CHAPTER-VI

Behaviour and nutritive ecology of *Macaca munzala*

This chapter has been written in four sections as follows;

6.1. Activity and feeding pattern of *Macaca munzala* in heterogeneous habitats of western Arunachal Pradesh, India

6.2. Home range and habitat use pattern of *Macaca munzala*

6.3. Nutritional ecology of *Macaca munzala*

6.4. Acoustic analysis of “alarm call” of *Macaca munzala*

6.1 Activity and feeding pattern of *Macaca munzala* in heterogeneous habitats of western Arunachal Pradesh, India

6.1.1. Introduction

Primate behaviour is an important aspect to understand its complexity in habitat composition in terms of resource requirement. The time allocation in different activities by primates signifies its habitat specific requirements and thus, determines its dietary spectrum [1]. Nevertheless, primates' ecological adaptations are influenced by the vegetation structure, distribution and abundance of food plants [2–8]. Subsequently, the seasonal difference in time spent activities correlated to the thermoregulatory cost of animal [3,9]. Macaque species has wide latitudinal distribution and found to inhabit in tropical, temperate and alpine meadow forest in Asia [10]. The food preference of macaque species differs according to the forest type and seasonal basis [11]. Further, the behavioural adjustment in time activity budgets and spatial movement enables macaque species to cope up with changing habitat [7,12–14]. Macaque species are capable to inhabit in human dominated matrix and secondary forest due to its greater feeding plasticity [14]. Thus, it is essential to generate proficient scientific knowledge on activity pattern and feeding preference of the similar species that ranges both forest and human dominated matrix for the species conservation.

Only a few studies are available on behavioural aspect of newly discovered *M. munzala* [15,16]. Kumar et al. [15] reported the feeding and ranging behaviour of *M. munzala* in secondary scrub forest of Zemithang, Arunachal Pradesh, while seasonal variation in behavioural activity was reported by Mendiratta et al. [16]. However, both of the above studies were carried out only for limited periods considering only the pre-monsoon, monsoon and winter seasons of the study year. On these backdrops, the present study aims to study the time budget of *M. munzala* inhabited in three different types of forest by quantifying the percentage time spent in different activities in its daily active period. Data were also collected to understand the feeding pattern of *M. munzala* to answer the research question whether the species has any preference in resource use in three different habitats having different vegetation composition.

6.1.2 Methods

6.1.3 Study site and study animal

Study on behavioural activity and feeding pattern was conducted in Pangchen Valley (Zemithang Circle), Tawang district of Arunachal Pradesh (27°42´N, 91°43´E), India (Fig. 3.1). Pangchen valley is a Community Conservation Area (CCA) bordering to China and Bhutan. The recorded mean temperature of the valley during the study period was highest during monsoon (min 14º- max 25º C) followed by pre-monsoon (range, 10º C-19ºC), post-monsoon (range, 8ºC- max 17º C) and lowest was recorded during winter season (range, 1º C -12º C). Three (3) troops of *M. munzala* viz., Khelengteng-Zemithang troop (KZ), Kharman-Soctsen (KS) and Lumpo-Muchut troop (LM) were selected for behavioural study. Troops were selected based on the land use and forest types of their habitat and each troop represents a habitat type.

Troop KZ was selected from Eastern Himalaya Broad Leaf Forest (EHBLF), KS was selected from degraded scrub forest (DSF) in Human Modified Landscape (HML), and LM troop was selected from Mixed Coniferous Forest (MCF). Troop size and age sex of study troops classified as per Sinha et al. (2005) is given in Table 6.1.1.

Table 6.1.1 Age sex classification of the study troops according to Sinha et al. [17]

Troop	TI	Adult			Sub Adult			Juvenile			Infant		Habitat type
		M	F	?	M	F	?	M	F	?	I	?	
KS	47	6	9	2	3	5	2	3	5	3	9	0	Human Modified Landscape (1600 m msl to 1800 m amsl)
KZ	35	4	7	0	3	3	2	2	3	3	8	0	Eastern Himalaya Broadleaf Forest (1600 m msl to 2000 m amsl)
LM	40	5	8	0	4	8	3	2	2	0	8	0	Mixed Coniferous Forest (2000 m msl to 3000 m amsl)

Note: Khelengteng-Zemithang troop (KZ); Khelengteng-Soctsen troop (KS), Lumpo-Muchut troop (LM), Total individual (TI), Unidentified sex (?), Male (M), Female (F) and Infant (I)

6.1.4 Time activity budget and feeding pattern:

The three selected study troops were habituated (6 months) prior to behavioural observation. During behavioural data collection, troops were followed from dawn (06:00 AM) to dusk (05:00 PM) and samples were collected using scan sampling method in 5 (five) minute interval [18]. The study was continued for 12 consecutive months in a year and minimum 3 full days were spent with each troop in every month. The behavioural activities of the study animal were noted and given into five categories namely: Feeding, moving, resting, grooming and others, following Mendaratta et al. [16] (Table 6.1.2). To study the feeding pattern and feeding items of the troops, the food plants were identified and parts eaten during the behavioural scan sampling were recorded. The percentage contributions of food plants were calculated from the monthly feeding records/bouts. The percentage time spent in different food items were recorded separately to know the diet composition of the species and the seasonal and annual variation in diet composition were also estimated averaging the monthly percentages [19].

Table 6.1.2. Behavioural activities of *M. munzala*

Feeding :	Manipulating food material, placing and chewing food and raiding (Fig. 6.1.1.A)
Moving:	Included all the locomotion (Fig. 6.1.1.B)
Resting :	Siting, lying and inactive body approach (Fig. 6.1.2.C)
Grooming :	Auto-grooming and allo-grooming (Fig. 6.1.2.D)
Others :	Aggression, copulation, non-copulatory mounting, playing etc. (Fig. 6.1.2.E)

Figure 6.1.1. Feeding (A), Moving behaviour (B) of *M. munzala*

Figure 6.1.2. Resting (C), Grooming (D) and Copulation, considered one of the sample for others (E) activities of *M. mumzala*

6.1.5 Habitat Characteristics and Food Availability Index (FAI):

Habitat characteristics for each of the three habitats were translated from the vegetation analysis carried out using quadrat sampling method. A total of 150 quadrats (50 quadrats in each habitat) of 10 m × 10 m were laid for trees and lianas, within that 5 m × 5 m quadrats were laid for herb and shrub species [20]. The community parameters such as frequency, density, dominance, and important value index (IVI) were determined following Cottam and Curtis [21].

Food availability index was calculated from a total of 17 major food plant species monitored during the study period. 10 individuals of each of the major food plant species were tagged, out of which 7 were tree species (GBH ≥30 cm), 4 were shrub (GBH ≥10 cm), 2 were lianas and 4 were herb species. The tagged food plant species were monitored twice in a month (15 days' interval) for availability of food items and scored 0 and 1, where 1 (one) is the presence of any of the food items and 0 (zero) signifies absence of food items. Food Availability Index (FAI) was calculated using the following formula [16,22,23]:

FAI= Average of annual score of the availability of food items× relative density food plant species in respective habitat (in ha)

6.1.6 Selection ratio and Dietary spectrum

Selection ratio can be explained, whether primate feed on a plant due to its dominance in the habitat or particularly chosen to feed on. On that basis, selection ratio has been studied on Eastern Hoolock Gibbon (*Hoolock leuconedys*) and Western Hoolock Gibbon (*Hoolock hoolock*) [24,25]. Selection ratio was calculated following the formula;

$$\text{Selection ratio} = \frac{\text{Percentage contribution of feeding species for each troop}}{\text{Relative dominance of species in each troop habitat}}$$

In the present study, higher the value of selection ratio is considered as a highly preferred food plant of studied troop of *M. munzala* among the food plants.

Dietary spectrum defines as a number of food plants species required to fulfil 80% of diet of primate species. Dietary spectrum was calculated from the cumulative feeding percentage of each food plants in descending order [25].

6.1.7 Data analysis

Data was entered in Microsoft Excel spreadsheet and basic statistics were calculated in the same. Statistical analyses were performed in SPSS 16.0 package. 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. As the data consisted of proportions, those were transformed to square roots prior to analyses. Significance was set at 95% confidence interval i.e. $p<0.05$ for all statistical tests. Variations were given around the mean for all results and standard error was presented with mean statistics i.e. mean ± S.E. The influence of food plant availability in percentage contribution of diet was estimated using Simple Linear regression model (Dependent Variable: Percentage contribution of major food plant; Predictor: Availability).

6.1.8 Result

6.1.9 Annual Activity Pattern

Annually, the three troops of *M. munzala* spent highest percentage time of its daily activity period on feeding (33.27 ±0.55) followed by resting (26.96 ±0.56), moving (23.30 ±0.64), grooming (10.12 ±0.20) and other activities (6.46 ±0.19) (Fig. 6.1.3).

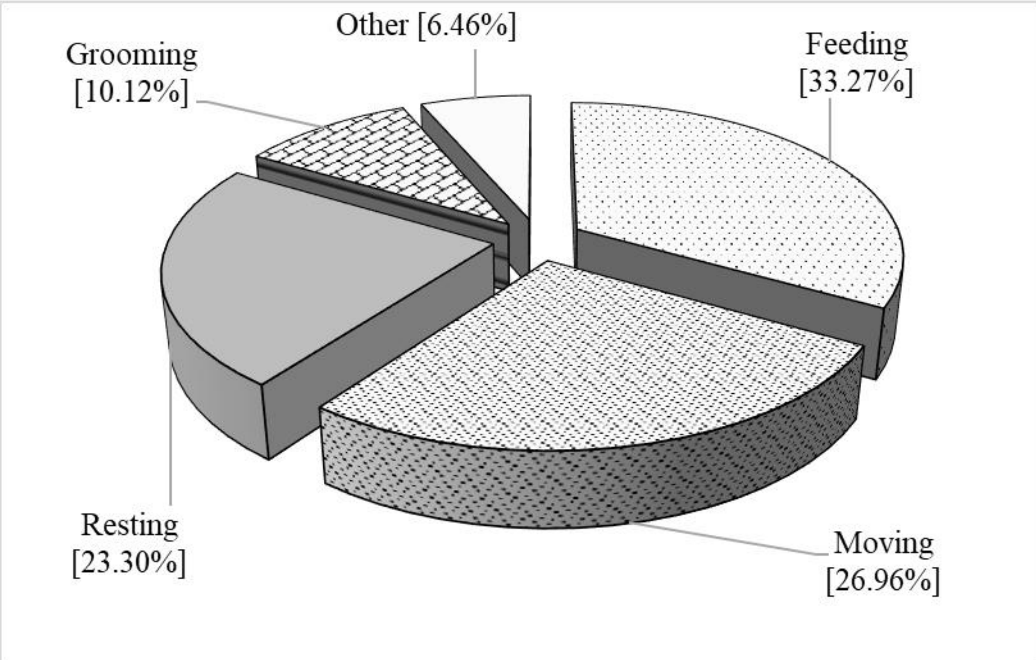

Figure 6.1.3. Mean percentage composition of annual activity pattern of 3 troops *Macaca munzala*

The three troops viz., KZ, KS and LM had marginal difference in annual pattern of activity budget. The troop KZ spent highest percentage time on feeding (34.25±0.83) followed by LM troop (33.61±0.92) and KS troop (31.96±1.06). Similarly, time spent on movement was found to be highest in KS troop (28.22± 1.05); time spent on resting was highest in KZ (24.12±1.12) and time spent on grooming was highest in LM (10.37±0.32) (Fig. 6.1.4).

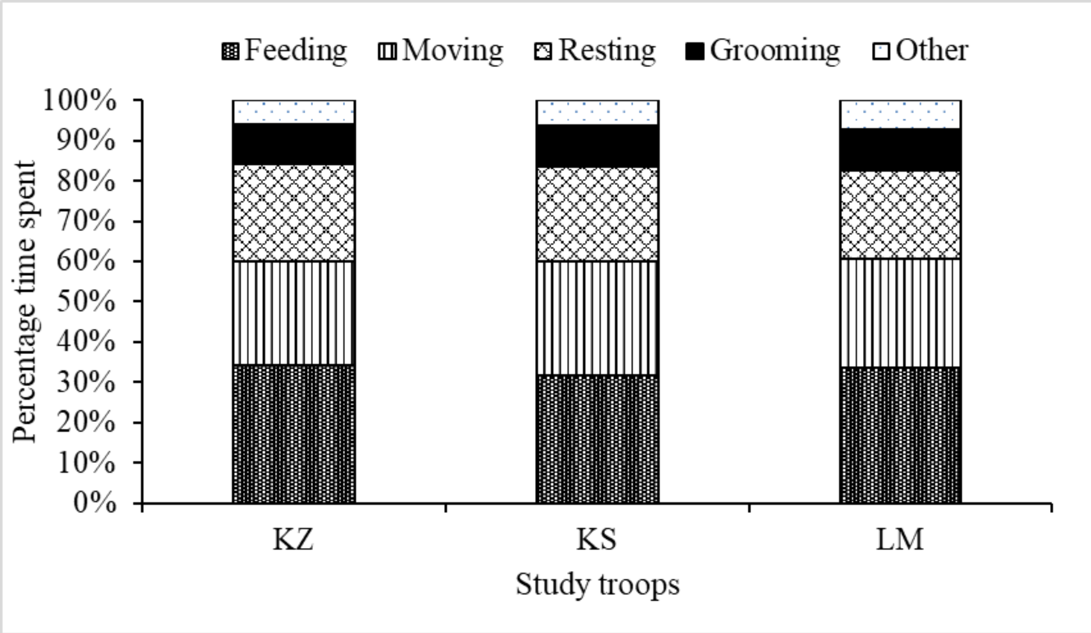

Figure 6.1.4. Annual activity pattern of **3 (**three) study troops of *Macaca munzala*

6.1.10 Monthly variation in activity pattern

The study troops spent maximum time (43.26±1.58%) on feeding in the month of November, while time spent on moving (37.49±0.97) was found highest for the month of June (Fig. 6.1.5). For resting, resting (36.31±0.96), grooming (11.58±0.66) and others (7.23±0.47), the troops spent highest time during December, February and August, respectively. Likewise, the lowest percentage time on feeding (25.08±1.21) and moving (18.25±0.63) was recorded in the month of December and January, respectively. In the month of November, troops spent lowest time in both resting (17.14±1.59) and grooming (8.02±0.62). The percentage time spent on feeding, moving, resting, grooming and others significantly differ among the months (Table 6.1.3).

Table 6.1.3. Percentage time spent in different activities of 3 (three) troops in different month of the year; statistics shows F value of ANOVA

Months	**% time spent (Mean±SE)**				
	Feeding	**Moving**	**Resting**	**Grooming**	**Other**
January	27.30±1.41	20.19±1.34	35.58±1.42	10.56±0.74	6.37±0.58
February	28.39±1.48	18.25±0.63	36.00±1.54	11.18±0.66	6.19±0.67
March	33.74±1.29	28.30±1.45	21.21±1.70	10.49±0.69	6.26±0.49
April	37.84±0.97	29.44±1.00	17.94±0.62	8.58±0.76	6.22±0.60
May	35.99±0.87	27.71±0.88	19.90±0.86	10.29±0.69	6.76±0.56
June	29.57±0.59	37.49±0.97	17.58±0.85	10.15±0.58	5.36±0.40
July	29.80±1.53	33.43±1.46	19.52±0.54	10.24±0.78	6.20±0.66
August	30.27±1.36	31.97±1.35	18.72±0.87	12.19±0.62	7.23±0.47
September	35.28±1.14	30.98±1.88	18.65±0.67	10.09±0.62	7.11±0.55
October	42.78±1.17	21.02±1.21	21.02±1.55	9.12±0.50	6.24±1.00
November	43.26±1.58	24.06±1.21	17.14±1.59	8.02±0.62	6.21±0.99
December	25.08±1.21	20.71±1.39	36.31±0.96	10.52±0.48	7.39±0.73
Total	33.27±0.55	26.96±0.56	23.30±0.64	10.12±0.20	6.46±0.19
F (ANOVA)	22.45**	22.95**	43.56**	2.89**	0.72^{ns}

**Significant at p<0.01; ns=Non significant

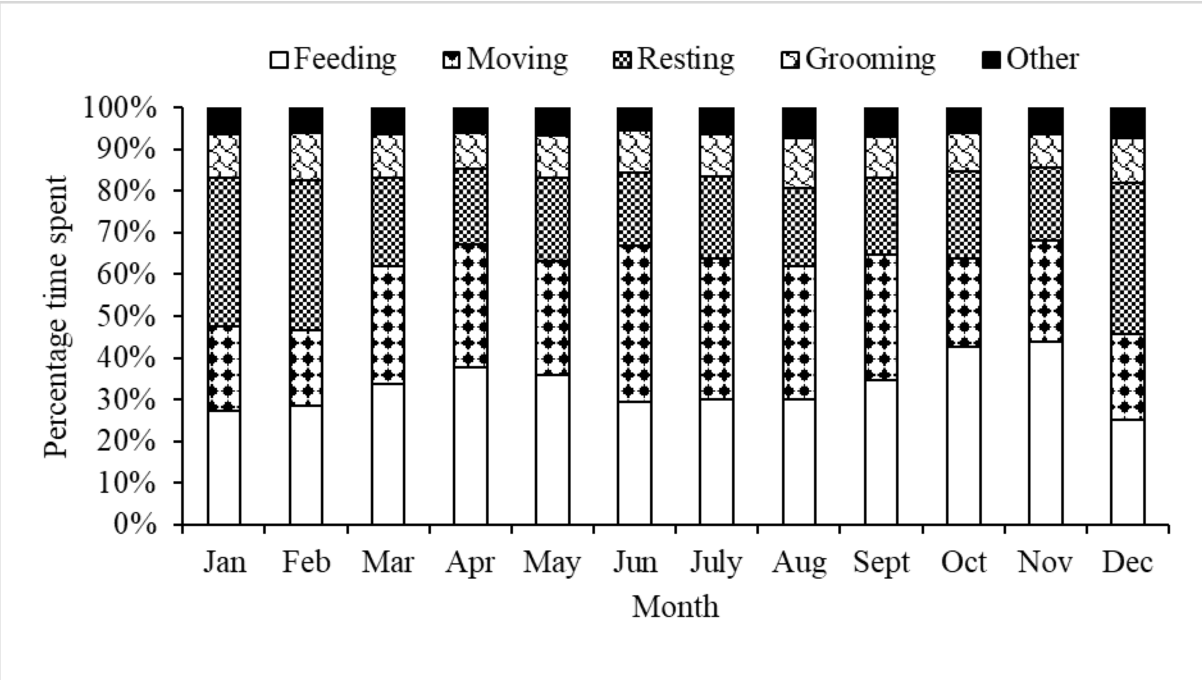

Figure 6.1.5. Monthly variation in percentage time spent on different activities shown by 3 (three) troops of *Macaca munzala*

The time spent on feeding (43.33±2.62) of KZ troop was found highest in the month of October and lowest (27.08±2.31) in December. The time spent on moving was highest (37.45±1.42) in July and lowest (15.76±1.21) in January, time spent on resting was highest (38.44±2.07) in the month of February and lowest (17.29 ±1.46) in March. The highest time spent on grooming (11.38±0.49) and other activities (8.51±1.41) was recorded in the month of December. The time spent on feeding, moving, resting and others were found to be significantly different among the months (Table 6.1.4).

Table 6.1.4. Percentage time spent in different activity categories of KZ troop in different month of the year; statistics shows F value of ANOVA

Month	% time spent (Mean±SE)				
	Feeding	**Moving**	**Resting**	**Grooming**	**Other**
January	27.67±1.38	15.76±1.21	38.07±1.98	10.52±1.61	7.99±1.41
February	28.94±1.13	16.56±1.23	38.44±2.08	9.97±1.38	6.10±1.91
March	36.93±2.19	30.47±2.26	17.30±1.46	9.20±1.14	6.10±0.83
April	40.56±1.00	25.36±1.39	16.76±1.47	9.81±1.17	7.52±1.09
May	34.44±1.55	29.27±1.24	19.95±1.03	8.77±0.91	7.57±1.12
June	31.22±0.64	34.52±0.78	18.66±0.77	10.34±0.62	5.71±0.49
July	31.53±1.10	37.45±1.43	19.52±0.74	7.60±0.75	3.90±0.96
August	32.85±2.82	30.06±2.29	21.38±1.53	11.15±1.65	5.70±0.72
September	36.61±1.37	28.30±1.56	20.54±1.45	9.20±0.79	5.34±0.44
October	43.33±2.62	19.24±1.79	25.60±1.98	8.94±0.64	2.90±0.50
November	39.85±3.41	25.00±2.10	17.47±2.06	8.95±1.30	4.79±1.22
December	27.08±2.31	17.32±2.08	35.71±1.40	11.38±0.49	8.51±1.41
Total	34.25±0.84	25.78±1.00	24.12±1.12	9.65±0.32	6.01±0.35
F (ANOVA)	7.18**	18.43**	28.68**	0.96^{ns}	2.35**

**Significant at p<0.01; ns=Non significant

KS troop spent highest percentage of time on feeding (45.41±1.84) in the month of November and lowest in February (22.52±2.11), but highest time spent on resting activity (39.99±0.84) was recorded in February. The percentage time spent on moving was recorded highest in June (39.90±2.21) and lowest in October (18.74±2.21) while percentage time spent on grooming was found highest in August (13.49±1.04) and lowest in November (6.25±0.69). The percentage time spent by KS on feeding, moving, resting and grooming were found to be significantly different across months (Table 6.1.5).

Table 6.1.5. Percentage time spent in different activity categories of KS troop in different month of the year; statistics shows F value of ANOVA

Month	**% time spent (Mean±SE)**				
	Feeding	**Moving**	**Resting**	**Grooming**	**Other**
January	26.70±2.96	23.38±1.38	33.46±3.16	10.88±1.50	5.58±0.62
February	22.52±2.11	19.03±0.88	39.99±0.84	11.90±0.96	6.56±0.77
March	31.28±2.51	28.88±3.28	24.73±4.58	9.12±0.50	5.99±0.56
April	35.35±2.17	32.38±0.81	18.50±0.95	7.66±1.50	6.19±1.10
May	36.75±1.33	29.77±0.87	19.21±1.43	10.05±1.51	6.18±0.89
June	29.85±0.29	39.90±2.21	14.98±1.30	11.10±1.34	4.16±0.51
July	23.68±1.56	34.93±1.81	19.57±1.07	13.21±0.82	7.89±1.09
August	30.46±2.58	33.53±3.43	15.18±0.70	13.49±1.04	7.33±0.51
September	37.49±1.93	32.10±5.00	16.87±0.49	10.74±1.50	8.35±1.17
October	41.17±1.29	18.74±2.21	22.43±2.30	10.70±0.80	6.96±0.87
November	45.41±1.84	21.16±1.82	22.31±2.45	6.25±0.69	4.88±0.87
December	22.89±2.10	24.82±0.92	38.04±2.45	8.89±0.81	5.37±0.74
Total	31.96±1.06	28.22±1.05	23.77±1.22	10.33±0.40	6.29±0.28
F (ANOVA)	13.66**	7.99**	16.02**	3.46**	1.85^{ns}

**Significant at p<0.01; ns=Non significant

LM troop spent highest time on feeding (44.50±2.61) and moving (38.04±0.84) in the month of November and June, respectively. Time spent on feeding activity was lowest in December (25.27±1.85), while for moving it was lowest in in February (19.17±0.87). The percentage time spent on resting was highest in the month of January (35.21±2.14) and lowest in November (11.64±1.07). Grooming activity was maximum in March (13.14±0.87) and minimum in April (8.28±1.34). The percentage time spent on feeding, moving, resting and grooming were found to be significantly different among the months (Table 6.1.6).

Table 6.1.6. Percentage time spent in different activity categories of LM troop in different month of the year; statistics shows F value of ANOVA

Month	% time spent (Mean±SE)				
	Feeding	**Moving**	**Resting**	**Grooming**	**Other**
January	27.54±3.16	21.44±2.77	35.21±2.14	10.27±0.95	5.55±0.39
February	33.71±1.23	19.17±0.87	29.55±2.01	11.67±1.10	5.90±0.59
March	33.03±1.48	25.54±1.75	21.61±0.57	13.14±0.87	6.69±1.20
April	37.62±0.84	30.58±1.12	18.57±0.65	8.28±1.34	4.95±0.75
May	36.78±1.69	24.08±0.98	20.55±2.10	12.04±0.70	6.54±0.96
June	27.63±1.25	38.04±0.84	19.10±1.68	9.02±0.87	6.21±0.79
July	34.19±2.43	27.91±2.22	19.48±1.18	9.92±1.07	6.81±0.59
August	27.48±1.03	32.32±0.76	19.60±0.32	11.94±0.72	8.66±0.70
September	31.75±1.79	32.55±2.62	18.54±0.80	10.34±0.93	7.63±0.65
October	43.85±2.17	25.09±0.99	15.03±1.08	7.72±0.71	8.85±1.89
November	44.50±2.61	26.04±2.06	11.64±1.07	8.85±0.86	8.97±2.29
December	25.27±1.85	19.97±2.78	35.18±0.72	11.29±0.75	8.28±1.26
Total	33.61±0.93	26.89±0.85	22.01±0.99	10.37±0.32	7.09±0.34
F (ANOVA)	10.77**	9.64**	30.72**	3.33**	1.42^{ns}

**Significant at p<0.01; ns=Non significant

6.1.11 Seasonal variation in activity pattern

During post-monsoon season, feeding was found highest (43.02±0.97) for the study troops and lowest in winter (26.92±0.80); moving was highest in monsoon season (33.47±0.78) and lowest in winter season (19.72±0.68) (Table. 6.1.7). Percentage time spent on resting was highest in the winter season (35.96±0.75) and lowest in the post-monsoon season (19.08±1.15). Likewise, percentage time spent on grooming was found highest in the winter season (10.75±0.36) and lowest in monsoon (10.67±0.35). The statistical analysis reveals a significant difference in percentage time spent among all activities (Table 6.1.7 and Fig. 6.1.6).

