) and killing (6.4%). Only one male was succumbed to injuries caused by sun bear.

7.3.1.3 Monthly variation

There was marked monthly variation in human casualties by sun bear in Namdapha Tiger Reserve during 2002-2010. Bear attacks were recorded in all the months, but human casualties were highest in winter months **(Figure 3)**. Out of 31 cases, highest number of human casualties occurred in November (n=7, 22.6%), followed by 6 casualties (19.4%) in December. Few human casualties also occurred in October (n=4, 12.9%), August (n=3, 9.7%), and there were two casualties (6.5%) each during March, April and September months. During January, February, May, June and July, there was only one case (3.2%) in each month.

7.3.1.4 Seasonal variation

During 2002 to 2010, number of attacks on humans showed some seasonal variation **(Figure 4)**. The mean occurrence of human casualties was found to be highest in monsoon (4.25±1.31) as compared to casualties in summer (2.5±0.50) and winter (1.0±0.40). However there was no significant difference in human casualties during summer and monsoon seasons based on 'Two-Sample T Test' report (df=6.00, T-value=2.265, P=0.0641). Likewise there was also no significant difference in human casualties during summer and winter seasons (df=6.00, T- value=-1.256, P=0.2557). But there was significant difference in human casualties during winter and monsoon seasons based on 'Two-Sample T Test' report (df=6.00, T- value= -2.389, P=0.0270).

7.3.1.5 Age group of victims

Among 31 human casualties by sun bear, highest number of the victims (n=16, 51.6%) was in the age group of 21-30 years, followed by 9 cases (29.0%) in the age group of 31-40 years **(Table 2)**. There were 4 cases (12.9%) in the age group of 41-50 years. Bear attacked one boy of age group 11-20 years and one attack (3.2%) was in the age group of more than 51 years.

7.3.1.6 Nature of injuries

Sun bear were found to attack on people and cause injuries on their head, face, chest, hands, abdomen and legs **(Table 3)**. Highest number of victims had head injuries (n=11, 35.5%) and facial injuries (n=10, 32.3%). There were 4 victims (12.9%) with leg injuries, 3 victims (9.7%) with injuries in hands, and 2 victims (6.5%) with injuries in chest and 1 victim (3.2%) with abdominal injuries.

7.3.1.7 Place of human casualties

In Namdapha Tiger reserve, maximum human casualties (n=19, 61.3%) occurred in forest areas, followed by 10 cases (32.3%) in crop fields and 2 cases (6.5%) in the vicinity of villages **(Table 4)**. Most of the attacks were in the morning and day time, and few incidences took place in the evening time.

7.3.1.8 Time of attacks

Diurnal pattern of occurrence of human casualties by sun bear showed significant variation (χ^2=105.6, df=6, p<0.01). Most of the cases i.e. 25.8% occurred in the morning time between 0600-0800h, followed by incidences occurred between 1601-1800h (22.6%), 1401-1600h (16.1%), 1801-2000h (12.9%) and 1201-1400h (9.7%) **(Figure 5)**. There were 6.5% human casualties each between 0801-1000h and 1001-1200h.

7.3.1.9 Activities of victims

The victims were found to be engaged in different activities like defection, walking, collection of NTFP, farming and cattle grazing at the time of bear attacks **(Figure 6)**. Incidences of human mauling and killing were highest when the victims were engaged in NTFP collection (41.9%), followed by incidences occurred when victims were walking (22.6%), engaged in farming (19.4%), defection (9.7%) and cattle grazing (6.5%).

7.3.2 Crop damage

In the vicinity Namdapha Tiger Reserve, paddy, maize, jack fruit, Chinese apple, pineapple and banana were the main crops grown **(Table 5)**. The main wildlife species reported to raid crop fields and gardens during the study period were monkeys, wild boar, sun bears, squirrels, civets and yellow throated martin.

7.3.3 Damage to agricultural crops

Out of 265 respondents, crop depredation was reported by 139 respondents, and rest of them did not report about any type of crop damage by sun bear. During the study period 2008 to 2010, monkeys, wild boar, sun bears, squirrels, civets and yellow throated martin were found to cause damage to agricultural crops **(Table 6)**. Number of crop raiding incidences was 20.6%, 25.8%, 20.2%, 13.5%, 10.2% and 9.7% by monkeys, wild boar, sun bears, squirrels, civets and yellow throated martin respectively. Sun bear were reported to visit crop fields during the night hours. The levels of damage to agricultural crops by black and sun bear were high during the harvesting season of the crops, and this inflicted great economical losses to each family.

Among the respondents who reported crop damage, 74.1% reported that their agriculture crops were depredated during night time, while only 10.1% reported that it used to occur during both day and night time. The remaining 15.8% could not tell the time of damage. Only 12.2 % reported that they could keep continuous vigil and provide protection to their crop fields during the harvesting season.

7.3.4 Damage to horticultural crops

According to respondents, highest number of crop raids by sun bear was to jack fruits (n=39), followed by crop raids in maize crop (n=35), Chinese apple (n=24), pine apple (n=17), bananas (n=9) and paddy crop (n=1) **(Figure 7)**. Sun bears were found to return in the early morning and come back at night according to a few villagers. Nearly one quarter (22%) of farmers reported that sun bears raided their gardens repeatedly at the time of forest fires and fruiting failure. Damage to gardens and orchards was highest during winter (n=23), followed by monsoon (n=11) and summer season (n=13).

There were also few cases of sun bears eating pineapple and jack fruit in the kitchen garden of village houses situated in the vicinity of forest areas. They were reported to eat these fruits during the night when the people were asleep.

7.3.5 Crop raiding behaviour

All farmers who reported sun bear visits to their gardens stated that sun bears entered their gardens during the night time. Sun bears were found to build temporary nests in small orchard trees 2-5 m above the ground, usually close to the main trunk. These nests were created by bears by breaking surrounding branches toward them. These nests appeared to function as resting platforms rather than feeding platforms, which were occasionally encountered in fruiting trees within the forest. Such nests in orchards possibly provided some security, because they were off the ground and offered a wider olfactory view to detect approaching humans or dogs. Bears probably left these nests before day break as no farmer reported seeing bears in the morning. Chinese apple were reported to be consumed by sun bear sitting on branches and pulling fruit branches down.

7.3.6 Damage to beehives

Thirty-three incidents of damage to beehives were reported in different villages; all occurred on private apicultural sites or beehives nest inside the tree hollows raised by villagers **(Figure 8)**. Sun bear were found to damage these beehives in boxes or tree hollows. Highest level of damage to beehives occurred during winter (36.4%), followed by summer (33.3%) and monsoon (30.3%). Damage to beehives was almost equal during monsoon (n=12), summer (n=11) and winter (n=10) in villages situated in and around Namdapha Tiger Reserve.

7.3.7 Protection methods used

During the study period, most of the farmers (31%) used dogs to guard their gardens, followed by small wooden fences (28%), scarecrows or dummy (20%), drum beating (15%), and regular night patrolling or check-ups of their gardens (6%) **(Figure 9)**. None of these methods were efficient in keeping sun bears out.

Because one of the aims was to test an inexpensive method to discourage sun bears from damaging trees, farmers were involved in placing the metal sheets and wires around crop fields. Efficacy of the use of metal sheets and wires in deterring bears from climbing as well as placement of these sheets was evaluated by interviewing villagers. There were reports of using poisoned baits by few farmers to deter wild animals including sun bears. Although these poisoned baits were primarily targeted against wild pigs, a variety of wildlife could be killed by this. Some farmers were found to set wire neck snares along the edges of their gardens, mainly for pigs and barking deer, but a few farmers were reported to use locally made foot snares designed to capture bears. A few farmers also indicated that they had looked into hiring a hunter who could spear a bear climbing down from fruiting trees. Only four farmers admitted killing of bears prior to our study period, but this type of information was difficult to obtain during interviews, as such killing was illegal and farmers might have feared prosecution. A few jack fruit trees were covered with metal sheeting by farmers, and none of these were subsequently climbed by bears during the study.

7.3.8 Poaching of sun bear

During the study period from 2008 to 2010, thirteen poaching cases were found in Namdapha Tiger Reserve **(Figure 10)**. Out of these cases, poaching was highest in 2009 (38.4%), followed by 2007 and 2008 (23.1% each) and 2010 (15.4%).

7.4 Discussion

Bears, as to their association with man, they have been exterminated or driven out by man from many parts of their former domains. Contact with man has naturally affected the habits of bears. Where subjected to constant menace from man, they become much more alert, shyer, and more rigidly nocturnal in habit. Contact with man also gives bears the opportunity to raid his fields and orchards. Individuals developing this habit may become notorious pests (Prater, 2005).

In rural areas especially in the periphery of protected areas, majority of the people still depends on shifting cultivation which continuously leads into degradation of forest habitat every year as a result of slash and burn. This is the major factor that plays the role of sun bear as well as wildlife habitat destruction and fragmentation. Poverty also increases the need to extract forest resources which often lead to wild animal habitat exploitation. People have to depend on forest resources like timber and non-timber produces for their daily need, apart from the agriculture harvest. Fuel wood, timber, bamboos and food plants are the biggest needs from the forest, minor needs such as medicinal plants practice, fodder plants as life stock rearing are nowhere to be seen at a large scale, canes, thatches, etc. results into forest exploitation. The extents of extraction of forest produces are more or less at the same level in all the villages. Extraction of timber and bamboo and conversion of forests to other uses have adversely impacted sloth bear habitat (Cowan, 1972, and Servheen, 1990).

