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## **CHAPTER-III**

### **STUDY AREA, MATERIALS AND METHODS**

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### 3.1. Study area: Arunachal Pradesh

Arunachal Pradesh, India is situated in the latitude of 26° 28' to 29° 39' N and longitude of 91° 30' to 97° 30' E and altitude range from 87 m above mean sea level at plain to 7090 m amsl at high Eastern Himalaya. The region shares its political boundary with Tibet (China) at northern side (1080 km), Bhutan at western side (160 km), eastern boundary with Myanmar (440 km) and southern part by Brahmaputra valley of Assam, India. Arunachal Pradesh is one of the 8 states of north-east India and it has largest land cover (83,743 km<sup>2</sup>). The population of the state is 13.84 Lakh with a density of 17 individual km<sup>-2</sup>, which is the lowest population density in India (Census 2011) [1]. There are 26 major tribes with 110 sub-clans that sparsely distributed in 23 district of the state [2]. The major tribes of the state have Tibeto-Burman origin but each tribe has each own dialect and traditional follow up. About, 76% of people the state are engaged in agricultural activities that largely support the economic growth of the state (Planning commission, Govt. of India 2009). The people of the state mostly practice slash and burn (shifting cultivation), wet-rice cultivation and settled cultivation at low elevation area. About, 53% of total cultivated area comes under the shifting cultivation of the total cultivated land ([www.india-wris.nrsc.gov.in](http://www.india-wris.nrsc.gov.in)) [3].

Geographically, Arunachal Pradesh has three tectonic domains viz., Himalaya belt, trans-Himalayan belt and Eastern tertiary belt (Naga Patkoi range). Further, Himalayan belt can be sub-divided to High Himalaya and Lesser Himalaya. The Lesser Himalaya in the state rise from low altitude of foot hills to 3500 m amsl and High Himalaya ranges from >3500 m amsl. The northern most part of the region including Mishmi hill comes under the High Himalaya region that route through the northern borderline of India and China. The highest peaks of state are distributed in the extent of High Himalaya range; such as, Kangto (7,090 m amsl), Nyegi Kangtsang (7047 m amsl), Chomo (6937 m amsl) and Gorichen (6538 m amsl). The slope of Lesser Himalayan range of western and central part gradually declines towards the Brahmaputra valley of Assam. In extreme eastern part of the region, Himalayan range inclines towards the Naga Patkoi hill ranges and arises as a physical barrier between India and Myanmar. The major river of Arunachal Pradesh has source in High Himalaya of Tibet, China and mostly feed by the glacier. Dibang, Siang, Subansri, Kameng and Lohit are the five major river of Arunachal Pradesh that curve through the mountain and created deep

valleys in the landscape. Dibang, Siang and Lohit rivers are adjoins at eastern most corner of Assam and flows as a Brahmaputra river that afterwards towards west. Further, Subansri and Kameng are drained at Brahmaputra at downstream. Arunachal Pradesh experiences four major season i.e., pre-monsoon (March-May), South-West monsoon (June-September), post-monsoon (October-December) and winter season (January-February). The annual rainfall of the state is 2745 mm and highest rainfall occurs during SW monsoon (1583.5 mm) and lowest in winter season (94.4 mm) [4]. The ambient temperature of the region decrease according to increase of altitudinal gradient.

Arunachal Pradesh has 2 national park and 11 wildlife sanctuary that cover an area of 9,536 km<sup>2</sup>. Forest survey of India [5] estimated 66,964 km<sup>2</sup> of Arunachal Pradesh under forest cover that account 79.96% of the total geographical area of the state. The highest “very dense forest” cover (20,721 km<sup>2</sup>) in India was estimated in Arunachal Pradesh. Based on the altitudinal gradient, different climatic zones are divided i.e., tropical (87 m-795 m amsl), sub-tropical (802-1800 m amsl), temperate (1824-2788 m amsl) and alpine (2803-4161 m amsl) [6]. The major forest type of Arunachal Pradesh can be classified in 10 major group viz., tropical semi evergreen (at plains upto 250 m amsl), tropical ever green forest (upto 610 m amsl), tropical wet ever green (upto 900 m), sub-tropical broad leaved (900-1900 m amsl), sub-tropical pine (1000-1800 m amsl), wet temperate (1800-2750), mixed coniferous forests (2300-3350 m amsl) and sub-alpine, moist alpine, dry alpine forest (3000-5500) [7].

