CHAPTER-V

HABITAT STRUCTURE, STATUS AND CONSERVATION OF *Macaca Munzala* In PROTECTED AND NON-PROTECTED HABITAT, WESTERN ARUNACHAL PRADESH, INDIA

5.1 Introduction

Habitat quality and heterogeneity has significant effect in animal species diversity, distribution and movement pattern [1,2]. Primate species richness and abundance has been study extensively in relation to habitat structure that emphasised on vegetation [3–8]. Globally, ~75% of population of primates have been declining due to the habitat degradation by anthropogenic activity [9]. Species composition plays an important role in diet selection of primates. Subsequently, several workers studied extensively on primate's diet in terms of time-spent activity, feeding ecology, ranging behaviour and physiological evolution in primates [10–14]. Studies on primate behavioural pattern influences by change in vegetation of habitat are also reported [15–20]. Tsuji et al. [21] also reported feeding pattern of macaque species are influence by vegetation composition. Moreover, diet of similar primate species changes according to the vegetation characteristics of habitat [11,13,22]. Thus, knowledge on species composition in terms of phytosociology is one of the key factors for understanding primate niche [6,23]. The habitat disturbance on change in plant species composition; fragmentation, patch size and forest cover loss [24,25] and impact of disturbance on population and distribution, behaviour, fecundity and parasite prevalence has been extensively studied [5,17,26–29]. The selective logging in primate's habitat is in response with population density and behavioural change of primates [3,15,30–32]. While, the impact of habitat fragmentation, selective logging, unsustainable agricultural practices and hunting for bush-meat was studied in terms of population declination of primates in Arunachal Pradesh [7,33–36]. Globally, hunting has been emerges as a reason of rapid declination of primate population [17,30,37–39].

Macaca munzala is categorized as an 'Endangered species' and its decreasing population has been reported (IUCN, 2018) [40]. The distribution of *M. munzala* was reported from the altitude of 1000 m to <3000 m above mean sea level in sub-tropical forest and temperate forest habitat in western Arunachal Pradesh [41–43]. However, the detail phytosociology of these habitats is yet to be study quantitatively. Kaul and Haridasan [44] classified major forest type of Arunachal Pradesh based on climate and vegetation occurrence. The forest types of Arunachal Pradesh vary according to the altitudinal gradient. Similarly, Saikia et al. [45] classified forest of Arunachal Pradesh based on altitudinal gradient i.e., Tropical forest (87-795 m amsl), Sub-tropical (802-

1800 m amsl), Temperate (1824-2788) and Alpine forest (2803-4161 m amsl). Plant community structures of different part of Arunachal Pradesh are in disturbed state due to various anthropogenic activities [46–52].

The main objective of the present study is to quantify the phytosociological characteristics of different habitat type used by *Macaca munzala* with emphasised on altitudinal variation. Additionally, an assessment on conservation threat in protected and non-protected habitats of *M. munzala* in western Arunachal Pradesh is also a part of the study.

5.2. Methods

5.2.1. Study area

Study on phytosociology and anthropogenic threats were undertaken based on occurrence of *M. munzala* population as given in population distribution survey (Chapter 4). The study areas are unclassified state forest of Zemithang, Pangchen valley, Tawang district and Protected area (Sessa orchid sanctuary) of West Kameng district (Fig. 5.1). Zemithang, Pangchen valley is situated in north-western most corner of Tawang district (27º 42′N, 91º 43′E); bordering to Tibet, China at northern side and Bhutan on the eastern side. The valley has altitudinal range of >1600 m to <4000 m above mean sea level and major forest type of the valley are Eastern Himalaya broad leaved forest (EHBLF), Mixed coniferous forest (MCF), alpine meadow and Degraded scrub forest (DSF) in human modified landscape. Monpa is agro-pastoral tribe predominantly inhabited in the Pangchen valley. The temperature of the valley ranged from -3ºC to 19ºC during winter to summer [53]. The Sessa orchid sanctuary, situated in the West Kameng district (27^0 3 -27^0 11 N and 92^0 23.4 - 92^0 36 E), covers an area of 100 km^2. The sanctuary is part of Kameng Protected Area Complex (KPAC) that adjoins Eaglenest wildlife sanctuary at western side and Pakke Tiger reserve at eastern side. The altitudinal range of the sanctuary is >900 m amsl to <2000 m amsl and major forest type is subtropical forest, specifically, Eastern Himalaya sub-tropical wet hill forest (EHSWHF) [54]. Miji and Sulung are the two tribes inhabited in and around the protected area.

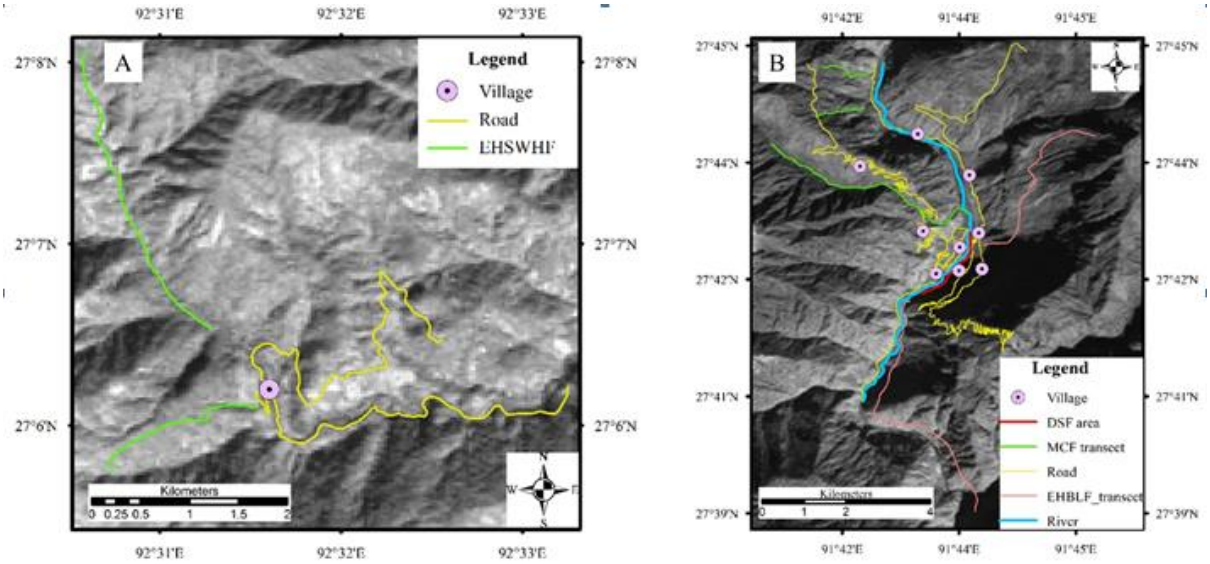

Figure 5.1. Sessa orchid sanctuary (A); Zemithang Pangchen valley (B), Colour line are the tracks that used for disturbance according to the habitat characteristics

5.2.2. Plant community structure

Plant community structure was undertaken in four habitats of *M. munzala* namely; East Himalayan subtropical wet hill forest (EHSWHF) at altitude of 1000 m amsl-1600 m amsl, Eastern Himalaya broadleaf forest (EHBLF) at altitude of 1600 m amsl-2200 m amsl, Mixed coniferous forest (MCF) at altitude of 2200 amsl-2800 amsl [55] and Degraded scrub forest (DSF) in human modified landscape. These habitats were classified based on vegetation characteristics and altitudinal gradient of encountered troops of *M. munzala*.