The food resources for bears have diminished because of extensive damage to its habitat (Sankar and Murthy, 1995). In addition, human beings and bears have direct competition for food resources (Rajpurohit and Chauhan, 1996). In search of food, bears frequently invade human habitation and cultivation areas and cause human casualties and extensive damage to agricultural and horticultural crops. Consequently, human-bear conflicts have increased to alarming levels. These activities inside the forest area often lead to human sun bear encounter. As a result, it may be related to the majority of human casualties attacked by sun bear which happened inside the forest areas. When encounter with bears, short of sight and hard on hearing, the bear is likely to be surprised at close quarters not because bears are aggressive in nature

(Prater, 2005). Human-sun bear interactions include attacks on people, crop depredation and hunting for consumption and sale of bear parts and effects of human resource extraction activities on bears (Mills and Servheen, 1991). Bears are known to attack on people and cause damage to agricultural and horticultural crops.

The human casualties were caused by black bear and sun bear in the vicinity of Gandhigram, Vijoynagar, Kuanal basti, 52 mile, 77 mile, Ram Nagar, Hazulu, 38 mile, Upper 38 mile, Deban, Lama camp, Chhemile, Tera mile, Tuhat, Phapar bari, Miao and Dayung villages and Military base camp. Informal interviews conducted in 18 villages and of 785 households in and around the Tiger Reserve indicated considerable damage to agricultural crops and other plantations by sun bear.

A total of 31 human casualties were caused by Malayan sun bear in Namdapha Tiger Reserve, Arunachal Pradesh during 2002 to 2010. Marked annual variation in human casualties by sun bear was recorded in Namdapha Tiger Reserve. Human injury cases occurred almost every year from 2002 to 2010. Maximum casualties (25.8%) were recorded in 2008 and least casualties (3.2%) each in 2009 and 2010. As such there was no pattern of human casualties in these years. Annual variation in the sun bear attacks on people could be directly correlated with the human activities and human-bear interactions in forests. There has been increasing degradation and fragmentation of bear habitat and resources utilization. Due to reduction, fragmentation and deterioration of habitat, there has been direct impact on bear populations (Rogers and Allen, 1987 and Schoen, 1990). Sloth bear habitat has been altered drastically with the major impact from forest cutting and intrusion into forests by local settlements (Servheen, 1990), and as result, human beings got increasingly exposed to bears in their habitats (Schoen, 1990).

Human casualties occur when humans enter sun bear habitat or when sun bears invade agricultural fields. From 2002 to 2010, there were 31 cases of human casualties in Namdapha Tiger Reserve. Incidences of human casualties were slightly on the increase in recent years. Out of the total 18 villages, 17 villages were affected from these conflicts. There were more incidences of human casualties in Gandhigram range than in Deban range. In this range, almost all the nesting sites were situated in hillocks, which provided shelter to the bears in patchy, degraded and fragmented forests. These hillocks were surrounded by agricultural crop fields and human habitations. Number of human injuries and deaths caused by bears is substantial. Sun bear caused 98 human casualties in Manipur state and 28 human casualties in Mizoram from 2000 to 2010 (Chauhan and Sethy, 2011a and Chauhan and Sethy, 2011b).

As elsewhere in Southeast Asia, villagers recognized close encounters with sun bears to be potentially or extremely dangerous (Servheen, 1999). Sun bears have been known as fierce animals in their range and would attack humans and inflict serious wounds when surprised in the forests (Meijaard, 1997). Reports of black bear attacking humans, killing livestock and subsequent public backlash were regular in Himalayan region (Sathyakumar, 1999). Human casualties by brown bear were reported in the Great Himalayan national park (Chauhan, 2003) and Ladhak and Suru valley (Sathyakumar, 1999) in India. Human casualties by sloth bear were common in many states in India (Rajpurohit and Chauhan, 1996; Rajpurohit and Krausman, 2000). In Madhya Pradesh, Bihar and Orissa, sloth bears caused 607, 47 and 67 human casualties respectively during 1989-1994. Sloth bears caused 47 human casualties in Bihar and 67 human casualties in Orissa from April 1990 to March 1995 (Rajpurohit and Chauhan, 1996). Human-sloth bear conflicts in Madhya Pradesh were reported from 17 forest divisions and 13 protected areas. Most of the human casualties occurred in 5 forest divisions, namely, Raigarh, Sarguja North, Bilaspur North, Korea and Raipur North, and most of the attacks were outside the protected areas in managed forests.

Human injuries were caused by grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*) in North America (McCullough, 1982 and Herrero, 1985). In North America, only approximately 100 people have been killed by grizzly bears in the past 100 years. Other reports from North America indicate that in 17 National Parks from 1969 through 1978, black bears caused 263 and grizzly bears caused 36 injuries to humans. In Yellowstone National Park, 1,927 injuries from black bears and 75 from grizzlies occurred between 1930 and 1978. In Glacier National Park, the ratio of deaths to injuries from grizzly attacks was even greater: between 1939 and 1980 there were 24 injuries and 6 deaths. Conversely, there was only one death from a black bear in Yellowstone Park and none in Glacier Park from 1939 to 1978 (McCullough, 1982).

In Japan, Canada, Mexico and United States, black bears were found to cause human casualties (Michael *et al.*, 1999; Toshihiro, 1999 and Tsutomu and Joseph, 1999). In North America, approximately 100 people have been killed by grizzly bear in the past 100 years (Herrero, 1985). In Scandinavia, the brown bear population is increasing and dispersing, resulting in more interaction with humans (Swenson *et al.*, 1999).

Out of 31 human casualties by sun bear, majority of attacks were on males (n=22, 71.0%) and there were 11 attacks (29.0%) on females in Namdapha Tiger Reserve during 2002 to 2010. Incidences of male mauling (58.1%) and killing (12.9%) were higher than female mauling (22.6%) and killing (6.4%). The males were more vulnerable to attacks than the females in both in and around Tiger Reserve; number of casualties cases of males was comparatively high than the females. This may be correlated with the intense activity pattern of men in forests in this region. Men regularly visit forests for hunting purpose and collection of fuel wood and fodder for their livestock, medicinal plants and also they spend more time in farming activities. Whereas women had restricted activities in the forests and agricultural areas. All the casualties were accidental due to sudden encounters when villagers ventured into the forests. Sun bear occurred in the tropical rainforests and dense mixed coniferous forests interspersed with villages and crop fields, making them the best available bear habitats. This could be corroborated with occurrence of 31 incidences of bear attacks in the vicinity of in and around Namdapha Tiger Reserve, Arunachal Pradesh.

Among 31 human casualties by sun bear, highest number of the victims (n=16) was in the age group of 21-30 years, followed by 9 cases in the age group of 31-40 years. There were 4 cases in the age group of 41-50 years. The extent of human casualties by sun bear seem to be related to the increasing movement of people of 21-30 years and 31-40 years age group into forests for hunting purpose and collection of NTFP. Mostly the people of this age group were engaged in carrying out different works such as NTFP collection, fuel wood collection and labour etc., which increasingly exposed them to face bear encounters. People of above this age group were involved less and less in carrying out different works so they got comparatively less exposed to bear attacks. People of very old age and children mostly stayed at homes or restricted their activities in crop fields and as a result, there were only a few victims of these age groups.

In Namdapha Tiger reserve, maximum human casualties occurred in forest areas, followed by 10 cases in crop fields and 2 cases in the vicinity of villages. Highest number of human casualties in forests seems to be related to increasing movement of people into forests when sun bear remain active. In the vicinity of Namdapha Tiger reserve, villages and cultivation areas were interspersed with forests, and people increasingly invaded forests for hunting and NTFP collection. While going from one village to another, they had to cross the forests, crop fields and villages. This might have led to occurrence of more human casualties in the forests. Few human casualties also occurred in crop fields and villages. As bears invaded crop fields and villages more and more in search of food or crossed to reach to other forest areas, possibility of encounters with people active in farming activity was enhanced.

Sun bear were found to attack on people and cause injuries in the head, face, chest, hands, abdomen and legs. Highest number of victims had head injuries and facial injuries. There were four victims with leg injuries, three victims with injuries in hands, and two victims with injuries in chest and one victim with abdominal injuries. Interviews with the survived victims of black bear attacks revealed that bears have poor sight and become aware of human presence only when they are encountered very closely.

Most humans mauled by sun bears were severely disfigured, particularly on the face, scalp, eyes, ears, and leg and arm muscles. Similar injuries have been observed in human mauling by grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*) in North America (McCullough, 1982, and Herrero, 1985). In Namdapha Tiger Reserve, bears caused multiple injuries to the victims in majority of the cases. In different attacks, the victims got injuries in their legs, followed by injuries in hands or chest and head. At the time of attacks, the victims fell down and bear injured thigh or hips, back or abdomen or other body parts. Injury to hands was mainly caused in self defence by struggling with the bear.

During 2002 to 2010, number of attacks on humans showed some seasonal variation in Namdapha Tiger Reserve. Bear attacks were recorded in all the seasons. The mean occurrence of human casualties was found to be highest in monsoon as compared to casualties in summer and winter, but human injury cases were high during spring and autumn seasons and winter months**.** But it was not significant across seasons. However there was no significant difference in human casualties during summer and monsoon seasons. There was marked monthly variation in the human casualties in these years. Out of 31 cases, highest number of casualties occurred in November and December. Monthly variation in human casualties seems to be correlated with influx of villagers into forests for hunting purpose and collection of non-timber forest produce (NTFP).