The different forest type, climatic gradient and geographical confluence in the region results a greater diversity and richness of species. Arunachal Pradesh is an integral part of biodiversity hot spot of the world and 200 globally important eco-regions [8,9]. The state has 4117 angiosperm species and 29 gymnosperm species and 605 species of orchid. Out of the 87 species of Rhododendrons in India, Arunachal Pradesh alone have 75 species [10]. The forest of the state is home to 244 species of mammals, more than 600 species of avifauna, 58 species of amphibian, 23 species of snake and 259 species of fishes [11–17]. Of the total 17 species of primates of India, Northeast India has reported have 10 species [18]. A total of 10 primate species was found to occur in Arunachal Pradesh belongs to Cercopithecidae and Hylobatidae family [19–22]. The genus macaca represent the highest number of species (7) in the state namely, Rhesus macaque (*Macaca mulata*), Assamese macaque (*Macaca assamensis*), Pig-tailed

macaque (*Macaca leonina*), Stump-tailed macaque (*Macaca arctoides*), Tibetan macaque (*Macaca thibetana*), Arunachal macaque (*Macaca munzala*) and White cheeked macaque (*Macaca leucogenys*). The region is the only home of two lesser apes of India i.e., Eastern Hoolock Gibbon (*Hoolock leuconedys*) and Western Hoolock Gibbon (*Hoolock hoolock*). The distribution of Capped langur (*Trachypithecus pileatus*) and Slow loris (*Nycticebus bengalensis*) was reported from the state [23,24]. Forest cover of Arunachal Pradesh has been found rapidly decreasing due to the anthropogenic activity related to infrastructure development such as hydroelectric project, road widening, and agricultural activity [5,7,25,26]. Thus, loss of forest cover and presence of extensive hunting in the state imposes greater threat to the rich flora and fauna of state [27].