For the purpose of study quadrat method was used and 50 quadrats were laid in each habitat (EHSWHF of Sessa orchid sanctuary, and EHBLF, MCF and DSF of Zemithang, Pangchen valley). Nested quadrat of 10 m × 10 m size was laid for tree species and within that, 5 m × 5 m quadrat was used for shrub and herb species [56]. The tree girths are measured at height of 1.3 m from base of the individual using measuring tape; shrub and herb layer were measured at the base using measuring tape and digital slide calliper as applicable. Tree individuals having girth ≥30 cm were considered as adult; ≥10 cm but <30 cm considered as sapling and <10 cm as seedling. Individuals are group into ten girth classes i.e., 10-30 cm, >30-50 cm, >50-70 cm, >70-90 cm, >90-110 cm, >110-130 cm, >130-150 cm, >150-170 cm, >170-190 cm and >190 cm for studying population structure. Herbariums are prepared following the method given by Jain and

Rao [57]. Identification of plant species are done using relevant book, 'Flowers of the Himalaya' [58] and other appropriate literature [45–47,49,50,52,59]. The online plant database has also used in species identification (www.efloras.org; www.plants.jstor.org). The study extensively followed Cottam and Curtis [60] to calculate the frequency, abundance, density and basal area. Important value index (IVI) were calculated using the following formula of Curtis [61].

IVI=Relative frequency + Relative density + Relative dominance

As per Whiteford [62], distribution pattern of species was calculated.

WI=Abundance/Frequency

Diversity indices, Shannon-Wiener diversity index [63], Simpson's index of dominance [64], Evenness index [65] and Similarity index [66] 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.

Similarity index (S) =2C/A + B

where, A=Number of species in sample A, B= Number of species in sample B and C=Number of species in common for A and B.

5.2.3. Anthropogenic disturbance

Anthropogenic disturbance was studied in terms of events encounter during the survey like, hunting, logging, NTFP collection, firewood collection, and cattle grazing. The

presence and absence of agriculture activity in forested area and evidence of forest fire were also noted during the survey. For the purpose of study, a total of 15 days has been devoted in each habitat (EHSWHF of Sessa orchid sanctuary, and EHBLF, MCF and DSF of Zemithang, Pangchen valley) to record the presence and absence of various anthropogenic disturbances. Walked approximately 15 km of the forested trail of the study sites (habitats) during forenoon for survey. The study considered hunting event, when encounter people with hunting equipment such as Catapult, Riffle, Snare etc. and also sound of gun shots were also considered as a hunting event. Timber extraction was considered, when encounter people with chain saw, sound of chain saw, sound of tree felling by axe, and carrying large sized logged. People carrying logs, cutting young and immature tree, felling branches with machete was considered as firewood collection. Similarly, grazing by any domestic animal inside the forest area is considered as cattle grazing. The evidence of forest fire and agricultural activity inside the forest were also considered as an anthropogenic disturbance. The score 1 (one) is given upon encounter of disturbance. The total score was divided by total sampling days to estimate the disturbance index. The high and low disturbance was decided based on the scale of 0-1, where, 1 being the highest disturbance in the study site.

5.2.4. Statistical analysis

The study carried out One-way ANOVA test to perceive the statistical difference in density, basal area, girth class and diversity indices of studied habitat. Statistical software SPSS 16.0 (Statistical Package for the Social Sciences) was used for all statistics analysis.

5.4.3. Result

5.3.1. Species diversity

A total of 151 plant species belonging to 126 genera and 66 families were recorded from the four habitats. Of that, 58 species were tree (52 genera under 34 families), 41 species were shrub (38 genera under 24 families) and 52 species were herb (42 genera under 24 families). The habitat was comprised with 38.41% of tree species followed (34.45%) of herb species and 27.15% of shrub species. The maximum number tree species was recorded from the Fagaceae family (7) followed by Betulaceae (4). For the shrub layer

maximum 8 number of species was recorded from Rosaceae family, whereas, Asteraceae family (13) recorded maximum number of species in herb layer.

The highest number of tree species was recorded in EHSWHF (29 species under 28 genera and 22 families) followed by EHBLF (22 tree species under 20 genera and15 families), MCF (20 species under 16 genera and 12 families, whereas, the lowest number of tree species was recorded in DSF (9 species under 9 genera and 8 families). The highest number of shrub species was recorded in EHBLF (21 species under 19 genera and 14 families) and lowest was found in DSF (10 species under 8 genera and 8 families). Similarly, the highest number of herb species was found in EHBLF habitat (33 species under 32 genera and 19 families) and lowest was recorded in EHSWHF (10 species under 9 genera and 6 families) (Table 5.1). EHSWHF was recorded with highest species richness for tree species (2.57) followed by EHBLF (1.84), MCF (1.73) and lowest in DSF (1.34). The highest species richness for shrub species was recorded in EHBLF (1.67) and lowest in DSF (0.99). Similarly, the highest species richness for herb species was recorded in EHBLF (1.66) and lowest in EHSWHF habitat (0.60) (Table 5.1).

Table 5.1. Species diversity in different studied habitat of *M. munzala*

Vegetation	Diversity parameters	EHSWHF	EHBLF	MCF	DSF
Tree	No. of species	29	22	20	9
	Genera	27	20	17	9
	Family	23	15	12	8
	Species richness	2.57	1.84	1.73	1.34
Shrub	No. of species	13	21	14	10
	Genera	12	19	11	8
	Family	10	14	12	8
	Species richness	1.06	1.67	1.33	0.99
Herb	No. of species	10	33	19	22
	Genera	9	30	16	33
	Family	6	19	16	14
	Species richness	0.60	1.66	1.10	1.24

Note: East Himalayan subtropical wet hill forest (EHSWHF), Eastern Himalaya broadleaf forest (EHBLF), Mixed coniferous forest (MCF) and Degraded scrub forest (DSF)

In East Himalaya sub-tropical wet hill forest (EHSWHF), the highest number of tree species was recorded from the family of Annonaceae (3); Rubiaceae (4) for shrub and Urticaceae (3) for herb species. Moraceae (3) and Fagaceae (3) had the highest number of tree species in Eastern Himalaya broadleaf forest (EHBLF), where, Ericaceae (3) for shrub species and Urticaceae (5) recorded highest for shrub and herb species. Mixed coniferous forest (MCF) had the highest number of tree species from the family Fagaceae (3) and Pinaceae (3); Rosaceae (4) for shrub and Lamiaceae (4) for herb species. Similarly, Betulaceae family (2) had the highest number of tree species in Degraded scrub forest (DSF); Adoxaceae (2) and Elaeagnaceae (2) for shrub species and Asteraceae (4) recorded highest number of herb species.

5.3.2. Density, Basal area, IVI and Diversity indices

Tree species density was highest in the habitat of EHBLF (286 individual ha^{-1}) and lowest in DSF (90 individual ha^{-1}). For shrub species, the highest density was recorded in EHSWHF (1128 individual ha^{-1}) and lowest in MCF (936 individual ha^{-1}), while for herb species highest was recorded in EHBLF (3151 individual ha^{-1}) and lowest in EHSWHF (1864 individual ha^{-1}) (Table 5.2).

For tree species, basal area was highest in MCF having 209.76 m^2ha^{-1} and lowest in DSF with 46.10 m^2ha^{-1}. But, DSF recorded highest basal area for herbs having 4.38 m^2ha^{-1}. Highest basal area (18.14 m^2ha^{-1}) for shrub was recorded in EHBLF (Table 5.2).