Table 6.1.7. Percentage time spent in different activities recorded in studied 3 (three) troops in different season of the year; statistics shows F value of ANOVA

Season	% time spent (Mean ±SE)				
	Feeding	**Moving**	**Resting**	**Grooming**	**Other**
Pre-monsoon	35.86±0.65	28.48±0.65	19.69±0.68	9.79±0.42	6.41±0.31
Monsoon	31.23±0.66	33.47±0.78	18.62±0.37	10.67±0.35	6.48±0.28
Post-monsoon	43.02±0.97	22.54±0.88	19.08±1.15	8.57±0.41	6.22±0.69
winter	26.92±0.80	19.72±0.68	35.96±0.75	10.75±0.36	6.65±0.38
F (ANOVA)	68.50**	71.71**	153.45**	5.64**	0.16^{ns}

**Significant at p<0.01; ns=Non significant

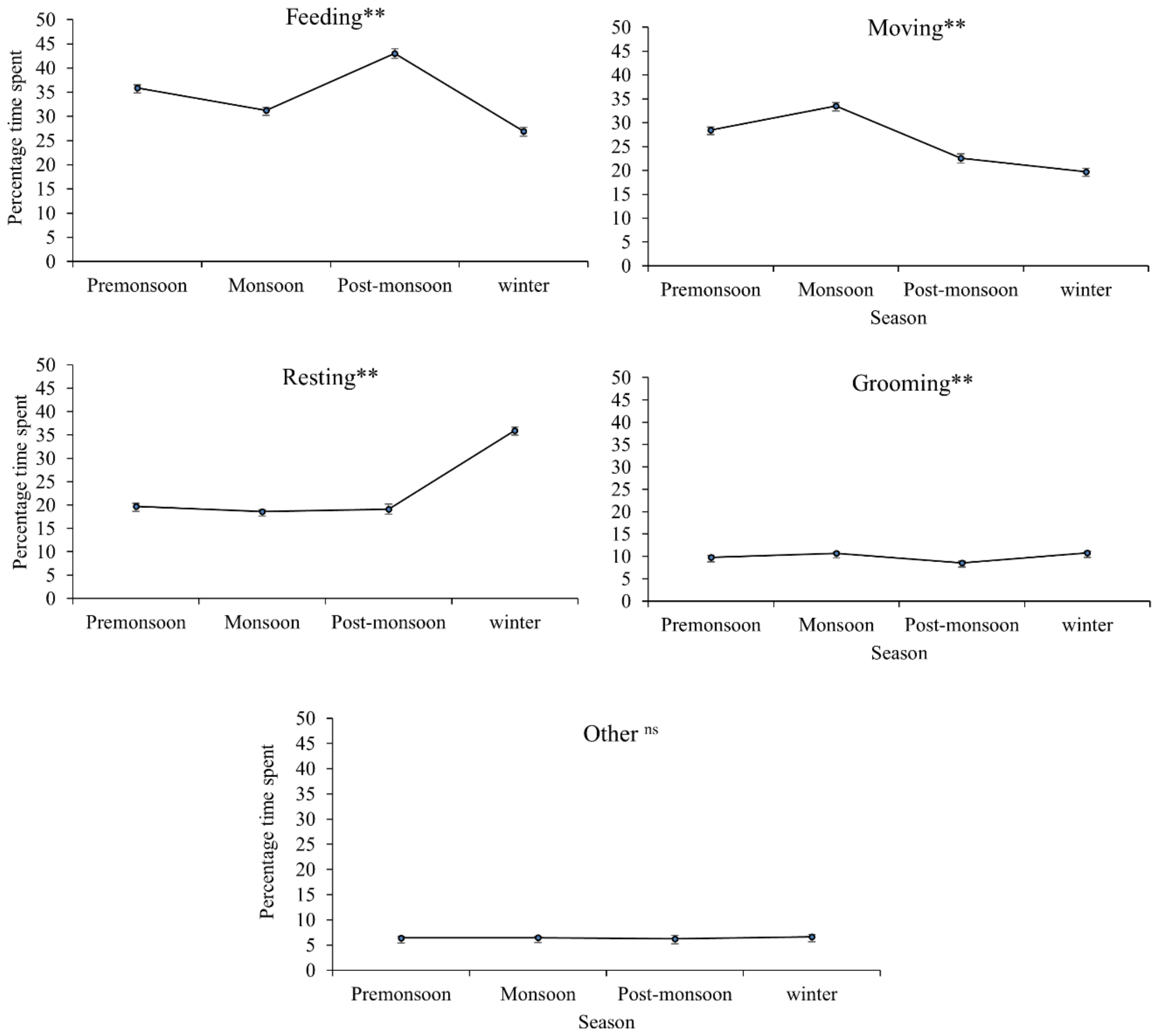

Figure 6.1.6. Seasonal variation in percentage time activity pattern of study troops of *M. munzala*

The seasonal variation on time spent by different troops was not very prominent in the study. For example, KZ troop spent highest time on feeding (41.59±2.11), moving (32.58±1.10) and resting (37.40 ±1.03) in post-monsoon, monsoon and winter season, respectively (Fig. 6.1.7). The same pattern of percentage time spent was evident in KS and LM troops as well (Fig. 6.1.8 and Fig. 6.1.9)

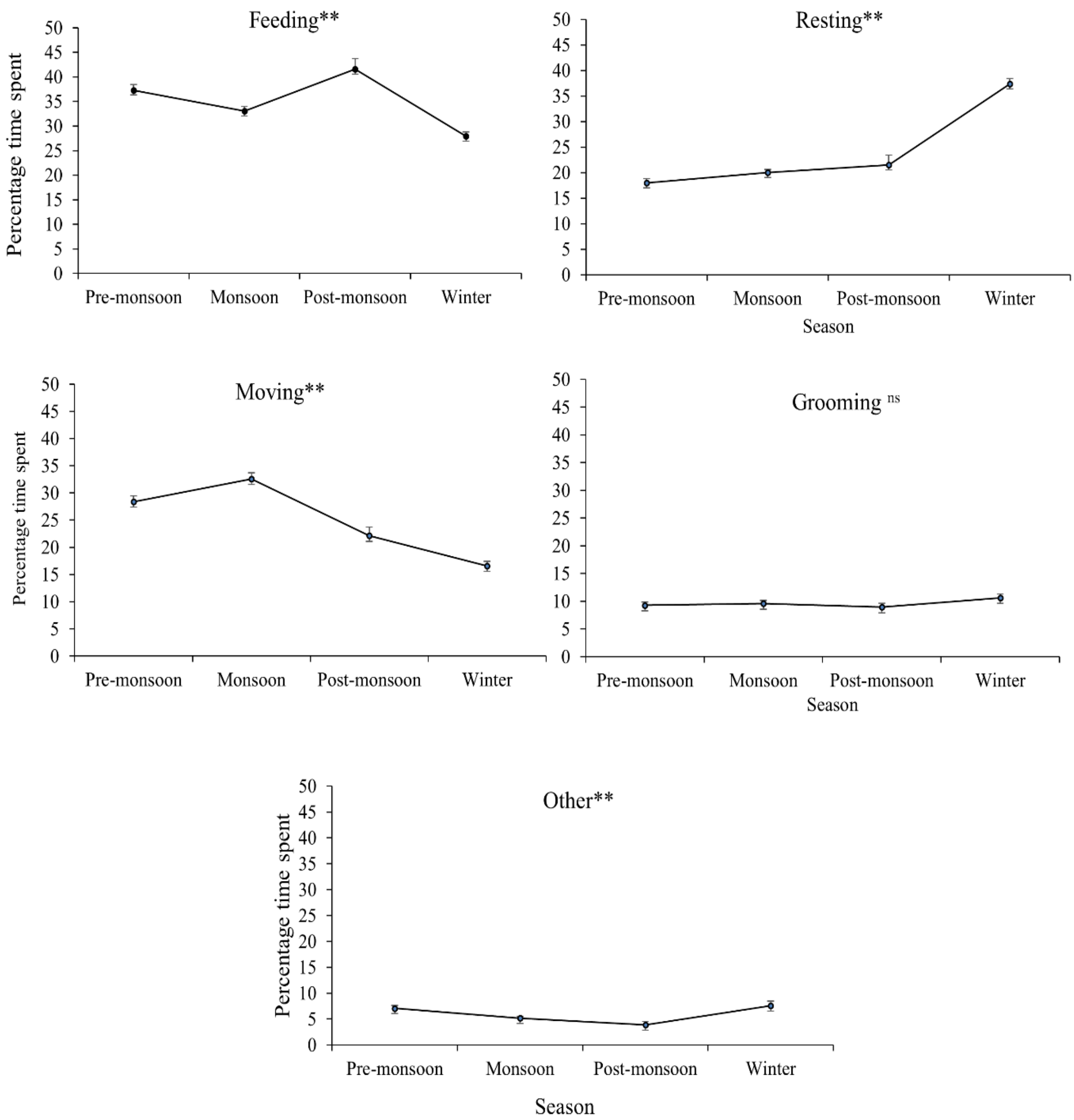

Figure 6.1.7. Seasonal variation in activity pattern of KZ troop (**Significant at $p<0.01$; ^{ns}=Non significant)

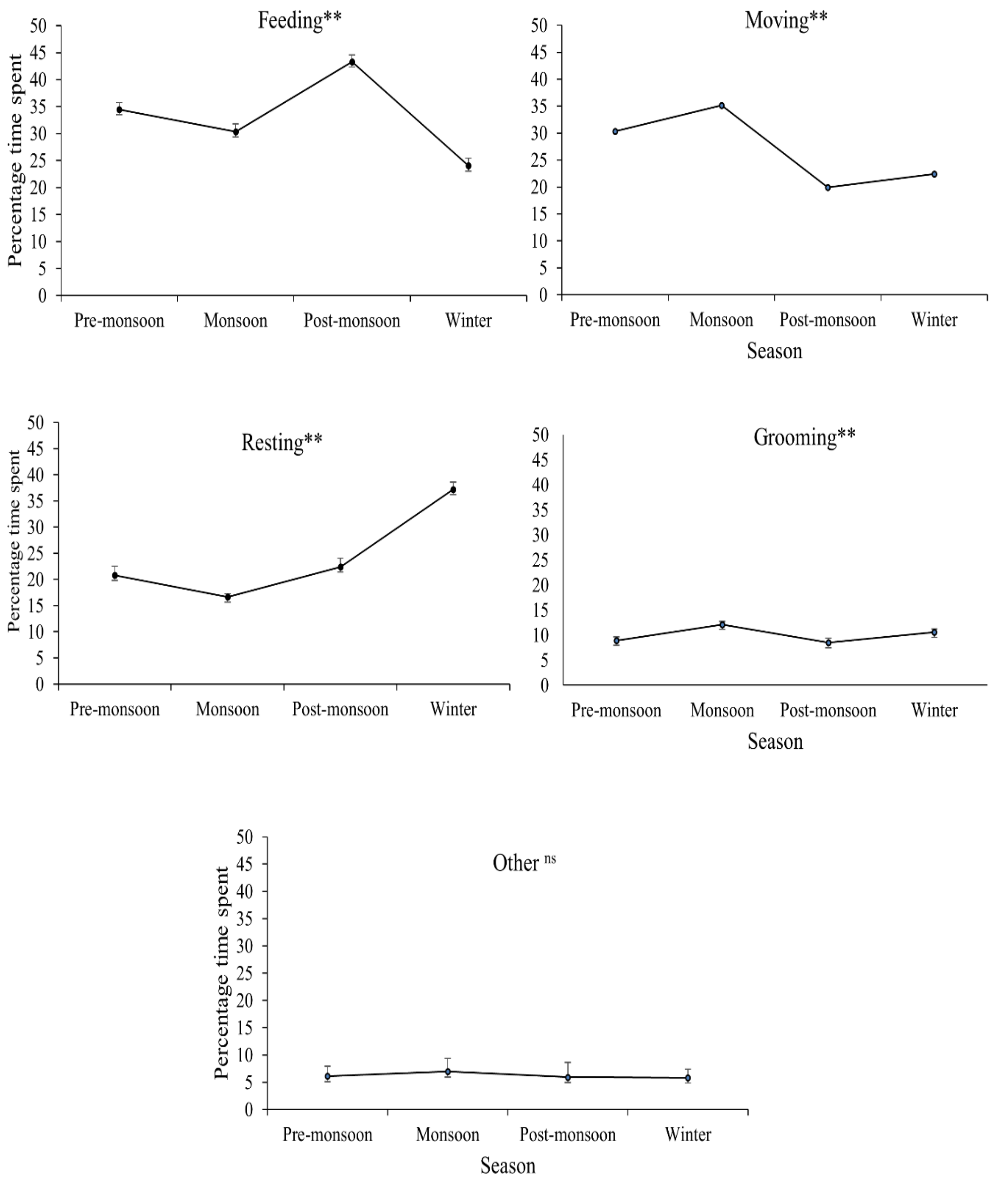

Figure 6.1.8. Seasonal variation time activity pattern of LM troop (**Significant at p<0.01; [ns]=Non significant)

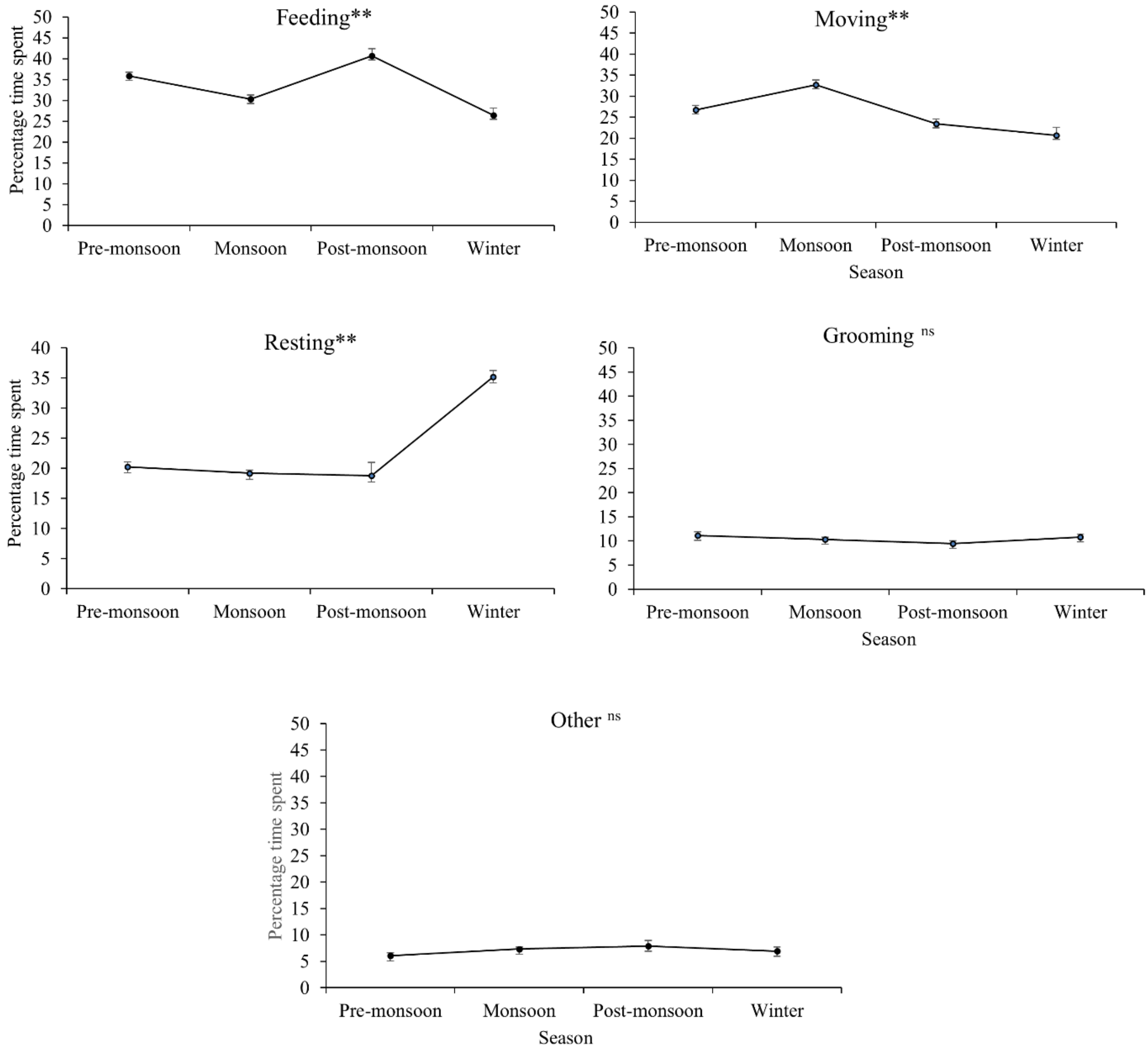

Figure 6.1.9. Seasonal variation in time activity pattern of KS troop (**Significant at $p<0.01$; ^{ns}=Non significant)

6.1.17 Food materials and feeding plants

The diet of study troops comprised mostly of plant material having 97.83% and 2.17% by animal matter. Out of the total recorded time spent on feeding, *M. munzala* devoted 35.12%±3.48 time on young leaf, 19.10% ± 2.93 on fruits and 17.64%± 2.22 on stem and these three food items constituted a major portion of their diet (Fig. 6.1.10).

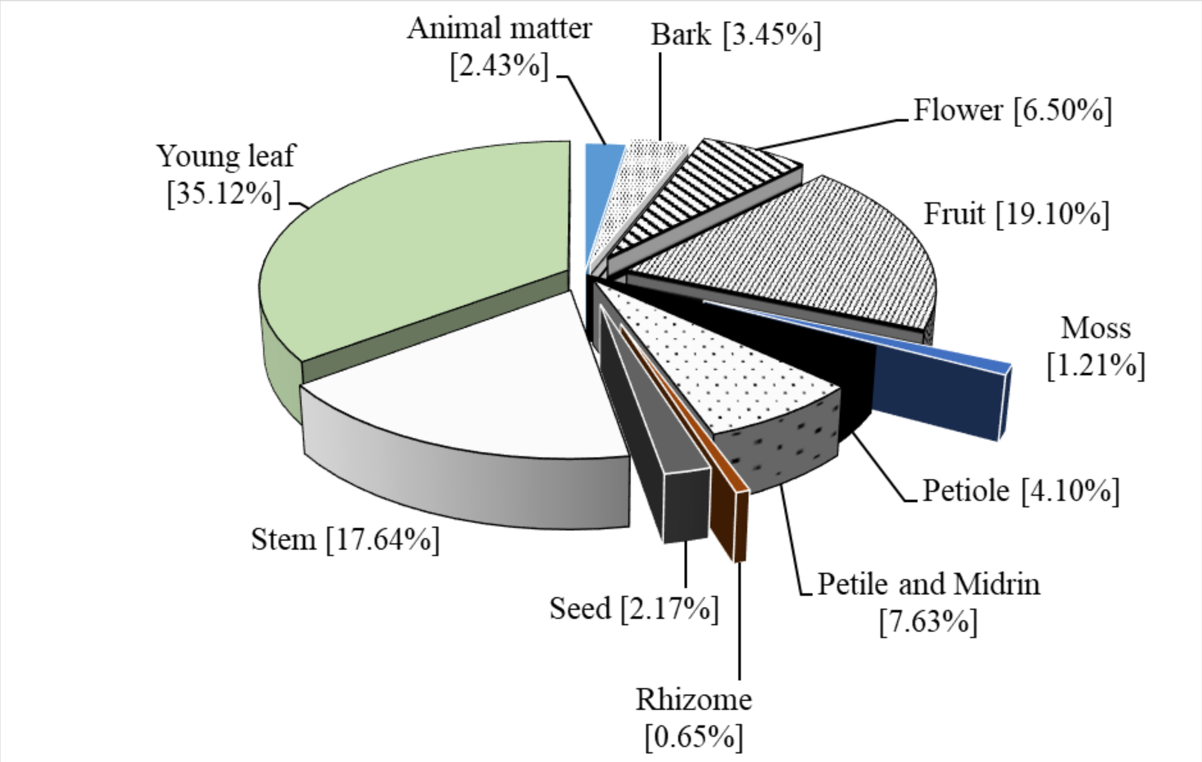

Figure 6.1.10. Overall diet composition of 3 (three) troops of *M. munzala*

The highest percentage feeding on young leaf was recorded in the month of May (66.15±3.59) and lowest in August (4.55±4.55) whereas, the time spent on fruit was found highest in November (44.58±5.89) (Fig. 6.1.11). There was no record of feeding on fruits in the month of January and February. Flower was highly consumed in the month of October (11.9±2.64) and lowest in May (3.43±3.13) without any record of feeding in the month of February and March. The percentage feeding on stem was highest in the month of September (37.49±7.74) and lowest in the month of December (5.47±2.04). The time spent on different food items such as petiole and midrib, fruit, bark, rhizome and animal matter were found to be significantly different among the months (Table 6.1.8 and Fig. 6.1.11).

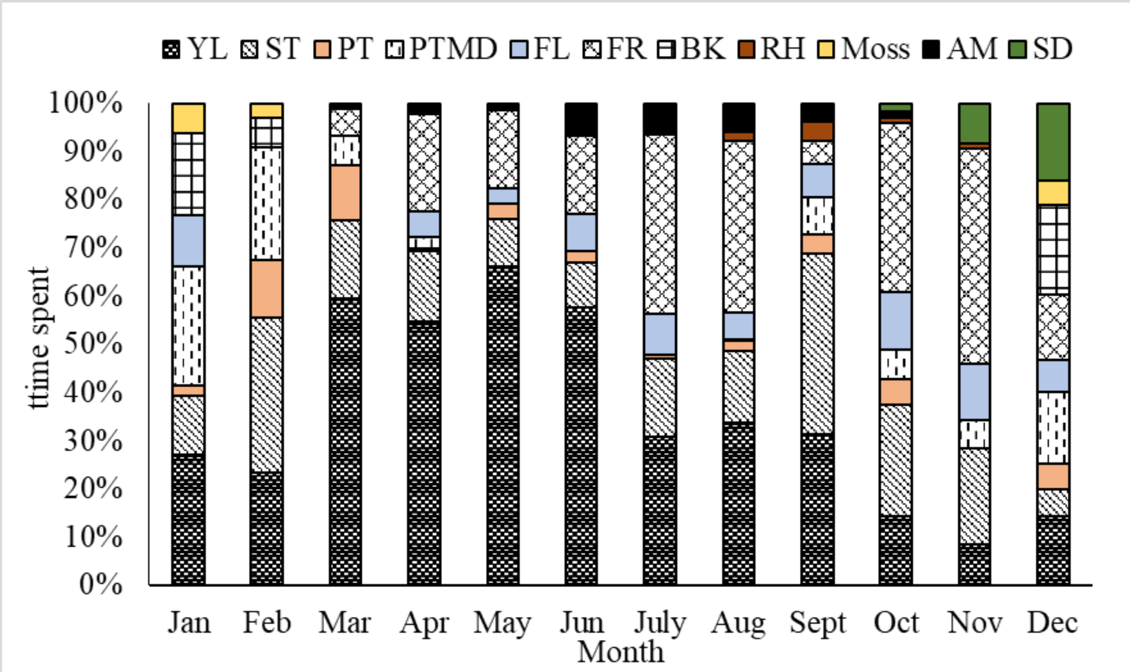

Figure 6.1.11. Monthly variation in percentage contribution of food plant material in diet of three troops of *M. munzala;* (YL-Young leaf; ST-Stem, PT-Petiole, PTMD- Petiole and midrib, FR- Fruit, BK- Bark, RH- Rhizome, AM-Animal matter and SD-Seed)

The young leaf was found to be contributed highest in pre-monsoon season (60.12±2.91), whereas, in post-monsoon season, stem (21.59±5.57), flower (11.78±2.17) and fruit (39.94±7.74) contributed highest in the diet of the studied troops. *M. munzala* feeding on tree bark (13.79±4.75) and moss (4.85±1.75) were recorded only in the winter season (Fig. 6.1.12). The percentage feeding on young leaf, petiole and midrib, flower, fruit, bark, moss and animal matter were found to be significantly different among the seasons (Table 6.1.9 and Fig. 6.1.12).

Table 6.1.8. Percentage contribution of different food material of 3 troops of *M. munzala* in different month of the year; statistics shows F value of ANOVA

Month	YL	ST	PT	PT MD	FL	FR	BK	RH	Moss	AM	SD
Jan	27.07±11.64	12.13±8.62	2.24±1.15	24.73±11.63	10.61±3.44	-	16.93±8.54	-	6.27±4.26	-	-
Feb	23.35±7.13	32.15±7.15	11.96±6.86	23.48±9.27	-	-	5.95±5.95	-	3.10±3.10	0.00	-
Mar	59.45±3.63	16.33±5.17	11.49±5.04	6.00±3.32	-	5.72±3.67	-	-	-	1.02±1.02	-
Apr	54.77±6.56	14.53±5.73	0.60±0.60	2.38±2.38	5.42±2.73	20.21±6.53	-	-	-	2.10±2.10	-
May	66.15±3.59	9.89±5.06	3.25±3.25	-	3.13±3.13	16.05±5.37	-	-	-	1.53±0.94	-
Jun	57.73±6.90	9.14±8.42	2.60±1.41	-	7.69±1.35	16.00±	-	-	-	6.85±1.78	-
July	30.76±4.25	16.38±2.83	0.64±0.33	-	8.57±0.60	37.20±0.59	-	-	-	6.45±0.72	-
Aug	4.55±4.55	14.99±6.56	1.92±1.11	0.42±0.42	5.46±1.64	35.72±0.40	-	1.75±	-	6.00±1.43	-
Sept	31.44±4.44	37.49±7.74	3.75±2.03	7.86±4.04	6.82±5.93	4.80±3.15	-	3.92±1.96	-	3.92±2.56	-
Oct	14.28±3.09	23.16±8.61	5.44±4.22	5.94±3.07	11.90±2.64	35.31±15.62	-	1.07±1.07	-	1.28±1.28	1.62±1.62
Nov	8.41±2.04	20.02±8.88	0.00	5.86±1.53	11.68±4.07	44.58±5.89	-	1.05±1.05	-	0.00	8.41±8.41
Dec	14.34±6.12	5.47±2.04	5.31±2.83	14.87±8.34	6.73±4.11	13.62±7.73	18.49±10.78	-	5.19±2.59	0.00	15.98±10.55
Total	35.12±3.48	17.64±2.22	4.10±0.99	7.63±1.91	6.50±0.97	19.10±2.93	3.45±1.52	0.65±0.27	1.21±0.55	2.43±0.53	2.17±1.24
F (ANOVA)	11.28**	1.92^{ns}	1.59^{ns}	2.79*	1.76^{ns}	6.33^{**}	2.53*	2.27*	1.84^{ns}	4.23**	1.61^{ns}

Note: YL (Young leaf); ST (Stem), PT (Petiole), PTMD (Petiole and midrib), FR (Fruit), BK (Bark), RH (Rhizome), AM (Animal matter), SD (Seed)
**Significant at p<0.01; ns=Non significant

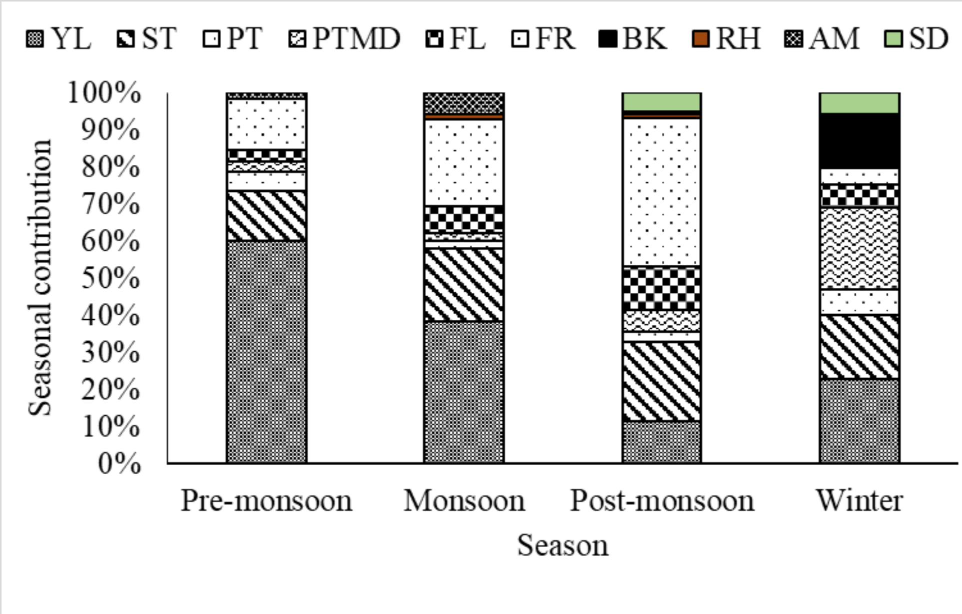

Figure 6.1.12. Seasonal variation in percentage time spent on major food plant part of *M. munzala* exhibited by 3 troops; (YL-Young leaf; ST-Stem, PT-Petiole, PTMD- Petiole and midrib, FR- Fruit, BK- Bark, RH- Rhizome, AM-Animal matter and SD-Seed)

Table 6.1.9. Seasonal contribution of different food materials in diet of *M. munzala*; statistics shows F value of ANOVA

Food Items	% time spent (Mean ±SE)				
	Pre-monsoon	**Monsoon**	**Post-monsoon**	**Winter**	**F (ANOVA)**
YL	60.12±2.91	38.42±4.03	11.34±2.11	21.59±4.71	25.66**
ST	13.58±2.83	19.50±4.33	21.59±5.58	16.59±5.18	0.52^{ns}
PT	5.11±2.39	2.23±0.67	2.72±2.25	6.51±2.60	1.1^{ns}
PTMD	2.79±1.47	2.07±1.33	5.90±1.53	21.03±5.16	9.94**
FL	2.85±1.43	7.14±1.39	11.79±2.17	5.78±2.19	3.56**
FR	13.99±3.42	23.43±4.31	39.94±7.75	4.54±3.18	9.09**
BK	-	-	-	13.79±4.75	8.41**
Rh	-	1.42±0.69	1.06±0.67	-	2.19^{ns}
Moss	-	-	-	4.85±1.76	7.62**
AM	1.55±0.74	5.80±4.03	0.64±0.64	-	16.35^{ns}
SD	-	-	5.02±4.12	5.33±4.05	1.49**

Note: YL (Young leaf); ST (Stem), PT (Petiole), PT MD (Petiole and midrib), FL (Flower), FR (Fruit), BK (bark), RH (Rhizome), AM (Animal matter, SD (Seed)
**Significant at $p<0.01$; ^{ns}=Non significant

Young leaf was highest (55.19%) in the diet of KZ troop in the month of May; stem in September (44.51%), fruit in July (38.17%) and bark in the month of January (23.53%) (Fig. 6.1.13). For KS troop also, the young leaf consumption was highest in the month of May (70%). The consumption of stem (46.46%) and fruit (37.29%) were highest in the month of November (Fig. 6.1.14). LM troop was found to spent maximum percentage of time on young leaf in the month of March (66.67%). The consumption of stem (28.81%) and petiole and midrib (47.46%) were highest in January, whereas, the consumption of fruit (65.95%) and seeds (35.90%) were highest in October and December, respectively. The LM was found to spent highest time on feeding moss (14.41%) in January and animal matter (9.84%) in the month of June (Fig. 6.1.15). Seasonal contribution of young leaf in diet was found significantly different in all the studied troops (Table 6.1.10; Table 6.1.11 and 6.1.12).