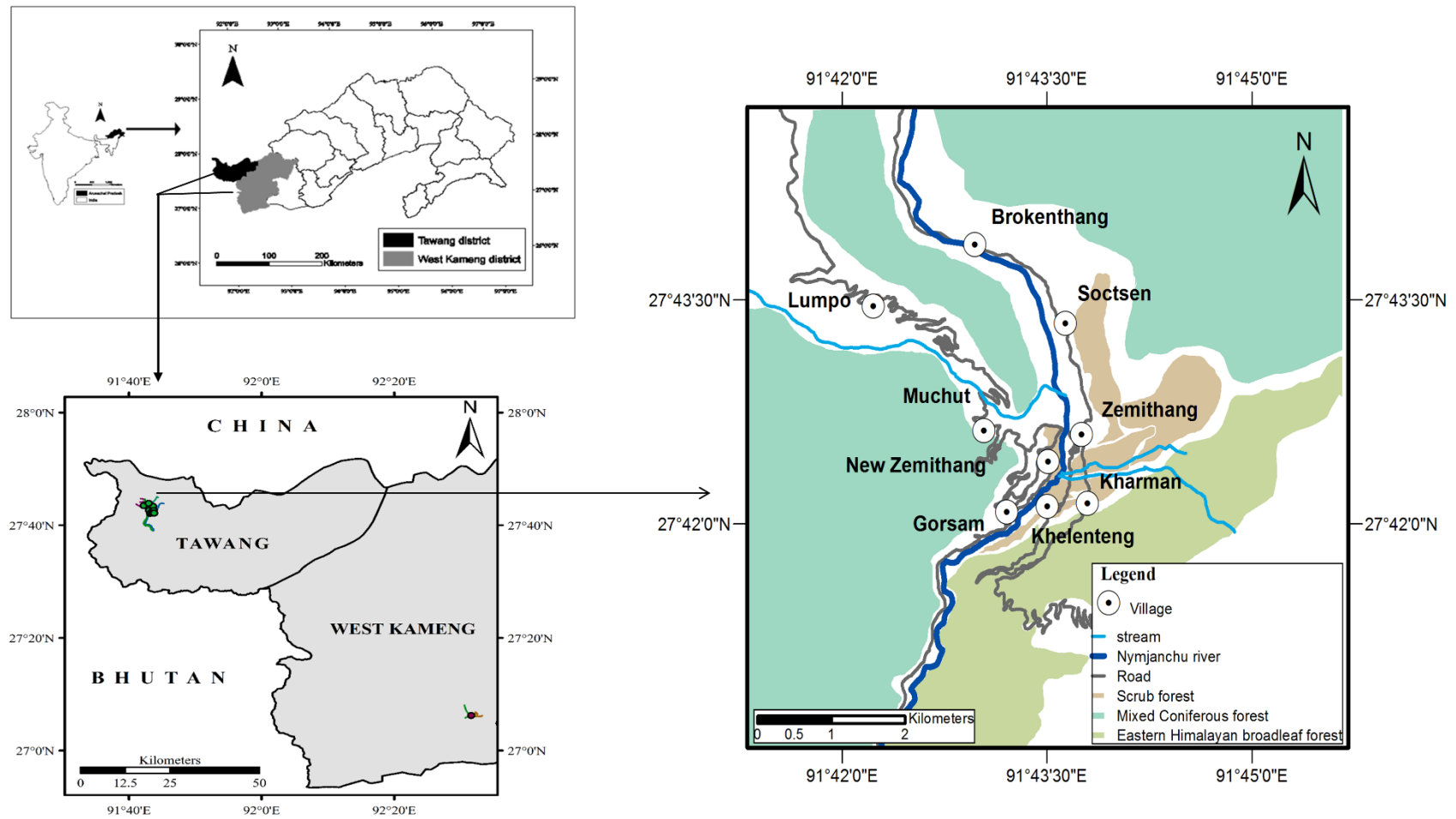


Figure 3.1. Map of study area showing western Arunachal Pradesh and Pangchen valley (Khelengteng-Kharman locality of KZ troop; Zemithang-Soctsen locality of KS troop and Muchut-Lumpo locality of LM troop)

### **3.1.1. Study site (Population and habitat survey):**

The study was conducted in two districts of Arunachal Pradesh (91°36'–93°13'E, 26°52'–27°58'N) i.e., Tawang and West Kameng district (Fig. 3.1). About 11.46% of total landmass of the state comes under Tawang and West Kameng district. The highest population abundance of *Macaca munzala* is known from these two districts [28].

### **3.1.2. Geo-political and socio-economic demography**

West Kameng district is situated on the longitude of 91° 30' to 92° 40' E and latitude of 26° 54' to 28° 01' N. The total landmass of the district is 7,422 km<sup>2</sup> that account 8.86% of the total area of the state. The district shares its political boundaries with Bhutan at western side, East Kameng district at eastern side, Tawang district at north and southern part by Assam, India. Headquarter of West Kameng district is Bomdila. The total population of the district is 49,977 and population density is 11 individual km<sup>-2</sup>. Monpa, Miji, Sherdukpen, Aka and Bugun are main inhabitant of the district, of that Monpa, Miji and Sherdukpen followed Buddhism while Aka and Bugun followed indigenous religion. The main occupation of the people is agriculture (75%). Maize, millet, wheat and barley are major crop grown in the region.

Tawang district is situated on the longitude of 27° 22' to 27° 45' E and latitude 90° 45' to 92°45'N and covers an area of 2,172 km<sup>2</sup>. Tawang district shares political boundary with Tibet of China at northern side, south-west boundary with Bhutan and eastern boundary with west Kameng district. The population of the district is 49,977 and density 23 individual km<sup>-2</sup>. Monpa tribe is predominantly inhabited in the valley and followed Buddhism as a religion. About, 38% people of the district are employed in agricultural activity and mostly cultivated wheat, maize, millet and rice.

### **3.1.3 Altitude, Geo-morphology, soil and climate**

The topography of the study area is mountainous along with deep and gorge valley cut by the numerous river and its rivulet. The altitude varies from 100 m amsl to 7090 m amsl in the study site. Dirang chu is the major river that drained at high altitude region of West Kameng district followed by Bichom, Tenga, Domkho and Tammaphu river flows towards the low altitude region and fed Kameng river. Further, Kameng river drained to Brahmaputra River in Assam. Tawang chu and Nymjang chu are the two major river that flows through the Tawang district towards the Bhutan. The western extension of eastern

Himalaya region is linked by West Kameng and Tawang district hill and mountain range in Arunachal Himalaya. The high Himalaya zone is structured by sela group (Lithostratigraphic unit) comprised by migmatite, garnetiferous gneiss, lit-par-lit biolite gneiss, staurolite schist, quartzite. The lesser Himalaya comes under the group of Dirang formation, Lumla formation and Bomidila gneiss structured by crystalline limestone quartzite and carbon phyllite and granite gneiss [29]. The soil of the low altitude region at foothills area are alluvial, sandy loamy mixed and valley area are mostly clay alluvium and rich in organic content.