The diversity indices i.e., Simpson diversity index (*D*), Shannon diversity index (*H´*) and Evenness index (*J´)* were differ significantly among the habitats (Table 5.2). Simpson diversity index of tree species was within of 0.05 to 1 and Shannon diversity index was between 1.75 to 3.22. For shrub species, Simpson diversity index was in the range of 0.10 to 1, and 2.09 to 2.69 for Shannon diversity index. Similarly, Simpson diversity index for herb species was in range of 0.08 to 0.17 while for Shannon diversity index it range from 1.93 to 2.96. The estimated Simpson diversity index (*D*) for tree species was found highest in DSF habitat (*D*=1) and lowest in EHSWHF (*D*=0.05), whereas, Shannon diversity index (*H´)* was found highest for EHSWHF (*H´*=3.22) and lowest in DSF (*H´*=1.75). The Simpson diversity index for shrub species was found highest in MCF (*D*=1) and Shannon diversity index (*H´)* in the habitat of EHBLF (*H´*=2.69). Likewise, EHSWHF recorded highest Simpson diversity index (*D*=0.17) and lowest

Shannon diversity index (1.93) for herb species (Table 5.2). The IVI distribution curve has shown irregular dominant distribution of tree, shrub and herb species in the entire studied habitat (Fig. 5.2).

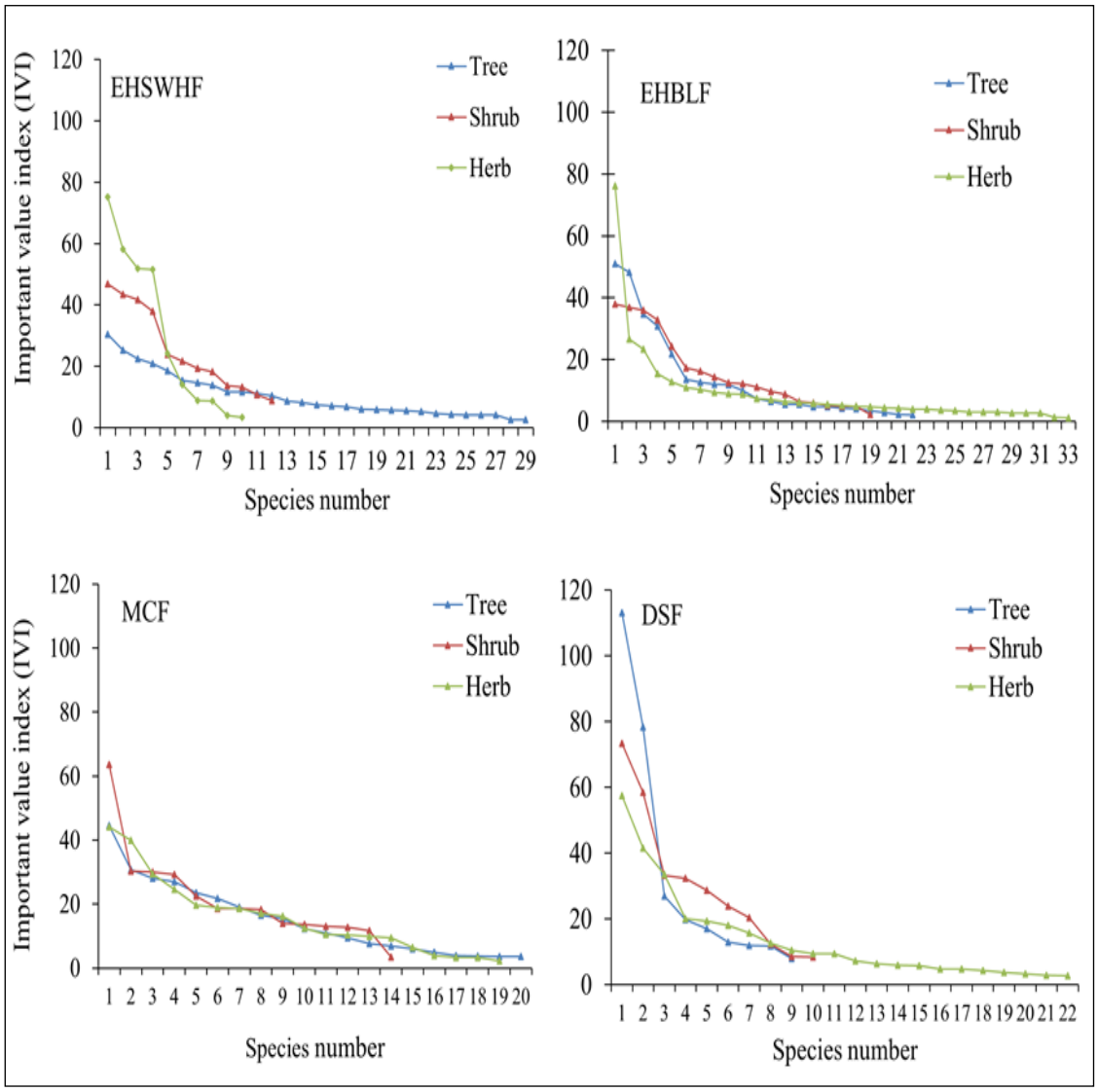

Figure 5.2. Dominant distribution curve of tree, shrub and herb species of studied habitat

Table 5.2. Plant community characteristics of studied habitat of *Macaca munzala*; statistics shows F value of ANOVA

Community parameter	EHSWHF	EHBLF	MCF	DSF	F (ANOVA)
Tree					
Density (l ha^{-1})	232^{ns}	286^{ns}	266^{ns}	90^{ns}	2.12
Basal area (m^2 ha^{-1})	167.88^{**}	195.18^{**}	209.76^{**}	46.10^{**}	28.15
Simpson diversity index (*D*)	0.05**	0.09**	0.08**	1**	4.51
Shannon diversity index (*H´)*	3.22*	2.67*	2.75*	1.75*	4.07
Evenness index (*J´*)	0.95**	0.88**	0.90**	0.73**	12.62
Species richness	2.57	1.84	1.73	1.34	
Shrub					
Density (ha^{-1})	1128^{ns}	984^{ns}	936^{ns}	992^{ns}	1.95
Basal area (m^2 ha^{-1})	6.06**	18.14**	14.73**	16.98**	21.57
Simpson diversity index (*D*)	*	0.08*	1*	0.15*	2.88
Shannon diversity index (*H´)*	2.39	2.69	2.46	2.09	2.58
Evenness index (*J´*)	0.91**	0.88**	0.91**	0.91**	8.26
Species richness	1.06	1.67	1.33	0.99	
Herb					
Density (ha^{-1})	1864.80^{ns}	3151.86^{ns}	2400^{ns}	2097.90^{ns}	1.94
Basal area (m^2ha^{-1})	3.48^{ns}	2.80^{ns}	1.72^{ns}	4.38^{ns}	1.78
Simpson diversity index (*D*)	0.17**	0.09**	0.08**	0.10**	4.16
Shannon diversity index (*H´)*	1.93**	2.96**	2.69**	2.70**	5.25
Evenness index (*J´*)	0.84**	0.49**	0.92**	0.87**	28.87
Species richness	0.60	1.66	1.10	1.24	

Note: EHSWHF- East Himalayan subtropical wet hill forest, EHBLF- Eastern Himalaya broadleaf forest, MCF-Mixed coniferous habitat, DSF-Degraded scrub forest

5.3.3. Plant community structure

In EHSWHF, *Cinnamomum bodinier* (22 individual ha^{-1}) had highest density among tree species, where *Grewia serrulata* (192 individual ha^{-1}) and *Razisea* sp. (566 individual ha^{-1})

recorded highest among shrub and herb species, respectively (Table 5.3). *Tetrameles nudiflora* (IVI=30.51) was found dominant tree species based on Important value index (IVI); *Pandanus emarginatus* (Basal area= 2.16 m^2ha^{-1}; IVI=46.94) for shrub species and *Musa acuminata* for herb species (Basal area= 1.9 m^2ha^{-1}; IVI=75.13) in the habitat of EHSWHF (Table 5.3).