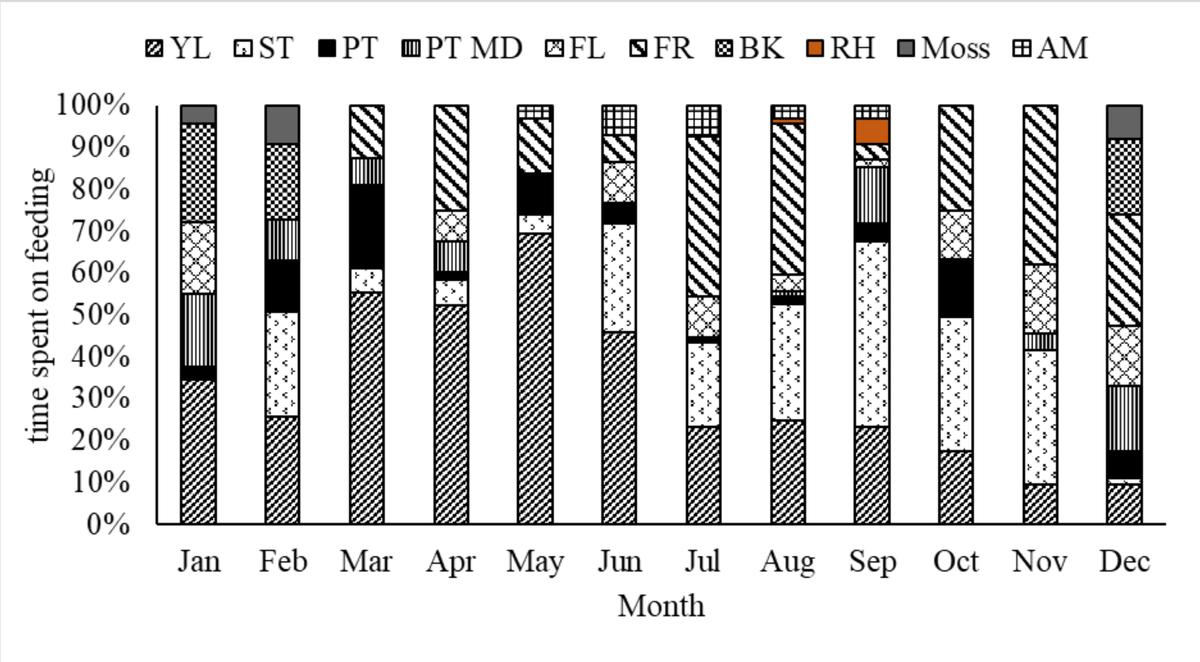

Figure 6.1.13. Monthly variation in percentage time spent of KZ troop on different feeding material

Table 6.1.10. Percentage contribution of different food materials in diet of KZ troop in different season; statistics shows F value of ANOVA

Feeding materials ±SE	Season				F (ANOVA)
	Pre-monsoon	Monsoon	Post-monsoon	Winter	
YL	58.97±5.33	29.23±5.59	13.38±4.05	23.24±7.35	9.26**
ST	5.60±0.53	29.69±5.18	32.12±0.05	8.86±8.08	6.13*
PT MD	10.40±2.29	3.03±3.26	6.88±2.08	7.13±2.30	0.82^{ns}
FL	2.53±2.53	6.26±2.03	14.03±2.56	10.36±5.24	3.64^{ns}

FR	16.85±4.07	21.10±9.27	31.53±6.29	8.92±8.92	1.90^{ns}
BK	-	0.00	-	19.83±1.85	114.96**
RH	-	1.84±1.45	-	0.00	0.95^{ns}
Moss	-	0.00	-	7.19±1.45	24.62**
AM	1.0833±1.08	5.19±1.21	-	-	8.68*

Note: YL (Young leaf); ST (Stem), PT (Petiole), PT MD (Petiole and midrib), FL (Flower), FR (Fruit), BK (Bark), RH (Rhizome), AM (Animal matter, SD (Seed)
**Significant at p<0.01; ns=Non significant

Seasonal variation in the consumption of different food items has shown that, feeding on young leaf recorded highest during the pre-monsoon season for all the three troops (KZ=58.97±5.33%; KS=64.56±4.12% and LM=56.84±6.38) (Table 6.1.10; Table 6.1.11 and Table 6.1.13). A significant difference was observed for KZ troop's time spent on feeding on young leaf, stem, bark, moss and animal matter (Table 6.1.10). Further, the percentage time spent on young leaf, flower, and animal matter was significantly different across the seasons for KS troop (Table 6.1.11). On the other hand, for LM troop, the percentage time spent on young leaf, petiole and midrib and fruit was found significantly different among the seasons (Table 6.1.12).

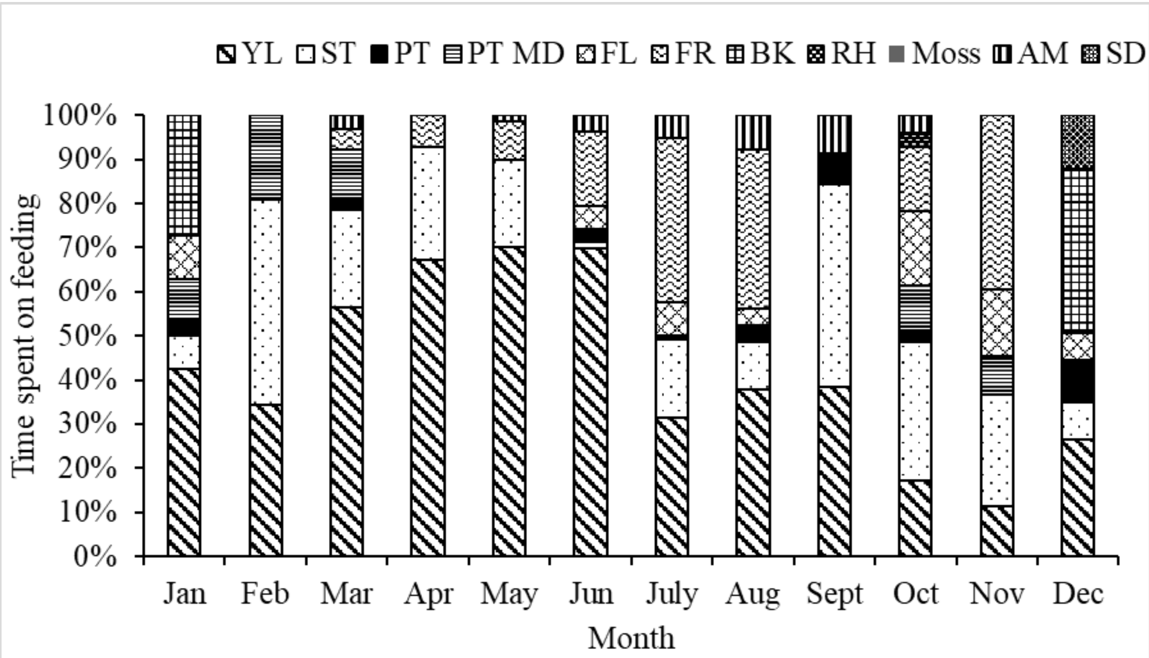

Figure 6.1.14. Monthly variation in percentage time spent of KS troop on different feeding material

Table 6.1.11. Percentage contribution of different food items in diet of KS troop in season; statistics shows F value of ANOVA

Name of Food Items	% contribution in different seasons (±SE)				F (ANOVA)
	Pre-Monsoon	Monsoon	Post-Monsoon	Winter	
YL	64.56±4.12	44.32±8.66	14.35±2.96	34.42±4.59	7.57*
ST	22.55±1.61	18.99±9.58	28.33±3.08	20.82±12.82	0.15^{ns}
PT	0.76±0.76	3.66±1.27	1.28±1.28	4.48±2.80	1.03^{ns}
PT MD	3.82±3.82	-	9.59±0.68	9.43±5.54	2.00^{ns}
FL	-	4.16±1.59	15.76±0.91	5.29±2.87	10.10**
FR	6.85±1.20	22.59±8.86	27.17±12.43	-	2.93^{ns}
BK	-	-	-	21.54±11.16	3.73^{ns}
RH	-	-	1.61±1.61	-	2.22^{ns}
AM	1.46±0.88	6.29±1.16	1.93±1.93	-	7.48*
SD	-	-	-	4.02±4.02	1.00^{ns}

Note: Feeding materials (FM);YL (Young leaf); ST (Stem), PT (Petiole), PT MD (Petiole and midrib), FL (Flower), FR (Fruit), BK (bark), RH (Rhizome), AM (Animal matter, SD (Seed)

*Significant at p<0.05; **Significant at p<0.01; ns=Non significant

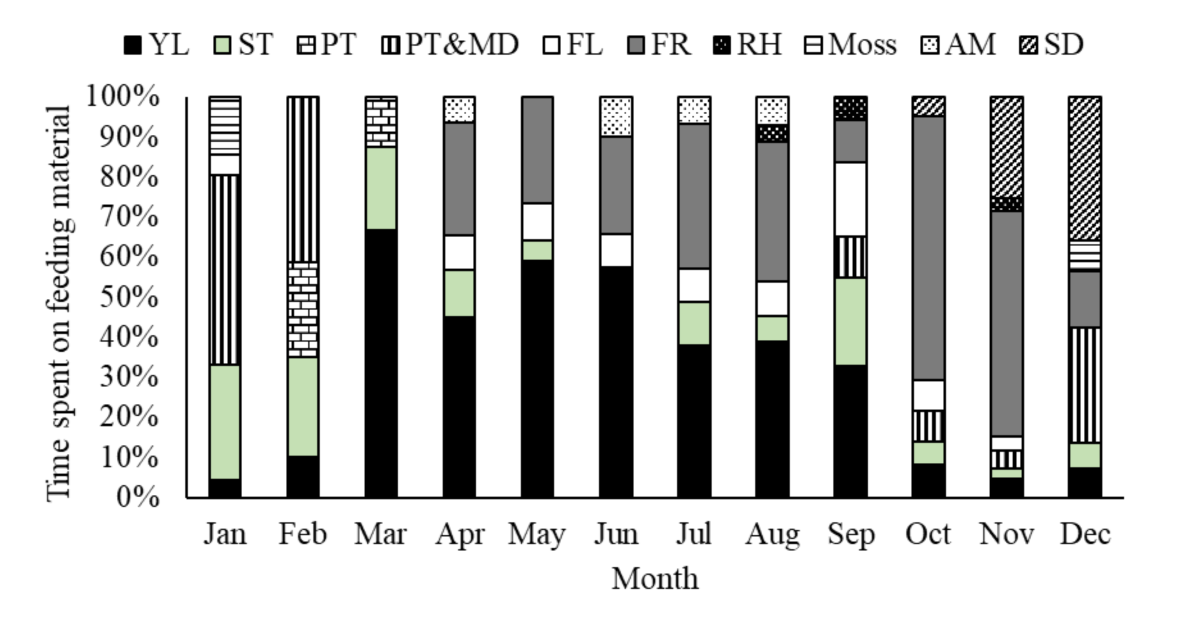

Figure 6.1.15. Monthly variation in percentage time spent of LM troop on different feeding material

Table 6.1.12. Percentage contribution of different food material in diet of LM troop in season; statistics shows F value of ANOVA

FM±SE	Season				F (ANOVA)
	Pre-monsoon	Monsoon	Post-monsoon	Winter	
YL	56.84±6.38	41.71±5.39	6.31±1.80	7.10±1.66	23.36**
ST	12.59±4.55	9.83±4.64	4.32±1.62	20.07±6.92	1.3^{ns}
PT	4.17±4.17	-	-	7.92±7.92	0.72^{ns}
PTMD	-	2.54±2.54	6.04±1.53	39.18±5.47	31.33**
FL	6.02±3.02	10.99±2.55	5.59±1.98	1.69±1.69	2.57^{ns}
FR	18.28±9.16	26.59±5.89	61.13±4.82	4.70±4.70	9.695*
RH	-	2.40±1.43	1.58±1.58	-	1.31^{ns}
Moss	-	-	-	7.37±4.16	3.13^{ns}
AM	2.10±2.10	5.93±2.09	-	-	2.656^{ns}
SD	-	-	15.05±10.18	11.97±11.97	1.29^{ns}

**Significant at p<0.01; ns=Non significant

Feeding materials (FM);YL (Young leaf); ST (Stem), PT (Petiole), PT MD (Petiole and midrib), FL (Flower), FR (Fruit), BK (bark), RH (Rhizome), AM (Animal matter, SD (Seed)

6.1.18 Food plant diversity

M. munzala feed on 74 food plant species from 65 genera belongs to the 48 families (Table 6.1.13). The highest percentage contribution of food plant species was recorded from the herb species (36.48%) followed by shrub species (28.38%), herb species (28.38%), climber (4.05%); whereas epiphyte and bryophyte contribute (1.35%) each in the annual diet of *M. munzala*. The maximum number of food plant species for tree (4) and shrub (5) was recorded from the Rosaceae family. Similarly, a total of 7 species (seven) from the family of Asteraceae was found highest among the herb food plant species. Araliaceae (2) recorded highest representatives for climber species.

Among the tree species, *M. munzala* spent maximum feeding time on *Erythrina arborescens* (14.92±1.35%) throughout the year followed by *Quercus seretta* (2.29±0.65%), *Betula utilis* (2.27±0.62%), *Malus sieversii* (2.07±0.82%), *Pinus wallichiana* (1.84±0.61%), *Prunus cerasoides* (1.79±0.55%), *Quercus semecarpifolia* (1.07±0.40%) and other tree food plants contribute less than 1%. Similarly, among the shrub species the maximum time spent was found on *Leucosceptrum canum* (12.46±1.43%) followed by *Elaeagnus umbellate* (5.00±0.97%), *Debregeasia longifolia* (2.79±0.75%) and *Viburnum cylindricum* (3.22%). *M. mumzala* spent maximum time on *Polygonum molle* (10.60±0.94%) followed by *Oenanthe javanica* (5.30±0.55%), *Hedychium gardenium* (1.49±0.29%) among the herb species. Among the climber species, *Secamone elliptica* (6.62±0.83%) and *Hedera nepalensis* (2.18± 0.59%) had the maximum contribution in their diet (Table 6.1.13).

Table 6.1.13. Overall annual percentage contribution of food plants in diet of *Macaca munzala*

Sl. No.	Food source	Family	Items	Average percentage contribution in troop			Overall annual % (Mean)
				KZ	KS	LM	
Tree species							
1.	*Erythrina arborescens*	Fabaceae	YL, BK, FL	20.46±2.45	24.40±2.18	-	14.92±1.35
2.	*Quercus seretta*	Fagaceae	YL	5.17±1.74	-	1.75±0.78	2.29±0.65
3.	*Betula utilis*	Batulaceae	YL	3.62±1.14	2.92±1.41	0.31±0.31	2.27±0.62
4.	*Malus sieversii*	Rosaceae	FR	-	-	6.17±2.38	2.07±0.82
5.	*Pinus wallichiana*	Pinaceae	SD	-	-	5.50±1.73	1.84±0.61
6.	*Prunus cerasoides*	Rosaceae	YL, FL	2.62±1.28	2.45±0.98	0.30±0.30	1.79±0.55
7.	*Quercus semecarpifolia*	Fagaceae	PT	-	-	3.19±1.14	1.07±0.40
8.	*Rhododendron arboreum*	Ericaceae	FL, PT	0.19±0.15	-	0.17±0.13	0.92±0.07
9.	*Ficus sp.*	Moraceae	PT	1.67±0.56	-	-	0.55±0.19
10.	*Schima wallichii*	Theaceae	PT	0.80±0.28	0.67±0.27	-	0.49±0.13
11.	*Morus alba*	Moraceae	FR	0.31±0.23	1.11±0.58	-	0.47±0.21
12.	*Eurya acuminata*	Pentaphylacaceae	PT	-	0.44±0.24	0.81±0.47	0.42±0.18
13.	*Salix wallichiana*	Salicaceae	FL	-	-	1.13±0.53	0.38±0.18
14.	*Magnolia*	Magnoliaceae	FR	1.03±0.71	-	-	0.34±0.24
15.	*Prunus persica*	Rosaceae	FR	0.16±0.11	-	0.51±0.37	0.22±0.13
16.	*Albizia chinensis*	Fabaceae	PT	0.16±0.16	0.16±0.12	-	0.11±0.07
17.	*Toona sinensis*	Maliaceae	FL, YL	0.31±0.24	1.01±0.45	-	0.10±0.08

18.	*Pyrus pashia*	Rosaceae	FR	-	0.28±0.18	-	0.10±0.06
19.	*Rhus wallichi*	Anacardiaceae	FL	0.15±0.15	-	-	0.05±0.05
Shrub species							
20.	*Leucosceptrum canum*	Lumiaceae	YL, PT	6.33±1.54	5.60±1.44	25.35±3.11	12.46±1.43
21.	*Elaeagnus umbellata*	Elaeagnaceae	FR	5.91±1.86	4.05±1.31	5.07±1.83	5.00±0.97
22.	*Debregeasia longifolia*	Urticaceae	FR	3.41±1.11	2.07±1.45	2.90±1.32	2.79±0.75
23.	*Viburnum cylindricum*	Adoxaceae	FR	2.51±1.01	1.45±0.65	1.76±0.88	1.90±0.49
24.	*Polygala sp.*	Polygalaceae	PT	--	2.21±0.74	--	0.74±0.26
25.	*Rubus ellipticus*	Rosaceae	FR	0.71±0.40	1.12±0.44	0.22±0.15	0.68±0.20
26.	*Viburnum erubescens*	Adoxaceae	FR	0.30±	0.87±0.42	1.07±0.51	0.46±0.16
27.	*Symplocos dryophila*	Symplocaceae	PT	0.50±0.29	--	0.49±0.39	0.40±0.17
28.	*Cotoneaster dammeri*	Rosaceae	FR	--	--	1.15±0.59	0.39±0.20
29.	*Mahonia nepalensis*	Berberidaceae	FR	1.02±0.53	--	--	0.34±0.18
30.	*Elaeagnus conferta*	Elaeagnaceae	FR	--	--	0.82±0.49	0.27±0.16
31.	*Cotoneaster acuminatus*	Rosaceae	FR	-	0.58±0.37	--	0.20±0.12
32.	*Gaultheria fragrantissima*	Ericaceae	FR	-	-	0.44±0.34	0.15±0.11
33.	*Brassaiopsis hainla*	Araliaceae	L	-	0.40±0.25	-	0.13±0.09
34.	*Caseria glomerata*	Flacourtiaceae	YL, PT	-	0.45±0.26	-	0.12±0.07
35.	*Ocotea sp.*	Lauraceae	PT	0.27±0.27	-	-	0.09±0.09
36.	*Cotoneaster ganghobaen*	Rosaceae	FR	-	0.23±0.17	-	0.08±0.06
37.	*Coragana species*	Fabaceae	YL, PT	0.23±0.23	-	-	0.08±0.08

38.	*Symplocos ramosissima*	Symplocaceae	PT	-	0.21±0.16	-	0.07±0.72
39.	*Neillia sinensis*	Rosaceae		0.18±0.18	-	-	0.06±0.06
40.	*Maesa indica*	Myrisnaceae	PT	0.12±0.12	-	-	0.04±0.04
41.	*Drymaria cordata*	Caryophyllaceae	YL	-	0.05±0.05	-	0.02±0.02
Herb species							
42.	*Pollygonum molle*	Polygonaceae	PT, YL	9.39±1.57	10.71±1.55	11.70±1.74	10.60±0.94
43.	*Oenanthe javanica*	Apeaceae	YL, ST	5.63±1.02	6.05±0.98	4.23±0.87	5.30±0.55
44.	*Hedychium gardenium*	Zingiberaceae	ST, RZ	1.07±0.40	1.30±0.44	2.09±0.62	1.49±0.29
45.	*Colebrookea oppositifolia*	Lamiaceae	PT	0.34±0.17	0.25±0.18	3.53±0.94	1.38±0.34
46.	*Artemisia argyi*	Asteraceae	YL	-	1.88±1.05	1.05±0.50	0.98±0.39
47.	*Athyrium filix-femina*	Athyriaceae	LT, RZ	0.23±0.14	1.48±0.56	-	0.57±0.20
48.	*Acorus calamus*	Araceae	ST	0.18±0.15	0.86±0.32	0.65±0.34	0.57±0.17
49.	*Cannabis sativa*	Cannabaceae	SD	-	1.29±0.83	-	0.43±0.28
50.	*Carduus acanthoides*	Asteraceae	FL	0.28±0.21	0.88±0.37	-	0.39±0.14
51.	*Crassocephalum crepidioides*	Asteraceae	FL	0.61±0.24	0.38±0.25	-	0.33±0.11
52.	*Raphistemma pulchellum*	Asclepiadaceae	ST	0.23±0.16	0.74±0.33	-	0.32±0.12
53.	*Thunbergia sp*	Acanthaceae	ST	0.09±0.09	0.57±0.27	0.12±0.12	0.26±0.10
54.	*Persicaria wallichii*	Polygonaceae	ST, YL	0.08±0.08	0.25±0.16	0.35±0.25	0.23±0.10
55.	*Lindera neesiana*	Lauraceae	FR	0.34±0.18	-	-	0.11±0.06
56.	*Bidens biternata*	Asteraceae	YL, ST	0.17±0.12	0.11±0.08	-	0.09±0.05
57.	*Triumfetta sp.*	Maliaceae	PT	0.12±0.09	-	0.13±0.13	0.08±0.05

58.	*Rubus nepalensis*	Rosaceae	FR	0.21±0.21	-	0.60±0.42	0.07±0.07
59.	*Asperula sp.*	Asclepiadaceae	ST	0.18±0.18	-	-	0.06±
60.	*Hemiphragma heterophyllum*	Plantaginaceae	FR	0.15±0.15	-	-	0.05±0.05
61.	*Nannoglottis sp.*	Compositae	ST	0.13±0.13	-	-	0.04±0.04
62.	*Veronica sp.*	Plantaginaceae	YL, ST	0.11±0.11	-	-	0.03±0.03
63.	*Ligularia sp.*	Asteraceae	ST	0.09±0.09	-	-	0.03±0.03
64.	*Aster sp.*	Asteraceae		0.06±0.06	-	-	0.02±0.02
65.	*Strobilanthes atropurpureus*	Acanthaceae	PT	-	0.06±0.06	-	0.02±0.02
66.	*Ajuga sp.*	Lamiaceae	ST	0.05±0.05	0.00±	0.000.00	0.02±0.02
67.	*Pedicularis sp.*	Orobanchaceae	ST	0.04±0.04	-	-	0.01±0.01
68.	*Wedelia chinensis*	Asteraceae	ST	0.04±0.04	-	-	0.01±0.01
Grass							
69.	*Arundinella species*	Poaceae	YL	2.39±0.63	0.29±0.16	-	0.89±0.23
70.	*Eulalia mollis*	Poaceae	YL	0.68±0.36	0.42±0.21	0.32± 0.20	0.47±0.15
Climber							
71.	*Secamone elliptica*	Asclepiadaceae	ST, YL	8.83±1.57	7.79±1.50	3.26± 1.11	6.62±0.83
72.	*Hedera nepalensis*	Araliaceae	FR	2.97±1.17	-	3.58± 1.31	2.18± 0.59
73.	*Mikania sp.*	Asteraceae	PT	1.34±0.78	-	-	0.44±0.26
Moss and Epiphyte							
74.	*Smitinandia micrantha*	Orchidaceae	YL	0.30±0.23	-	-	0.10±0.08
75.	Moss	-	-	1.82±0.83	-	2.02± 0.79	1.28±0.39

Other							
1.	Animal matter			1.42±0.65	3.09±0.82	1.80± 0.64	2.11±0.41
2.	Raid			2.33±0.97	8.87±1.75	5.45± 1.49	5.57±0.85

YL (Young leaf); ST (Stem), PT (Petiole), PT MD (Petiole and midrib), FL (Flower), FR (Fruit), BK (Bark), RH (Rhizome), AM (Animal matter, SD (Seed)

For tree species, *Erythrina arborescens* recorded highest Food Availability Index (FAI) for KZ (8.87) and KS troop (64.36) troop while, *Pinus wallichina* (2.05) recorded highest for the LM troop. *Erythrina arborescens* was absent in LM troop habitat. Similarly, *Leucosceptrum canum* had the highest FAI for KZ (18.59), KS (25.64) and LM (30.52) troops with respect to shrub species. *Pollygonum molle*, herb species had highest FAI in the habitats of the study troop. In climber, *Secamone elliptica* recorded highest FAI for KS (0.45) and LM troop (0.02) but, *Hedera nepalensis* shown highest FAI value (10.51) for KZ troop (Table 6.1.14).

Table 6.1.14. Annual percentage contribution (PC) of major food plant in diet and food plant availability index (FAI) of troops

Major food plant		KZ		KS		LM	
		PC	FAI	PC	FAI	PC	FAI
Tree	*Erythrina arborescens*	20.46	8.87	24.40	64.36	-	-
	Quercus seretta	5.17	5.38	0.00	0.00	1.75	0.48
	Betula utilis	3.62	1.60	2.92	4.14	0.31	0.88
	Malus sieversii	-	-	-	-	6.17	1.57
	Pinus wallichiana	-	-	-	-	5.50	2.05
	Prunus cerasoides	2.62	0.53	2.45	0.89	0.30	0.09
	Quercus semecarpifolia	0.00	0.00	0.00	1.25	3.19	4.71
Shrub	*Leucosceptrum canum*	6.33	18.59	5.60	25.64	25.35	30.52
	Elaeagnus umbellata	5.91	1.46	4.05	6.92	5.07	3.25
	Debregeasia longifolia	3.41	1.62	2.07	1.55	2.90	1.82
	Viburnum cylindricum	2.51	2.34	1.45	0.87	1.76	1.36
Herb	*Pollygonum molle*	9.39	70.71	10.71	43.78	11.70	32.97
	Oenanthe javanica	5.63	2.38	6.05	16.91	4.23	2.25
	Hedychium gardenium	1.07	7.35	1.30	13.64	2.09	29.89
	Colebrookea oppositifolia	0.34	1.22	0.25	3.68	3.53	11.43
Climber	*Secamone elliptica*	8.83	0.05	7.79	0.45	3.26	0.02
	Hedera nepalensis	2.97	10.51	0.00	0.00	3.58	0.01

The Linear regression model had found that percentage contribution of food plant items significantly correlated to the Food Availability Index (Table 6.1.15).

Table 6.1.15. ANOVA table for Simple Linear regression (Dependent Variable: Percentage contribution of major food plant; Predictor: Availability)

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	638.50	1	669.59	35.98*	p<0.01
	Residual	942.85	49	18.60		

Constant=0.64; B=2.49; R Square=0.40

*Significant at 99% confidence interval i.e. p<0.01

Among the troop, KZ had the highest number of food plant species (54 species belonging to 33 families) followed by KZ troop with 41 species belonging to the 27 families and LM troops with 34 species belonging to 23 families for the LM troop (Table 6.1.13). The troops KZ and KS were found to spent highest time on *Erythrina arborescens* having 20.46±2.45% and 24.40±2.18%, respectively. Likewise, in shrubs, *Leucosceptrum canum* recorded highest percentage time for all three troops (KZ, 6.33±1.54; KS, 5.60±1.44 and LM, 25.35±3.11). *Polygonum molle* was the major herb species used by KZ (9.39±1.57), KS (10.71±1.55) and LM (11.70±1.74) troops (Table 6.1.14).

6.1.19 Selection ratio and annual dietary spectrum for the study troops

Among the food plant, highest selection ratio has shown for climber species of *Secamone elliptica* for all the studied troops i.e., KZ (591.14), KS (23.89) and LM troop ((391.17). Similarly, *Hedera nepalensis* had the higher selection ratio for KZ (88.09) and LM troop (183.16). The herb species of *Hedychium gardenium* (8.40) recorded higher selection ratio for KZ troop (Table 6.1.16). A total of 14 food plants for KZ troop; 12 food plant for KS troop and 13 for LM troop contributed 80% diet of *M. munzala* (Fig. 6.1.16).