The human-bear conflicts arise simply when human beings and wildlife come into contact and share resources. Bear’s wide-ranging movement, their opportunistic nature, and capacity for learning also increased the probability of encounters with humans (Schoen, 1990). Some black bear-man encounters took place in wilderness, while bears were most active in its feeding on seasonal flowers and fruits, and villagers were engaged in collecting non-timber forest produce. Besides, local people were also found collecting mushrooms, bamboo (*Dendrocalamus strictus*) shoot and rhizomes as food and medicinal items during August to December. Bears living near human settlements raid the ripening crops, which leads to direct encounters with people guarding their crop fields (Prater, 1980; Sankar and Murthy, 1995 and Chauhan and Rajpurohit, 1996). When bears were with their cubs, people entering into their habitat for the collection of firewood were vulnerable to their attacks.

Diurnal pattern of occurrence of human casualties by sun bear showed significant variation. Most of the cases occurred in the morning time when bears were active. At this time, bears were active and people were out in the crop fields or forest areas for hunting, or NTFP collection. In such situation, there were increased chances of encounters of bears with villagers. Sometimes bears were late to return to their nesting sites, and during encounters with men they were chased by the people. In self defence, bears increasingly attacked on people.

7.4.1 Activities of victims

Incidences of human mauling and killing were highest when the victims were engaged in NTFP collection. Besides, incidences also occurred when the victims were engaged in walking, farming and hunting activities.

At the time of human casualties, the victims were engaged in different activities like moving in forests, walking, collection of NTFP and farming. In crop fields, incidences occurred mainly when the victims were active in farming activities, moving from one place to another or crossing fields. In forests, incidences of mauling and killing were highest when the victims were moving from one place to another and for NTFP collection. Villagers were taking their livestock to forest areas daily, and spending lots of time for NTFP collection. For their sustenance, they were dependent on forests directly or indirectly through cattle grazing, collection of NTFP for their use or selling in the market to get some other commodity. This was also attributed to the extent of forest cover and nest distribution, availability of food resources, competition for food items in the two ranges. In Namdapha Tiger Reserve, forests were mainly along the Burma and China hills far from villages, and the villages generally used crop fields for defecation. In Namdapha Tiger Reserve, monkeys, wild boar, sun bears, squirrels, civets and yellow throated martin were found to cause damage to agricultural crops. Sun bear were reported to cause 20.2% raids during 2008 to 2010. Sun bear were reported to visit crop fields during the night hours. The levels of damage to agricultural crops by black and sun bear were high during the harvesting season of the crops, and this inflicted great economical losses to each family. Only 12.2 % respondents reported that they could keep continuous vigil and provide protection to their crop fields during the harvesting season.

Highest number of crop raids by sun bear was to jack fruits, followed by crop raids in maize crop, Chinese apple, pine apple, bananas and paddy crop. Sun bears were found to return in the early morning and come back at night according to a few villagers. Few farmers reported that sun bears raided their gardens repeatedly at the time of forest fires and fruiting failure. Farmers had less antagonism toward bears that fed on ripe fruits from orchards. Farmers generally considered financial losses related to sun bear damage to be low.

Crops grown in these areas were mainly annual crops, and the yield was not even enough to supply a family for a year. So when wild animals caused huge loss for the family, people turned more aggressive to these animals because of the loss of crops. They have to do anything in order to retain as much harvest as they could. So when it comes to this condition, conservation can be a very difficult issue. Most species of bears were found to be opportunistic omnivores that may be considered pests when attracted to human-related foods (Fredriksson, 2005). More intensive systematic study needs to be done to find out the causal factors and intensity of the conflict between human and sun bears.

Human-sun bear conflict was reported in East Kalimantna by Fredriksson (2005). Few recent reports were about sun bear crop raiding. Fetherstonhaugh (1940) reported that ‘‘the Malayan sun bear is an inoffensive jungle dweller and unlike some species, conflict is very little with human activities when it comes in contact with cultivation, the glaring exception being coconuts to which the bears are a positive menace, but there is nothing to fear from their presence near other forms of cultivation’’. O-Viri (1925), on the other hand, described at length how sun bears devastated coconut plantations where they fed on the palmite and damaged papaya plantations, sugarcane, pineapple, and fruit orchards. Several Dutch colonial sources mentioned damage in plantations due to sun bear depredations, especially to coconut stands (van Balen 1914; Feuilletau-de Bruyn, 1933 and Nederlandsch-Indische Vereeniging, 1939). In other parts of Borneo and Sumatra, sun bears have been reported to enter sugarcane fields, and more recently to feed on fruits in oil palm plantations (Nomura, 2003 and T. Maddox, Zoological Society of London, Jambi, Sumatra, Indonesia, personal communication, 2001).

Among the 265 respondents who had direct sightings of sun bear in Namdapha Tiger Reserve, 222 respondents had come across sun bear body parts. Whereas 33 respondents reported that they did not come across any sun bear body parts and evidences of sun bear poaching. Sun bears face numerous threats throughout their range. Sun bear numbers, as with those of the other bear species in Southeast Asia (the Asiatic black bear and the sloth bear), are rapidly decreasing due to the intense pressure exerted by rapidly expanding human populations. Humans cut down the bears' forest homes for timber or to make room for agriculture. These timber practices are destroying sun bear habitat and sources of food, as well as fragmenting bear populations.

Apart from exploitation of forest resources, illegal hunting is also still at large. Hunting and killing of wild animals still attached to their lifestyle. Sun bears are also being exploited for the pet-trade, or killed for food or sale of bear parts, especially for the gall bladder for use in traditional medicines (Roberson, 2006). In the north-eastern states of India, continuous degradation of forest and poaching are the major threats (Chauhan, 2006). The sun bear body parts which the respondents reported of which they came across, clearly indicates that illegal hunting is still at large which may be due to different reasons. As personal communication with the villagers, hunters in villages are given a high status in their respective community plus it's a kind of a habit which they could not let it go at an instant. Perception against wild animals is still very primitive that when seen, the desire to kill is the first thought in their mind. Poverty is also a major factor that plays a huge threat to wild animals and their habitat; they are the source of meat for rural village people. Interestingly enough, sun bears are killed mainly for the consumption of meat; there are no specific hunts for sun bears as there are no particular uses reported. Gall bladders are considered as traditional medicines for stomach ailment, but as per communication, sun bear gall bladders are less preferred than black bear's as their gall bladders are comparatively small. Each and every village had their own issue in bear killings as sun bear body parts reported are from their own respective villages.

Map 1: Location of villages with human-sun bear conflict in Namdapha Tiger Reserve.

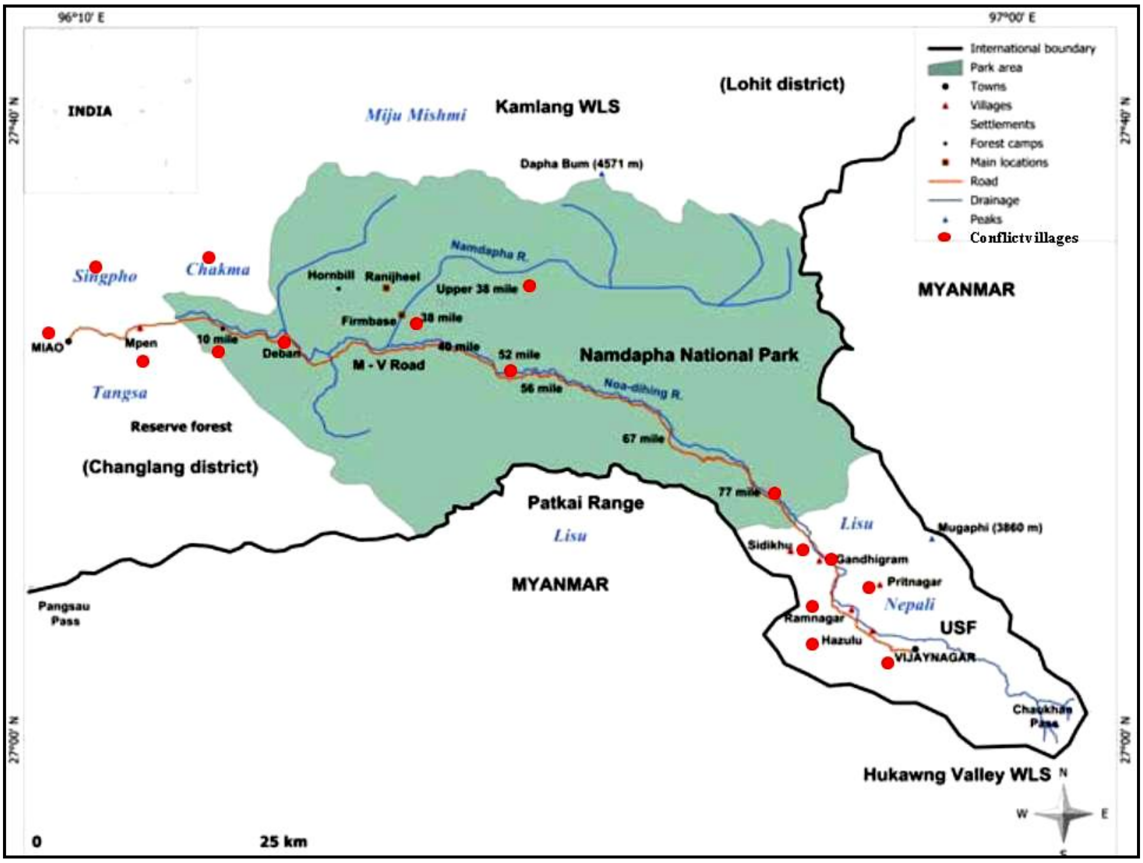


Figure 1: Yearly variation of human casualties by sun bear in and around Namdapha Tiger Reserve during 2002- 2010. (n=31)