For the habitat of EHBLF, *Alnus nepalensis* was found dominant tree species having highest density (56 individual ha^{-1}) and IVI (51.02), followed by *Quercus serrata* with a density of 32 individual ha^{-1} and IVI of 48.19. Highest basal area was also recorded in *Quercus serrata* having 30.92 m^2 ha^{-1}. *Viburnum erubescens* was recorded dominant among shrub species having highest density (152 ha^{-1}) and IVI (38.04) followed by *Debraegesia longifolia* (Density 120; IVI 36.82). Among the herb species, highest density and IVI was recorded for *Pollygonum molle* (Density=240 ha^{-1}; Basal area =1.69 m^2 ha^{-1}; IVI=76.09) and *Oenanthe javanica* (Density=360 ha^{-1} and IVI=26.65) (Table 5.3).

In MCF habitat, *Pinus wallichina* (42 individual ha^{-1}) and *Rhododendron* sp. (42 individual ha^{-1}) had the highest density among tree species, while, *Leucosceptrum canum* (160 individual ha^{-1}) was recorded highest for shrub species. The highest density among herb species was in *Potentiala* sp. (360 individual ha^{-1}) (Table 53). Dominant species among tree species was *Pinus wallichina* (Basal area= 46.29 m^2ha^{-1}; IVI=44.54). Among shrub species *Leucosceptrum canum* (Basal area=4m^2ha^{-1}; IVI= 63.71) and *Polygonum molle* (Basal area=0.48 m^2ha^{-1}; IVI=44.11) was dominant for herb species.

In DSF habitat, *Erythrina arborescens* was dominant tree species having density 34 $ha^{-1,}$ basal area of 17.37 m^2ha^{-1} and IVI of 114.34. *Viburnum erubescens* (304 individual ha^{-1}) for shrub species and *Oenanthe javanica* (440 individual ha^{-1}) for herb species (Table 5.3). *Viburnum eurbescens* (304 individual ha^{-1}) and *Oenathe javanica* (440 individual ha^{-1}) was recorded highest density among shrub and herb species respectively. *Elaeagnus umbellate* (Basal area=4.03 m^2ha^{-1}; IVI=73.44) and *Pollygonum molle* (Basal area=1.64 m^2ha^{-1}; IVI=57.52) was dominant species among shrub and herb species respectively.

Table 5.3. Density, Basal area and Important value index (IVI) of each recorded species in the four habitats of *M. munzala*

Sl. No.	Tree	Family	Density (individual ha^{-1})				Basal area (m^2 ha^{-1})				IVI			
			EHBLF	EHSWHF	MCF	DSF	EHBLF	EHSWHF	MCF	DSF	EHBLF	EHSWHF	MCF	DSF
1	*Abies densa*	Pinaceae	-	-	10	-	-	-	15.22	-	-	-	12.27	-
2	*Acer oblongum*	Sapindaceae	-	8	4	-	-	2.06	1.23	-	-	8.3	3.55	-
3	*Aglaia lawii*	Meliaceae	-	20	-	-	-	7.48	-	-	-	25.25	-	-
4	*Albizia chinensis*	Fabaceae	6	-	-	4	1.85	-	-	0.82	6.41	-	-	11.77
5	*Alnus nepalensis*	Betulaceae	56	-	38	24	16.9	-	21.26	11.51	51.02	-	30.76	79.41
6	*Alphonsea sclerocarpa*	Annonaceae	-	4	-	-	-	0.4	-	-	-	4.21	-	-
7	*Alseodaphne petiolaris*	Lauraceae	-	6	-	-	-	1.36	-	-	-	5.81	-	-
8	*Altingia excelsa*	Hamamelidaceae	-	12	-	-	-	4.18	-	-	-	13.83	-	-
9	*Amoora wallichii*	Meliaceae	-	6	-	-	-	2.67	-	-	-	6.82	-	-
10	*Anthocephalus cadamba*	Rubiaceae	-	4	-	-	-	2.29	-	-	-	4.58	-	-
11	*Aporsa lindleyana*	Phyllanthaceae	-	6	-	-	-	2.17	-	-	-	7.51	-	-
12	*Betula alnoides*	Betulaceae	10	-	-	10	4.54	-	-	5.72	11.84	-	-	26.29
13	*Betula utilitis*	Betulaceae	-	-	10	-	-	-	7.44	-	-	-	9.51	-
14	*Cedar deodar*	Pinaceae	-	-	20	-	-	-	45.71	-	-	-	28.14	-
15	*Cinnamomum bodinieri*	Lauraceae	-	22	-	-	-	5.55	-	-	-	22.45	-	-
16	*Cinnamomum sp.*	Lauraceae	12	-	-	-	2.53	-	-	-	9.99	-	-	-
17	*Dendrocnide sinuata*	Urticaceae	-	8	-	-	-	5.9	-	-	-	11.25	-	-

18	*Diospyros blancoi*	Ebenaceae	-	2	-	-	-	0.77	-	-	-	2.54	-	-
19	*Dubanga grandiflora*	Lythraceae	-	4	-	-	-	4.11	-	-	-	7.06	-	-
20	*Elaeocarpus chinensis*	Elaeocarpaceae	6	-	-	-	-	1.99	-	-	-	5.58	-	-
21	*Engelhardia spicata*	Juglandaceae	2	-	-	-	-	2.32	-	-	-	3.5	-	-
22	*Erythrina arborescens**	Fagaceae	16	-	-	34	4.04	-	-	17.37	12.6		-	114.34
23	*Eugenia jambolana*	Myrtaceae	-	6	-	-	-	1.04	-	-	-	5.56	-	-
24	*Euonymus fimbriatus*	Celastraceae	4	-	-	-	-	0.72	-	-	-	2.92	-	-
25	*Ficus glaberrima*	Moraceae	2	-	4	-	-	0.5	1.49	-	-	2.04	3.64	-
26	*Ficus hederacea*	Moraceae	-	-	8	-	-	-	4.37	-	-	-	6.86	-
27	*Ficus sp.*	Moraceae	6	4	-	-	0.87	1.94	-	-	4.68	4.31	-	-
28	*Goniothalamus sp.*	Annonaceae	-	12	-	-	-	5.16	-	-	-	14.58	-	-
29	*Havea sp.*	Euphorbiaceae	-	4	-	-	-	1.73	-	-	-	4.14	-	-
30	*Helicia nilagirica*	Proteaceae	-	8	-	-	-	4.9	-	-	-	10.48	-	-
31	*Hopea parviflora*	Dipterocarpaceae	-	12	-	-	-	6.19	-	-	-	15.38	-	-
32	*Hydnocarpus kurzii*	Achariaceae	-	14	-	-	-	10.84	-	-	-	20.9	-	-
33	*Lannea coromanderica*	Anacardiaceae	4	-	-	-	1.2	-	-	-	4.24	-	-	-
34	*Lithocarpus elegans*	Fagaceae	-	8	-	-	-	6.49	-	-	-	11.71	-	-
35	*Litsea coreana*	Lauraceae	8	-	-	-	3.42	-	-	-	7.42	-	-	-
36	*Lophopetalum wightianum*	Celastraceae	-	8	-	-	-	6.38	-	-	-	11.62	-	-
37	*Macaranga denticulata*	Euphorbiaceae	-	8	4	-	-	2.65	2.33	-	-	8.75	3.93	-
38	*Magnolia sp.**	Magnoliaceae	20	-	14	-	10.29	-	28.08	-	21.83	-	19.03	-
39	*Malus sieversii**	Rosaceae	-	-	24	-	-	-	26.54	-	-	-	23.55	-
40	*Meiogyne sp*	Annonaceae	-	6	-	-	-	1.6	-	-	-	5.99	-	-
41	*Morus alba*	Moraceae	2	-	-	2	0.72	-	-	2.95	2.22	-	-	11.39