Table 6.1.16. Top 10 food plant selection ratio of studied troops

Troop	Sl. No.	Food plant	APC	SR
KZ	1.	*Secamone elliptica*	8.83	591.14
	2.	*Hedera nepalensis*	2.97	88.09
	3.	*Erythrina arboscense*	20.46	13.45
	4.	*Hemiphragma heterophyllum*	0.15	4.90
	5.	*Oenanthe javanica*	5.63	4.54
	6.	*Wedelia chinensis*	0.04	3.43
	7.	*Athyrium filix-femina*	0.23	2.50
	8.	*Ficus species*	1.67	2.50
	9.	*Crassocephalum crepidioides*	0.61	2.49
	10.	*Morus alba*	0.31	2.27
KS	1.	*Secamone elliptica*	7.79	23.89
	2.	*Hedychium gardenium*	1.30	8.40
	3.	*Crassocephalum crepidioides*	0.38	2.39
	4.	*Oenanthe javanica*	6.05	1.86
	5.	*Athyrium filix-femina*	1.48	1.01
	6.	*Leucosceptrum canum*	5.60	0.81
	7.	*Rubus ellipticus*	1.12	0.79
	8.	*Erythrina arborescens*	24.40	0.73
	9.	*Polygala species*	2.21	0.52
	10.	*Cannabis sativa*	1.29	0.41
LM	1.	*Secamone elliptica*	3.26	391.17
	2.	*Hedera nepalensis*	3.58	183.16
	3.	*Cotoneaster dammeri*	1.15	6.48
	4.	*Polygonum molle*	11.70	1.61
	5.	*Artemisia argyi*	1.05	1.59
	6.	*Leucosceptrum canum*	25.35	1.54
	7.	*Malus sieversii*	6.17	1.10
	8.	*Oenanthe javanica*	4.23	1.01
	9.	*Viburnum erubescens*	1.07	1.01
	10.	*Prunus cerasoides*	0.51	0.82

APC (Annual percentage contribution), SR (Selection ratio)

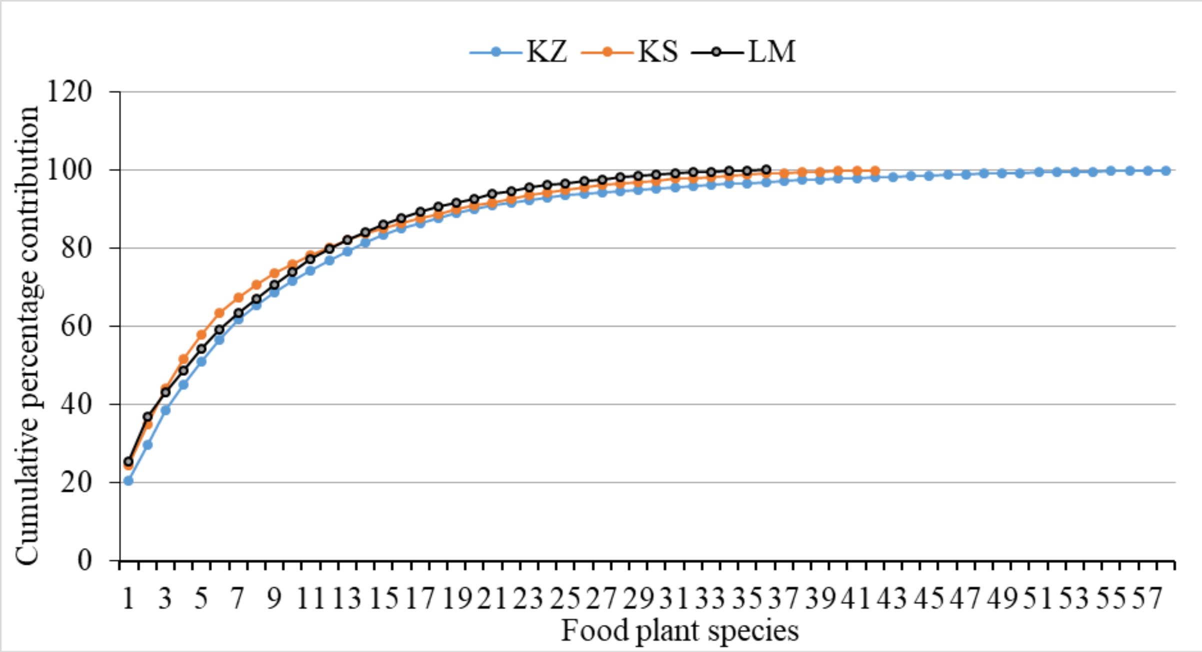

Figure 6.1.16. Annual dietary spectrum of *M. munzala*

6.1.20 Discussion

Macaca munzala, a habitat generalist species found in heterogeneous habitat in high altitude area of Arunachal Pradesh, India. The present study revealed that activity and feeding pattern of *M. munzala* differ spatially and temporally. However, annual variation is not significant among the habitat types but seasonal variation had significant difference. Thus, it signifies that the species has shown variation in percentage time spent in terms of availability of food resources, as well as distribution of food plants. The time spent on feeding by study troops in three different habitats (Eastern Himalaya broad-leaved forest, Degraded scrub forest in human dominated landscape and Mixed coniferous forest) revealed that species emphasized on feeding activities than that of other activities. Similarly, Koirala et al. [26] reported that Assamese macaque (*Macaca assamenensis*) spent highest time on feeding and activity budget was significantly influence by the seasonal change. Moreover, seasonal variation in time spent activities of high altitude dwelling Japanese macaques (*Macaca fuscata*) was also found profound [27]. It is noted that the present data also includes raiding activities that essentially questioned the quality of natural food available for the species in the three habitats as well. Further, time spent on feeding activity of the troop (KS) that engaged more in raiding activity had less time spent on feeding in comparison to other studied troops.

This might be due to of consumption of nutritional rich anthropogenic food that minimizes the feeding effort [28]. Besides that, patch distribution of food plant in human modified landscape is providing balance diet to the troop throughout the year. It was found that primates spent less time on feeding, when consumption of anthropogenic and cultivated food is higher [29,30]. Subsequently, studies on primates are reported to adapting agricultural matrix and human dominated landscape rapidly [31,32]. Thus, higher energy gain from food might reduce time spent on feeding in primates. The present study found that activities associated with locomotion were comparatively low in winter season among troops. This might be a strategy to reduce thermoregulatory cost by spending less time on movement. Similarly, Mendiratta et al. [16] found that *M. munzala* spent less time on movement during the winter season to avoid thermoregulatory cost. The high altitude dwelling Japanese macaque (*Macaca fuscata*) also perform similar pattern of time allocation according to the temperature gradient [3,27,33]. However, time spent on movement of troop's increases with increases of availability of food plant materials in the habitat. Thus, highest time spent on movement of studied troops was found in monsoon season might be the reason of higher availability of food plant material. Likewise, Mendiratta et al. [16] described that time spent on movement of *M. munzala* was highest, when availability of food plant material was higher during spring season.

In this study, *M. munzala* was found to be folivorous in pre-monsoon and monsoon season but, it became frugivorous when fruit was more abundant in post-monsoon season in the habitat. It was also reported that macaque maximized their feeding on fruits when availability of fruit was more [16,26,34]. *M. assamensis* was reported folivore primarily but preferred to feed on fruit, when abundant in the habitat [35]. Thus, it might be a strategy of primates to cope up with food scarcity in winter season by accumulating quality food when fruit availability was more [6,36]. There were 73 food plants for *M. munzala* in the study area with varying percentage contribution in the diet of the study animal. For habitat generalist species like *M. munzala*, there is very less probability of food preference and that is well described by Tsuji et al. [37]. In the present study, food plant material selection is considered as a function of food availability and there were 6-7 components which explain more than 70% variation among the percentage contributions by each of the food items. However, the food plants preferences have been evaluated because the food materials (eaten part such as young leaves, stem, fruit etc.) that have been recorded to be eaten by the species are almost available in each of the food plants. Young leaves were the mostly eaten food item irrespective of the plant species specifically. In the dietary spectrum of the troops, it was evident that to contribute 80% of *M. munzala*'s diet, minimum 13 plant species are required whereas; there were 73 numbers of different food plant species available in the study area. Based on habitat analysis and food plant contribution in diet, it was found that seasonal availability of food plant material has greater influence in food plant selection in diet rather than the dominant species in the habitat. *Alnus nepalensis* is one of the dominant tree species in the habitats of 3 (three) troops but *M. munzala* did not feed on any part of the species during the study period. The estimated selection ratio described that dominant food species have less selectivity in the habitat. For example, *Secamone elliptica* is the highly selected plant for all the troops but relative dominance of this climber is small. Thus, it makes *S. elliptica* in the top of the selection list of *M munzala*. But, there are other plant species with higher percentage of annual contribution with higher dominance distribution so, not getting priority in the selection list.

In the habitat analysis, it was found that the food plants were covering 45.71% of the total plant species recorded in all the three habitat types. Therefore, the variation in the habitat of *M. munzala* might affect the ecology of the species in terms of food resource availability. The FAI indicates that among the tree species, *Erythrina arborescens* has highest availability in the Eastern Himalaya broadleaved forest (EHBLF) and Degraded scrub forest (DSF) and thus, becomes most available food for KZ and KS; whereas, *Leucosceptrum canum*, a shrub species has highest available food items for LM troop. However, *Malus sieversii* and *Pinus wallichiana* has contributed a major part in the diet of the species especially in post-monsoon season as the fruit and seeds are highly fed by LM troop. It is noted here that, the food items available in *E. arborescens* might also be provided by *Quercus serrata* for LM troop. Similarly, it was reported that with respect to seasonal changes macaque species spent highest feeding time in particular food plants that has availability throughout the year [38,39]. Furthermore, the simple linear model of the present study has predicted that availability of food plant material has significance influence in contribution diet of troops. Nevertheless, the importance of food plants in terms of providing food materials is subject to seasonal changes and thus, requires more specific study to get a conclusive statement. The distribution of *E. arborescens, Malus sieversii, Pinus wallichiana,* *Pollygonum molle* and *Secamone elliptica* had influenced greatly on feeding pattern of *M. munzala* (Photo plate 6.1.1). Therefore, these food plant species are consider having critical importance in conservation of endangered *M. munzala*.

The present study concluded that activity pattern of *M. munzala* is related to availability of feeding material in habitat. Seasonal variation in time spent on activities of *M. munzala* was related to thermoregulatory cost and distribution of food plant material in the habitat. Further, study revealed that habitat type of *M. munzala* has less influence in activity pattern of *M. munzala* but diet composition varies significantly according to the vegetation composition of habitat. The availability of food plant material in the habitat had profound influence in food plant selection of *M. munzala* rather than dominance distribution of food plant. Moreover, time activity pattern of *M. munzala* in the present study has shown similarity with geographically closer Assamese macaque (*M. assamensis*) that inhabit in subtropical habitat (Table 6.1.17).

Table 6.1.17. Percentage time spent in activities of *Macaca munzala* and geographically closer *M. assamenesis*

Species	Habitat	Study period	Feeding	Moving	Resting	Grooming	Social Inter ac-tion	Other	Reference
M. munzala	EHBLF	January, 2016-May, 2017	34.25	25.78	24.12	9.65	-	6.01	Present study
	DSF		31.96	28.22	23.77	10.33	-	6.29	
	MCF		33.61	26.89	22.01	10.37	-	7.09	
	Degraded sub-tropical forest	Winter (Dec-Feb)	41-66	10–32	2–14	-	-	-	Mendiratta et al. [16]
		Spring (March-April)	33-51	12–50	31	-	-	-	
	Secondary scrub forest	Monsoon (July-August)	48 (Foraging)		36	-	16	-	Kumar et al. [15]
M. assamenesis	Sub-tropical broadleaved	March-April	44	25	18	13	-	-	Chalise [40]
	Semi-evergreen	June, 1997-May, 1998	40 (Foraging)	25 (Locomotion)	13	10	3	9	Sarkar et al. [41]
	Sub-tropical and lime stone	May	37.86	21.88	30.06	NA	10.18	NA	Koirala et al. [42]

Note: M (Male); F (Female), EHBLF (Eastern Himalaya broadleaved forest), DSF (Degraded scrub forest) and MCF (Mixed coniferous forest)

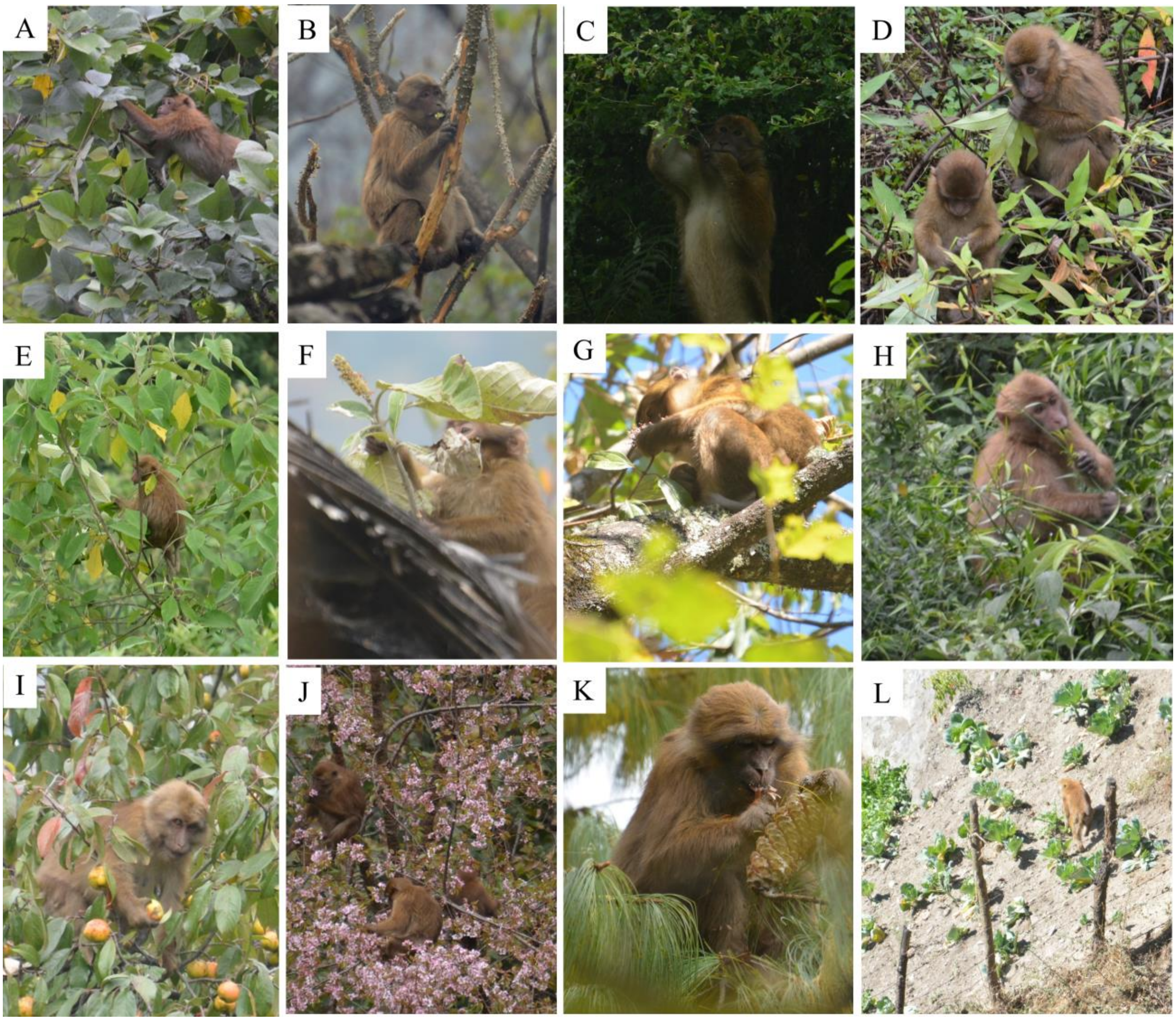

Photo plate 6.1.1. *M. munzala* feeding on *Erythrina arborescens* young leaf (A) and bark (B), fruit of *Elaeagnus umbellate* (C), stem of *Polygonum molle* (D), young leaf (E) and petiole (F) of *Leucosceptrum canum,* fruit of *Viburnum cylindricum* (G), young leaf of *Secamone elliptica* (H), fruit of *Malus sieversii* (I), young leaf of *Prunus cerasoides* (J), seed of *Pinus wallichiana* (K) and raid on home garden (L)

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6.2. Home range use and habitat use pattern of Arunachal macaque *Macaca munzala* in western Arunachal Pradesh, India

6.2.1 Introduction

The study of home range is the indicator of ecology of non-human primates as it describes the resource use and resource availability in its habitat. The home range size of non-human primates with special reference to macaque depends on the availability, distribution and quality of food [1–4]. The availability of fruit has been significantly correlated to the variability of home range in primates [5–7]. On that contrary, studies have found food that abundance of fruit did not have correlation with home range variability [8,9]. In disturb habitat, distribution of a primary food plants is the main driving factor for home range demarcation of primates [10]. On the other hand, food availability for primates in fragmented habitat is highly concentrated and accordingly there is a reduction in home range size and daily path length (DPL) [11,12]. However, lower resource availability in human dominated landscape also encourages primate groups to cover a larger area and travel a greater distance in order to obtain sufficient nutrients [7,13–15]. Concurrently, changes in home range size and DPL were shown to be affected by adaptability of the species and thus, habitat generalist species are prone to such kind of changes [16,17].

The less even use of space has been found in primates that inhabit in human altered habitat, as the foraging options are very limited in such habitats [18,19]. The preference of anthropogenic food in human modified landscape is probably due to its palatability, clumped distribution and accessibility to energy rich food [2,11]. However, the range use has been shown to be related to the presence of preferred food plant [3,20,21]. Besides that, the ranging behaviour of primates has been related to group size [19,22], forest structure [23], water availability [24], location of sleeping site [25], intergroup relationship [26,27], rainfall [28] and parasite avoidance [29].

The distribution of major food plant and availability has been reported to have significant influence in the ranging behaviour of the species. The highest population of *M. munzala* was reported from human-modified landscape [30]. However, troops were found to inhabit in different type of habitat but ranging behaviour of the species are known only from degraded habitat [21,31]. *M. munzala* dietary preference found to be vary according to seasonal availability of food plant materials [21,31]. The home range of the *M. munzala* is reported as a smallest among macaque species that inhabited in the similar type of habitat. The major goal of the present study is to enumerate the ranging behaviour of *M. munzala* that inhabited in Eastern Himalaya broadleaved forest (EHBLF), mixed coniferous forest (MCF) and Degraded scrub forest (DSF) in human-dominated landscape.

6.2.3 Methods

6.2.4 Study Area:

The study was conducted in Zemithang, Pangchen valley in three troops that was selected for behaviour study (KZ, KS and LM troops). Map of the study area showing the locations of selected troops; KZ (Eastern Himalaya broadleaved-scrub forest), KS (Degraded scrub forest) and LM (Mixed coniferous forest) is given in Fig. 3.1 (Chapter 3) KZ troop inhabit in EHBLF and also use human-dominated landscape. The dominant tree species of the habitat are *Quercus serrata*, *Alnus nepalensis, Schima wallichi* and *Rhododendron arboreum* species. Shrub layer was dominated by *Viburnum erubescens*, *Debregeasia longifolia*, *Elaeagnus umbellata,* while herb layer was dominated by *Polygonum molle*, *Oenanthe javanica*, Oxalis species, etc. KS troop inhabit in Degraded scrub forest (DSF) in human-modified landscape that occur at lower ridge of the valley. The dominant tree species in the habitat are *Erythrina arborescens* and *Alnus nepalensis*; shrub layer was dominated by *Elaeagnus umbellata, Debregeasia longifolia* herb layer was dominated by *Polygonum molle* and *Oenthea javanica.* LM troop inhabit in Mixed coniferous forest (MCF) and the habitat was dominated by tree species of *Pinus wallichiana, Cedar deodar, Alnus nepalensis* and *Rhododendron arboreum.* Shrub layer was dominated by *Leucosceptrum canum*, *Elaeagnus conferta*, *Elaeagnus umbellata* and *Debregeasia longifolia*, and herb layer was dominated by *Potentiala* species and *Polygonum molle.* The agriculture field were found in the habitat of KS (Degraded scrub forest in human modified landscape) and LM troop (Mixed coniferous forest) but there is no agriculture field in KZ habitat (Eastern Himalaya broadleaved forest). A total of 3 (three) villages are found near the ranging area KS troop and 2 villages each in KZ and LM troop (Fig. 6.2.1). A total of 47 individuals in KS troop; 38 individuals in KZ troop and 33 individuals in LM troop.

6.2.5 Home range and daily path length

The home range was estimated by grid method and intensity of habitat use pattern was determined by the frequency of spatial pattern of animal presence [3]. Troops were followed from morning (06:00 hrs) to entering to sleeping site (17:000hrs). Geo-coordinates were recorded using handheld GPS (Garmin Oregon 550) in every 30-minute interval. Then the GPS points were imported to the ArcGIS software and 1 ha (100 m × 100 m) grid map was superimposed. The total number of grids used was the area used in hectares by each troop. The intensity of habitat used by troops were categorized as; low (0.08%-1.9%), moderate (1.9%-2.9%) and high (>2.9%) based on frequency of troops' presence in the grids. The forest types used by the troops were estimated by overlaying the forest type information on the map from ground trothing. The daily path length of troops was calculated by adding all the GPS points successively for each day.

6.2.6 Vegetation survey and food plant

Vegetation survey was conducted in 2 (two) plots of home range area of each troop that were used highly >2.9% by the troops. Exceptionally, one plot in EHBLF habitat was selected in moderate intensity area (1.9%-2.9%) for KZ troop. A total of 30 quadrats were laid in each plot (1 and 2). The size of quadrat was 10 m ×10 m for tree species, within that 5 m × 5 m quadrat were laid for shrubs and herbs. The tree girth was measured at the height of 1.3 m from the base. The frequency, abundance, density and basal area are calculated following Cottam and Curtis [32].

IVI=Relative frequency + Relative density + Relative dominance

Diversity indices, Shannon-Wiener diversity index [33], Simpson's index of dominance [34], Evenness index [35] and Similarity index [36] were calculated using the following formula;

Shannon-Wiener diversity index $(H') = -\sum_{i=1}^{S} pi \ln pi$

where, pi was proportional abundance of i^{th} species in the community

Simpson index (*CD*) $= \sum_{i=1}^{S} (pi)^2$

where, pi is the similar with the Shannon-Wiener diversity index.

Evenness index (*e*) = H′/log S

where, H′= Shannon diversity index and S= total number of species.

6.2.7 Results

6.2.8 Daily path length (DPL)

The mean daily path length of three troops was 1.23 ±0.10 km (Mean ±SE), which varies from 0.24 to 5.14 km and data was estimated from the 69 full day follows (Fig. 6.2.1). *M. munzala* covers longest distance during the monsoon season (1.65 ±0.28 km) and shortest during the post-monsoon season (0.92 ±0.17 km). The average DPL for KZ was 1.34 ±0.17 km; 1.37 ±0.21 km for KS and for LM troop it was 0.97 ±0.17 km (Table 6.2.1).

Table 6.2.1 Seasonal variation in daily path length and home range of troops

Season	**Daily path length (in km ±SE)**			**Home range (in ha)**		
	KZ	**KS**	**LM**	**KZ**	**KS**	**LM**
Pre-monsoon	1.15±0.17	1.38±0.21	0.86±0.15	61	79	57
Monsoon	2.12±0.47	1.72±0.62	1.27±0.19	76	86	56
Post-monsoon	0.91±0.33	1.31±0.29	0.48±0.01	38	51	32
Winter	1.52±0.34	1.08±0.25	0.99±0.37	71	60	62

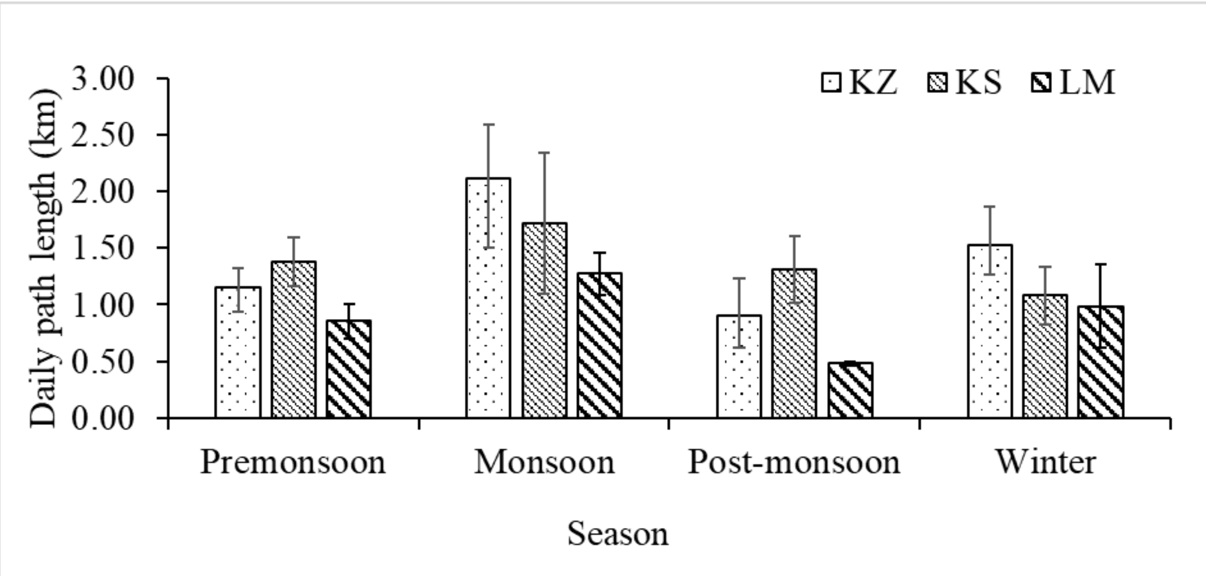

Fig. 6.2.1 Seasonal variation in mean (SE) daily path length of KZ, KS and LM troops

6.2.9 Home range size and habitat use pattern

A total of 3441 numbers of location points were collected to estimate the annual home range of the three study troops in the study area. Out of the total location points, 1320 points were for KZ troop; 1153 points for KS and 968 points for LM troop (Fig. 6.2.2).

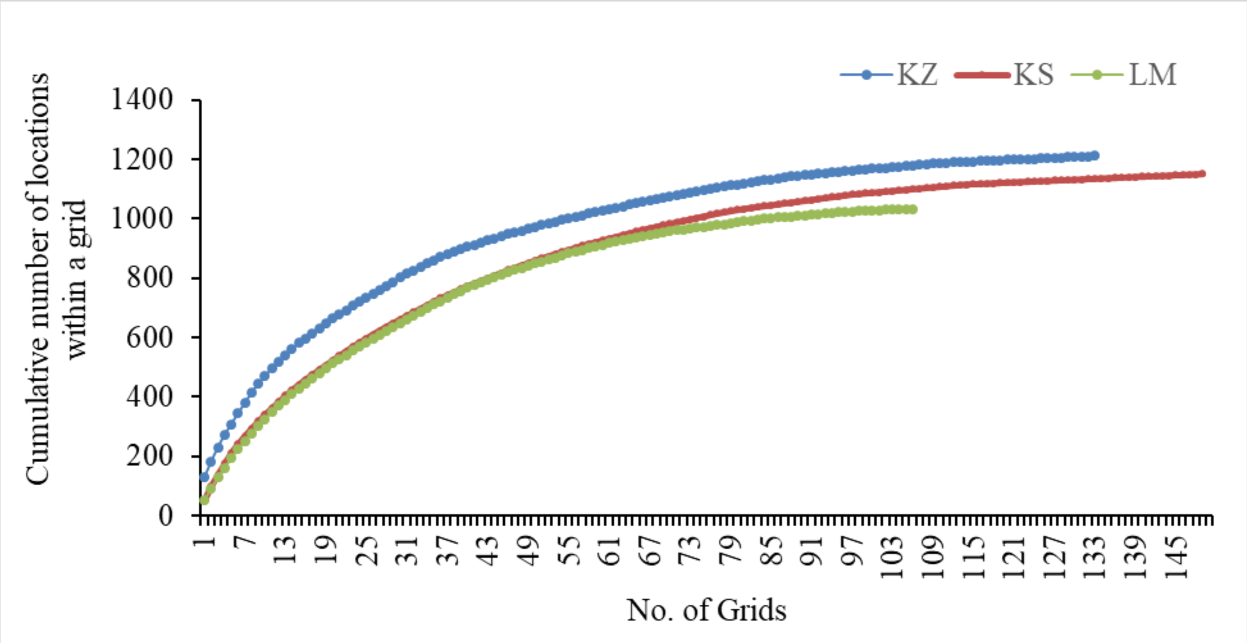

Fig. 6.2.2. Cumulative grids entered by the macaque study troops during the study period

The study found that KS troop cover the largest annual ranging area of 149 ha followed by KZ (133 ha) and lowest range size was estimated for LM troop (106 ha) (Fig.6.2.3). The home range sizes of KZ and KS troops were larger in monsoon season covering 86 ha and 62 ha, respectively; whereas in winter season LM troop covered largest range area of 62 ha. The ranging area became smallest in post-monsoon season for all the troops in comparison to that of other seasons (Table 6.2.2). There was overlapping home range in between troops KZ and KS and the estimate area was 23 ha (Fig.6.2.3).