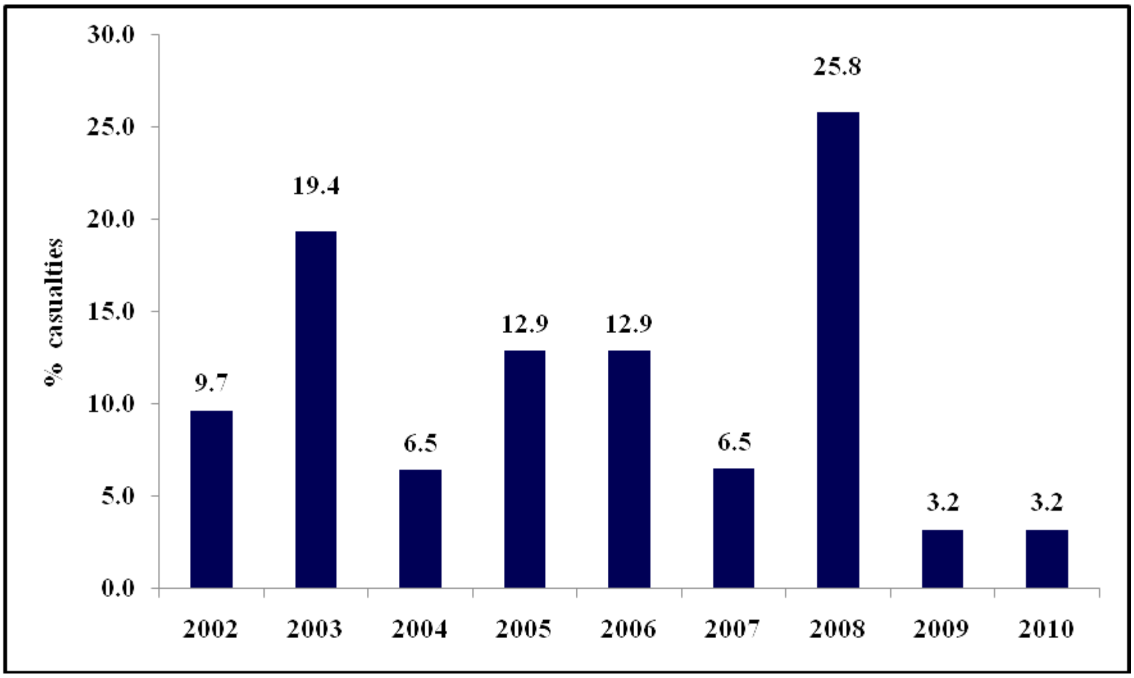


Figure 2: Male and female casualties in and around Namdapha Tiger Reserve during 2002- 2010.

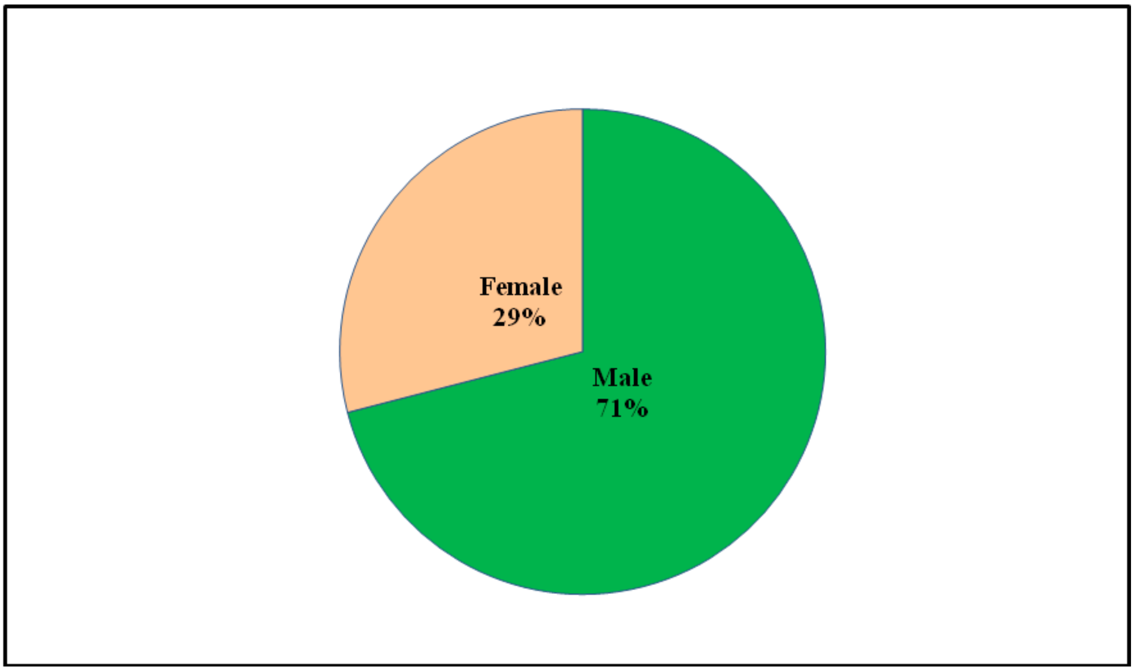


Table 1: Human casualties by sun bear in and around Namdapha Tiger Reserve based on village surveys and interviews.

Year	Male		Female	
	Death	**Injury**	**Death**	**Injury**
2002	-	2	-	1
2003	1	4	-	1
2004	-	2	-	-
2005	-	2	1	1
2006	1	2	-	1
2007	1	1	-	-
2008	1	3	1	3
2009	-	1	-	-
2010	-	1	-	-
Total	**4 (12.9%)**	**18 (58.1%)**	**2 (6.4%)**	**7 (22.6%)**

Figure 3: Monthly variation in human casualties by sun bear in and around Namdapha Tiger Reserve during 2002-2010. (n=31)

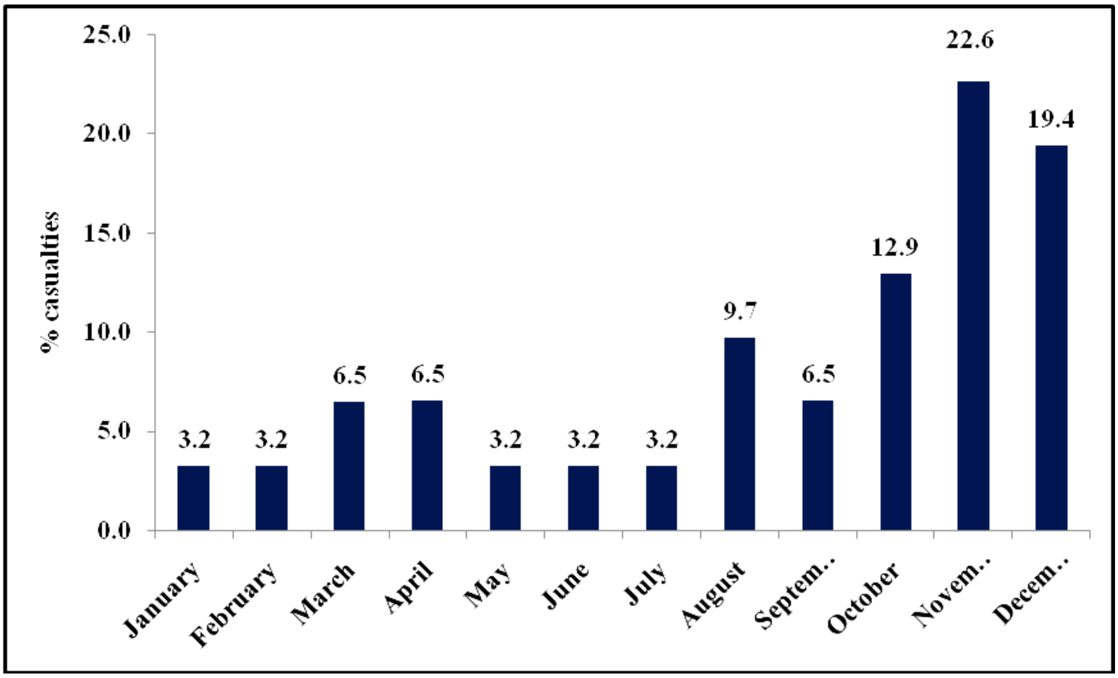


Figure 4: Seasonal variation in bear attacks in and around Namdapha Tiger Reserve during 2002-2010 based on survey.