42	*Pinus wallichina*	Pinaceae	-	-	42	-	-	-	46.29	-	-	-	44.54	-
43	*Polygala sp.*	Polygalaceae	-	-	-	4	-	-	-	1.88	-	-	-	16.86
44	*Populus nigra*	Salicaceae	6	-	-	-	1.93	-	-	-	5.53	-	-	-
45	*Prunus cerasoid**	Rosaceae	10	-	4	6	6.05	-	1.99	3.27	12.11		3.81	19.32
46	*Pterospermum diversifoliu*	Malvaceae	-	2	-	-	-	0.83	-	-	-	2.59	-	-
47	*Quercus lamellosa*	Fagaceae	26	-	4	-	21.37	-	2.87	34.68	-	-	5.03	-
48	*Quercus serrata*	Fagaceae	32	-	8	-	30.92	-	6.49	48.19	-	-	7.62	-
49	*Quercus semecarpifolia*	Fagaceae	-	-	20	4	-	-	17.75	1.3	-	-	21.83	12.82
50	*Rhododendron arboretum**	Ericaceae	36	-	-	-	5.08	-	-	30.8	-	-	-	-
51	*Rhododendron sp.**	Ericaceae	-	-	42	-	-	-	2.1	-	-	-	27.08	-
52	*Rhus chinensis**	Anacardiaceae	6	-	-	-	0.89	-	-	4.7	-	-		-
53	*Salix wallichiana**	Salicaceae	-	-	16	-	-	-	6.09		-	-	10.99	-
54	*Saurauia napalensis*	Actinidiaceae	-	4	-	-	-	1.81	-	-	-	4.21		-
55	*Schima wallichi*	Theaceae	12	-	6	-	5.86	-	3.74	-	13.6	-	5.99	-
56	*Taxus bacata*	Taxaceae	-	-	16	-	-	-	16	-	-	-	15.4	-
57	*Taxus sp.*	Taxaceae	-	-	12	-	-	-	25.21	-	-	-	16.46	-
58	*Terminalia bellirica*	Combretaceae	-	10	-	-	-	11.38	-	-	-	18.51	-	-
59	*Terminalia myriocarpa*	Combretaceae	-	4	-	-	-	2.59	-	-	-	5.89	-	-
60	*Tetrameles nudiflora*	Combretaceae	-	14	-	-	-	24.73	-	-	-	30.51	-	-
61	*Toona sinensis*	Meliaceae	4	-	-	2	1.15	-	-	1.29	4.2	-	-	7.81
62	*Zanthophyllum arnottianum*	Rutaceae	-	6	-	-	-	0.7	-	-	-	5.3	-	-
Shrub														
1	*Berberis insignis*	Berberidaceae	-	-	48	-	-	-	0.21	-	-	-	11.72	-
2	*Brassaiopsis hainla*	Araliaceae	8	-	-	32	0.54	-	-	0.54	4.84	-	-	8.51

3	*Calamus sp.*	Arecaceae	-	96	-	-	-	0.17	-	-	-	18.25		-
4	*Callicarpa sp.*	Verbenaceae	-	88	-	-	-	0.22	-	-		19.36	-	-
5	*Coriaria nepalensis*	Coriariaceae	56	-	-	40	0.4	-	-	0.69	14.31	-	-	12.39
6	*Cotoneaster dammeri*	Rosaceae	-	-	16	-	-	-	0.06	-	-	-	3.42	-
7	*Debraegesia longifolia**	Urticaceae	120	-	64	72	2.34	-	2.15	2.11	36.82	-	29.21	32.43
8	*Elaeagnus conferta*	Elaeagnaceae	40	-	120	64	0.51	-	1.43	1.62	11.15	-	30.32	28.75
9	*Elaeagnus umbellata*	Elaeagnaceae	96	-	80	240	0.91	-	1.64	4.03	24.34	-	30.08	73.44
10	*Eleutherococcus cissifolius*	Araliaceae	24	-	-	-	0.06	-	-	-	5.94	-	-	-
11	*Eurya sp.*	Theaceae	-	-	40	-	-	-	0.48	-	-	-	12.71	-
12	*Glautheria sp.*	Ericaceae	-	-	80	-	-	-	0.49	-	-	-	18.37	-
13	*Grewia serrulata*	Malvaceae	-	192	-	-	-	0.31	-	-	-	37.99	-	-
14	*Helicteres isora*	Sterculiaceae	-	72	-	-	-	0.15	-	-	-	13.75	-	-
15	*Leucosceptrum canum*	Lamiaceae	88	-	160	40	3	-	4	3.87	32.91	-	63.71	33.21
16	*Lyonia ovalifolia*	Ericaceae	40	-	-	-	1.82	-	-	-	17.3	-	-	-
17	*Mahonia nepalensis*	Berberidaceae	48	-	-	-	0.42	-	-	-	12.5	-	-	-
18	*Mycetia sp*	Rubiaceae	-	88	-	-	-	0.42	-	-	-	21.75	-	-
19	*Myrisine sp.*	Myrsinaceae	24	-	-	-	0.34	-	-	-	6.44	-	-	-
20	*Nageia nagi*	Podocarpaceae	-	40	-	-	-	0.08	-	-	-	8.86	-	-
21	*Neolitsea chui*	Lauraceae	8	-	-	-	0.08	-	-	-	2.32	-	-	-
22	*Oreocnide fruticosa*	Urticaceae	-	168	-	-	-	0.67	-	-	-	41.74	-	-
23	*Oreocnide pedunculata*	Urticaceae	-	136	-	-		1.18	-	-	-	43.46	-	-
24	*Pandanus emarginatus*	Pandanaceae	-	16	-	-	-	2.16	-	-	-	46.94	-	-
25	*Psychotria silhetensis*	Rubiceae	-	88	-	-	-	0.5	-	-	-	23.88	-	-
26	*Rosa sp.*	Ericaceae	40	-	-	-	0.09	-	-	-	8.83	-	-	-

27	*Rubus ellipticus*	Rosaceae	48	-	72	120	0.32	-	0.26	0.56	16.24	-	18.58	23.9
28	*Rubus hypargyrus*	Rosaceae	-	-	40	-	-	-	0.67	-	-	-	14.02	-
29	*Rubus sp.*	Rosaceae	-	-	48	-	-	-	0.22	-	-	-	13.1	-
30	*Smyplocos sp.*	Symplocaceae	40	-	-	32	0.91	-	-	0.52	12.28	-	-	8.43
31	*Sorbus microphylla*	Rosaceae	-	-	40	-	-	-	1	-	-	-	13.67	-
32	*Strobilanthes auriculata*	Acanthaceae	-	64	-	-	--	0.01	-	-	-	10.76	-	-
33	*Thunbergia sp.*	Symplocaceae	24	-	-	-	0.74	-	-	-	9.69	-	-	-
34	*Vaccinium retusum*	Acanthaceae	16	-	-	-	0.22	-	-	-	4.97	-	-	-
35	*Viburnum cylindricum*	Adoxaceae	96	-	48	48	3.4	-	1.6	1.19	35.93	-	22.47	20.34
36	*Viburnum erubescens*	Adoxaceae	152	-	80	304	1.78	-	0.52	1.85	38.04	-	18.6	58.57
37	*Wendlandia sp.*	Rubiaceae	-	56	-	-	-	0.15	-	-	-	13.3	-	-
38	*Zanthoxylum sp.*	Adoxaceae	-	-	-	-	0.25	-	-	-	5.16	-	-	-
Herbs														
1	*Ajuga lobata*	Lamiaceae	-	-	-	56	0.027	-	-	0.01	8.92	-	-	3.36
2	*Alpinia nigra*	Zingiberaceae	-	67	-	-	-	0.02	-	-	-	8.93	-	-
3	*Anemone indica*	Lamiaceae	-	-	-	-	0.009	-	-	-	10.34	-	-	-
4	*Anemone rivulari*	Ranunculaceae	-	-	32	-	-	-	0.02	-	-	-	3.35	-
5	*Anemone rupestris*	Ranunculaceae	-	-	-	-	0.025	-	-	-	10.95	-	-	-
6	*Anisomeles indica*	Lamiaceae	-	-	24	312	-	-	0.03	0.16	-	-	3.88	18.01
7	*Anisomeles sp.*	Lamiaceae	32	-	24	-	0.002	-	0.03	-	2.67	-	3.3	-
8	*Arisaema ciliatum*	Araceae	72	-		-	0.011	-	-	-	5.83	-		-
9	*Arisaema erubescens*	Araceae	-	-	72	-	-	-	0.03	-	-	-	6.51	-
10	*Artemesia argyi*	Asteraceae	224	-	16	160	0.252	-	0.02	0.27	23.45	-	2.23	20.08
11	*Aster thomsonii*	Asteraceae	-	-	128	-	-	-	0.09	-	-	-	17.1	-