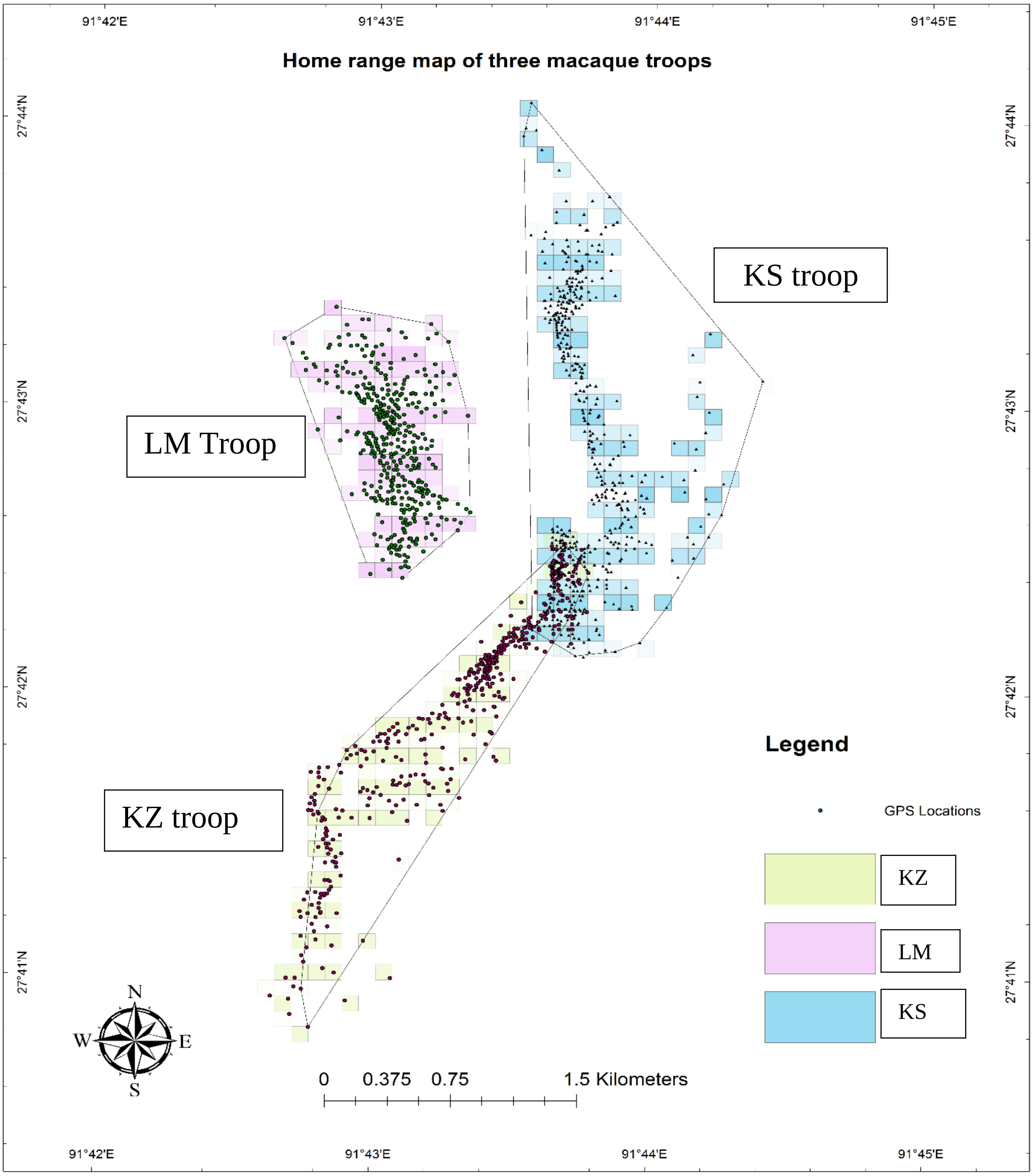

Fig. 6.2.3 Home range of three studied troops

Of the annual home range of KZ and LM troops, 6 ha area has been used in higher intensity (>2.9%) i.e. the members of the troops visited in this area are more frequently than the rest of the used grids home range (Fig. 6.2.4 and Fig. 6.2.6). At the same time, KS troop used only 5 ha of its annual home range in higher intensity (Fig. 6.2.5 and Fig. 6.2.5).

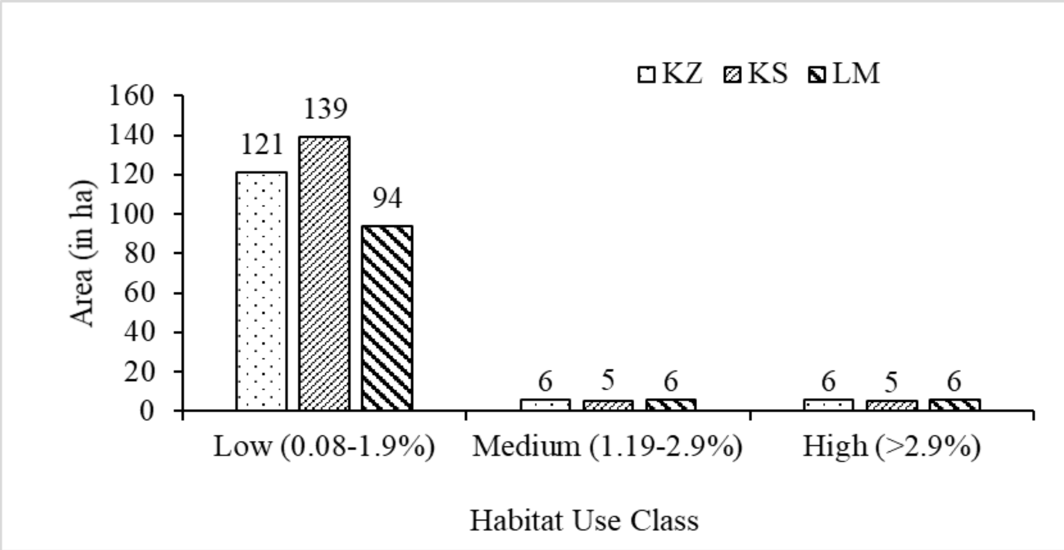

Figure 6.2.4. Area under different habitat use class in the study area

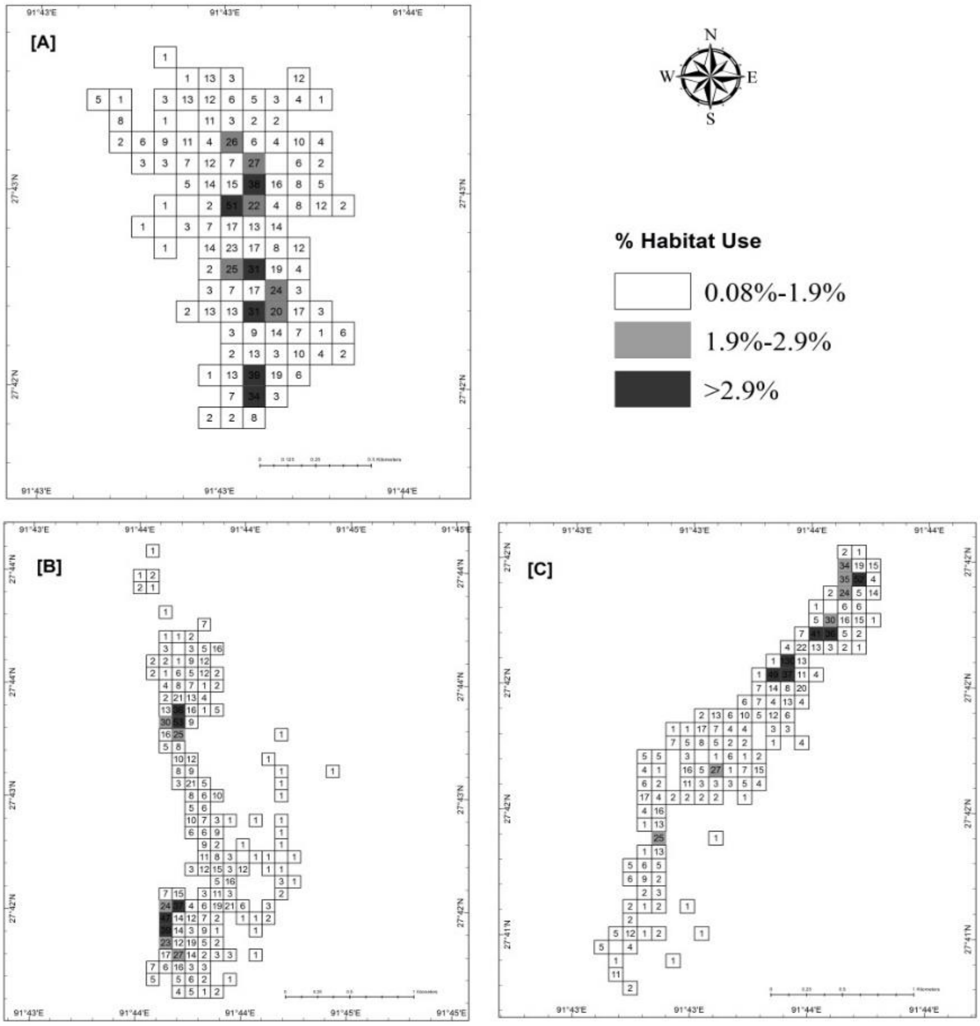

Figure 6.2.5. Habitat use pattern of troops; LM troop (A), KS troop (B) and KZ troop(C)

6.2.10 Use of different types of forest by the study troops

The study troops used different types of forests and non-forested area and based on their number of visits, a comprehensive map was prepared. The habitat like crop field and home garden area were categorised as non-forested land. The 3 (three) forest types inhabited by the KZ, LM and KS were Eastern Himalaya forest (EHBLF), Mixed coniferous forest (MCF) and Degraded scrub forest (DSF) in human modified landscape, respectively (Table 6.2.2).

Table 6.2.2 Percentage use of different types of forest by the study troops

Troops	% uses of forest types/Land use				
	HDFM			EHBLF	MCF
	Crop Field	Home Garden	DSF		
KZ	-	6.43	32.86	60.71	-
KS	3.36	18.79	77.85	-	-
LM	7.08	9.73	-	-	83.18

Note: EHBLF- Eastern Himalayan Broadleaf Forest, MCF- Mixed Coniferous Forest, HDFM-Human Dominated Forest Matrix DSF- Degraded Scrub Forest

Out of the annual home range area of KZ troop, 60.71% of area was within EHBLF, however, other two study troops were not extended their home range in EHBLF (Table 6.2.2). DSF was mostly used by troop KS (77.85%) at the same time MCF was mostly used by LM (83.18%). Non-forested area, home garden was highly used by KS troop (18.79%) followed by LM troop (9.73%) and lowest by KZ troop (6.43%) (Fig. 6.2.6; Fig. 6.2.7 and Fig. 6.2.8). Home range of KS and LM troops includes crop field covering a proportion of 3.36% and 7.08%, respectively.

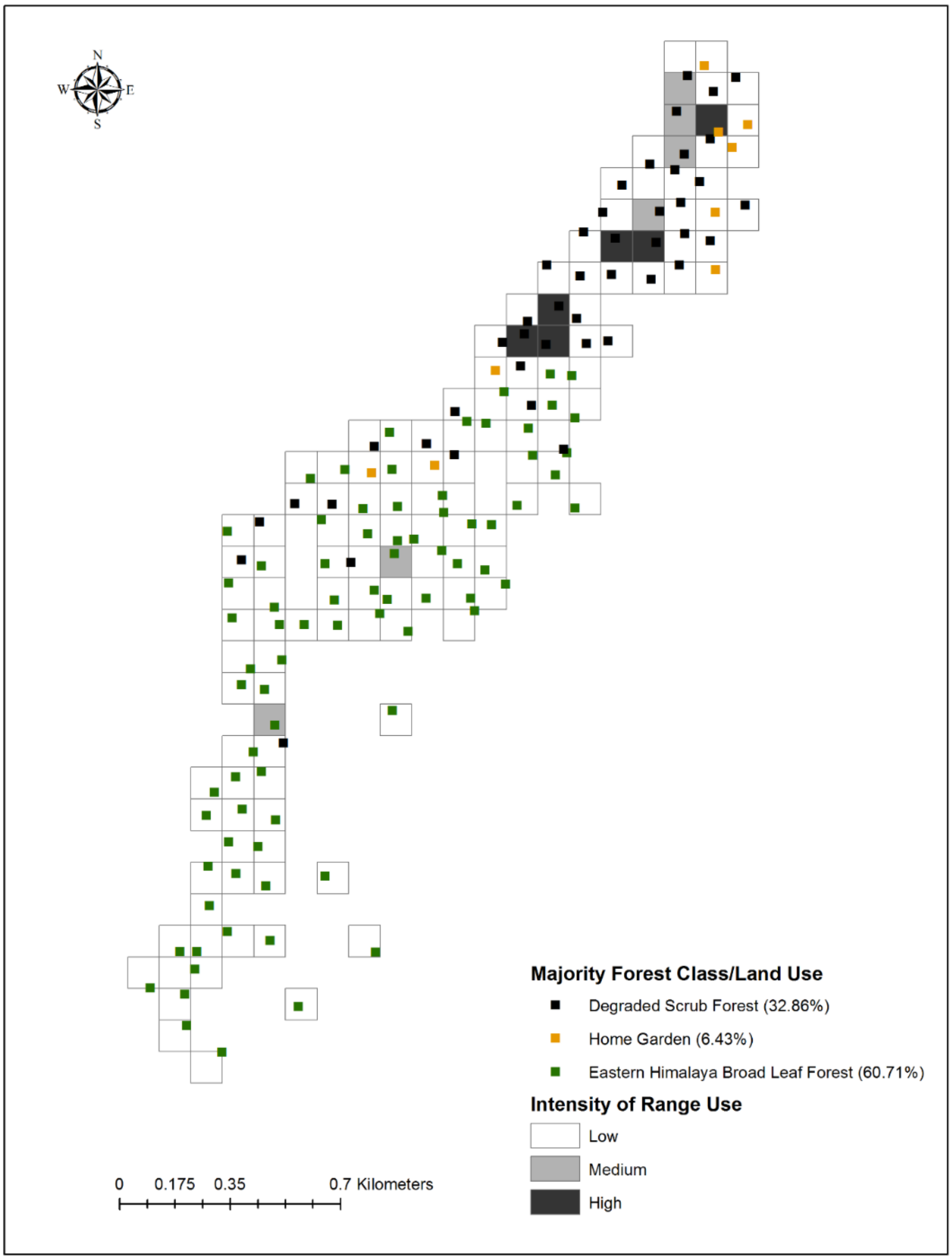

Fig. 6.2.6. The percentage area of different type of habitat use by the KZ troop

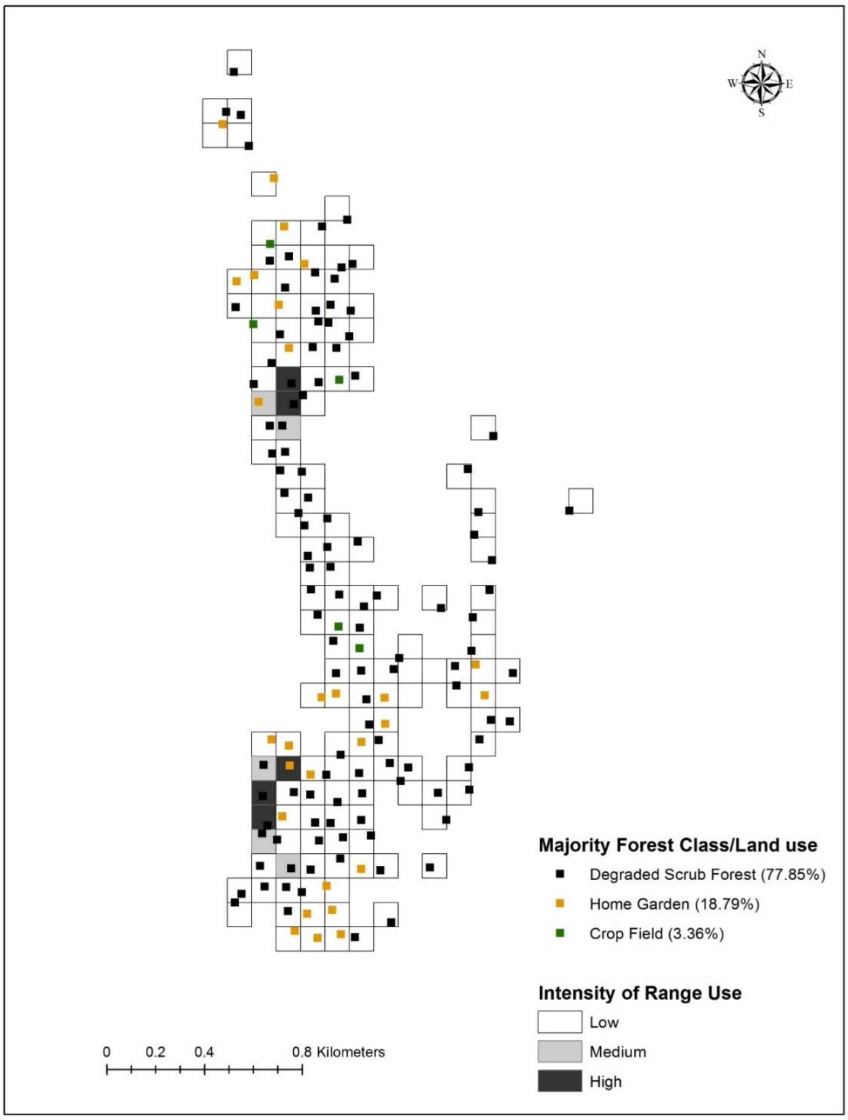

Figure 6.2.7. The percentage area of different type of habitat use by the KS troop

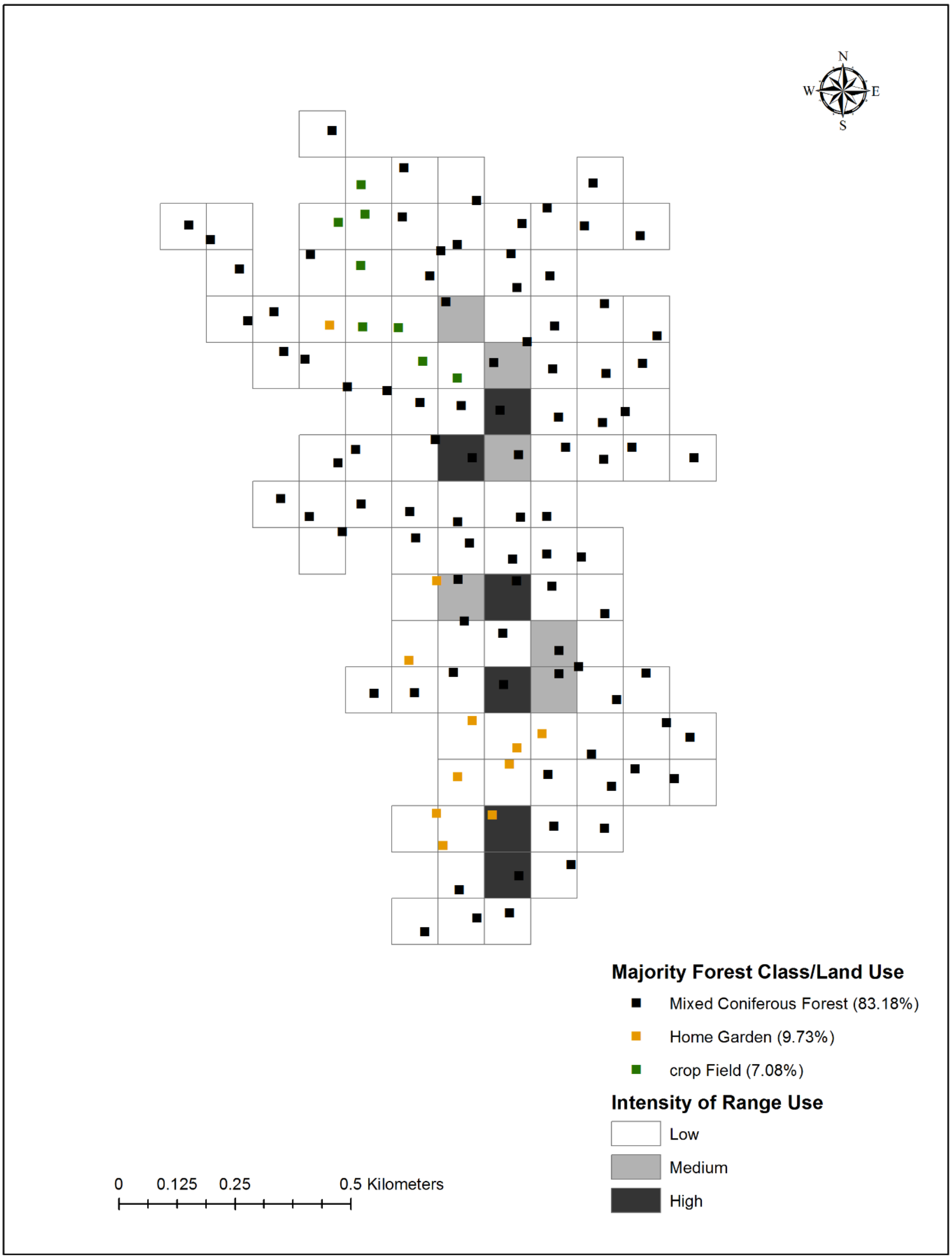

Figure 6.2.8. The percentage area of different type of habitat use by the LM troop

6.2.11 Plant community parameter and food plant diversity in core habitat

Core habitat is the higher intensity home range area where members of the troops visited very frequently (>2.9%). Highest number of tree (11 species and 2.2 species richness) and shrub (19 species and 2.18 species richness) was recorded in core habitat of plot 1 and plot 2 of KZ troop. Herb species richness recorded in plot 1 of LM troop (26 species, 1.26 species richness) was marginally differing among the other core habitat (Table 6.2.3). The highest proportion of food plant was recorded in KS troop habitat (trees: plot 1, 75% and Plot 2, 83.33%; shrubs: plot 1, 50% and plot 2, 90% and herbs: plot 1, 64.70% and plot 2, 54.54%) as given in Table 6.2.4. However, relative tree food plant density was recorded highest in LM troop habitat (plot 2, 119.88 individual ha^{-1}); for shrub in KZ & KS troop (plot 2, 93.68 individual ha^{-1}) and for herb in KS habitat (plot 1, 73.37 individual ha^{-1}) (Table 6.2.3).

Table 6.2.3. Plant community structure and food plant relative density of plot 1 and 2

Plant community structure		Plot 1			Plot 2	
		KZ	KS	LM	KZ & KS	LM
Tree	No. of species	11	6	11	6	9
	Genera	11	4	9	6	6
	Family	8	3	7	3	5
	Density (individual/ha)	96.57	99.9	236.43	126.54	249.75
	Basal area (m^2/ha)	56.27	23.85	30.80	25.36	56.56
	Simpson diversity index (*D*)	0.11	0.45	0.23	0.33	0.24
	Shannon diversity index (*H'*)	2.74	0.98	1.89	1.32	1.76
	Evenness index (*J'*)	0.79	0.96	0.68	0.74	0.81
	Species richness	2.22	0.73	1.60	0.97	1.96
	No. of food plant	5 (45%)	5 (75%)	6 (66.66%)	5 (83.33%)	4 (66.66%)

	Relative density food plant	54.55	74.68	69.21	68.46	119.88
Shrub	No. of species	19	8	10	8	8
	Genera	18	8	7	10	7
	Family	16	8	6	9	6
	Density (individual/ha)	1119.72	392.9	751.3	263.07	751.3
	Basal area (m^2/ha)	20.62	11.85	16.34	13.63	16.34
	Simpson diversity index (*D*)	0.09	1.00	0.16	0.13	0.16
	Shannon diversity index (*H'*)	2.68	1.99	2.01	2.18	2.01
	Evenness index (*J'*)	0.91	0.86	0.88	0.95	0.88
	Species richness	2.18	1.04	1.35	1.13	1.35
	No. of food plant	9 (47.36%)	4 (50%)	7 (70%)	9 (90%)	7 (77%)
	Relative density food plant	55.95	67.82	80.01	93.68	80.01
Herb	No. of species	18	17	26	22	11
	Genera	18	17	21	22	9
	Family	13	14	15	15	8
	Density (individual/ha)	1529.92	2513	1293.01	3551.6	506.16
	Basal area (m^2/ha)	1.88	1.144	2.15	1.14	0.33
	Simpson diversity index (*D*)	0.11	0.142	0.11	0.06	0.16

	Shannon diversity index (*H'*)	2.45	2.388	2.70	2.92	2.03
	Evenness index (*J'*)	0.85	0.773	0.82	0.94	0.88
	Species richness	1.16	1.24	1.26	1.23	1.14
	Food plant	6 (33.33%)	11 (64.70%)	14 (51.85%)	12 (54.54%)	5 (45.45%)
	Relative density food plant	45.43	73.37	58.49	60.43	64.10

Food plant, *Erythrina arborescens* was recorded as a dominant tree species in plot 1 habitat of KS troop (IVI=176.81). *Alnus nepalensis* (IVI=45.05) was dominant tree species in the plot 1 habitat of KZ troop and *Erythrina arborescens* (IVI=126.77) was dominant for plot 2 habitat (Table 6.2.5). *Pinus wallichiana* (IVI=127.99) was found dominant tree species in the plot 2 habitat of LM troop (Table 6.2.4). For shrub species, the plot 1of KZ troop found dominated by food plant *Rhododendron arboretum* (IVI=53.94) followed by *Viburnum erubescens* (IVI=56.67) respectively. Plot 1 of KS troop dominated by *Elaeagnus umbrelata* (60.69), while, plot 1 of LM troop was dominated by *Leucosceptrum canum* (82.66) and plot 2 was dominated by *Viburnum erubescens* (IVI=56.67) (Table 6.2.5). *Polygonum molle* was dominated herb species for plot 1 and 2 of three troops, except for plot 1 of KS and plot 2 of LM where *Athyrium filing-femina* (IVI=52.62) and *Hedychium gardnerianum* (IVI=72.90) dominant respectively (Table 6.2.6). The significant difference in occurrence of major food plants among troops i.e., *Erythrina arborescens* was recorded only in the core habitat of KZ and KS. Similarly, *Pinus wallichiana* and *Malus sieversii* recorded only in LM core habitat during the vegetation survey (Table 6.2.7).