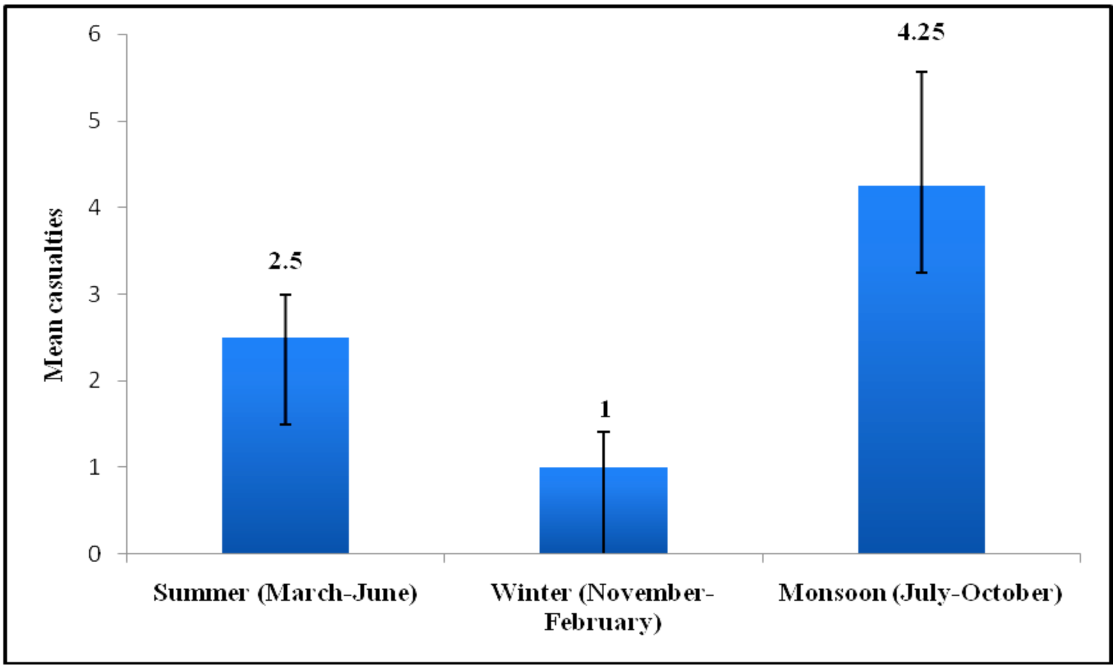


Table 2: Age group of victims in and around Namdapha Tiger Reserve during 2002-2010. (n=31)

Age group (yrs)	No. of victims (%)
11-20	1 (3.2%)
21-30	16 (51.6%)
31-40	9 (29.0%)
41-50	4 (12.9%)
51>	1 (3.2%)

Table 3: Body parts injured by sun bear in and around Namdapha Tiger Reserve during 2002-2010. (n=31)

Body part(s)	Type of injury (n)	% of injury
Head	11	35.5
Face (eye, ear, chin, nose)	10	32.3
Chest (shoulder, chest)	2	6.5
Hands	3	9.7
Abdomen	1	3.2
Leg(s)	4	12.9
Total	**31**	-

Table 4: Place of attack on humans by sun bear in and around Namdapha Tiger Reserve. (n=31)

Place	No. of casualties	Total (%)
Forest	19	61.3%
Crop field	10	32.3%
On road	2	6.5%
Total	**31**	

Figure 5: Human casualties versus time of attacks by sun bear in and around Namdapha Tiger Reserve.

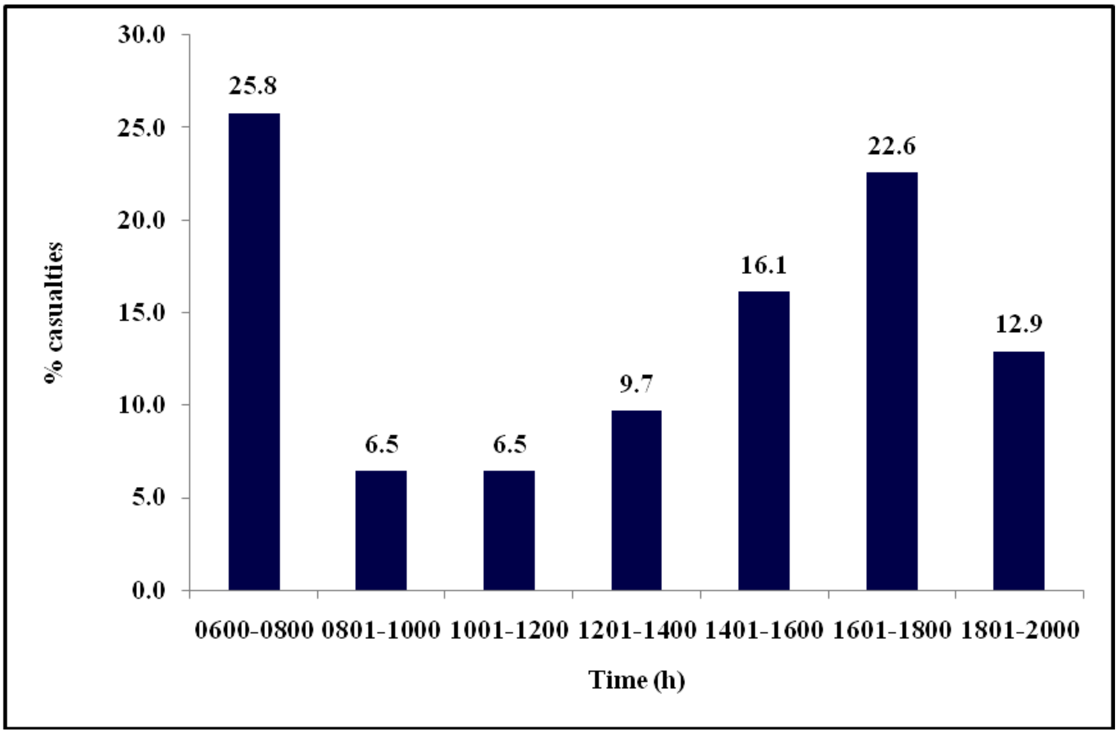
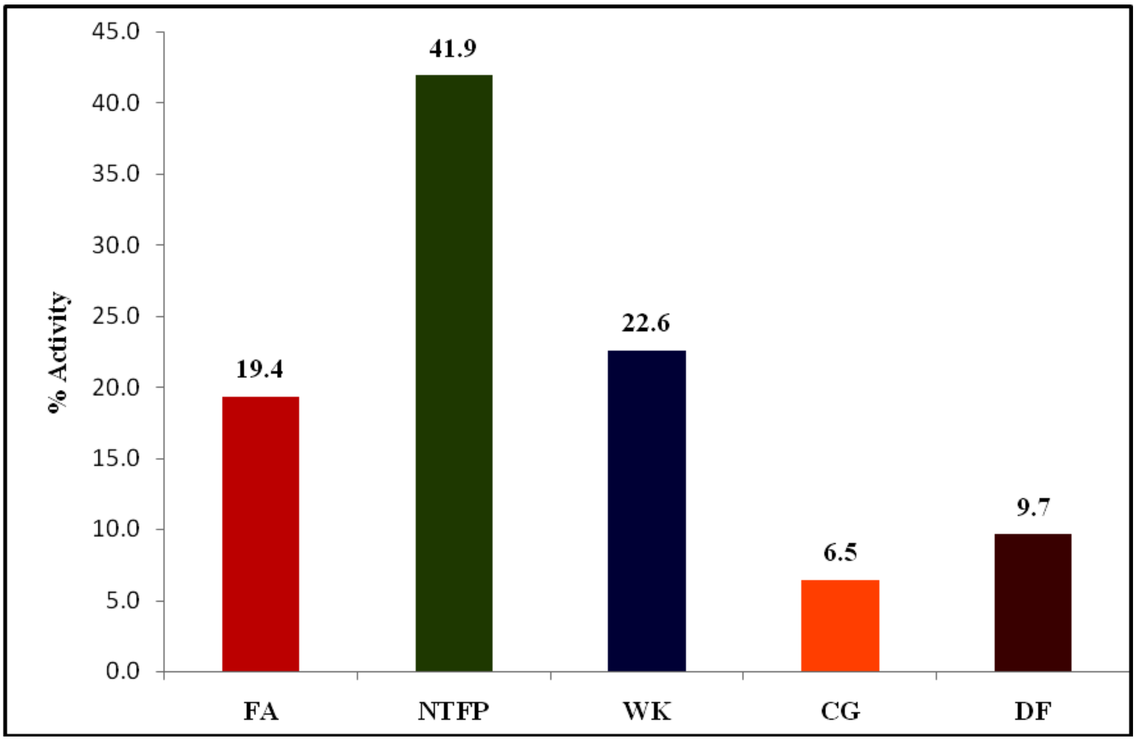


Figure 6: Activity of victims at the time of incidence in and around Namdapha Tigre Reserve.



FA - Farming, NTFP - Non-timber forest produce, WK - Walking, DF - Defecation

Table 5: Agriculture and horticultural crops grown in and around Namdapha Tiger Reserve.

Village	Crop(s)
Gandhigram	Jack fruit, Chinese apple, pine apple, banana, maize
Vijay Nagar	Chinese apple, banana, maize, rice
Kuanal basti	Chinese apple, banana, maize, rice
52 mile	Chinese apple, banana, maize, rice,
77 mile	Chinese apple, banana, maize, rice
Ram Nagar	Chinese apple, banana, maize, rice
Hazulu	Chinese apple, banana, maize, rice
38 mile	Chinese apple, banana, maize, rice
Upper 38 mile	Chinese apple, banana, maize, rice

Table 6: Number of crop raids by wild animals in villages in Namdapha Tiger Reserve during 2008-2010.