12	*Athriyum sp.*	Athyriaceae	88	53		88	0.013	0.001		0.01	4.31	8.72		9.42
13	*Athyrium filix femina*	Athyriaceae		-	208	-		-	0.03	-		-	18.87	-
14	*Barbarea vulgaris*	Brassicaceae	16	-	-	-	0. 003	-	-	-	1.14	-	-	-
15	*Boehmeria platyphylla*	Urticaceae	80	-	-	-	0.012	-	-	-	6.12	-	-	-
16	*Canabis sativam*	Cannabaceae	48	-	-	256	0.097	-	-	0.66	7.09	-	-	33.6
17	*Carduus acanthoides*	Asteraceae	80	-	-	136	0.13	-	-	0.22	8.76	-	-	15.79
18	*Colebrookea oppositifolia*	Lamiaceae	56	-	136	120	0.034	-	0.2	0.16	4.05	-	24.61	12.66
19	*Colocasia sp.*	Araceae	-	33	-	-	-	0.008	-	-	-	3.96	-	-
20	*Crassocephalum crepidioides*	Asteraceae	40	-	-	40	0.004	-	-	0.02	2.99	-	-	3.69
21	*Didymocarpus dissectus*	Gesneriaceae	48	-	-	-	0.006	-	-	-	2.79	-	-	-
22	*Drymaria cordata*	Caryophyllaceae	96	-	-	96	0.01	-	-	0.02	5.5	-	-	7.33
23	*Elatostema sessile*	Urticaceae	72	193	-	-	0.01	0.01	-	-	5.28	24.25	-	-
24	*Elatostema sp.*	Urticaceae	-	-	-	-	-	-	-	-	-	-	-	-
25	*Girardinia diversifolia*	Urticaceae	104		-	-	0.015	-	-	-	6.45	-	-	-
26	*Hedychium coronarium*	Zingiberaceae	-	100	-	-	-	0.06	-	-	-	14.01	-	-
27	*Hedychium gardneriaum*	Zingiberaceae	72	-	144	152	0.17	-	0.42	0.36	9.42	-	39.99	19.39
28	*Hemiphragma heterophyllum*	Scrophulariaceae	8	-	-	64	0.0002	-	-	0.01	1.31	-	-	4.84
29	*Heracleum nepalense*	Apiaceae	40	-		88	0.008	-	-	0.01	3.11	-	-	6.35
30	*Houttuynia cordata*	Saururaceae	40	-	96	80	0.007	-	0.02	0.03	3.61	-	10.33	5.96
31	*Jurinea sp.*	Asteraceae	40	-	112	-	0.01	-	0.03	-	4.76	-	9.43	-
32	*Lecanthus peduncularis*	Urticaceae	64	-	-	-	0.012	-	-	-	4.03	-	-	-
33	*Ligularia fischeri*	Asteraceae	16	-	-	-	0.003	-	-	-	2.71	-	-	-
34	*Musa sp.*	Musaceae	-	200	-	-	-	1.9	-	-	-	75.13	-	-
35	*Musa acuminata*	Musaceae	-	107	-	-	-	1.39	-	-	-	58.17	-	-

36	*Nepeta sp.*	Lamiaceae	-	-	96	-	-	-	0.03	-	-	-	10.52	-
37	*Oenanthe javanica*	Apiaceae	360	-	120	440	0.059	-	0.03	0.49	26.65	-	9.89	41.56
38	*Oxalis sp.*	Oxalidaceae	224	-	-	192	0.028	-	-	0.02	15.46	-	-	9.52
39	*Pellionia scabra*	Urticaceae	-	519	-	-	-	0.02	-	-	-	51.87	-	-
40	*Persicaria polystatchya*	Polygonaceae	-		-	112	-	-	-	0.13	-	-	-	10.49
41	*Pilea melastomoides*	Urticaceae	-	27	-	-	-	0.0008	-	-	-	3.39	-	-
42	*Pilea microphylla*	Urticaceae	256	-	-	-	0.042	-	-	-	12.78	-	-	-
43	*Pilea umbrosa*	Urticaceae	-	-	112	-	-	-	0.03	-	-	-	12.41	-
44	*Pollygonum molle**	Polygonaceae	240	-	200	264	1.697	-	0.48	1.64	76.09	-	44.11	57.52
45	*Potentiala sp.*	Potentilla	-	-	360	-	-	-	0.08	-	-	-	29.44	-
46	*Potentilla plurijuga*	Potentilla	-	-	136	-	-	-	0.03	-	-	-	16.17	-
47	*Primula denticulata**	Primulaceae	-	-	152	-	-	-	0.08	-	-	-	18.67	-
48	*Razisea sp.*	Acanthaceae	-	566	-	-	-	0.06	-	-	-	51.57	-	-
49	*Rubus nepalensis**	Rosaceae	-	-	232	-	-	-	0.02	-	-	-	19.66	-
50	*Sambucus adnata*	Adoxaceae	32	-	-	56	0.008	-	-	0.05	4.45	-	-	4.29
51	*Selinum tenuifolium*	Apiaceae	40	-	-	64	0.012	-	-	0.05	4.85	-	-	5.78
52	*Strobilanthes atropurpureus*	Acanthaceae	80	-	-	72	0.063	-	-	0.02	7.41	-	-	4.76
53	*Triumfetta sp.*	Malvaceae	16	-	-	40	0.013	-	-	0.01	3.07	-	-	2.77
54	*Wedelia chinensis*	Asteraceae	24	-	-	40	0.006	-	-	0.01	3.58	-	-	2.83

Note: EHSWHF- East Himalayan subtropical wet hill forest, EHBLF- Eastern Himalaya broadleaf forest, MCF-Mixed coniferous habitat, DSF-Degraded scrub forest

4.3.4. Girth class distribution and basal area

The mean girth of adult tree species >30 cm) was 48.98±1.73. The highest number of individuals (137 individual) was recorded in the girth class of 10-30 cm (Fig. 5.3).