The climate of the region is varying according to the altitudinal gradient i.e., tropical (100-500 m amsl), sub-tropical at >500-1800 (m amsl), temperate (1800-2800 m amsl) and alpine (>2800 m amsl) [6]. The maximum mean temperature of West Kameng district recorded 20.96 °C and minimum of 1.40°C. The mean annual rainfall of the district was 1387.5 mm, whereas, highest rainfall was found to occur during the monsoon season (1077 mm) and lowest in winter season (17 mm) [4]. The mean annual temperature of Tawang district was 11.04 °C, whereas, average minimum and maximum temperature ranges from -2.9°C to 31.1°C [30]. The annual rainfall of Tawang district is 115.64 mm, whereas, highest is recorded in monsoon season (269.33 mm) and lowest during the winter season (8.5 mm).

#### **3.1.4. Forest cover, forest type and biodiversity**

West Kameng district has 88.56% of forest cover from the total land mass; of that 318 km<sup>2</sup> cover protected area and 259.82 by reserve forest [5]. The total forest cover of Tawang district is 1,226 km<sup>2</sup> that account 56.45% from the total land cover of the district. Eaglenest wildlife sanctuary and Sessa orchid sanctuary are the only protected area recognized by Govt. of India in western Arunachal Pradesh. Eaglenest wildlife sanctuary is lie in the longitude of 27° 02′-09°N and latitude of 92°18′-35′E with an altitudinal range of 200-3,300 m amsl. The sanctuary covers an area of 218 km<sup>2</sup> and shares its boundary with Bhutan at west side, Sonai Rupai wildlife sanctuary of Assam at south, north side by Tenga valley and eastern side adjoin with Sessa orchid sanctuary.

Sessa orchid sanctuary of West Kameng district is selected for the habitat survey in present study. Sessa orchid sanctuary (SOS) lie in between 27° 3′ -27° 11′ N and 92° 23.4′ - 92° 36′ E and covered an area of 100 km<sup>2</sup>. The sanctuary was established in 1987 and declared as a protected area in the year of 1989 by Govt. of India. The altitudinal

range of the sanctuary is 700 m amsl to 2200 m amsl and major forest type is described as a subtropical forest. The sanctuary is part of Kameng Protected Area Complex (KPAC) that adjoin to Eaglenest wildlife sanctuary at western side and Pakhui tiger reserve at eastern side. Kameng river is dividing the boundary of Sessa orchid sanctuary and Pakhui tiger reserve.

Mishra et. al. [31] reported occurrence of 35 mammalian species in high altitude region of western Arunachal Pradesh that comprises of 12 carnivore species, 10 ungulates and 5 primate species. About of 353 bird species are reported from the Eaglenest and Sessa orchid sanctuary of West Kameng district and 113 from Tawang district [12,32]. A total of 23 species of snake, 9 species of amphibian and 10 lizard species are reported from the Eaglenest wildlife sanctuary of West Kameng district [15]. Tawang district is one of the known distribution range of vulnerable Red Panda (*Ailurus fulgens*) in Arunachal Pradesh [33]. Among the primate species, Capped langur (*Trachypithecus peletus*), Rhesus macaque (*Macaca mulata*), Assamese macaque (*Macaca assamensis*), Arunachal macaque (*Macaca munzala*) and Slow loris (*Nycticebus bengalensis*) have distribution in western Arunachal Pradesh [20,28,34]. The vegetation composition of western Arunachal Pradesh varied with the altitudinal gradient. The forest type of western Arunachal Pradesh can be categorized in Tropical to sub-tropical evergreen forest (100-900 m amsl), followed by sub-tropical pine forest at 900-1800 m amsl, temperate broad-leaved and conifer forest occurs at 1800-3000 m amsl, sub-alpine forest at 3000-4000 m amsl and alpine meadow at >4000 m amsl.

### **3.2. Behavioural study site**

The study on behaviour, nutritional ecology and morphological characterization of *Macaca munzala* was carried out in Zemithang, Pangchen valley of Tawang district (27° 42'N, 91° 43'E) that comes under the Lumla sub-division (Fig. 3.1). A total of 12 villages are under the Lumla sub-division and Zemithang is the circle of the division. The total population of the area is 2,805 from the total households of 647. Agriculture and cattle herding is the main occupation of the people, however, a large number of people are engaged as a labour work with Border Road Organization, Govt. of India. About, 389 ha area is used for agricultural activity in the valley and followed permanent terrace cultivation. The major crops grown in the valley are rice, maize, wheat, millet and barley. Pangchen valley has altitudinal range of 1500 m aml to 3500 m amsl and



shares its boundaries with Tibet of China at northern side and western part with Bhutan. A total of 7 villages are situated closely in the valley namely: Shoctsen, Lumpo, Muchut, Gorsam, Zemithang, Kharman and Khelengteng. Nymjang chu river is flowing through the Zemithang and adjoin with Tawang chu river that drained to Bhutan. The river course has created deep valleys and sharp hill ridges that divided the landscape west to east. The formation of Zemithang-Lumla is considered as an arc parallel extension of higher and lesser Himalaya that form during late quaternary period ~1 Ma [35].