No. of crop raids by wild animals						
Crop	**Sun bear**	**Wild boar**	**Squirrel**	**Monkey**	**Civet**	**Yellow throated martin**
Paddy	1	37	2	3	22	21
Maize	35	35	23	27	21	11
Jack fruit	39	0	2	0	5	6
Chinese apple	24	0	29	0	0	13
Pine apple	17	76	17	79	15	9
Bananas	9	12	11	19	0	0
Total	**125 (20.2%)**	**160 (25.8%)**	**84 (13.5%)**	**128 (20.6%)**	**63 (10.2%)**	**60 (9.7%)**

Figure 7: Damage to orchards by sun bear in different seasons according to respondents during 2008-2010.

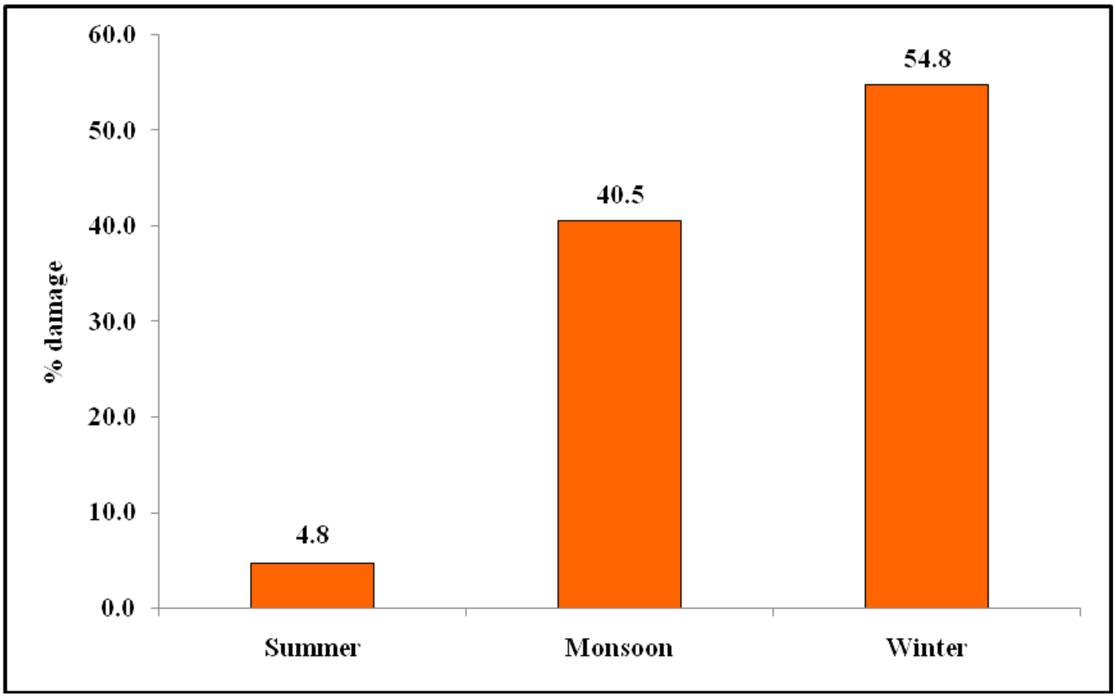


Figure 8: Damage to beehives by sun bear in different seasons during 2008-2010.

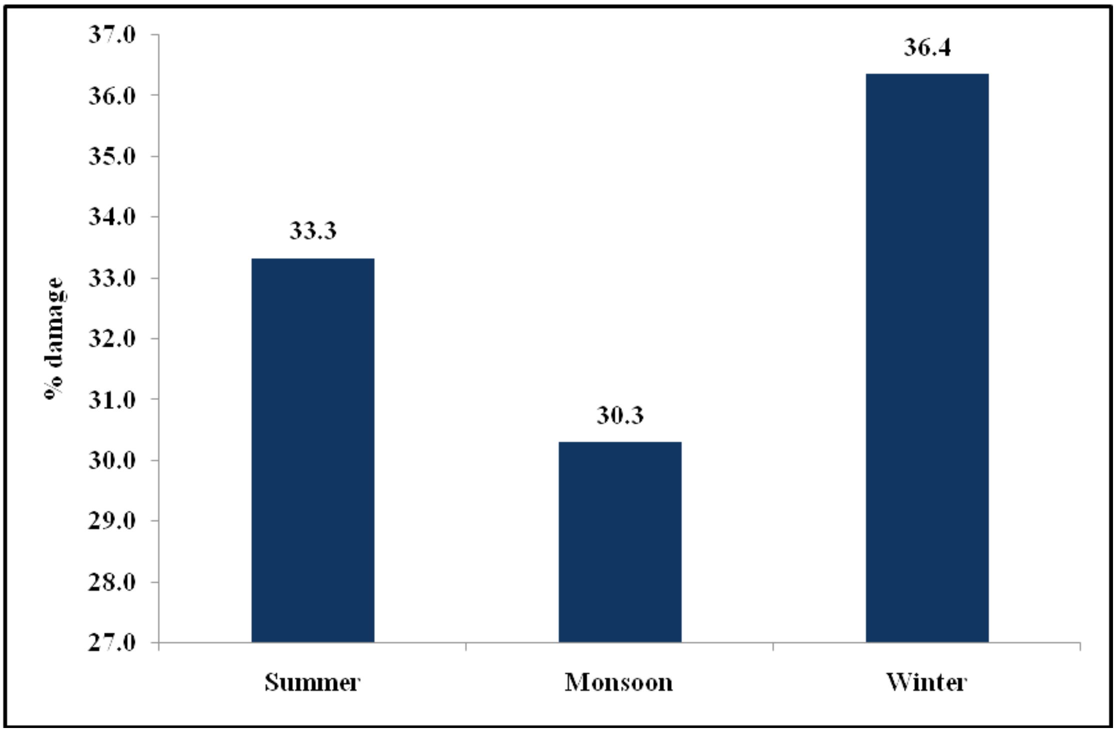


Figure 9: Protection methods used in crop fields in different villages.

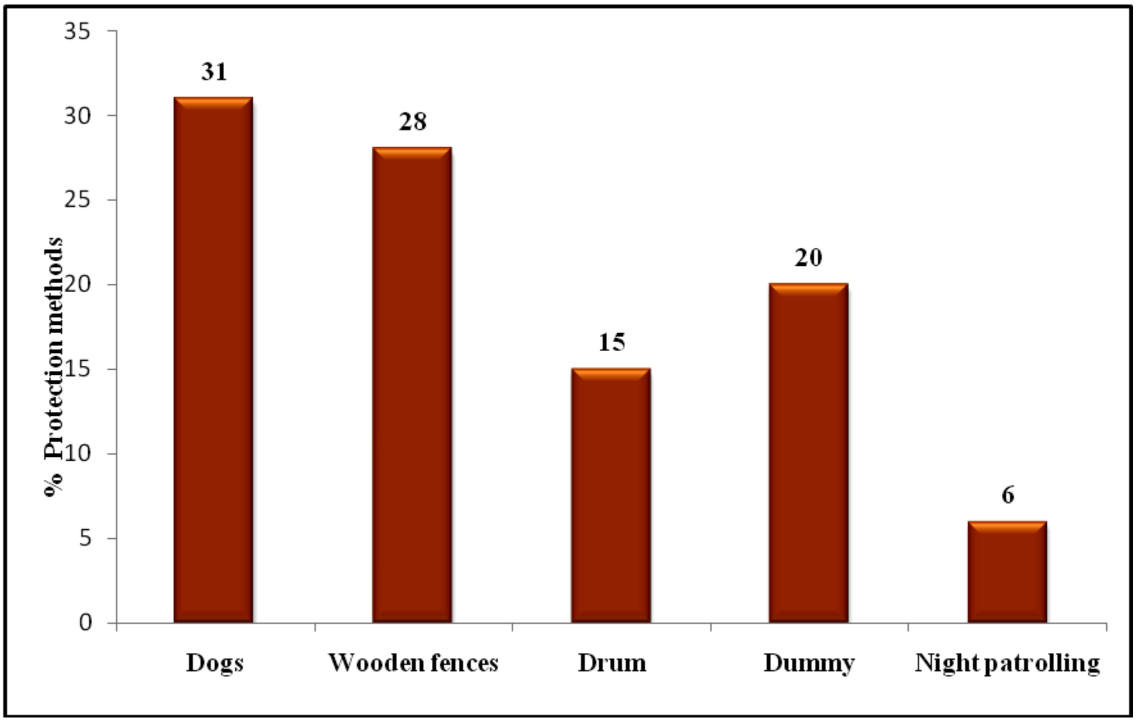
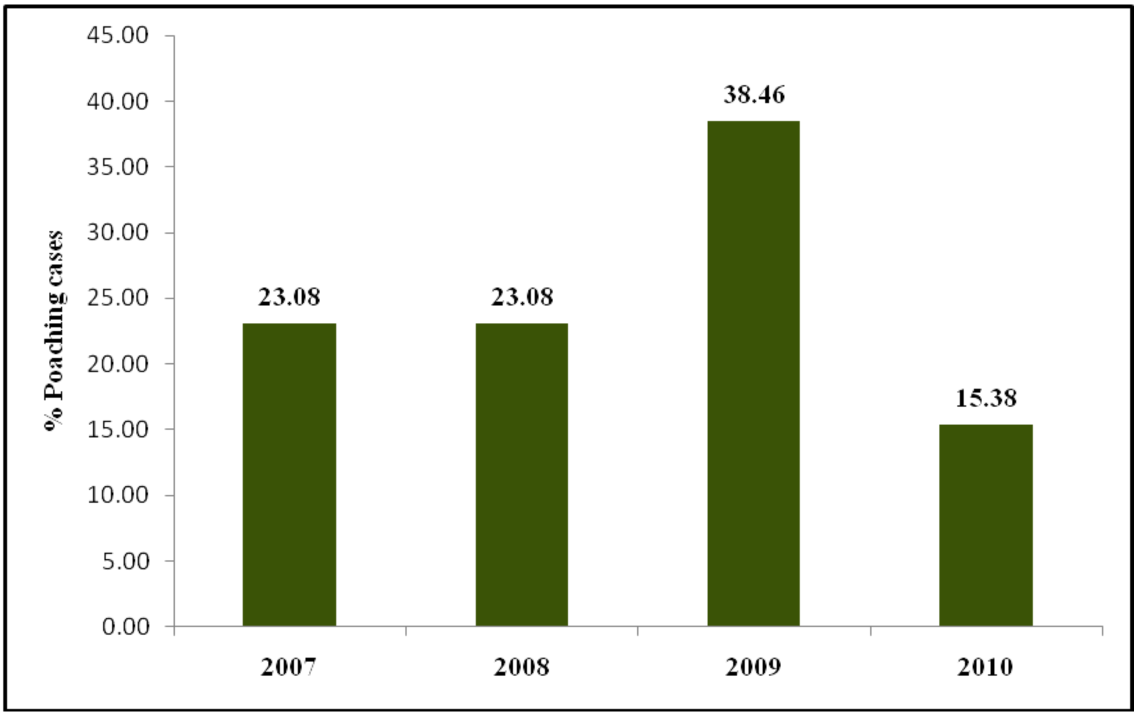