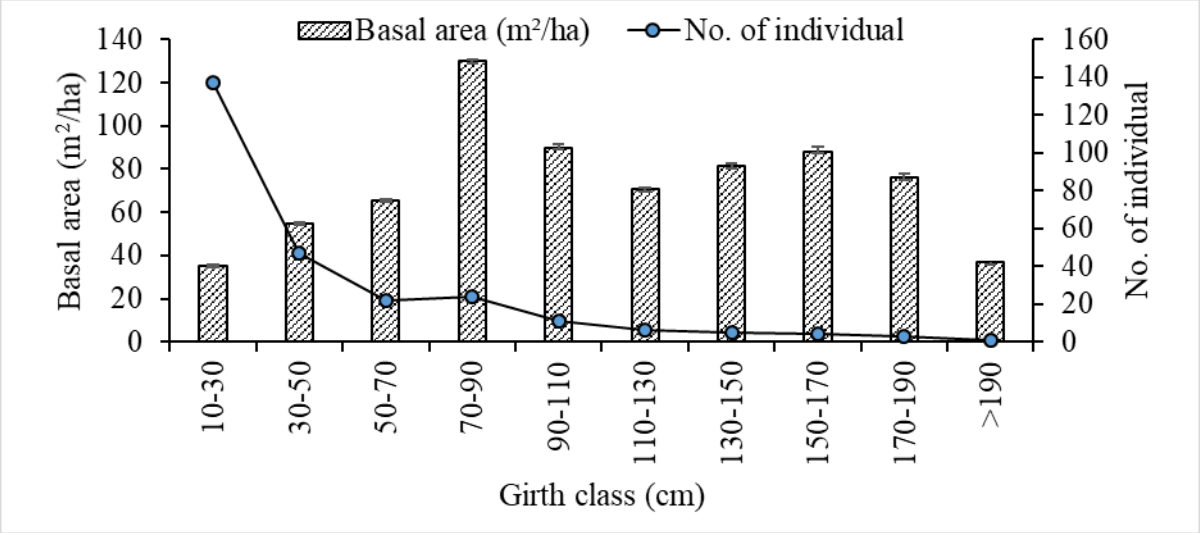

Figure 5.3. Girth class distribution of tree species in overall study stand

Among the three habitat, MCF had the highest mean girth size of tree individual (52.90 ±2.95) with a total basal area of 209.76 m^2ha^{-1} (Table 5.4). The lowest mean girth size of tree was found in DSF habitat (41.47 ±1.01) with basal area of 46.10 m^2ha^{-1} (Table 5.4; Fig. 5.4).

Table 5.4. Mean girth size of adult tree species in the studied habitat

Habitat	Mean girth size (cm ±SE)	Minimum	Maximum	TBA (m^2ha^{-1})
EHSWHF	48±2.73	31	145.57	144.55
EHBLF	48.81±3.22	30	121	125.13
MCF	52.90±2.95	30	145	209.76
DSF	41.47±1.01	30.85	55	46.10

Note: EHSWHF- East Himalayan subtropical wet hill forest, EHBLF- Eastern Himalaya broadleaf forest, MCF-Mixed coniferous habitat, DSF-Degraded scrub forest

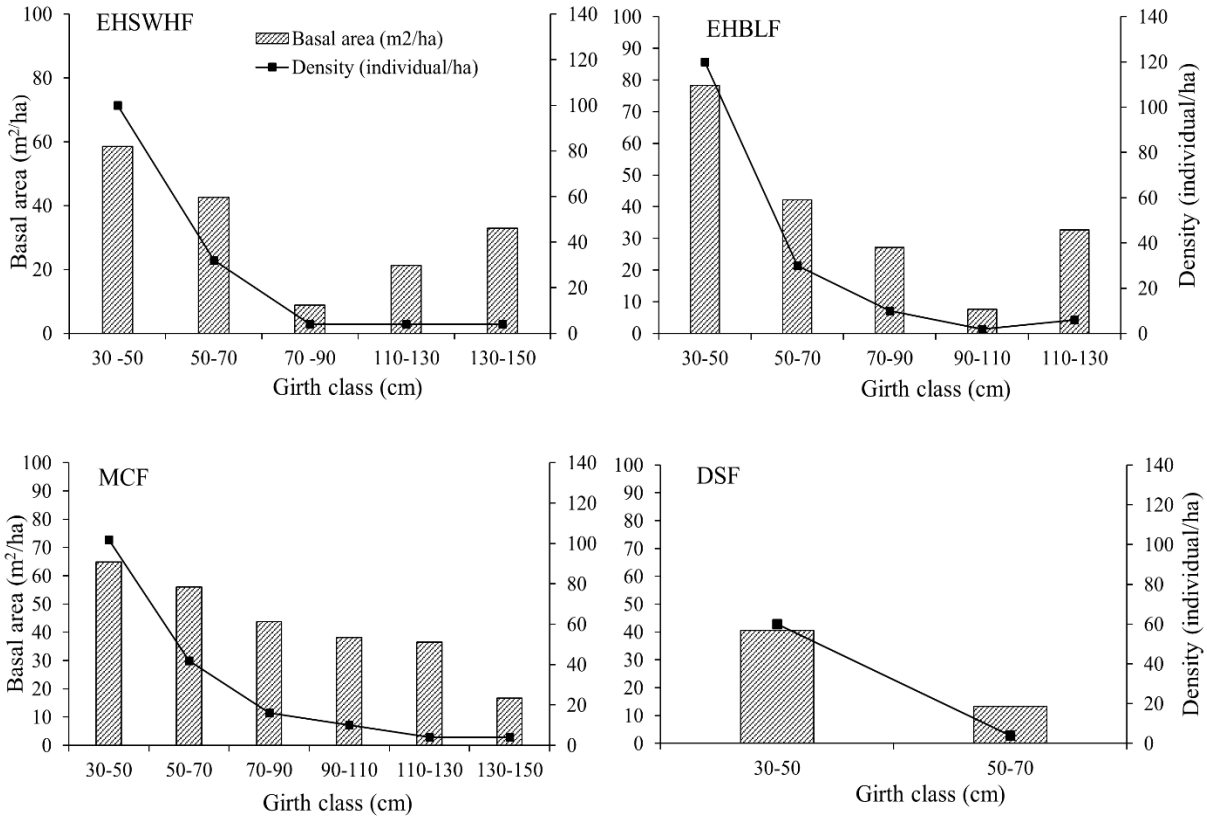

Figure 5.4. Girth class distribution of adult tree species in EHSWHF- East Himalayan subtropical wet hill forest, EHBLF- Eastern Himalaya broadleaf forest, MCF-Mixed coniferous habitat, DSF-Degraded scrub forest

4.3.5. Similarity index of habitat

In overall, the highest similarity index was found between the habitat of EHBLF and DSF (31.90%) and similarity index was between EHSWHF and EHBLF. The highest similarity index of tree, shrub and herb species were recorded between the habitat of EHBLF and DSF (Table 5.5).

Table 5.5. Vegetation similarity index (%) among the studied habitat of *Macaca munzala*

Vegetation	EHSWHF-EHBLF	EHSWHF-MCF	EHSWHF-DSF	EHBLF-MCF	EHBLF-DSF	DSF-MCF
Tree	3.92	2.33	0	16.28	19.35	13.33
Shrub	0.00	0.00	0	17.50	32.26	28.00
Herb	2.38	3.70	0	16.00	38.89	17.50
Overall	2.36	1.89	0	16.54	31.90	18.95

Note: EHSWHF- East Himalayan subtropical wet hill forest, EHBLF- Eastern Himalaya broadleaf forest, MCF-Mixed coniferous habitat, DSF-Degraded scrub forest

4.3.6. Anthropogenic disturbance

The study on anthropogenic disturbance was conducted in the habitat of EHSWHF, EHBLF and MCF. DSF habitat was excluded due to presence of highest level of disturbance. Among the studied habitat, the highest individual of cut stumps were recorded in EHBLF habitat (17 individual ha^{-1}) but highest basal area of cut stump was found in EHSWHF (97.23 m^2ha^{-1}) (Table 5.6).