Pangchen valley is a community conservation area managed by the village council of the valley supported of World Wildlife Fund, India and Forest department of Govt. of Arunachal Pradesh, India. The valley covers an area of 98 km<sup>2</sup>. The mammalian species that reported from the valley are Red Panda (*Ailurus fulgens*), Blue sheep (*Pseudois nayaur*), Himalayan black bear (*Ursus thibetanus*) and Wild pig (*Sus scrofa*) [33,36]. Kumar et al. [28] reported that the Zemithang has the highest population density (21 individual ha<sup>-1</sup>) of endangered *M. munzala* in western Arunachal Pradesh. Zemithang, Pangchen valley is also recognized as an important bird area in eastern Himalaya region. The major forest types of the valley can be classified into following group as per Champion and Seth, [37] classification:

Eastern Himalaya broad-leaved forest (EHBLF): The forest type occurs at 1600-2000 m amsl in the valley (Fig. 3.2 B). The dominated tree species are *Alnus nepalensis*, *Quercus serrata*, *Schima wallichii*, *Quercus lamellosa* and *Rhododendron arboretum*.

Mixed coniferous forest (MCF): The altitudinal range of temperate mixed coniferous forest in the valley is 1800-2800 m amsl (Fig. 3.2 C). The dominant tree species are found *Pinus wallichiana*, *Alnus nepalensis*, *Cedar deodar*, *Rhododendron arboreum*, *Malus sieversii* and *Quercus semecarpifolia*.

Sub-alpine forest: This forest type occurs at altitude of >2800 m amsl to 3500 m amsl. The *Rhododendron* species and herbaceous plant like *Primula*, *Goltheria* species and *Asataracea* species are dominant vegetation in this zone.

Degraded scrub forest (DSF): Degraded scrub forests are occurred on the bank Nymjangchu river and fallow agriculture land (Fig. 3.2 D). *Erythrina arborescens*, *Alnus nepalensis*, *Elaeagnus umbellata* and *Viburnum erubescens* are major plant species grown in DSF.



Figure 3.2. Major forest types of Pangchen valley of Tawang (A); Eastern Himalaya Broadleaved forest (B); Mixed coniferous forest (C) and Degraded scrub forest (D)

### 3.2.1. Climate

According to Attri and Tyagi [38] four seasons have been recognized in the valley i.e., Pre-monsoon (March-May), Monsoon (June-September), Post-monsoon (October-November) and winter season (December-February). Mendiratta et al. [39] reported that the temperature of the valley ranged from -3°C to 8°C during winter season and 6°C-11°C during the spring (Pre-monsoon in present study). The mean temperature for monsoon season was reported 17°C -35°C [40]. The mean temperature recorded during study period was 14°C-25°C in monsoon; 10°C-19°C in pre-monsoon season, 8°C-17°C in post-monsoon and 1°C -12°C during winter season. Fog cover is common in early morning in the valley (5 am-9 am) and highest sunlight is received during mid-day (12 noon-2 pm).

### 3.3. Study site (Morphometry and colour variation)

The comparative study on tail length and colour variation was conducted in *Macaca munzala* of Zemithang, Tawang district of Arunachal Pradesh and sympatric western Assamese macaque (*Macaca assamensis pelops*) of Tukreswari, temple, Goalpara district of Assam, India. Goalpara district is situated in longitude of 90°7'-91°5' E and latitude of 25°53'-26°-30' N with an average altitudinal range of 40 m above mean sea level. The district is situated on the southern bank of Brahmaputra river and land cover is 1,824 km<sup>2</sup>. The region has tropical hot and humid climate and *Shorea robusta* is a dominant tree species in forest. Goalpara district is the known distribution range of western Assamese macaque (*Macaca assamensis pelops*), whereas, Brahmaputra river acts as a physical barrier for population extension towards the northern bank of Brahmaputra towards the eastern Himalaya [41]. *M. a. pelops* photographic samples are collected from Tukreswari temple (26.0494°N-90.6322°E). The temple is situated at Tukura hill and surrounded by rocky hillock, sparse forest mixed with agricultural land [41,42]. The recorded highest altitude in temple was 110 m amsl. The annual mean temperature for Goalpara district is 23.57 °C ±3.96. The lowest mean temperature for the district is found in the month of January (10.51 °C) and highest during the month of August (30.33 °C).