Table 6.2.4. Density (individual ha^{-1}), Basal area (m^2/ha) and Important value index of tree species in plot 1 and plot 2 habitat of troops

SL. No.	Plot 1: KZ troop	Density	Basal area	IVI
1.	*Alnus nepalensis*	16.65	5.66	49.05
2.	*Quercus lemellosa*	9.99	13.00	46.49
3.	*Quercus serrata*	9.99	14.60	44.99
4.	*Betula utilitis#*	13.32	5.10	31.56
5.	*Prunus cerasoid#*	9.99	3.71	25.63
6.	*Schima wallichi#*	9.99	3.07	24.50
7.	*Erythrina arboscensce#*	9.99	1.28	21.32
8.	*Ficus glaberrima*	3.33	6.59	19.51
9.	*Lannea coromanderica*	6.66	1.07	17.50
10.	*Elaeocarpus chinensis*	3.33	1.35	10.19
11.	*Litsea coreana*	3.33	0.83	9.27
Plot 2: KZ and KS				
1.	*Erythrina arborescens#*	63.27	9.18	126.77
2.	*Alnus nepalensis*	39.96	10.64	114.09
3.	*Albizia chinensis#*	6.66	1.52	16.65
4.	*Betula utilis#*	6.66	1.41	16.23
5.	*Morus alba#*	6.66	1.03	14.74
6.	*Toona sinensis#*	3.33	1.58	11.57
Plot 1: KS troop				
1.	*Erythrina arborescens#*	53.28	16.09	176.81
2.	*Alnus nepalensis*	33.3	6.04	90.65
3.	*Albizia chinesis#*	6.66	1.52	21.03
4.	*Polygonum* spp#	6.66	0.20	11.52
Plot 1: LM troop				
1.	*Pinus wallichiana#*	83.25	19.53	126.06
2.	*Alnus nepalensis*	33.3	3.99	46.00
3.	*Quercus semecarpifolia*	33.3	3.47	35.81
4.	*Taxus* spp	13.32	1.13	17.12
5.	*Betula utilis#*	16.65	0.97	15.43

6.	*Salix daltoniana#*	16.65	0.56	14.00
7.	*Cedar deodar*	3.33	0.03	11.92
8.	*Abies densa*	9.99	0.41	9.00
9.	*Acer species*	13.32	0.53	9.00
10.	*Ficus glaberrima*	6.66	0.09	7.01
11.	*Schima wallichii#*	6.66	0.10	7.00
	Plot 2: LM troop			
1.	*Pinus wallichiana#*	83.25	36.76	127.99
2.	*Alnus nepalensis*	33.3	3.99	41.58
3.	*Malus sieversii#*	39.96	5.36	39.61
4.	*Quercus semecarpifolia*	33.3	4.71	32.96
5.	*Abies densa*	16.65	3.77	20.40
6.	*Salix daltoniana#*	16.65	1.25	14.53
7.	*Ficus glaberrima*	13.32	0.09	9.72
8.	*Schima wallichii#*	6.66	0.10	7.07
9.	*Acer* sp	6.66	0.53	6.43

#Food plant

Table 6.2.5 Density (individual ha^{-1}), Basal area (m^2/ha) and Important value index of shrub species in plot 1 and plot 2 habitat of troops

SL. No.	**Plot 1: KZ troop**	Density	Basal area	IVI
1.	*Rhododendron arboreum#*	159.96	5.56	53.94
2.	*Viburnum cylindricum#*	93.31	5.79	44.33
3.	*Debregeasia longifolia#*	79.98	1.94	21.30
4.	*Leucosceptrum canum#*	53.32	1.51	20.04
5.	*Grewia* spp	79.98	0.36	16.83
6.	*Elaeagnus conferta#*	53.32	0.87	15.35
7.	*Daphne papyracea*	66.65	0.81	14.62
8.	*Vaccinium retusum*	66.65	0.38	14.15
9.	*Rubus ellipticus#*	79.98	0.09	13.94
10.	*Coriaria nepalensis*	53.32	0.55	13.80
11.	*Lindera neesiana*	53.32	0.59	12.36

12.	*Smyplocos species*	53.32	0.55	12.17
13.	*Myrisine sp*	66.65	0.56	11.86
14.	*Maesa parvifolia*	53.32	0.45	11.71
15.	*Mahonia nepalensis#*	39.99	0.15	9.05
16.	*Aralia sp*	26.66	0.08	4.38
17.	*Melastoma species*	13.33	0.19	3.71
18.	*Dehaasia sp*	13.33	0.16	3.53
19.	*Maesa indica*	13.33	0.03	2.92
Plot 2: KZ and KS				
1.	*Viburnum erubescens#*	93.24	1.01	56.67
2.	*Debraegesia longifolia#*	46.62	3.34	54.68
3.	*Elaeagnus umbrelata#*	73.26	2.49	54.30
4.	*Smyplocos species#*	33.30	2.95	43.18
5.	*Rubus ellipticus#*	53.28	0.32	30.87
6.	*Lyonia ovalifolia*	39.96	0.68	23.24
7.	*Coriaria nepalensis*	33.30	0.51	22.54
8.	*Zanthoxylum sp.*	19.98	0.55	14.61
Plot 1: KS				
1.	*Elaeagnus umbrelata#*	53.28	3.16	60.69
2.	*Rubus ellipticus#*	59.94	0.41	48.24
3.	*Viburnum erubescens#*	43.29	0.98	40.91
4.	*Debraegesia longifolia#*	29.97	1.87	38.93
5.	*Viburnum cylindricum#*	13.32	2.42	26.27
6.	*Coriaria nepalensis*	16.65	0.66	19.78
7.	*Leucosceptrum canum#*	13.32	1.19	17.24
8.	*Brassaiopsis hainla#*	3.33	1.87	16.73
9.	*Smyplocos sp*	16.65	0.38	16.04
10.	*Elaeagnus conferta#*	13.32	0.68	15.20
Plot 1: LM troop				
1.	*Leucosceptrum canum*	177.58	5.74	82.66
2.	*Elaeagnus conferta*	122.94	1.79	40.58
3.	*Elaeagnus umbellata*	109.28	2.04	37.88

4.	*Debregeasia longifolia*	54.64	3.39	33.96
5.	*Sorbus microphylla*	81.96	1.77	27.95
6.	*Gaultheria sp*	68.30	0.30	20.11
7.	*Viburnum erubescens*	54.64	0.40	16.57
8.	*Colebrookea oppositifolia*	40.98	0.85	15.00
9.	*Viburnum cylindricum*	40.98	0.84	14.96
10.	*Rubus ellipticus*	40.98	0.08	10.52
	Plot 2: LM troop			
1.	*Viburnum erubescens#*	93.24	1.01	56.67
2.	*Debregeasia longifolia#*	46.62	3.34	54.68
3.	*Elaeagnus umbellata#*	73.26	2.49	54.30
4.	*Smyplocos sp#*	33.30	2.95	43.18
5.	*Rubus ellipticus#*	53.28	0.32	30.87
6.	*Lyonia ovalifolia*	39.96	0.68	23.24
7.	*Coriaria nepalensis#*	33.30	0.51	22.54
8.	*Zanthoxylum sp.*	19.98	0.55	14.61

Food plant

Table 6.2.6 Density (individual ha^{-1}), Basal area (m^2/ha) and Important value index of herb species in plot 1 and plot 2 habitat of troops

SL. No.	**Plot 1: KZ**	Density	BA	IVI
1.	*Polygonum molle#*	491.76	0.87	65.04
2.	*Oenanthe javanica#*	669.34	0.13	44.02
3.	*Girardinia diversifolia*	532.74	0.14	36.59
4.	*Lecanthus peduncularis*	423.46	0.13	30.32
5.	*Boehmeria platyphylla*	355.16	0.17	25.05
6.	*Artemisia agri #*	259.54	0.24	24.45
7.	*Athyrium filix-femina#*	177.58	0.04	11.12
8.	*Arisaema ciliatum*	163.92	0.03	8.98
9.	*Heracleum nepalense*	136.60	0.03	8.49
10.	*Clerodendrum sp*	136.60	0.02	8.33
11.	*Hedychium gardnerianum #*	109.28	0.04	7.49

12.	*Ajuga lobata#*	122.94	0.00	6.29
13.	*Didymocarpus sp*	109.28	0.01	5.99
14.	*Anisomeles indica#*	95.62	0.00	4.61
15.	*Barbarea vulgaris*	81.96	0.01	4.50
16.	*Ligularia fischeri*	68.30	0.01	4.11
17.	*Anemone rupestris*	54.64	0.00	2.54
18.	*Oxalis species*	40.98	0.00	2.08
Plot 2: KZ and KS				
1.	*Polygonum molle #*	409.80	0.31	43.48
2.	*Carduus acanthoides#*	204.90	0.26	31.71
3.	*Cannabis sativa #*	273.20	0.10	22.15
4.	*Oenanthe javanica#*	409.80	0.04	21.81
5.	*Artemisia argyi#*	204.90	0.11	20.00
6.	*Colebrookea oppositifolia#*	136.60	0.07	15.47
7.	*Hedychium gardnerianum#*	81.96	0.12	14.52
8.	*Houttuynia cordata#*	177.58	0.02	12.97
9.	*Strobilanthes wallichii*	177.58	0.01	12.90
10.	*Sambucus adnata*	163.92	0.01	12.08
11.	*Athyrium sp#*	163.92	0.03	12.07
12.	*Anisomeles indica#*	136.60	0.07	11.96
13.	*Drymaria cordata#*	177.58	0.01	10.49
14.	*Crassocephalum crepidioides*	81.96	0.04	8.67
15.	*Persicaria polystachya#*	136.60	0.01	8.33
16.	*Wedelia chinensis*	109.28	0.01	7.34
17.	*Oxalis sp*	109.28	0.01	7.09
18.	*Hemiphragma heterophyllum*	122.94	0.02	7.07
19.	*Ajuga lobata*	95.62	0.01	6.34
20.	*Triumfetta sps*	54.64	0.01	4.97
21.	*Selinum Tenuifolium*	68.30	0.01	4.80
22.	*Heracleum nepalense*	54.64	0.01	3.66
Plot 1: KS troop				
1.	*Athyrium sp#*	177.58	1.82	94.21

2.	*Polygonum molle#*	396.14	0.22	37.28
3.	*Cannabis sativum#*	355.16	0.12	29.77
4.	*Oenanthe javanica#*	259.54	0.01	18.91
5.	*Artemisia argyi#*	204.90	0.04	17.99
6.	*Persicaria polystachya#*	136.60	0.02	12.14
7.	*Carduus acanthoides#*	81.96	0.01	11.62
8.	*Anisomeles indica#*	109.28	0.01	9.73
9.	*Colebrookea oppositifolia#*	122.94	0.01	9.55
10.	*Houttuynia cordata#*	109.28	0.01	9.51
11.	*Wedelia chinensis*	109.28	0.01	9.46
12.	*Drymaria cordata*	109.28	0.01	9.44
13.	*Oxalis species*	109.28	0.00	9.26
14.	*Hedychium spp*	95.62	0.01	7.48
15.	*Triumfetta sps*	40.98	0.00	5.70
16.	*Heracleum nepalense*	40.98	0.00	4.13
17.	*Hemiphragma heterophyllum*	54.64	0.00	3.82
Plot 1: LM				
1.	*Polygonum molle#*	173.29	1.18	81.33
2.	*Adiantum sp.*	133.30	0.33	40.32
3.	*Hedychium gardneriaum#*	93.31	0.16	20.85
4.	*Girardinia diversifolia*	79.98	0.14	17.55
5.	*Artemesia agryi#*	66.65	0.12	16.45
6.	*Potentilla species*	66.65	0.04	16.05
7.	*Oenanthe javanica#*	66.65	0.02	13.10
8.	*Rubus nepalensis#*	53.32	0.03	11.60
9.	*Arisaema erubescens*	66.65	0.00	10.44
10.	*Potentilla plurijuga*	53.32	0.01	9.31
11.	*Pilea umbrosa*	53.32	0.02	8.06
12.	*Jurinea sp*	39.99	0.01	7.93
13.	*Houttuynia cordata#*	53.32	0.01	7.89
14.	*Ranunculus species*	39.99	0.00	5.28
15.	*Aster thomsonii#*	26.66	0.00	5.00

16.	*Aster sikkimensis*	39.99	0.01	4.90
17.	*Athyrium filing-femina#*	26.66	0.01	4.29
18.	*Anisomeles indica#*	13.33	0.01	2.85
19.	*Rubus calycinus*	13.33	0.00	2.42
20.	*Gnaphalium affine*	13.33	0.00	2.41
21.	*Anemone rivulari*	13.33	0.00	2.37
22.	*Loinicera ligustrina*	13.33	0.00	2.18
23.	*Thalictrium foliolosum*	13.33	0.00	1.97
24.	*Ligularia fischeri*	13.33	0.00	1.96
25.	*Ageratum conyzoides*	13.33	0.00	1.84
26.	*Glossocardia bosvallia*	13.33	0.00	1.73
Plot 2: LM				
1.	*Hedychiums gardenium#*	53.28	0.16	72.90
2.	*Artemisia argyi#*	59.94	0.12	62.40
3.	*Athyrium filing-femina#*	106.56	0.01	52.62
4.	*Potentilla plurijuga*	93.24	0.01	34.00
5.	*potentiala spp#*	39.96	0.01	18.96
7.	*Rubus spp#*	33.30	0.00	15.22
8.	*Anisomeles indica#*	33.30	0.01	13.87
9.	*Rubus calycinus*	39.96	0.00	10.98
10.	*Anemone rivulari*	33.30	0.00	10.73
11.	*Houttuynia cordata#*	13.32	0.00	8.45

#Food plant

Table 6.2.7 The occurrence of food plants within home range (based on high intensity of range use) based on quadrat study

Sl./No.	**Name of the food plant**	**Presence/Absence in the high intensity used home range area (Plot 1 & 2)**			**Annual percentage contribution in the diet of *M. munzala****
		KZ	**KS**	**LM**	
Tree					
1.	*Betula utilis*	P	P	P	2.27
2.	*Magnolia sp.*	P	-	P	0.34
3.	*Ficus glaberrima*	P	-		0.55
4.	*Prunus cerasoides*	P	P		0.22
5.	*Quercus serrata*	P	-		2.29
6.	*Schima wallichii*	P	-	P	0.49
7.	*Albizia chinensis*	-	P	-	0.11
8.	*Erythrina arborescens*	P	P	-	14.92
9.	*Morus alba*	-	P		0.47
10.	*Toona sinensis*	-	P	-	0.10
11.	*Pinus wallichiana*	-	-	P	1.84
12.	*Quercus semecarpifolia*	-	-	P	1.07
13.	*Salix wallichiana*	-	-	P	0.38
Shrub					
1.	*Maesa indica*	P	P	-	0.04
2.	*Debregeasia longifolia*	P	-	P	2.79
3.	*Elaeagnus conferta*	P	P	P	0.27
4.	*Leucosceptrum canum*	P	P	P	12.46
5.	*Lindera neesiana*	P	-	-	0.11
6.	*Mahonia nepalensis*	P	-	-	0.34
7.	*Rhododendron arboreum*	P	-	-	0.32
8.	*Rubus ellipticus*	P	P	P	0.68
9.	*Viburnum cylindricum*	P	P	P	1.90
10.	*Brassaiopsis hainla*	-	P	-	0.13
11.	*Elaeagnus umbellata*	-	P	P	5.00

12.	*Symplocos dryophila*	-	P	-	0.07
13.	*Viburnum erubescens*	-	P	-	0.46
14.	*Gaultheria fragrantissima*	-	-	P	0.15
15.	*Colebrookea oppositifolia*	-	P	P	1.38
Herbs					
1.	*Polygonum molle*	P	P	P	10.60
2.	*Ajuga lobata*	P	P	-	0.22
3.	*Artemisia argyi*	P	P	P	0.98
4.	*Athyrium filix-femina*	P	P	P	0.57
5.	*Hedychium gardnerianum*	P	P	P	1.49
7.	*Oenanthe javanica*	P	P	P	5.30
8.	*Cannabis sativa*	P	P	P	0.43
9.	*Carduus acanthoides*	-	P	-	0.39
10.	*Crassocephalum crepidioides*	-	P	P	0.33
11.	*Drymaria cordata*	-	P	-	0.02
12.	*Hemiphragma heterophyllum*	-	P	-	0.05
13.	*Strobilanthes atropurpureus*	-	P	-	0.02
14.	*Triumfetta sp.*	-	P	-	0.08
15.	*Aster sikkimensis*	-	-	P	0.02
16.	*Rubus nepalensis*	-	-	P	0.07

6.2.12 Discussion

The home range size of *M. munzala* in the present study is comparatively larger than the area reported earlier by Kumar et al. [31] and Mendiratta et al. [21]. The home range of the species during the monsoon season was within 16 ha to 28 ha [31], whereas in pre-monsoon and winter season, the home range was reported to be 38.8 ha and 6.67 ha, respectively [21]. The larger home range in monsoon season may be due to more foraging options and the troops explore more area for their preferred nutritional requirements. Although, the availability of fruit in post-monsoon season increases and accordingly the home range size of *M. munzala* decreases, but the preference of quality food is yet to be studied as the fruit availability is very much localised in the study area. As per other studies, when the high quality food is available, primates reduce their home range and DPL (e.g., White-Bellied Spider Monkeys [37], *Cebus capucinus* [5]). But, at the same time, some study also reported dissimilar result showing increase in DPL and home range in search of high-quality food (e.g., *Macaca leonina* [2], *Gorilla beringei beringei* [28] and *Macaca munzala* [21]). Therefore, the availability and quality food plant can have different influence on home range size of the species. It is noteworthy to state that macaque and other primate species decreases their home range area and daily path length in presence of abundant fruit and increases, when availability of fruit decreases [2,5].

The result of the present study has shown that the distribution of preferred food plants is limiting the home range and daily path length of *Maccaca munzala* in the study area. The study troops were found to use areas with preferred food plant species in terms of both quality and quantity. The higher number of food plant species and the presence of preferred food plants affects ranging pattern in macaque species [2,3,19,21] and in other primate species as well [9,38,39]. In the present study, it is evident that high intensity used areas within home range of LM troop are in proximity to each other and probably due to this fact, the average DPL of LM troop is shorter than that of the other two study troops. The distribution of food plants within high intensity used areas has shown the presence of important food plants in terms of annual percentage contribution in the feeding of *M. munzala* and also signifies the reasons for higher percentage use of those areas. A similar study on Assamese macaque (*Macaca assamensis*) also confirmed the effects of preferred food plants on the size of home range and pattern of habitat utilization [3]. Moreover, the home range size and DPL of KS troop was larger owing to its presence in human dominated forest matrix and the latter is characterized by patchy distribution of food resources as well as scattered human settlement in and around. In particular, studies have reported larger home range and longer daily path length of primates in heavily altered habitat [2,12,13]. KZ troop had the highest ranging area in EHBLF habitat but used of highest intensity area (>2%) was found in DSF habitat. *Erythrina arborescens,* the highest contributor in the diet of KZ and KS troop and the species was found as dominant species in DSF habitat. Similarly, the major contributor *Leucosceptrum canum* of LM troop was found as dominant species in core habitat. Thus, distribution of principle food has significance influence in ranging behaviour of *M. munzala*. The forest types have very little to explain in terms of habitat use pattern, except the fact that those troops which use the DSF area are tend to have larger home range. It may be conceptualized as outcome of availability of foraging options as well as high effort required in search for nutritional quality food in the range area. However, no specific trend has been observed in the result. The present study found that troop, which inhabit in human dominated forest matrix (KS troop) are more involved in raiding, thus they had larger home range than other (KS troop). Thus, it indicates that uneven distribution of feeding resource in human modified landscape has greater influence in raging behaviour *M. munzala*. The uneven use of home range was recorded in crop raiding primates [40]. Moreover, larger home range has been reported in primates that use human dominated landscape and feed on anthropogenic food [13]. Nevertheless, there are some contradictory results on this work [41,42]. The effect of spatial extent of the three troops along with the distribution of quality food thus, can have significant role in determining home range size and DPL. The three study troops of *M. munzala* in the present study were larger in population size (KS-45, KZ-38, LM-33) and that may be attributed to larger home range (KS-149 ha, KZ-133 ha and LM-106 ha). Similarly, it has been found in larger group of Sulawesi Crested Black Macaque (*Macaca nigra*) that inhabit in disturb habitat has larger home range in compare to the small size group that range primary forest [7].

In conclusion, the ranging pattern of *M. munzala* is found to be influence by three major factors in the habitat viz., distribution of food plants, spatial extent of forest type and nutritional requirement of the species. The species enlarges its home range when there are enough foraging option including the ease of raiding (when human settlement are nearby) and that is read in terms of not using other forest type except DSF. Therefore, the troops in DSF that has no accessibility to other forest types have larger home range and daily path length. As *M. munzala* is the habitat generalist species, it is difficult to find out distinct relation between various habitat parameters and home range size. However, the present study explains a major part of the species' ranging behaviour. Furthermore, the study also emphasised that ranging behaviour of primates might have significance impact by particular food plant distribution having higher nutritional quality.

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6.3. Nutritional ecology of *Macaca munzala*

6.3.1 Introduction

The non-human primates feeding preference is explained through the availability of food resources using observational method, which is not enough to conclude selection process of diet [1,2]. Recent advances in nutritional ecology highlight the potentiality of this framework in explanations of feeding adaptation, social and reproductive behaviour and physiological evolution of primates [3–5]. The systematic understanding of niche in non-human primates needs more attention through the perspective of nutritional ecology. Primate's food plant selection based on the chemistry can be explained by the primary plant metabolites, it showed that crude protein-fibre ratio had significant influence in diet selection [6,7]. Additionally, the consumption of plant secondary metabolites considered as an antifeedant component which cause several health hazards to the animal. Further, plants used for self-medication by primates are reported to content higher amount of secondary metabolite compound [8]. Gastrointestinal physiology in primates has evolved in a certain way that it can digest high fibre content food and detoxify plant secondary compound [9]. Therefore, the critical understanding of diet selection behaviour of primates based on chemical basis needs to integrate secondary metabolite, minerals with primary metabolite. Primates' energy expenditure is reported to vary seasonally and it can be related to the cost benefit strategies in terms of energy expenditure and gain. However, the calorific assessment of primates' food has not been given significance priorities in interpretation of diet selection [10].

Globally, about 50% of natural habitat of primate has been destroyed by anthropogenic activity and the existing population mostly thrive in fragmented and secondary forest [11,12]. To cope up with the vegetation changes many of primate species are inclusively adopting non-native, exotic and invasive-alliance plant species in diet [13–15]. However, it is not clear that on what basis primates adopt new food plants; availability or nutritional quality?

The present study is a sincere attempt to understand the major food plant selection by *Macaca munzala* through the assessment of nutritive value (calorific value) in terms of crude protein, total carbohydrates, fats. Moreover, secondary metabolites (Saponin) and minerals (Ca, Fe, Mg, Mn and Zn) also has been assessed for further interpretation in the study. The present study hypothesised that higher nutritive value of plant has greater possibility of being adopted as a staple food by *M. munzala.*

6.3.2 Methods

6.3.3 Food plant selection

The study was conducted in the two troops of *M. munzala* namely; KZ troop inhabited in eastern Himalaya broadleaved forest and LM troop inhabited in mixed coniferous forest. The percentage contribution of food plants in diet data were taken from the Chapter 6.1 (Time activity pattern and feeding ecology). The major food plant material has been selected based on the seasonal contribution in diet. The different parts of similar food plant were considered as an independent sample and analysed separately (Table 6.3.1)

Food plant sample collection and preparation

Food Plant samples like leaf, petiole, stem, flower, fruit, seeds and bark were collected from the feeding plant of the habitat corresponding to the season. The collected samples were stored in a sealed plastic bag until transfer to the laboratory. Later on, sample were oven dried at 55^0 C for 4 hours and passed through 1 mm stainless sieve (grounded sample) for further analysis.

6.3.4 Nutritive value

Nutritive values of the food plant samples were estimated following Atwater and Woods, [16];

Nutritive value (kcal/g) = 4 × protein (%) + 9 × fat (%) + 4 × carbohydrate (%).

6.3.5 Crude protein

CHN analyser (PERKIN ALMER, USA, Model: 2400 SERIES 2) was used to estimate the Nitrogen (N) value from dry sample and used conversion factor to estimate the percentage of crude protein (N×6.25).

6.3.6 Total carbohydrate

Carbohydrates are the important components of the storage and structural materials in the plants. They exist as free sugars and polysaccharides and its basic units are the monosaccharide which cannot be split or broken down by hydrolysis into simpler sugars. The carbohydrate content can be measured by hydrolysing the polysaccharides into simple sugars by acid hydrolysis and estimating the resultant monosaccharides. To estimate the total carbohydrates Anthrone method was adopted and calculated using the following formula [17].

$$\text{Total Carbohydrates (\%)} = \frac{\text{mg of glucose}}{\text{Volume of test sample}} \times 100$$

6.3.7 Crude fat

Soxhlet extractor (petroleum ether) method was used to estimate the crude fat [18]. The crude fat is determined by the weight of fat recovered from an extract using petroleum ether as a solvent. The sample is contained in a porous thimble that allows the solvent to completely cover it. The thimble is contained in an extraction apparatus called soxhlet extractor that enables the solvent to be recycled over and over again up-to a required time. This extends the contact time between the solvent and the sample; allowing the fat content of the sample to be dissolved. The weight of the residue after the evaporation of solvent is crude fat. To calculate the percentage, following formula was used,

$$\text{Crude fat (\%)} = \frac{\text{weight fat}}{\text{weight of sample}} \times 100$$

6.3.8 Determination of saponin content:

For the determination of saponin percentage, 5gm of sample was weighed and dispersed in 100 ml of 20% ethanol. The suspension was heated for 4 hours in a hot water bath with continuous stirring at about 55^{o}C. Then the mixture was filtered and the residue was re-extracted with another 100 ml of 20% ethanol. Both the filtrates were mixed and reduced to 40 ml by heating in a hot water bath at about 90^{o} C. The concentrated filtrate was transferred to a 250 ml separating funnel where 20 ml of diethyl ether was added and shaken vigorously. The aqueous layer was recovered and ether layer formed above the aqueous layer was discarded, and this purification process was repeated. And then 30 ml of n-butanol was added and this combined mixture was washed twice with 10 ml of 5% aqueous sodium chloride. While the foam or soap like layer was recovered and heated in a hot water bath. After the evaporation, the remaining sample was dried in the oven to a constant weight, which is the saponin present in the sample. The percentage of saponin present in the plant sample was estimated by difference between the sample weight and the dried sample weight [19].

6.3.9 Determination of minerals (macro and micronutrients)

The method of ICP-OES was followed for the acid digestion. 0.5gm of dried sample was taken in digestion tube and 5ml of concentrated nitric acid (HNO_3) added in the tube than the mixture was heated at about 120ºC-130º C for 14-16 hours and cooled at room temperature. The mixture was treated with 5 ml of hydrogen peroxide and diluted to 50 ml with distilled water. Further, these samples were analyzed in ICP-OES to estimate the minerals content (Ca, Fe, Mg, Mn and Zn) [20].

6.3. 10 Statistical analysis

As a statistical tool, multivariate analysis allows the analysis of more than two variables simultaneously [21]. There are a large number of techniques under the umbrella term “multivariate analysis”, the suitability of the method to be applied depends on the need of the study. For the current study, principal components analysis (PCA) was applied as a means to reduce the data to independent components representing the greatest variances in the diet patterns of the two different populations (troops) of *Macaca munzala*. PCA as a tool has been previously used to study the food pattern of chimpanzees and bonobos [22, 23]. Varimax rotation was utilized, an orthogonal mode of rotation which projects the data into unrelated principal components (PCs) [21]. Prior standardization of the data was done using Z score method which involves subtracting the mean from each of the values of the parameters and dividing the result by the standard deviation.

6.3.11 Results

6.3.12 Major food plant

A total of 17 food plant were selected, of that 12 food plant are common for both of the troops. The bark of *Erythrina arborescens* contributed highest in the diet of KZ troop during the winter season; young leaf of *Quercus serrata* (19.85%) in pre-monsoon season, fruits of *Elaeagnus umbellate* (12.79%) in monsoon season and fruit of *Debregeasia longifolia* (13.88%) in post-monsoon season (Table 6.3.1). *Leucosceptrum canum* had the highest contribution in the diet of LM troop during the winter (Petiole and midrib, 29.15%); pre-monsoon (Young leaf, 22.96%) and monsoon (Young leaf 26.30%). The seed of *Pinus wallichiana* (15.85%) had the highest contribution during the post-monsoon season (Table 6.3.1).

Table 6.3.1 Seasonal contribution of selected food plants in the diet of LM and KZ troops

Sl. No.	FP	FM	Troop	Winter	Pre-monsoon	Monsoon	Post-monsoon
1.	*Artemisia argyi*	YL	KZ	-	1.75	-	-
			LM	-	3.83	-	-
2.	*Betula utilis*	YL	KZ	-	14.04	-	-
			LM	-	1.28	-	-
3.	*Debregeasia longifolia*	FR	KZ	-	-	-	13.88
			LM	-	-	-	11.46
4.	*Elaeagnus umbellata*	FR	KZ	-	-	12.79	-
			LM	-	-	13.77	-
5.	*Erythrina arborescens*	BK	KZ	19.85	-	-	-
		YL	KZ	-	7.02	11.14	-
		FL	KZ	-	-	3.99	-
6.	*Magnolia species*	MS	KZ	-	-	-	5.65
7.	*Hedera*	FR	KZ	-	12.28	-	-

	nepalensis		LM	-	14.29	-	-
8.	*Hedychium gardnerianum*	Rz	KZ	-	-	1.38	-
			LM	-	-	2.68	-
9.	*Leucosceptrum canum*	PTMD	KZ	13.15	2.11	3.03	3.76
			LM	29.15	-	3.22	5.85
		YL	KZ	-	2.11	-	-
			LM	-	22.96	26.3	-
10.	*Malus sieversii*	FR	LM	5.21	-	-	30
11.	*Oenanthe javanica*	YL	KZ	7.69	2.63	0.83	6.82
			LM	5.69	4.59	4.29	-
12.	*Pinus wallichiana*	SD	LM	13.27	-	-	15.85
13.	*Polygonum molle*	ST	KZ	9.18	7.02	3.03	8
			LM	13.51	8.42	8.23	4.15
		DFL	KZ	7.69	-	-	-
14.	*Prunus cerasoides*	FL	KZ	2.48	-	-	11.53
15.	*Quercus serrata*	YL	KZ	1.99	26.32	-	-
			LM	-	6.63	-	-
16.	*Secamone elliptica*	YL	KZ	8.19	7.719	4.4	6.35
			LM	-	-	7.16	4.88
17.	*Viburnum cylindricum*	FR	KZ	1.99	-	-	10.59
			LM	-	-	-	12.2

6.3.13 Nutritive value

Overall, the estimated mean nutritive value of food plant was 285.26 ±95.19 (mean ±SD), ranging between 116.35% to 454.03% (Fig. 6.3.1). The estimated highest nutritive value was recorded in leaf of *Secamone elliptica* (420.97 kcal/ 100 gm) gm) for KZ troop and seed of *Pinus wallichiana* for LM troop (454.03 kcal/ 100 gm) followed by fruit of *Hedera nepalensis* (405.15 kcal/ 100 gm) for both the troops. KZ troop feed on *Erythrina arborescens* throughout the year and estimated nutritive value for young leaf, flower and pith and bark were 338.67 kcal/100 gm, 310.19 kcal/100 gm and 221.89 kcal/100 gm, respectively. The lowest nutritive value was recorded in fruit of *Debregeasia longifolia* (116.35 89 kcal/100 gm) followed by *Pollygonum molle* (167.36 kcal/100 gm) for both KZ and LM troop (Table 6.3.2 and Fig. 6.3.2).