Figure 10: Poaching of sun bear during 2007-2010. (n=13)



Appendix 1

QUESTIONAIRE SURVEY: OCCURRENCE OF MALAYAN SUN BEAR

(Village Interview)

SAMANG/MANGTIR CHUNGCHANGA MIPUITE HNENA ZAWHNA

(Local name: Malayan sun bear Samang / Mangtir …………………………)

(Koh dan)

S. No. ……….. Date ………………….
Ni

Name of Village: ……… ……….. Post:..……………. Time: ………………...

Khaw hming

Name of Respondent: ………. ……………………………………….. ………...
Chhangtu hming

Address: …………….………… ……………….. …………. ………………..…..
Chenna

………..…………………………………. ………….........................

Have you seen sun bear (Direct sighting)? Yes………….. No. ……………..……..
Samang/Mangtir hi mit ngeiin I hmu tawh em? Aw/hmu tawh
Aih/hmu lo

If yes, when: Hmuh tawh chuan, engtikin		Month …………… Thla		Date……….…………. Ni zat	
	Time Hun	(Morning, (Zing,	Noon, Chhun,	Evening, Tlai,	Night) Zan)

How many: One/Two/Three or more ……………………………………...
Engzat nge I hmuh Pakhat / Pahnih / Pathum / aia tam

Adult ……… Cubs …………………………………………….
A puitling A naute

If yes, where: Name of place ….. ………. ……………………………………
Hmuh tawh chuan, khawi hmunah Hmun hming

Forest (Name area) ……. ……… ……………………………..
Ram hming

Type of forest ……… ………………………………………….
Eng hmun nge (Entirnan Phul/Ngaw/adang te)

Crop field ………….. …………………………………………
Thlawhhma (Leipui, huan, lo, etc.)
Road ………. ………………….. …………………………..
Kalkawngah

Slope of hill forest …………. ……….………………….…..
Awih pang /eng ana awih nge

Valley …… ………………… ………………................……..
Kawr ruam (hmun hiam lam)

Bear activity:	Walking,	Feeding,	Resting …………………….……
A eng ti lai nge	A kal	Thil a ei	A mu/ a chawl hahdam

Has anybody seen sun bear?	Yes ……………….	No. …………….
Samang hi miin an hmu tawh thin em?	Aw	Aih
	When ……………...	Where ………….
	Engtikin	Khawi hmunah

Have you seen sun bear signs (Indirect)?
Samang/Mangtir hi a hnu hma (a tak ni lovin) I hmu tawh em?

Scats,	Foot prints,	Claw marks	Tree nest/Cavity……………….
A ek,	A hniak,	Thil a hamna	A bu, thingkawrawng/Thingzar

When ………….. Where ………… ………. (Name)
Engtikin Khawi hmunah

Have you come across/seen sun bear body parts?
Samang/Mangtir taksa bung hrang engemaw hmuh I nei tawh em?

Dead body / Skin / Bones / Gall bladder / Nails / Jaws
A ruan/ A vun / A ruh ro / A mit / A tin / A khabe ruh

………………. ………….. ………… ……….. ……………..…

Where did you find parts? (Place name) ………….. ………. ……….. …………..……
A taksa bung hrang te chu khawiah nge I hmuh? (Hmun hming)

Feeding habits (If known) Crops / fruits / …… … ...…………………………….……….
A thil ei thin (I hriat chuan) Thlai / Thei rah /
Any other wild animals seen?
Ramsa dang (Samang ni lo) I hmu tawh em?

What fuels are used? Mei chhem nan mahni inah enge in hman thin?

Biogas / LPG / Kerosene / Solar energy / fuel wood
Gas siamchawp / Khawnvartui / Ni zung chakna / Thingfak

What forest products are collected?
Ramhnuai atangin chakkhai / mamawh eng te nge in lak thin?

Fuelwood ….. ……………. ……………. ……………….……………
Thing tuah

Timber ….. …………… ……………. …….. ………………….……….
Thingzai

Fodder ……. …………….. …………….. ……………………..……….
Ran chaw

Drinking water for people / livestock …………………….….….…..
Tui, in tur leh thil dang atan

Medicinal plants ……………………………………….…….…..…..
Ramhmul damdawi

Food plants ……… ………………… ………………………….…...
Chawhmeh

Bamboos and Canes ……………………………………………….
Mau leh hrui hnang

Roofing materials/Thatches ……………………………….………….
In chung chihna hmanrua

Others (Thil dang te) ….………. ……………………...…………...

……………………………………….…………………………………

(Based on survey and also from Forest department)

Human casualties
Savawm hliam tawk / tuar tawh te

INJURY CASE:	Male……………..Female …………	Child…………………..	
Hliam tawrh dan	Mipa	Hmeichhia	Naupang

Age (Kum zat) ……………………………….……………...

Date: …………………. Time: …………………………..
Ni Hun/Dar zat

Place of incidence: (Hliam tawrh na hmun)

Forest…………Crop field……….Village……… Others………… ………

Ramhnuai/ngaw chhung Thlawhhma Khaw chhung Hmun dang

Time of casualties:………………………………………………………………..

Activity of casualties:…………………………………………………………….

Nature of Injury: ………………………………………………………………….

Engtin nge hliam a nih

Agricultural crop damage by sun bear

Samang/Mangtir in a thlawhhma thlai a tih chhiat te leh a tihchhiat dan

Crop (thlai)	Resting (a mut hnan)	Trampling (a chil chhia)	Feeding (a ei thin)	Damage (%) Za zela tihchhiat zat
Mustard (an tam)				
Rice (buh)				
Maize (vaimim)				
Sweet potato (kawl bahra)				
Pulses (be lam chi)				
Oil seed (hriak nei chi)				
Sugarcane (fu)				

(Thlai dang te chu a hnuai awllai ah khian ziah zawm mai tur a ni)

Crop damage month-wise: Tick mark yes (✓) or No (×).

(Thlabi a thlai a tih chhiat dan) A dik zawnah (✓) thai la, a dik lo ah (×) rawh

Crop (Thlai)	Month (Thla)											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mustard (An tam)												
Rice (Buh)												
Maize (Vaimim)												
Sweet potato (Kawl bahra)												
Pulses (Be lam chi)												
Oil seed (Hriak nei chi)												
Sugarcane (Fu)												

(Thlai dang te chu a hnuai awllai ah khian ziah zawm mai tur a ni

Damage pattern:

(A tih chhiat thin dan)

Time (Hun): Day .... Night ....
Khaw en lai Zanah

Circumstances: (Eng ang dinhmunah nge)

With Protection and Vigil ……………………………………...
Ven leh vil reng na hnuaiah

Without protection and vigil ………………………..……….
Ven lohna hmunah

Damage control methods (Samang laka thlai ven dan)

Traditional methods used.

Method	(✓/×)
Drum beating (Khuang/thil vuak rik)	[ ]
Crackers	[ ]

(Halpuah hal rik)

Gun shots [ ]
(Silai hmeh puah)

Driving away [ ]
(Hnawh bo)

Brush-wood fence [ ]
(Thir len/pal hung)

Barbed wire fence [ ]
(Thir hling nei pal hung)

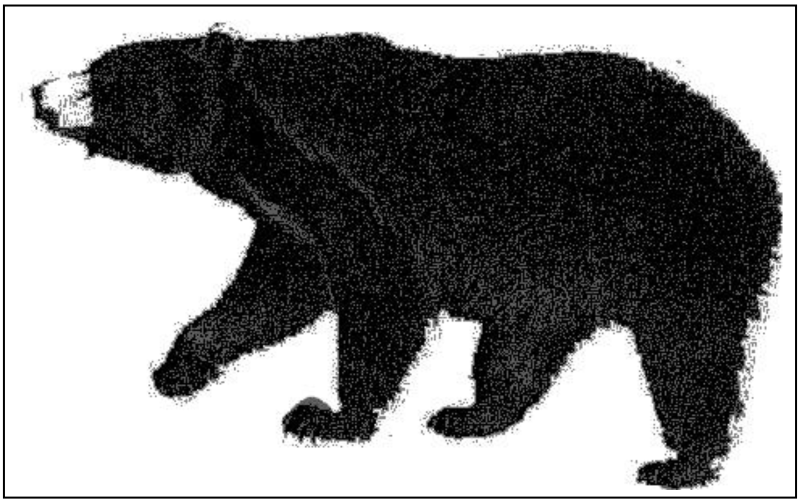
Any other [ ]
(Thil dang)

Bears (SAVAWM chi)

BEAR (SAMANG / MANGTIR) →

SLOTH BEAR

HIMALAYAN BLACK BEAR →



Savawm chi te lu (head) awm

Sloth Bear

Himalayan Black Bear (Savawm)

Sun Bear

Plate 1: Questionnaire surveys carried out in a village in and around Namdapha Tiger Reserve.