### 3.4. Study animal

#### 3.4.1. Taxonomic position and morphological characteristics of *Macaca munzala*

*Macaca munzala* belongs to the sinica group from the genus of *Macaca* of Cercopithecine family (Table 3.1). Sinha et al. [22] described *Macaca munzala* as a new species based on the relative short tail and distinct morphological suite that separated the species from geographically closer Assamese macaque (*Macaca assamensis*) and Tibetan macaque (*Macaca thibetana*). The species is recognized as a sinica group of species based on the penile morphology. Further, molecular genetic analysis of the species is found that *M. munzala* closer to allopatric Bonnet macaque (*Macaca radiata*) of southern India and geographically closer Assamese macaque (*Macaca assamensis*) and Tibetan macaque (*Macaca thibetana*) [43]. The craniodental size and structure, baculum and aspect of caudal structure of *M. munzala* reported as unique and measurement proximate with *M. assamensis* and *M. thibetana* [44].

Table 3.1. Taxonomic order of Arunachal macaque (*Macaca munzala*) as per Sinha [22]

Order	Primates Linnaeus, 1758
Super-family	Cercopithecoidea Gray, 1821
Family	Cercopithecidae Gray, 1821
Sub-family	Cercopithecinae Gray, 1821
Genus	<i>Macaca</i> Lacépède, 1799
Species	<i>Macaca munzala</i>

Holotype and paratype of *Macaca munzala* was described from Zemithang of Tawang district, Arunachal Pradesh [22,44]. *Macaca munzala* was described as a heavy set of primate with shorter tail that distinguish it from the geographically closer Assamese macaque (*Macaca assamensis*) and Tibetan macaque (*Macaca thibetana*). The body of adult *Macaca munzala* colour was vary from dark brown to dark chocolate in colour and relative darker in juvenile. The ventral part of adult was described as a lighter in colour. The tail is darker in colour whip like in appearance and tapering distally. Juvenile tail was described as a hairless. The distinctive facial mark on the temples and forehead, prominent dark pale-yellow with a central group of hair in crown and occasionally erect tuft in adult male, relatively stocky and dark colour tail, very prognathous head and flaring nose are described as a taxonomic identification of the species.

### 3.4.2. Study troop

Three troops of *Macaca munzala* were selected for the purpose of study from Zemithang, Pangchen valley of Tawang district, Arunachal Pradesh. One troop of western Assamese macaque (*Macaca assamensis pelops*) was selected for the comparative study of morphometry and colour variation from Goalpara district, Assam (Table 3.2).

Study troops were selected in Zemithang, Pangchen valley from three habitats namely; KZ troop (Eastern Himalaya broadleaf forest-EHBLF), KS (Degraded scrub forest -DSF) of human modified landscape) and LM troop (Mixed coniferous forest-MCF). KZ troop was comprises of 47 individual followed by LM troop with 40 individuals and KZ troop with 35 individuals. A detail of individual composition in terms of age/sex is described in Table 3.2. The individuals were recognized as description given by Sinha et al. [22] (Fig. 3.3). Age of individuals was recognized based on body size described by Dittus [45].

Table 3.2. Age/sex classification of the selected three study troops

Troop	TI	Adult			Sub Adult			Juvenile			Infant	Habitat type
		Male	Female	UD	Male	Female	UD	Male	Female	UD	Infant	
KS	47	6	9	2	3	5	2	3	5	3	9	DSF, Human Modified Landscape (1600 - 1800 m amsl)
KZ	35	4	7	0	3	3	2	2	3	3	8	Eastern Himalaya Broadleaf Forest (1600-2000 m amsl)
LM	40	5	8	0	4	8	3	2	2	0	8	Mixed Coniferous Forest (2000 m msl to 3000 m amsl)
<i>M. a. pelops</i>	50	6	9	4	5	7	5	2	3	5	4	Human modified landscape (100-200 m amsl)

Khelengteng-Zemithang troop (KZ); Khelengteng-Soctsen troop (KS), Lumpo-Muchut troop (LM), *M. a. pelops* (*Macaca assamensis pelops*, Goalpara), Total individual (TI) and Unidentified sex (UD)