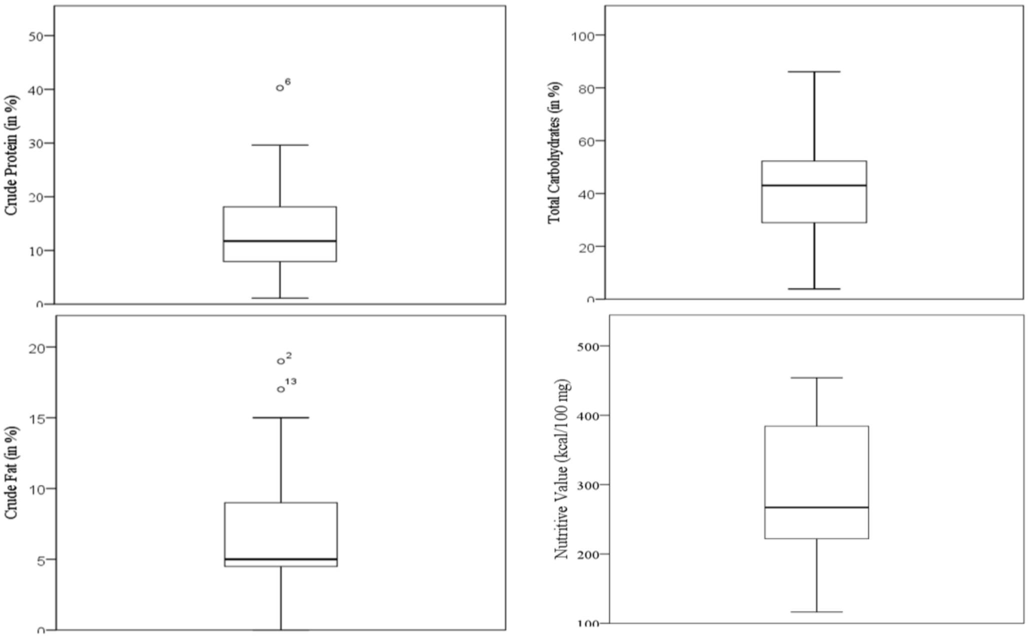

Figure 6.3.1. Overall nutritive value range of major food plant of studied groups

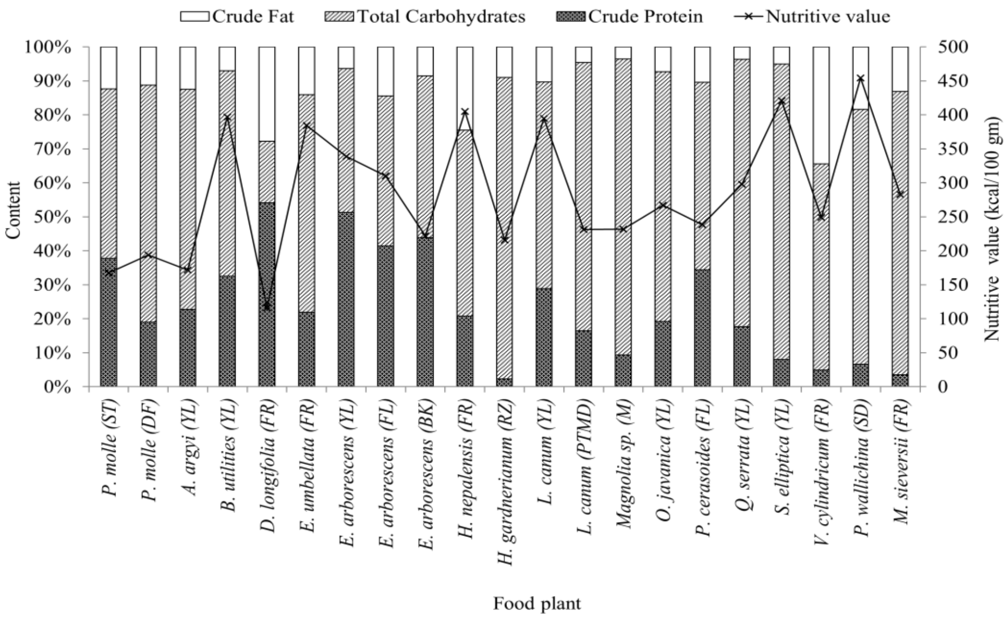

Figure 6.3.2. Mean nutritive value, crude protein, total carbohydrates and crude fibre content of selected food plants materials (ST, Stem; DF, Dry flower; YL, young leaf; FR, Fruit; FL, Flower; BK, Bark; RZ, Rhizome; PTMD (Petiole midrib), M, Mesocarp, SD, Seed)

Table 6.3.2 Nutritive value (crude protein, total carbohydrates, crude fat) and minerals of major food plants of studied troops (KZ and LM)

Sl. No.	Name of the food plant	Plant part	CP (%)	TC (%)	CF (%)	SAP (%)	NV (Kcal/ 100 gm)	Ca (ppm)	Fe (ppm)	Mg (ppm)	Mn (ppm)	Zn (ppm)	Troop	Season
1	*Artemisia argyi*	YL	8.43	24.08	4.62	14.5	171.71	136.9	2.57	28.04	1.81	1.08	KZ	PrM
2	*Betula utilis*	YL	29.62	55.11	6.45	11.94	396.98	71.64	2.35	38.99	1.59	0.51	KZ	PrM
3	*Debregeasia longifolia*	FR	11.69	3.9	6	13.6	116.35	108.3	2.26	51.16	0.57	0.08	KZ	PoM
4	*Elaeagnus umbellata*	FR	17.88	52.29	11.5	14.94	384.16	74.24	1.09	16.17	1.28	0.96	KZ	Mon
5	*Erythrina arborescens*	BK	20.5	22.22	4	10.48	221.9	4.82	0.4	1.68	0.02	0.9	KZ	Wn & PoM
		YL	40.25	33.17	5	15.13	338.67	74.24	1.095	16.17	1.28	0.96	KZ	PrM & Mon
		FL	27.19	28.98	9.5	20.42	310.19	122.7	1.521	16.82	0.42	0.92	KZ	Mon
6	*Magnolia sp*	MS	5.19	48.28	2	10.6	231.87	93.16	7.43	29.08	3.44	0.1	KZ	PoM
7	*Hedera nepalensis*	FR	16.12	42.47	18.98	8.16	405.15	26.28	0.53	19.97	0.21	0.37	KZ	PrM
8	*Hedychium gardnerianum*	Rz	1.13	43.03	4.35	11	215.74	63.2	1.62	20.64	0.18	1.6	KZ	Mon & PoM
9	*Leucosceptrum canum*	PTMD	9	43.24	2.5	9.8	231.45	116.9	1.38	17.41	0.45	0.06	KZ	PoM & Win
		YL	25.19	53.19	9	9.8	394.5	26.36	1.18	12.62	0.3	1	KZ	PrM & Mon
10	*Malus sieversii*	FR	2.13	50.63	8	21.8	283.04	73.96	4.2	33.22	0.75	0.1	LM	PoM & Win
11	*Oenanthe javanica*	YL	11.75	44.92	4.5	25.24	267.18	18.33	0.57	13.9	0.35	0.92	KZ	AS
													LM	PrM, Mon & PoM

12	*Pinus wallichiana*	SD	6.06	69.19	17	3.2	454.03	21.88	4.63	22.99	0.98	0.07	LM	PoM & Win
13	*Polygonum molle*	ST	13.69	18.03	4.5	7.31	167.36	47.55	1.315	20.6	1.49	0.68	KZ & LM	AS
		DFL	8.06	29.62	4.76	12.77	193.59	44.11	1.54	27.51	2.45	0.06	KZ & LM	PoM & Win
14	*Prunus cerasoides*	FL	18.13	29.12	5.5	13.28	238.47	51.95	1.55	27.83	1.46	0.08	KZ	PoM & Win
15	*Quercus serrata*	YL	12.56	56.03	2.63	12.58	297.98	21.51	1.75	29.74	0.53	0.53	LM	PrM
16	*Secamone elliptica*	YL	7.94	86.06	5	13.2	420.97	67.08	0.77	26.96	2.47	1.86	KZ	AS
													LM	Mon
17	*Viburnum cylindricum*	FR	2.13	26.43	15	8	249.21	48.14	2.10	65.14	4.01	0.09	KZ	PoM

PrM (Pre-monsoon); Mon (Monsoon); PoM (Post-Monsoon), Win (Winter); AS (All four seasons)

6.3.14 Crude protein

The estimated mean crude protein for food plant was 14.03% ±10.09 (mean ±SD), ranging from 2.13%-40.25% (Fig. 9.1). The highest protein content was recorded in the bark (20.50%) followed by young leaf (17.96% ±12.21), flower (17.79% ±9.56) and minimum was estimated in fruit (2.13 ±7.52%). Among the food plant of KZ troop; the highest protein content was recorded in *Erythrina arborescens*; (young leaf; 40.25%; flower, 27.19%; bark & pith, 20.5%) while young leaf (25.19%) of *Leucosceptrum canum* had the highest crude protein for LM troop (Table 6.3.2).

6.3.15 Total carbohydrates

The estimated mean total carbohydrate of food plants was 40.95 ±18.61 ranging from 3.90% to 86.08%. The estimated highest total carbohydrate was recorded in leaf of *Secamone elliptica* (86.06% ±1.25) for both the studied troops during the monsoon season followed by mesocarp of *Magnolia spp*. (48.28 ±5.20) for KZ troop and seeds of *Pinus wallichina* (69.19% ±2.69) for LM troop (Table 6.3.2)

6.3.16 Crude fat

The estimated mean crude fat was 7.18% ± 4.76 ranging from 2.00% to 18.98% (Fig. 6.3.1). The highest fat content was found in the fruit of *Hedera nepalensis* (18.98% ±1.48) for the troops during the pre-monsoon season. For dry post-monsoon and winter season, the highest fat content was recorded in fruit of *Viburnum cylindricum* (15% ±2.07) for KZ troop and seeds of *Pinus wallichina* (17% ±1.05) for LM troop (Table 6.3.2).

6.3.17 Saponin

The mean saponin content of food plants of troops was 12.69 ±5.51 (range, 3.20%-25.24%). Among the food plant; young leaf of *Oenanthe javanica* had the highest saponin content among the food plants of troops followed by flower of *E. arborescens* (20.42%) for KZ troop and fruit of *Elaeagnus umbellata* (14.94%) for LM troop (Table 6.3.2).

6.3.18 Minerals

The highest concentration of Ca was recorded in young leaf of *Artemisia argyi* (136.9 ppm) followed by flower of *Erythrina arborescens* (122.7 ppm); Fe was highest in *Artemisia argyi* (2.58 ppm) followed by young leaf of *Betula utilis* (2.36 ppm), Mg on the other hand was highest in fruit of *Viburnum cylindricum* (65.14 ppm) followed by the fruit of *Debregeasia longifolia* (51.16 ppm), Mn in fruit of *Elaeagnus umbellata* (4.82 ppm) recorded highest followed by mesocarp of *Magnolia* spp (3.44 ppm), while highest levels of Zn were found in young leaf of *Secamone elliptica* (1.86 ppm) followed by stem of *Hedychium gardnerianum* (1.6 ppm) (Table 6.3.2).

6.3. 19 Discussion

6.3.20 Broad leaf forest troop (KZ troop)

Seasonal changes bring the change in the availability of primate food species and also variation in nutritional content of the same species. PCA enabled us to examine this trend to a great extent in the two troops of *Macaca munzala*. A general examination of the food plants for the two troops revealed that, the broad leaved troop inhabitant in forest i.e., EHBLF had access to a larger variety of food plants (Table. 6.3.1). This was particularly true because of the greater variety of vegetation in the broad leaved forest compared to the mixed coniferous forest inhabitant by LM troop. Another important factor was the exposure of the KZ troop to human settlement. *E. arborescens* is used mainly as a hedge plant in home garden to protect crops from animal threat, but this plant has emerged as the primary food source for the KZ troop. Proximity to the human settlement could be one of the factor which influenced the use of *Erythrina arborescens* as the dominant food plant in KZ troop. It is likely that *E. arborescens* is concentrated in a confined locality near the human settlement making it possible for this population to have an easy access to this plant. During the pre-monsoon young leaves (YL) of *E. arborescens* provide a bulk of (crude) protein and also the (total) carbohydrate. However, the crude fat content of the *E. arborescens* leaves is much lower than the fruits (FR) of *Hedera nepalensis*. PCA provides a much better clarity in this regard. PCA yielded three principal components which explained a very high 91.6 %

variance in the pre-monsoon season for the KZ troops (Table 6.3.3). The dominant component, PC2 is governed by Total carbohydrate, nutritive value, Ca, Fe, Mg, Mn and Zn. The second PC has high loadings due to saponin and in the third component PC3, the only loading is due to crude protein.

The result of PCA of KZ troop explained some interesting trends, first of all the dominance of young leaves (YL) of *E. arborescens* as a food plant is due to its high content of total carbohydrate, nutritive value and crude proteins. The plant has also the highest content of calcium, and relatively high amounts of Zn. The second major observation is that *E. arborescens* (YL) has a high saponin content, as saponin is a toxic compound, it is likely that this population of *M. munzala* has developed a resistance to the elevated saponin content in *E. arborescens* (YL). Although fruits (FR) of *Hedera nepalensis* are an important source of total carbohydrates, it has comparatively lower crude protein content. Also, *H. nepalensis* is a highly seasonal plant which is not available in any other season apart except during pre-monsoon.

The number of available food plant species varied across the season; however, *E. arborescens* (YL) still remains a choice of food plant of choice among the troops of *M. munzala* all throughout the season as observed from the percentage contribution (Table. 6.3.1). Flowers (FL) of *E. arborescens* also contain high concentrations of total carbohydrates and crude proteins, yet it contributes very less to the total nutrition as they are limited in number and quickly develop into fruits. The results of the PCA reveal that TC, NV, Mn, Zn and Mg continue to remain the most important nutritional requirements of this population as these variables are represented in PC1 (Table. 6.3.3 B). The second component, PC2 has high loadings from Ca and Fe, as Ca content is the highest in *E. arborescens* along with high levels of TC, therefore it remains the most important plant in the monsoon season as well. Principal component 3 reveals that crude protein and crude fat are also very important in their dietary requirement. *E. arborescens* (YL) has a high CP content, however, *E. arborescens* (FL) and fruits (FR) of *Elaeagnus umbellata* are the next important food plants based on their CP content. The fruits of *E. umbellata* are very high in crude fats, which explains its high percentage contribution in the diet.

Table 6.3.3 Principal component analysis of KZ troop food plant

Season	**A. Pre- monsoon**					**B. Monsoon season**			**C. Post-monsoon**			**D. Winter**		
Component	PC1	PC2	PC3	PC4	PC5	PC1	PC2	PC3	PC1	PC2	PC3	PC1	PC2	PC3
CP	-.064	.036	-.006	-.038	.982	-.250	-.012	.821	-.362	-.510	-.494	-.287	-.368	-.713
TC	.080	.971	.050	.104	-.158	.923	-.163	-.219	.972	-.067	.164	.858	.240	.433
CF	-.227	.161	-.389	-.779	.082	.044	.029	.771	-.122	.925	-.309	.201	.731	-.639
NV	-.068	.872	-.141	-.291	.337	.741	-.157	.646	.926	.120	-.127	.909	.210	.211
SAP	-.020	.031	-.252	.838	-.001	-.341	-.768	.329	.248	-.293	-.354	.493	-.043	-.297
Ca	.829	-.314	.304	-.030	.120	-.154	.870	.306	-.089	-.007	.822	-.138	.144	.943
Fe	.235	-.344	.843	.039	.121	-.361	.855	-.078	-.067	.126	.846	-.700	.588	.379
Mg	.142	.180	.938	-.070	-.106	.875	.282	-.301	-.225	.867	.246	-.045	.939	.301
Mn	.886	.101	.325	.052	-.101	.905	-.071	.318	.195	.764	.378	.120	.930	.150
Zn	.751	.379	-.289	.325	-.232	.708	-.196	-.120	.738	-.228	-.343	.901	-.024	-.132
% variance	21.77	43.13	64.23	79.46	91.60	38.20	60.72	82.22	26.55	52.80	74.99	32.67	61.55	85.56

Crude protein (CP); Total carbohydrates (TC), Crude fat (CF), Nutritive value (NV), Saponin (SAP)

The greatest diversity and therefore, the choice of food was observed in the post-monsoon season (Table. 6.4.3 C). PCA resulted in three principal components with 75% variance. Here PC1 and PC2 appear to be equally important as the percentage variance of both these components are similar. Total carbohydrate, NV from PC1 and CF, Mg and Mn from PC2 explained most of the variance (Table. 6.3.3 C). Flowers (FL) of *Prunus cerasoides* and fruit (FR) of *Viburnum cylindricum* (FR) emerge as more dominant food plants mainly due to their high Total carbohydrate content, *V. cylindricum* with the highest crude fat content compared to all other plants also has very low saponin levels (Table. 6.3.3 C) which could play an important role in its dominance. A very important observation is that as the winter months' approach crude fats emerge as much more important than crude protein, as crude protein was not represented in any of the PCs. High crude fat content of fruits compared to leaves or bark is another important reason for the relative high percentage contribution of *V. cylindricum*. Crude protein is not represented in any of the principal components, yet it cannot be established that it is completed unnecessary during post-monsoon. However, compared to pre-monsoon and monsoon, it becomes relatively less important. The last component, PC3 is represented by Ca and Fe, which are obtained mostly from *P. cerasoides* (FL) and *V. cylindricum* (FR).

During the winter season, three PC represent a variance of 85.6% (Table. 6.4.3 D). Majority of the variance in PC1 is explained by TC, NV and Zn, which are contributed mainly by bark of *E. arborescens* and petiole and midrib (PTMD) of *Leucosceptrum canum*; Young Leaves (YL) of *Oenanthe javanica* has a high total carbohydrate content, yet high saponin content of this species could be a factor resulting in its avoidance as observed from the low percentage contribution. Another important food plant species is *Secamone elliptica* mainly because of its high total carbohydrate content. The second PC has positive loading due to CF, Mg and Mn, thus from post-monsoon season to winter crude fat overtakes crude protein as the second most important macro nutrient. Most of the crude fat content in the food of the primates is met by *E. arborescens* (BK), *O. javanica* (YL), *P. molle* (ST) and *Secamone elliptica* (YL). As the saponin content of *P. molle* (ST) is the lowest, it could be one of the most important sources of crude fats in the diet of the macaques. Calcium alone is represented in the last component PC3.

6.3.21 Mixed coniferous troop (LM troop)

The food plants on the diet of the mixed coniferous (LM) troop is different from KZ troop. Absence of anthropogenic influence was one of the key highlights in this group. The food variety was also found to be limited compared to the habitat of the KZ troop (Table. 6.3.1). PCA of the pre-monsoon data produced two principal components which explained 88.3% of the variance (Table. 6.3.4 A). The first component PC1 is represented mostly by CF, Fe and Zn, while the PC2 is represented by Ca, Mg and Mn has positive loadings. The result was found to be inconclusive to some extent as none of the two PCs had representation from total carbohydrates. This was observed in fruits of *Hedera nepalensis* which formed one of the most important food species of this troop and was found to have a very high crude fat content. Based on the percentage contribution, *Leucosceptrum canum* (YL) was the most important food plant which had the highest content of crude carbohydrate (Table. 6.3.1), showing that carbohydrate was still the dominant macro nutrient for this troop.

For the monsoon data PCA resulted in four components explaining 93% of the variance (Table. 6.3.4 B). Carbohydrate remain the most important part of the diet during the monsoon season, it was observed that PC1 has positive loadings from TC, Ca, Mg, Mn and Zn. High crude carbohydrate content of *Leucosceptrum canum* (YL) and *Elaeagnus umbellata* (FR) qualify as the primary food plants for the primates. *Elaeagnus umbellata* (FR) also has a very high Ca content along with high Mg content. These two plants, especially *Elaeagnus umbellata* (FR) are also well represented in PC2 due to their high crude fat content. Strong representation of Fe indicates that *Pollygonum molle* (ST) along with *Leucosceptrum canum* (YL) and *Elaeagnus umbellata* (FR) emerge as the main sources of Fe as all three of these plant parts had the high levels of Fe. In principal component 3, weak positive loadings were observed due to CF and TC, while NV has a stronger presence.

Table 6.3.4 Principal component analysis of LM troop food plants

Season	A. Pre-monsoon		B. Monsoon			C. Post-monsoon				D. Winter		
Component	PC1	PC2	PC1	PC2	PC3	PC1	PC2	PC3	PC4	PC1	PC2	PC3
CP	.542	-.791	-.832	.133	.494	-.689	-.545	.381	.049	-.586	-.782	.206
TC	-.883	-.330	.323	.890	-.272	.844	-.368	-.095	.289	.943	.133	-.291
CF	.792	-.583	-.548	.560	.505	.621	.470	.467	.324	.955	-.061	.280
NV	-.928	-.037	-.059	.992	.010	.853	-.179	.225	.402	.997	-.052	-.043
SAP	-.738	.206	-.208	.072	-.895	-.077	-.174	-.582	-.175	-.271	.927	-.180
Ca	-.053	.890	.573	.439	.492	-.195	-.005	.022	-.931	-.427	.128	-.895
Fe	.834	-.515	-.152	-.250	.951	.834	.107	.354	-.191	.899	.352	.040
Mg	-.308	.944	.984	.131	.094	-.049	.894	.250	-.254	.164	.920	.327
Mn	.154	.940	.937	.243	.233	-.139	.792	.360	.343	-.368	.080	.829

Zn	.789	-.577	.608	.709	-.241	-.146	-.197	-.789	.350	-.462	-.477	.364
% of variance	45.44	88.29	37.09	66.56	92.99	30.85	52.76	69.78	85.70	45.78	72.95	92.63

Crude protein (CP); Total carbohydrates (TC), Crude fat (CF), Nutritive value (NV), Saponin (SAP)

The data sets for post-monsoon and winter reveal the pre-dominance of the first two principal components during these seasons (Table. 6.3.4 C & D). With 85.7% variance, the post-monsoon season presented with four PCs (Table. 6.3.4 C). The first PC is represented by carbohydrate and fat consumption; Iron and nutritional value also project positive loadings on PC1. Closer observation of the post-monsoon data revealed that these nutrients are mostly met from four plant species, *Pinus wallichina* (SD), *Malus sieversii* (FR), *Leucosceptrum canum* (PTMD) and *Viburnum cylindricum* (FR). *Malus sieversii* (FR) has a high saponin content (Table. 6.3.2) compared to the other three plants yet contributes a significant percentage to the overall nutrition of this population in post-monsoon. Therefore, this troop could also be resistant to the effects of saponin to some extent. Another similarity with the broad leaf forest troop is that the consumption of fat becomes a higher priority towards winter. PC3 and PC4 do not have clear representation of any nutrient in particular (Table. 6.3.4 C).

During the winter, PCA is explained by three principal components with 92.63% variance (Table. 6.3.4 D). The importance of crude fats becomes much higher in winter as it along with total carbohydrates impart high positive loadings on PC1. Predominance of crude fats in diet could be a strategy to meet energy requirement during harsh winter conditions in the both troops inhabited in broad leaf forest and mixed coniferous forest. *Pinus wallichiana* (SD), *Malus sieversii* (FR), *Leucosceptrum canum* (PT MD) and *Pollogonum molle* (ST) are important food plants in the winter season. The high saponin content, *Malus sieversii* (FR) also exhibit in the diet during this season as the saponin loading on PC2 is very high. The high levels of carbohydrates and Mg; and moderate levels of crude fats in *Malus sieversii* (FR) could be the reason behind this choice. It also shows that like the KZ troop, this troop could also have some sort of resistance against saponin. PC3 is not represented by any of the nutrients clearly and remain inconclusive.

Crude fat consumption in both the troops increases as the season progresses from pre-monsoon to winter as it could be an evolutionary adaptation to cope against the cold and limited food supply during the winters. Earlier studies [7] also suggest that young leaves have higher percentage of crude protein as towards maturation crude protein content decreases. This could be a very important factor contributing to the dominance of crude fats during winter, as young leaves are replaced by older leaves, bark, seeds and fruit. Young leaves were found to be almost selectively consumed in mass amounts by both population during the pre-monsoon and monsoon seasons. Even during the post-monsoon and winter seasons, the selection of food was found to be on the crude protein content in both troops even though its prominence was masked by crude fat during the multivariate statistical analyses. The importance of proteins can be properly observed in the diet of the KZ troop, as the bulk of the food consumed consisted of different parts of *Erythrina arborescens*. Despite the high concentration of saponin, a toxic substance, *E. arbosrecens* was the most preferred food in the KZ troop. This observation also suggests that the population could be tolerant of saponin to some extent. Likewise, LM troop could also display resistance to saponin as one of the main food item on its menu during winter was the fruit of *Malus sieversii* which has a high saponin content (Table. 6.3.2). Because of the abundance of *E. arbosrecens* around the year and having rich nutritional quality, it has emerged as the "common species/staple food" for KZ troop. On the other hand, *Prunus cerasoides* which gives flowers during the post-monsoon serve as a preferred food during this season, as its flowers are high in crude protein and total carbohydrate. In case of the LM troop, young leaves of *Leucosceptrum canum* and seeds of *Pinus wallichiana* are the "common food/staple food" because of their abundance, and high total carbohydrate and crude protein content. The findings of present study suggest that primate might avoid the consequence of saponin, if nutritional benefit is high [23–25].

Conclusion

A common factor in the selection of the food plants is the nutritive value (NV), the plants which constituted the major portion of the menu had high NV, not only were these plants rich in carbohydrates, fats and proteins, but also had higher levels of Ca, Mg and Mn. Although, the two troops differ in the fact that the broad leaf forest group (KZ troop) is more exposed to humans compared to the group in mixed coniferous forest (LM troop), but both the troops adopt a food plant as a staple food; which has higher nutritive value, protein content and available across the year to feed on.

6.3.22 Reference

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6.4. Acoustic characterization of *Macaca munzala* alarm call

6.4.1 Introduction

Vocalization in primate (including human) is a process of cognitive function [1–4]. Primate vocalization has been given significant interest from the early period of research in terms evolution of "speech" [5–11]. The different functional aspect of vocalization of primate has been studied in terms of vocal learning hypothesis, social context of vocalization, male-male competition hypothesis, body size correlation, caller identity, species identification [12–15]. Based on signal, primate vocalization has been given several name such as, "Travel calls" [16], "Food calls" [17], "Loud call" [18,19], "Copulation call" [20] and "Alarm call" [21]. The quantitative classification of vocal repertoire has been given importance in primate vocalization [19,22–25]. Bioacoustics method has been extensively followed to quantify fundamental frequency, intensity and formant structure in primate [19,26,27].

Primate produce distinct vocalization (alarm call and loud call) in presence of potential predatory threat. In group living primates, alarms calls are also function as a signal to alert other member. It has been found that primate have different acoustically distinct alarm call to refer different predator type [28,29]. The referential alarm call has been reported in both new and old world monkey [12,29,30]. Vervet monkey (*Chlorocebus pygerythrus*) alarm call in response to Leopards, Eagles, and Snakes has been reported as a distinctly differ [31]. Casar et al. [28] found that alarm call in Titi monkey (*Callicebus nigrifrons*) is a signal of predator type and location. Male blue monkey (*Cercopithecus mitis*) alarm call was reported as predator specific and acoustically differ [32]. Similarly, alarm call in titi monkeys (*Callicebus nigrifrons*), Vervet monkeys (*Chlorocebus pygerythrus*) [31,33,34] has been reported predator specific. Srivathsan and Meier [35] reported high pitch sound associated with alarm call of Proboscis monkeys (*Nasalis larvatus*). On that contrary," Loud calls" of primate reported to have relatively low frequency sound [Mitani, and Stuht, 1998]. In case of macaque, alarm call reported as a threat perspective rather than predator type [Fischer, and Hammerschmidt, 2001; Coss et al., 2007]. Rhesus macaque *(Macaca mulata*), Japanese macaque (*Macaca fusucata*) and Tibetan macaque (*Macaca thibetana*) produces "Coo" call that related to threat and group cohesion [22,36]. Owen and Casale [37] reported that fundamental frequency of peak position in *"*Coo" calls of *M. fusucata'*s varied more consistently between animal than the behavioural context. Recent study on White cheeked macaque (*Macaca leucogenys*) and Assamese macaque (*Macaca assamensis*) was reported that fundamental frequency of alarm call significantly differs between the species [38]. Moreover, calls of similar species was found differs acoustically under the influence of habitat type, geographical and age/sex variation [39–42].

The vocal repertories and its function in Arunachal macaque (*Macaca munzala*) is significantly unknown. There are circumstantial report of distinct alarm call in *M. munzala* but details spectral characteristics yet to be study [43]. Thus, present study has given emphasised to investigate different vocalization of the *Macaca munzala* and detail acoustic analysis of a distinct call of the species.

6.4.2 Methods

The study was conducted in Zemithang Pangchen valley during the behaviour study. The different vocalization with behavioural aspect were studied using Ad libitum sampling. During the vocalization, details of event and caller identity (Age/Sex) were noted upon occurrence. Among different vocalization only a type of loud call could able to recorded in the present study and further detail acoustic analysis has been done on that specific calls.

6.4.3 Sound sampling

The studied call was found as a distinct than any other vocalization of *M. munzala* in terms of loudness. A total of 20 (twenty) similar type of alerm calls has been recorded, of that 7 calls has been selected for detail acoustic analysis (Fig. 6.4.1). The calls were recorded from a distance of ~10 m from the callers using Sony ICD-PX470 sound recorder. The selected calls were converted to .wav format and digitized with 44.1 kHz with a sample size of 16 bits prior to study [38].

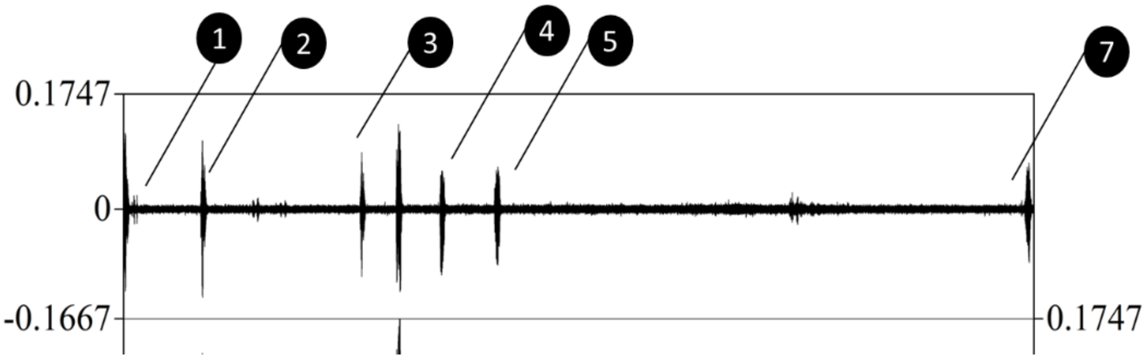


Figure 6.4.1 Studied alarm call of adult male *Macaca munzala* recorded during the “Dog” enter to the ranging ground

6.4.4 Spectrogram analysis

PRAAT software was extensively used for quantification of pitch, intensity and formant of calls (www.fon.hum.uva.nl) in the view range of 0.0-5000 Hz; window length of 0.002 sec and dynamic range of 30 db.