Table 5.6. Cut stump girth class distribution and basal area in three studied habitat of *Macaca munzala*

Girth class (cm)	EHSWHF		EHBLF		MCF	
	No. of cut stumps (ha^{-1})	Basal area (m^2ha^{-1})	No. of cut stumps (ha^{-1})	Basal area (m^2ha^{-1})	No. of cut stumps (ha^{-1})	Basal area (m^2ha^{-1})
10-30	-	-	6	2.40	6	3.14
30-60	-	-	11	18.30	5	5.62
60-90	-	-	-	-	-	-
>90	4	97.23	-	-	-	-
Overall	4	97.23	17	20.70	11	8.76

Note: EHSWHF- East Himalayan subtropical wet hill forest, EHBLF- Eastern Himalaya broadleaf forest and MCF-Mixed coniferous habitat

The encounter rate of hunting activity and firewood collection were recorded highest in EHSWHF habitat (encounter rate: 0.87 per day), whereas, hunting was found absent in EHBLF and MCF habitat during study period. The timber extraction was frequent in EHSWHF compare to other studied habitats. In EHSWHF, cattle grazing was not recorded but it was recorded highest in EHBLF (1 per day) and MCF (0.6 per day) (Table 5.7).

Table 5.7. Anthropogenic disturbance in the habitat of Eastern Himalaya subtropical wet hill forest (EHSWHF); Eastern Himalaya broadleaf forest (EHBLF) and Mixed coniferous forest (MCF) of *M. munzala*

Disturbance parameter	Encounter rate (Per day)			
	EHSWHF	EHBLF	MCF	Sampling effort (days)
Hunting activity	0.87	-	-	15
Cattle grazing	-	1	0.6	15
NTFP collection	0.67	0.67	0.8	15
Firewood collection	-	0.73	0.53	15
Timber extraction	0.53	-	-	15
Other observations				
Cultivation	Slash and burn cultivation	Absent	Terrace cultivation	15
Forest burning	Present	Absent	Present	

NTFP -Non-timber forest product

4.4. Discussion

The present study has shown that species composition and community structure of *Macaca munzala* habitat varied according to the forest type and altitudinal gradient. The low altitude habitat (EHSWHF) has shown higher tree species richness in comparison to the habitats that occurred in high altitude (EHBLF and MCF). The result of the present study is in line with the fact that species richness decrease with increase in altitude [68]. The tree species richness was lowest in DSF habitat and mostly occupied by secondary vegetation. The pattern of species richness has coincided with the earlier report on vegetation survey in the study area [45]. The studied habitats have old growth forest, thus higher basal cover of *Pinus wallichiana, Cedar deodar*, *Quercus serrata* and *Tetrameles nudiflora* are recorded, which contribute to high basal area. The irregular pattern of dominance distribution curve of tree species indicates the presence of disturbance in the habitats. The higher number of cut stumps of tree species recorded in EHBLF and MCF habitat was in girth size between 10-60 cm. These may be due to extensive firewood collection in EHBLF and MCF habitat. While, in

EHSWHF cut stumps of tree was found in girth size >90 cm does exhibit highest basal area of cut stumps and timber extraction was common in protected habitat of EHSWHF.

In Indian forests Shannon-Wiener diversity index ranged between 0.83 to 4.1 and it is generally higher in tropical forests [69,70, 71]. Simpson's index for different Indian tropical forests ranged between 0.03 to 0.89 [52,48]. The estimated values of Shannon-Wiener diversity index and Simpson's index in the present study areas within the reported ranged. The similarity index of the present study has shown that sub-tropical habitat (EHSWHF) significantly differs from high altitude habitats (EHBLF and MCF) in terms of species composition. The vegetation composition of subtropical habitat (EHSWHF) did not record any food plant species of *M. munzala* as reported in earlier studies [53,67]. In present study the highest number of food plant species are recorded in degraded scrub forest (DSF) followed by Eastern Himalaya broadleaved forest (EHBLF) and mixed coniferous forest (MCF). However, *Erythrina arborescens* one of the major food plants of *M. munzala* was absent in mixed coniferous habitat but, appeared as dominant species in degraded habitat [53,67]. The studied habitats (EHSWHF, EHBLF, MCF and DSF) differ in dominant distribution of tree species i.e., EHBLF forest was dominant by *Alnus nepalensis*, *Pinus wallichiana* in MCF and *Erythrina arborescens* in DSF habitat and *Tetrameles nudiflora* in EHSWHF. *Alnus nepalensis* occurred commonly among the three habitats (EHBLF, MCF and DSF). The present study exhibited that species composition of EHBLF and MCF habitats have shown similarity with the other habitats of the state [45,49]. About, 17 tree species are occur commonly in between the high altitude habitat of West Siang district and *M. munzala's* habitat (EHBLF and MCF) of present study [46]. Nevertheless, Chakraborty et al. [72] reported population occurrence of *M. munzala* in West Siang district. Thus, species composition and presence of food plant might have significant influence in population distribution of *M. munzala* in Eastern Himalaya of Arunachal Himalaya. Further, plant species composition (including food plant) of Assamese macaque's (*Macaca assamensis*) of Nepal found to have similarity with MCF and EHBLF habitat of *M. munzala* of the present study [73].

The highest population occurrence of *M. munzala* was recorded in community conservation area of Zemithang, Pangchen valley and lowest in protected habitat of EHSWHF in Sessa orchid Sanctuary. Kumar et al. [42] reported highest population of *M. munzala* in degraded habitat of Tawang district and estimated highest density of the species

in Zemithang, Pangchen valley (21 individual ha^{-1}). It has been noted that *M. munzala* are found to be tolerant to anthropogenic disturbance in habitat, unlike prototypical branchiate primate [35,42]. The present study recorded the occurrence of extensive hunting in protected habitat of Sessa orchid sanctuary (EHSWHF) but hunting activity was absent in community conservation area of Zemithang, Pangchen valley (EHBLF and MCF). The presence of hunting in Sessa orchid sanctuary (EHSWHF) might be one of the reasons to have low population abundance of *M. munzala* in the sanctuary. On the other hand, local people participation in conservation of wildlife in Pangchen valley and prohibition in hunting protect highest population occurrence of the species in Pangchen valley. Thus, it may be specify that hunting is a major threat for survivability of the *M. munzala* in its distribution range. Studies also stated that hunting is one of the greater threats for population of primate species than the habitat degradation [25,74]. Nevertheless, hunting in Arunachal Pradesh was reported intensive that endangered primate as well as other rich wildlife of the state [33,36,75–78].

The present study concludes that the species composition of *M. munzala* habitat varies according to the altitude and distribution of the species. Anthropogenic disturbance such as firewood collection, selective logging, forest fire and agricultural activity are major factor for disturbance of natural habitat of the species (Photo plate 5.1 and 5.2). It is indeed important to mention that hunting in protected habitat imposes serious threat for the population of endangered *M. munzala*. The study suggested a long term monitoring of population status of *M. munzala* in the protected habitat and non-protected habitat of the species. Further, the present study also reciprocates that community based conservation may act as an instrumental tool which policy maker need to use for long term conservation of the species.

Photo plate 5.1. Sessa orchid sanctuary, Eastern Himalayan subtropical wet hill forest (EHSWHF); Old growth tree (A), Selective logging (B.C. E) and Slash and burn cultivation (D.E)

Photo plate 5.2. Zemithang, Pangchen valley, Eastern Himalaya broadleaf forest (**EHBLF)** and Mixed coniferous forest (**MCF)**; Old growth tree (A), Firewood collection (B, C, D), Forest fire (E) and Permanent terrace cultivation (F,G).

4.5 References

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