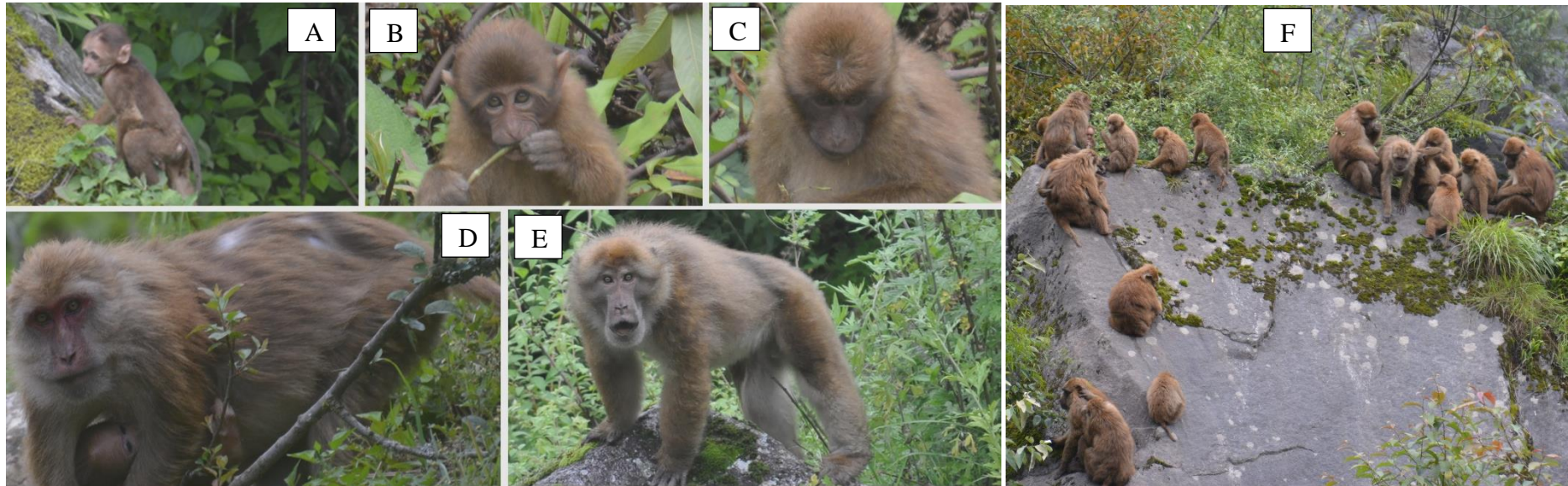


Figure 3.3. Individuals of *M. munzala*. Infant (A); Juvenile (B); Sub-adult (C); Adult female (D); Adult male (E) and Multi male-female troop (F).

### 3.5. Methods and data analysis

The overall study was carried out for three years during May, 2014 to May, 2017. A preliminary survey was conducted in western Arunachal Pradesh followed by distribution modelling, population survey and phytosociology of habitat following different standard methods. Further, behavioural pattern, nutritional ecology, vocalization, morphometry and colour variation study were conducted (Table 3.3).

Table 3.3. Study period and method use as per the objectives studied

Sl. No.	Objective	Method	Data collection period
1.	Ecological niche modelling and population distribution	Maximum Entropy modelling [46]	May, 2014-December 2016
2.	Phytosociology and conservation status	Quadrat sampling [47]	October, 2014-May, 2016
3.1.	Time spent activity, and feeding pattern	Scan sampling [48]	January, 2016-May, 2017
3.2.	Home range and habitat use pattern	Grid method [49]	January, 2016-May, 2017
3.3.	Nutritional ecology	Nutritive value [50]	January, 2016-May, 2017
3.4.	Acoustic analysis of alarm call	Spectrogram analysis	January, 2016-May, 2017
4.	Morphometry and phenotypic characterization	Photogrammetry [51,52]	January, 2016-May, 2017

#### 3.5.1. Ecological niche modelling, population status and habitat survey

Initial occupancy survey has been carried out using random sampling method in known distribution range of *Macaca munzala* [28]. Geo-coordinates points and associated habitat data are collected upon sighting of troop. Ecological niche modelling has been carried out following the method of Elith et al. [52]. Species occurrence data has been drawn from initial occupancy survey and associated environmental data were downloaded from WorldClim database (www.worldclim.org from). Species occurrence data along with 19 (nineteen) bioclimatic data are fitted in MaxEnt software version 3.1.0 (Computer Sciences Department—Princeton University, 2004) and final output map of predicted potential habitat area was projected using ArcGIS 10.1. The Jackknife validation methodology has been used to validate the model [54]. Population survey of *M. munzala* was carried out in high threshold area of potential habitat predicted by the model. For the population survey, the study area was divided in valleys based on the



river course. The forested and non-forested trail were followed by walking since morning (06.00 hours) and terminated in the evening (16.00 hours). Upon encounter of troop, number of individuals (troop size), troop structure (age-sex) and GPS point were noted along with major habitat type of the location. Population data were represented as an encounter rate per km and percentage of age/sex composition.