6.4.5 Spectral moment

The first spectral moment or spectral centre of gravity is associated with highest energy concentration [44]. For the study of spectral characteristics, a segment of 30 ms alert calls that associated with high energy was selected. The 30 ms segment was resample to 16 kHz and normalized with maximum of absolute value of the signal (Fig. 6.4.2)

The call was multiplied with a Hamming window to compensate the edge effect while taking the Fourier Transform on the signal. Fast Fourier Transform (FFT) was computed with 512-points and linear prediction (LP) analysis has done to obtain smooth spectral envelope (Order; fs/1000 + 4, i.e. 20). The linear prediction was found to overlapped with Fourier spectrum (Fig. 10.4.C). Further, call signals were short-term processed by the 20 ms Hamming window with the step of 10 ms. For each short-term processed speech segment, 512-points FFT was computed, and normalized power spectrum across discrete frequency samples were considered to calculate the spectral moments. The power spectrum was normalized as follows [45]:

$$P(f_k) = \frac{p(f_k)}{\sum_{k=0}^{N/2} p(f_k)}$$

Where, $P(f_k)$= Power spectrum; f_k=fsk/N, k=0, 1; N=512 and fs=sampling frequency (16 kHz).

The mean (M1), standard deviation (M2), skewness (M3) and kurtosis (M4) and can be calculate as follows;

Mean (M1): $\mu = \sum_{k=0}^{N/2} P(f_k) f_k$

Standard deviation (M2): $\sigma = \sqrt{\sum_{k=0}^{N/2} (f_k - \mu)^2 P f_k}$

Skewness (M3) $= \sum_{K=0}^{N/2} \left(\frac{f_k - \mu}{\sigma}\right)^3 P(f_k)$

Kurtosis (M4) $= 3 + \sum_{k=0}^{N/2} (\frac{f_k - \mu}{\sigma}).^4$

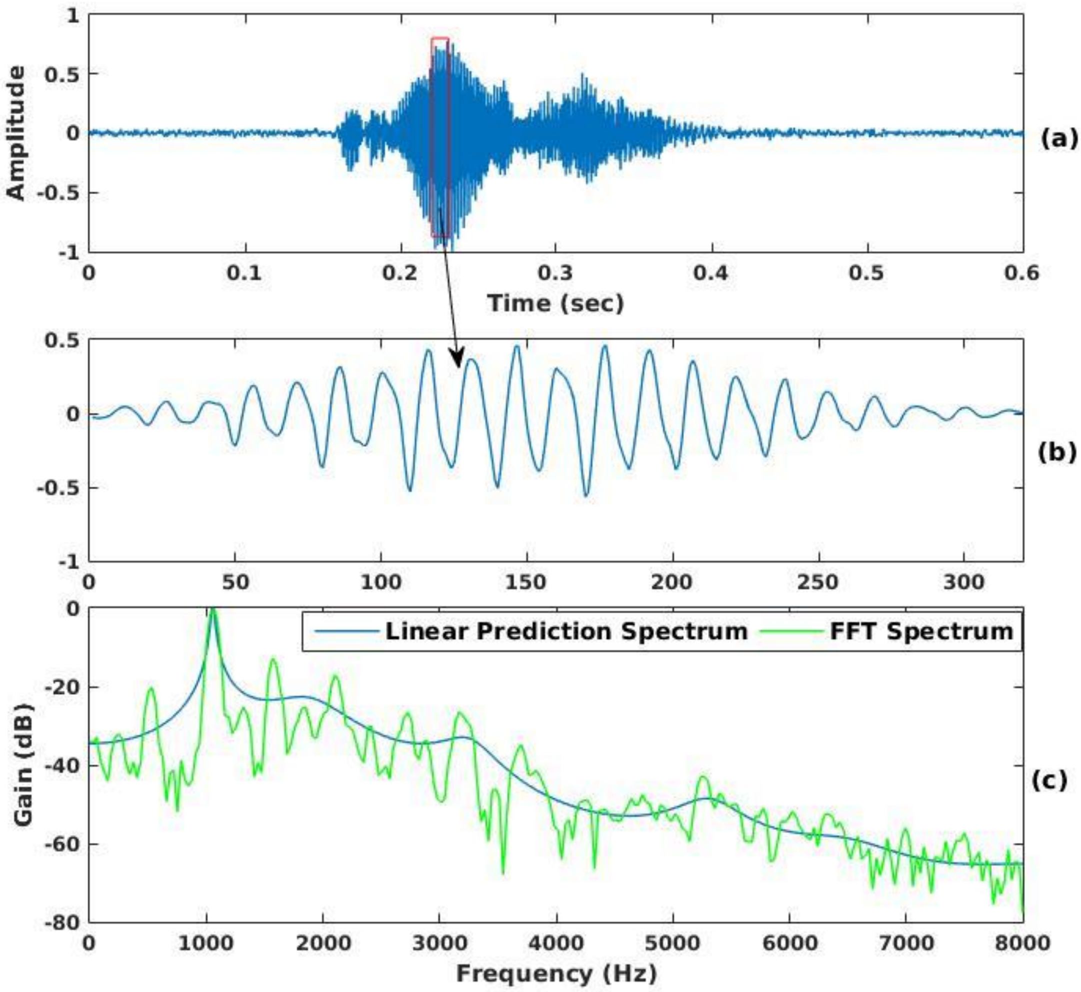


Figure 6.4.2. Spectral characteristics of alarm call for 30 ms segment. (a) A waveform of the call, (b) Hamming windowed 30 ms call segment, and (c) Linear prediction and Fourier spectrum of the 30 ms call segment.

6.4.6 Data analysis

Analysis of Variance (ANOVA) was perform to study the difference in pitch, intensity and formant among studied calls. Significance was set at 95% confidence interval i.e. $p<0.05$ for all statistical tests. Variations were given around the mean for all results and standard deviation was presented with mean statistics i.e. mean ± S.D. Statistical analyses were performed in SPSS package.

6.4.7 Result

6.4.8 Vocalization behaviour

The present study has recognized different type of vocalization of *M. munzla* that differs according to the event such as; aggression and dominance exhibition, quarrel, copulation, social communication, dispersion and presence of potential threat around. Of that, most distinct call of the *Macaca munzala* was utter in presence of disturbance such as "dog" or human presence. The bout of calls was found very short and repeating. The repetition of call was very frequent with increasing gradation of threat, for e.g. "Dog" approach to the troop ranging area. The loudness of call was increase with increase of degree of threat. Further, calls were found using as a signal for communication, when troop disperse in large area or separated from troop (Fig. 6.4.3 and Fig. 6.4.4).

Figure 6.4.3 Alert call utter by an adult male, when other troop member involves in raiding near human settlement area

Figure 6.4.4. Alarm call utter by adult in forested area in presence of human near troop (Photographs captured from recorded video)

6.4.9 Frequency (Pitch) and Intensity

The mean time of calls was found 0.25 ±0.03 and ranges from 0.21 sec to 0.30 sec (Table 6.4.1). The mean pitch of calls was found 346.22±66.15 Hz that ranges from 238.14 to 495.77 Hz (Table 6.4.1 and Fig. 6.4.5). The calls were not found significantly differ in terms of pitch (N=141; df=6, F=0.24, $p>0.05$).

Table 6.4.1. Pitch of studied "Alarm calls" of *M. munzala*

Pitch (HZ)	Mean ±SD	Minimum	Maximum	Time (sec)
Call 1	352.21±55.16	258.68	475.47	0.26
Call 2	332.33±71.45	252.91	495.77	0.21
Call 3	366.79±57.22	280.24	487.59	0.22
Call 4	360.77±36.86	303.53	467.88	0.26
Call 5	317.69±76.20	238.14	486.91	0.23
Call 6	341.47±87.03	252.35	490.39	0.25
Call 7	350.55±69.06	272.01	485.75	0.30
Mean ±SD	346.22±66.15	265.41±21.73	484.25±9.45	0.25±0.03

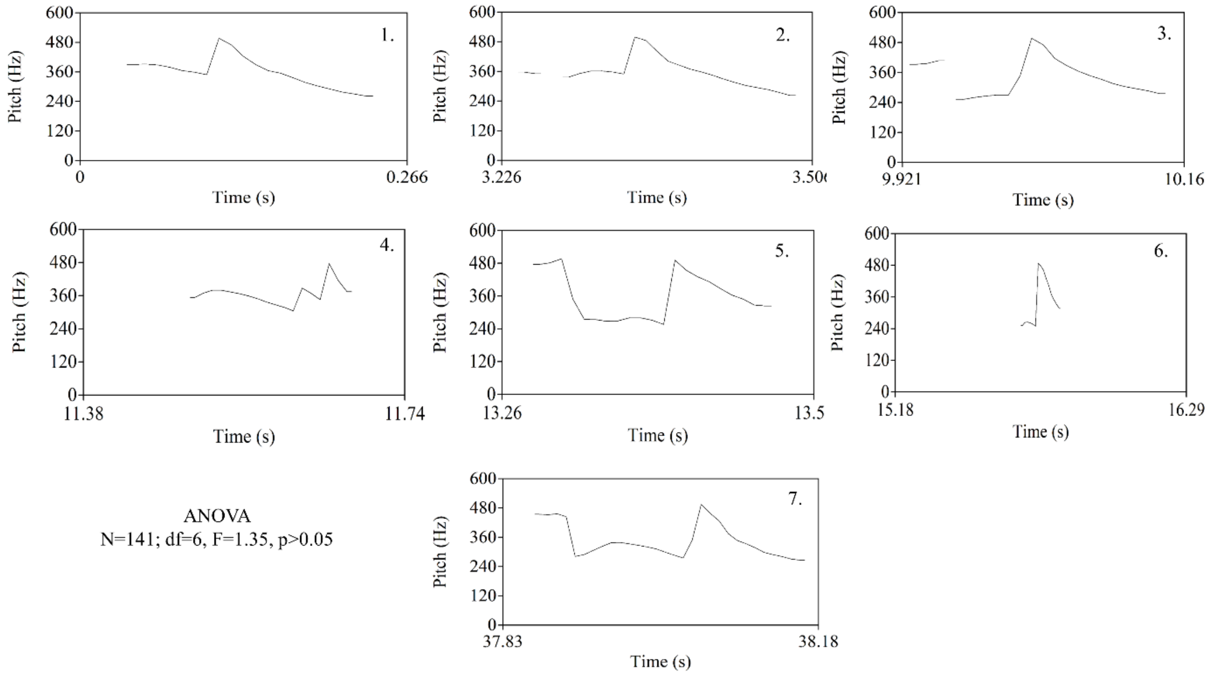


Figure 6.4.5 Pitch contour of studied alarm calls of adult *M. munzala*

The mean of calls intensity was found 60.34 (dB) ±6.79 and range from 43.01 dB-71.32dB (Table 6.4.2 and Fig. 6.4.6). The present study found that intensity was significantly differs among the calls (N=162, F=2.68, p<0.05).

Table 6.4.2. Intensity of alarm call of *M. munzala;* F statistics of ANOVA

Intensity	Mean (dB)	Std. Deviation	Minimum	Maximum
Call 1	60.16	8.40	43.01	70.76
Call 2	60.41	6.81	45.89	70.26
Call 3	58.16	5.23	47.85	66.20
Call 4	64.34	7.26	43.59	71.32
Call 5	61.31	5.64	48.28	67.22
Call 6	60.27	4.77	49.97	65.91
Call 7	57.87	7.12	44.39	66.88
Total mean	60.34	6.79	43.01	71.32

N=162, F=2.68, p<0.05

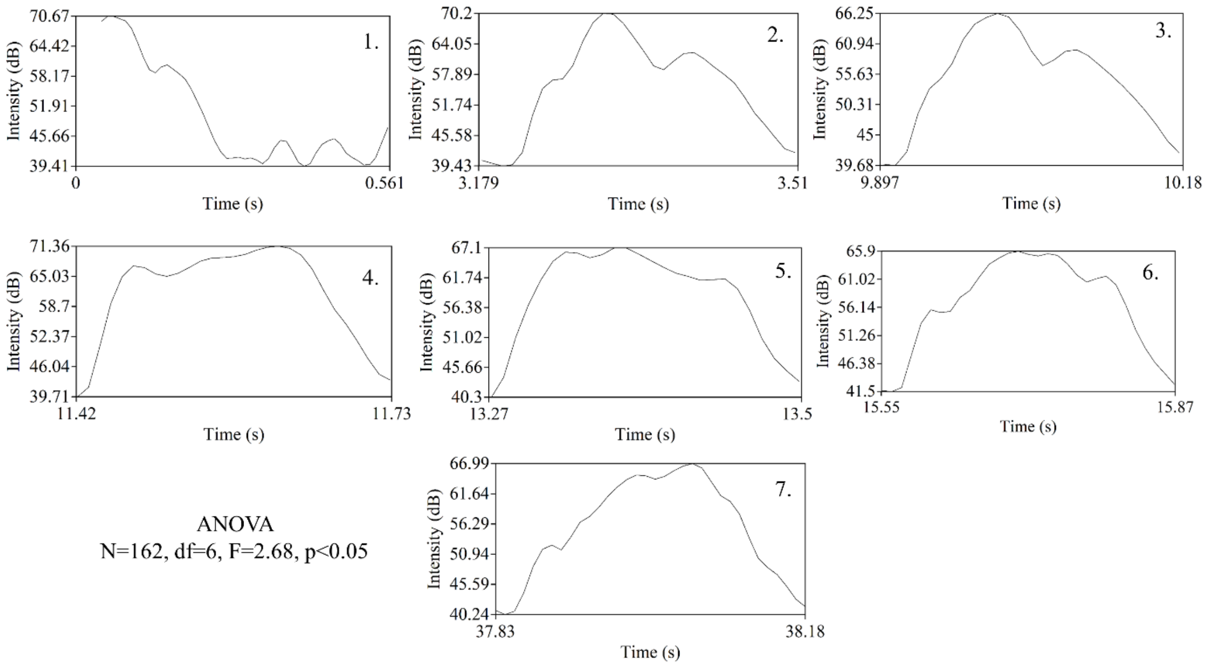
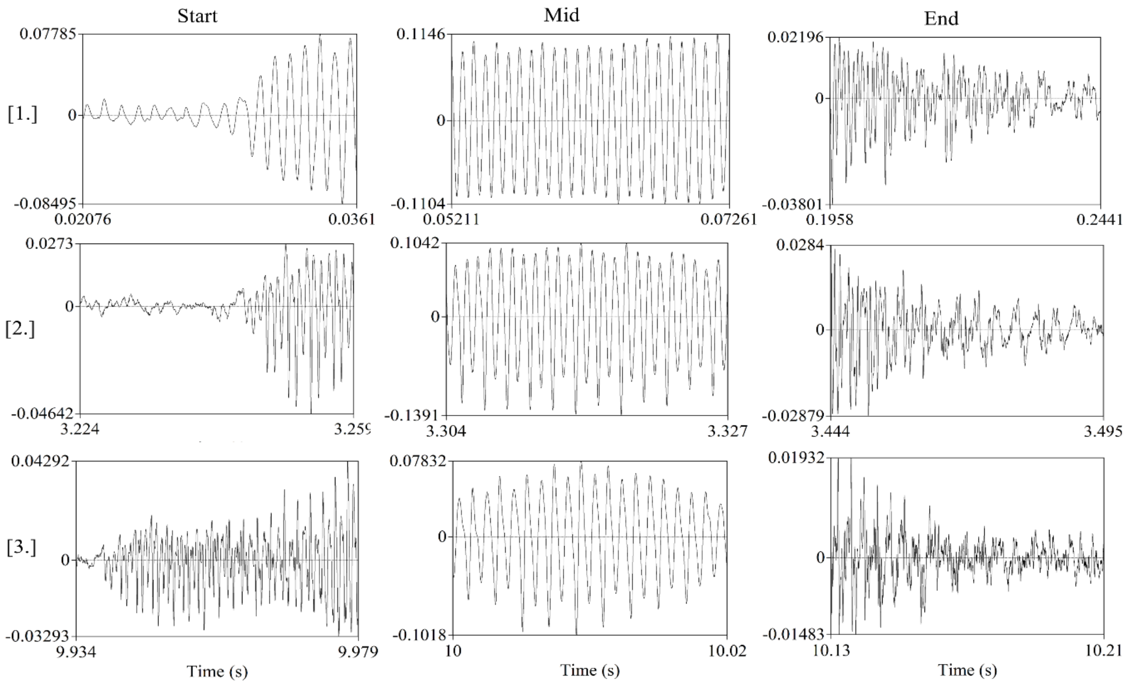


Figure 6.4.6 Intensity contour of alarm calls of adult *M. munzala*

6.4.10 Structure of waveform

The wave of call sequence are follows the periodic cycle but it has non-sinusoidal waveforms. The starting and end sequence were found complex wave but mid sequence has shown sign wave pattern in all the studied calls (Fig. 6.4.7).



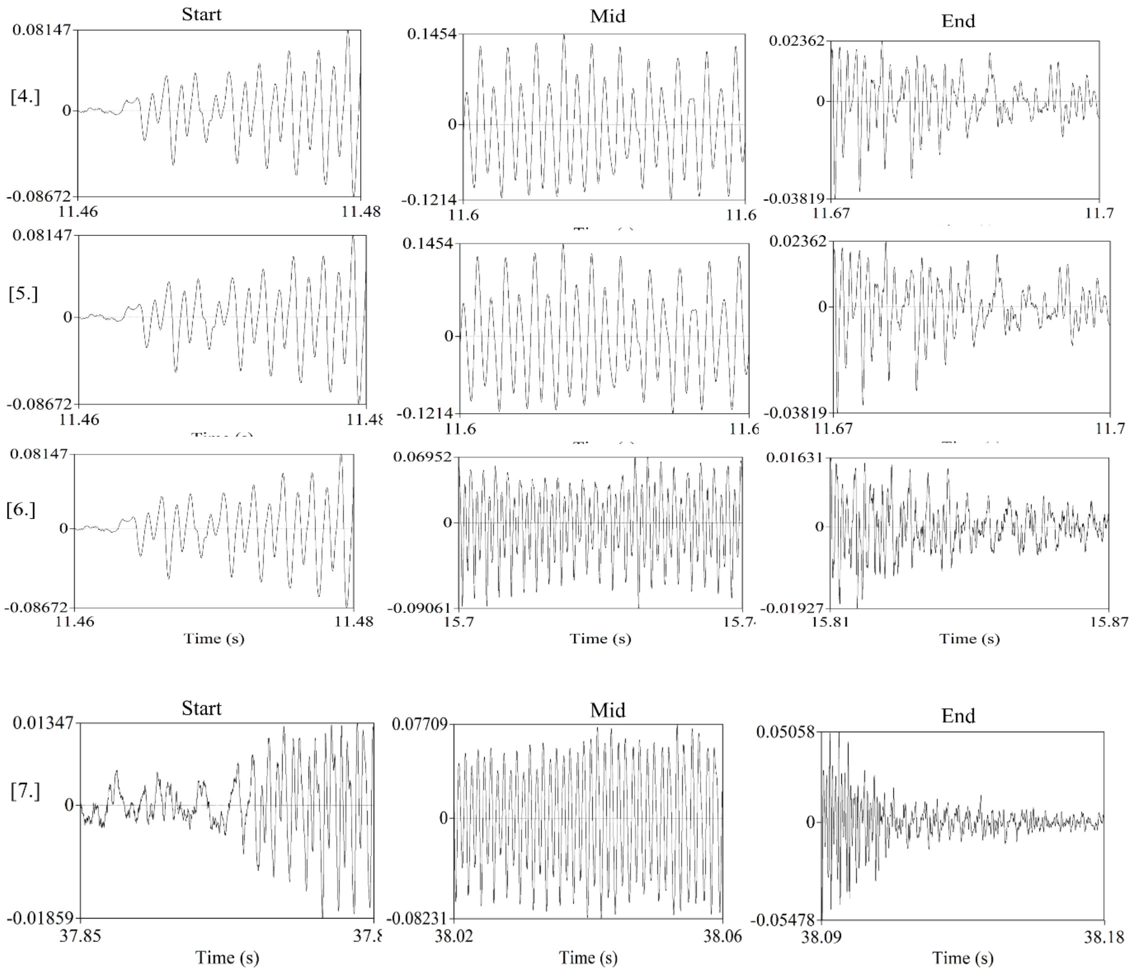


Figure 6.4.7. The pattern of wave formation alarm calls of adult *M. munzala*

6.4.11 Formant and spectral moments

The formant analysis has shown only a single distinct formation of formant at lower frequency range i.e., F1 (Fig. 6.4.2 and Fig. 6.4.8). The mean of formant was 1028.20 ±130.74 Hz and ranges from 442.65-1338.06 Hz (Table 6.4.3). The formant of the calls has been found significantly differ (N=228, df=6, F=7.75, $p<0.01$). Similarly, the spectrum analysis (FFT and LP) has shown the dominant formant in the range of 1000 Hz (Fig. 6.4.2).

The mean of spectral centre gravity (M1) was found from 1437.28 Hz- 1739.56 Hz and standard deviation (M2) ranges from 1067.12 Hz- 1239.42 Hz. The positive left skewed distribution has shown in the spectral (1.92-2.68). Similarly, kurtosis (M3) has shown positive value for spectrum that ranges from 4.90-10.26 (Table 6.4.4).

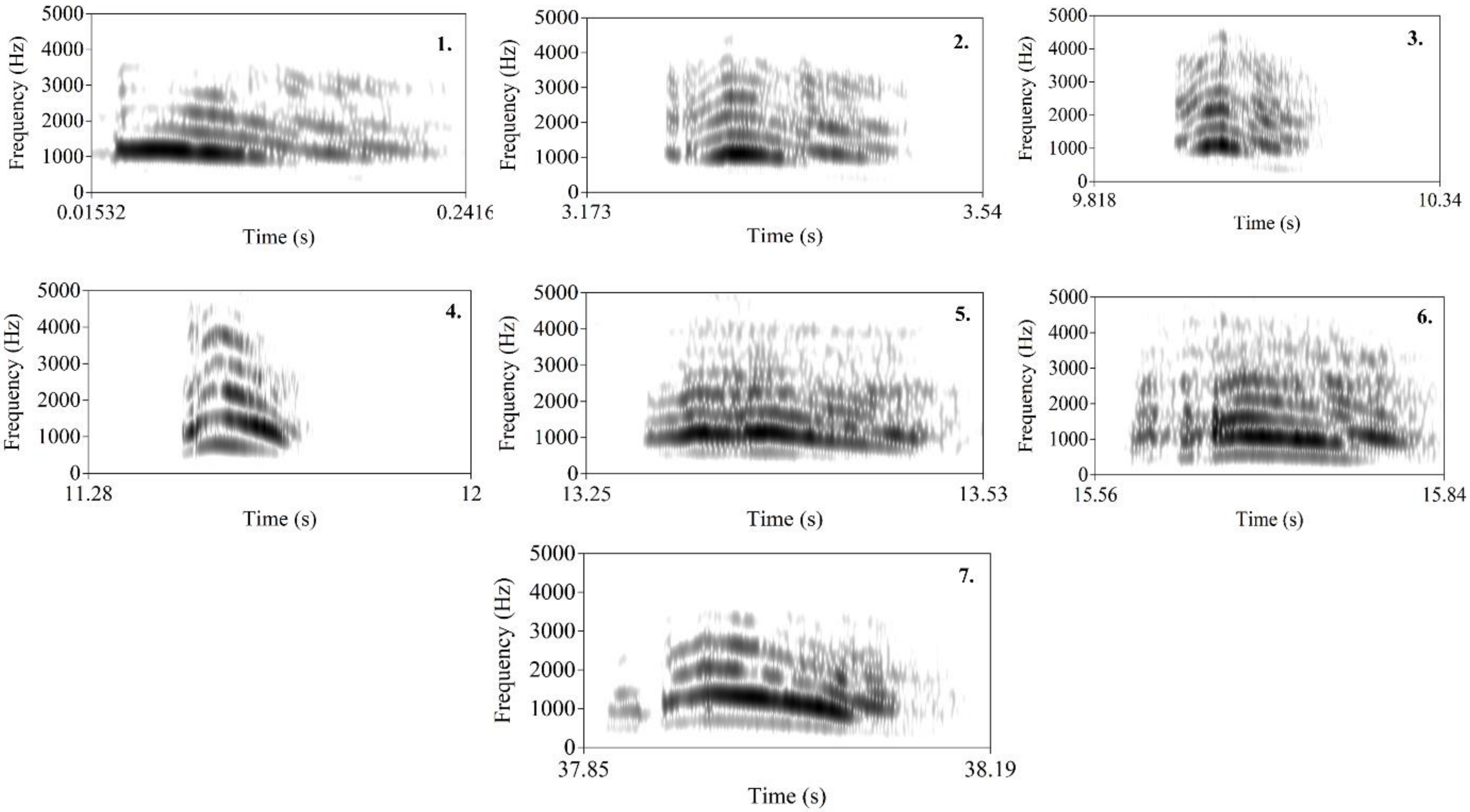


Figure 6.4.8 Spectrogram of studied alarm calls of adult male of *M. munzala*; dynamic range set at 30dB; F1 (Formant 1)

Table 6.4.3 Formant of studied calls of *M. munzala;* F statistics of ANOVA

Formant (F1)	Mean	Std. Deviation	Minimum	Maximum
Call 1	1116.8	54.12685	995.18	1189.05
Call 2	1071	54.44025	977.62	1163.45
Call 3	1065.5	61.58231	971.76	1177.83
Call 4	945.68	176.1579	760.78	1288.17
Call 5	1004.2	83.42196	831.12	1119.87
Call 6	984.37	74.30203	827.27	1115.57
Call 7	1016.4	213.1751	442.65	1338.06
Total mean	1028.2	130.7417	442.65	1338.06

N=228, df=6, F=7.75, $p<0.01$

Table 6.4.4 Spectral moment of studied calls of *M. munzala*

Spectrum gravity	Calls						
	1	2	3	4	5	6	7
Mean of M1 (mean or centre of gravity)	1544.50	1667.84	1739.56	1601.81	1499.33	1451.96	1437.28
Mean of M2 (Std. deviation)	1079.54	1113.60	1239.42	1115.44	1067.12	1153.43	1085.21
Mean of M3 (skewness)	2.60	2.05	1.92	2.11	2.46	2.25	2.68
Mean of M4 (kurtosis)	9.27	6.10	4.90	6.48	8.26	6.67	10.26

6.4.12 Discussion

The studied vocalization of *Macaca munzala* was urgency based call rather than threat deterrence. The "alarm call" was found to use for different purposes i.e., predatory threat, caller position, disperse in large area and alert during raiding activity.

Alarm call was distinct than any other vocalization of in terms of loudness and can be hear from a distance of ~30-40 m. The pitch of alarm calls did not differ statistically that indicated studied calls were similar type. The spectrogram analysis has shown formation of only single dominant dark band (higher intensity) in the calls unlike vowels formant of human speech [44], loud calls of Gorilla [7], hoot and grunt vocalization of Bonobos [16,46] and "Coo" calls of Rhesus macaque [47]. Subsequently, Fast Fourier Transform (FFT) and Linear prediction (LP) analysis of calls have depicted a single dominant formant in call spectrum. The positive skewness (M3) in a spectrum indicates higher acoustic energy in low frequency and positive value of Kurtosis (M3) describes "peaky" distribution of spectrum [45]. On that term, studied alarm calls of *M. munzala* has shown higher amount of energy in low frequency and "peaky" distribution. Similarly, "Gecker" vocalization of young Rhesus monkey (*Macaca mulatta*) has shown "peaky" distribution that function as distress cue [48]. The lost and cohesive "Coo" calls of Tibetan macaque (*Macaca thibetana*), and Japanese macaque (*Macaca fusucata*) have "peaky" formation rather than normal frequency distribution [39,49]. However, "Coo" calls of *M. thibetana* and *M. fusucata* was found differ from alert call of *M. munzala* in terms of multiple distinct formant. The reported peak frequency of Mentawai macaques, Mentawai leaf monkeys, Mentawai langurs peak frequency of loud calls have similar range of alarm calls of *M. munzala* [50]. Further, spectral structure of alarm call of *M. munzala* was found significantly similar with newly discovered White cheeked macaque (*Macaca leucogenys*) alarm calls that produce in presence of human nearby [38]. Thus, there is a need of further comparative study in vocalization of *M. munzala*, *M. leucogenys* and *M. assamenesis* to understand acoustic difference of alarm call of these species.

6.4.13 References

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