Plate 2: Dried skin of sun bear.

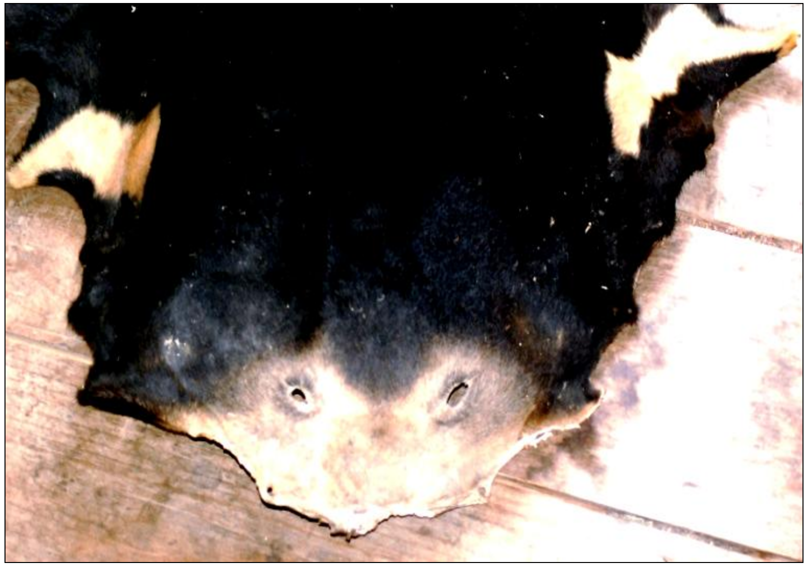


Plate 3: Gall bladder of sun bear.

Plate 4: Paws of sun bear.

Plate 5: Canines and claws of sun bear.

Plate 6: Skull of sun bear used as trophy.

Plate 7: Trophy and gall bladder of sun bear.

Plate 8: Gall bladder of sun bear.

Plate 9: Maize crop damage by sun bear.

Chapter 8

To suggest strategies for mitigation of human-sun bear conflict and conservation of sun bear population.

In Arunachal Pradesh, human population is constantly on the increase and as a result, there are increasing biotic pressure on protected areas and reserve forests. The local people venture into forests anytime of the day to collect non-timber forest produce. Collection of NTFP from bear denning areas should also be completely banned. People can continue to collect these food items from revenue land including villages and cultivated areas.

To resolve human-sun bear conflicts, we know that both the rights of wildlife and the livelihood rights of communities dependent on natural habitats need to be protected. The current processes of development and commercialization threaten both wildlife and local community livelihoods. Therefore, there is an urgent need to build a system that integrates biodiversity conservation and people's livelihood rights. The integration of wildlife conservation and people's livelihood requires actions to enable local communities to manage and sustainably harvest natural resources for their livelihoods, through establishing appropriate tenurial rights, and combining traditional and modern knowledge to monitor the ecological impacts of such harvesting. There is also a need to devise ecologically and culturally appropriate and equitable alternatives for livelihoods that are currently unsustainable. So there is need to develop innovative mechanisms or strategies including the use of traditional methods used by the local communities, which can reduce sun bear damage problem. Ecology of problematic species, nature and extent of damage and circumstances of damage has been evaluated for developing mitigation strategies. Based on the ecological study, human-sun bear conflicts and survey of affected areas, the following general recommendations are made to reduce human-sun bear conflicts.

1. The systematic collection of conflict reports by the forest department will provide baseline information. Efforts must be made to inspect conflict sites immediately by the forest staff. A depredation inspection record will be further useful for the department and affected people in understanding the damage problem and in developing appropriate mitigation measures.

2. Systematic study on status and population ecology of sun bear needs to be carried on priority basis to develop a database on its presence and absence. Existing bear inhabited areas need to be identified and a realistic sun bear distribution range map needs to be developed. There is a need for site-specific application of methods to assess distribution, relative density and the impacts of biotic pressure on sun bear populations.

3. Factors leading to degradation and fragmentation of sun bear habitats should be identified in areas occupied by this species, and strategies should be developed to remove these threats. Cattle grazing, illicit cutting and lopping of trees should be completely banned in bear areas.

4. Poaching of sun bears for trade of bear parts is severely affecting the existing sun bear populations in the north-eastern states, and it may lead to extinction of this species from this country. Strict punishment should be imposed on people involved in hunting of sun bears. Control on poaching will require proper intelligence network and greater enforcement efforts. Trade in bear parts, dead or live sun bears and keeping them as pets should be thoroughly checked by making intelligence system very effective.

5. Conservation of sun bears should be accorded both International and National priority to deal with poaching for illegal trade of bear body parts. Using new provisions of Indian Wildlife (Protection) Act 1972, conservation and community reserves could be established by different states to protect sun bear populations both within and outside protected area network.

6. Local people venture into forests anytime of the day to collect non-timber forest produce, which may be of bear interest also i.e. food plants. There should be restriction on collection of these food plants from the bear areas.

7. Selected forest patches away from potential bear areas are required to be delineated where local people can be allowed for regulated extraction of fuel wood and lopping activity. Keeping in view the dependency of local people on forests and increasing demand for fuel wood and non-timber forest produce, afforestation activities in suitable areas need to be planned and taken up.

8. For mitigation of human-sun bear conflicts under given socio-economic and political framework, one of the ways is to minimize the ill effects of socio economic constraints and socio-ecological constraints in these areas. Livestock killings and agricultural and horticultural crop damage are the socio-ecological constraint identified. To minimize their ill effects on people, education and awareness programmes related to wildlife conservation, ecology of sun bear and genesis of human-sun bear menace is necessary.

9. People should be educated and discouraged to use bear bile as medicine, meat for their consumption, skull and bones as trophies and other body parts for false religious beliefs.

10. A study on assessment of nature and extent of human-sun bear-black bear conflict and circumstances is essentially required to develop mitigation strategies.

11. People still possess the remnants of a conservation ethic. The education and awareness programmes about ecosystem, conservation, natural history of bears, habitats, feeding habits, behaviour, activity pattern, human-bear interaction and safety measures are important for the local community. Constitution of village committees would help in confidence building and awareness messages will help to gain community support for anti-poaching endeavours.

12. People are required to be alert and vigilant moving in wildlife areas. To reduce crop depredation by sun bear, protection measures such as co-operative crop guarding, use of barriers, scaring sounds or frightening devices: scare-crows and dummies, or fire sticks and crackers especially during the crop maturation stage in areas frequently raided by bears are suggested.

13. Very limited information is available on ecology of sun bear. Basic research on the sun bear should be the highest priority need for any bear species in India. Basic information on the status, distribution, ecology, food habits, activity pattern and conflict aspects of the sun bear is essentially required in India. Research on assessment of impacts of forestry practices, timber harvest and monoculture plantations on the sun bear habitats is also important. The study will greatly help in management and conservation of sun bears in India.

14. For conducting systematic research study on bear menace, we should take into account people's feelings, perceptions and attitudes towards the menace, and involve local community including migratory graziers in the planning, and implementation of wildlife conservation programme. It is also very crucial that all stakeholders viz. forest department, administrators, local community and migratory graziers are involved in developing tools and strategies to address human-sun bear conflicts. This partnership would give much needed credibility to management.

15. In Deban, Namdapha and Gandhigram ranges, cattle grazing should be completely banned in bear habitat sites. There has to be some regulation imposed on cattle grazing in forest areas distantly away from den sites. While planning strategy for conflict mitigation and conservation of bear, emphasis should be laid on proper sustainable resource management in forest areas in the two ranges.

16. Bears increasingly invade habitation and agriculture fields, and cause extensive damage to agricultural crops, especially groundnut and maize. Venturing of people into forest causes more competition for resources that lead to more and more man-bear conflict in Namdapha Tiger Reserve. To reduce crop damage,

crops should be protected when mature, crackers, lilting of fire and loud shouting can be used to keep away animal form the fields. Changing in cropping pattern, insurance of crops and possibility of fencing around the crop fields or villages may be helpful for poor villagers to some extent and their resentment for conflicts can be reduced. Similarly to avoid human casualties, people should move in groups in morning and evening hours, do not chase and disturb bear when see, and give escape path for bears to avoid confrontation.

17. In most of the states, payment of compensation for human casualties by the state forest department is a good gesture. This would help develop understanding between affected people and forest department and help conserving wildlife. Compensation procedure for incidences should be simplified and payment should be made immediately. However, we believe compensation should be discouraged in protected areas. Reduction or even a complete ban on livestock grazing within forests will help replenish habitat and increase in wild animal population.

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