Phytosociology of habitat of *Macaca munzala* was studied using quadrat method. A total of 50 quadrats were laid in each habitat using 10 m × 10 m quadrat for tree; within that 5 m × 5 m quadrat were used for shrub and herb species [47]. The study extensively followed Cottam and Curtis [55] to calculate the frequency, abundance, density and basal area. The collected data were used to calculate Important Value Index, Shannon-Wiener diversity index, Simpson's index of dominance and Similarity index [56–58]. One-way ANOVA test was performed to perceive the statistical difference in density, basal area, girth class and diversity indices of studied habitat. Investigation on anthropogenic disturbance was conducted in terms of hunting, timber extraction, firewood collection, forest fire and cattle grazing. Encounter rate of different anthropogenic disturbance has been assessed on daily basis. The higher encounter rate has been assessed on the scale of 0-1, where score 1 (one) considered as a higher degree of anthropogenic disturbance in the study site. The detail method is explained in the habitat chapter 5.

### **3.5.2. Time spent activity, feeding pattern and ranging behaviour**

Altmann [48] scan sapling method has been extensively followed for the time spent activity, feeding pattern and ranging behaviour study. The time spent activity of the species studied in terms of feeding, moving, resting, grooming and others [39]. The percentage time spent on different activities was estimated from the total scan sample. Feeding pattern has been studied based on the percentage contributions of food plants estimated from the monthly feeding records/bouts. The different food items have been calculated separately to study the seasonal variability in feeding pattern. Further, food availability index was estimated multiplying average availability of food items and relative density of food plant in respective habitat [39,59,60]. Analysis of Variance (ANOVA) was used to see the effect of seasons and habitat types on the percentage time spent of different behavioural categories and food items. Habitat use pattern, home range and daily path length of the troops estimated using the grid method [61]. The intensity of

habitat uses and seasonal variance has given emphasised in studies. Detail methods of the study is given in chapter 6.

### **3.5.3. Nutritional ecology**

Major food plant materials are selected from behavioural studied troops based on the percentage contribution in diet. The study assessed crude protein using CHN analyser (PERKIN ALMER, USA, Model: 2400 SERIES 2) followed by total carbohydrates by Anthrone method [62] and 'crude fat' using petroleum ether soxhlet method. Secondary metabolite; Saponin content was determined following Obadoni et al. [63] and minerals content (Ca, Fe, Mg, Mn and Zn) were assessed using ICP-OES [64]. Nutritive value of food plants was assessed using the Atwater specific factor system [50,65]. Principal components analysis (PCA) has been adopted to analysis the variances in the diet patterns in terms nutritive value of the studied troops. The detail method is discussed in respective chapter 6.3.

### **3.5.4. Morphometric and colour variation**

Tail length/head-body length measurements of *Macaca munzala* and *Macaca assamensis pelops* was conducted using the photogrammetry method. The morphometric measurement of tail length (Base to tail tip) and body length (head to base of the tail) were assessed from the photograph using ImageJ software ([www.imagej.nih.gov](http://www.imagej.nih.gov)) [51,52]. The relative tail length was estimated using the formula of tail length/head-body length  $\times 100$  [66].

Colour variation study was conducted using RGB additive colour model from the digital photographs. A custom white balance profile was created using X-rite colour checker passport (natural colour reference with 26 patches) and all the photographs are synchronized in Adobe Photoshop Lightroom 5.7.1. RGB value of photographs was obtained using ImageJ software. Mean RGB value were compared using t-test statistics and significance was set at 95% confidence interval i.e.  $p < 0.05$  for statistical tests. The detail methods of photogrammetry for morphometric and colour variation are explained in methodology section in the chapter 7.

### **3.5.5. Spectrogram analysis**

The different vocalization of *Macaca munzala* has been studied in LM troop of mixed coniferous forest during the behaviour sampling. The “alarm” calls have been selected for the detail acoustic analysis. The calls were recorded using Sony ICD-PX470 and digitized with 44.1 kHz with a sample size of 16 bits [67]. Pitch, Intensity and Formant of the calls are quantified using PRAAT. Further, Fourier transformation has been done to detail study of highest peak frequency. The spectrograms are studied in the view range of 0.0-5000 Hz at window length of 0.001 sec and dynamic range of 30 db. The details of the analysis are described in method section of chapter 6.4.

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