Chapter-VII

Comparative morphometric analysis of *Macaca munzala* and *Macaca assamensis pelops*

7.1. Introduction

The *sinica* group (genus macaca) species are distributed in Indian sub-continent to mainland Southeast Asia [1]. A total of four species viz., Toque macaque (*Macaca sinica*), Bonnet macque (*Macaca radia*ta), Assamese macaque (*Macaca assamensis*), Tibetan macaque (*Macaca thibetana*) have been recognized in this group [1]. Arunachal macaque (*Macaca munzala*) and White cheeked macaque (*Macaca leucogenys*) are newly added to the list based on the penile morphology and phylogenetic study [2–4]. *M. munzala* have dark pink glans, whereas penis is sagittate in shape that prominently inflected from the shaft [2]. The relative tail length of the species is shorter and intermediate to eastern Assamese macaque (*Macaca assamensis pelops*) and western Assamese macaque (*Macaca assamenesis pelops*) but longer than the Tibetan macaque (*Macaca thibetana*) [2]. However, Biswas et al. [5] reported that tail length to head body length ratio of *M. munzala* is proximate to *M. a. assamensis.* Further, they found significance variation in morphometry and phenotypic characteristics within the same population of *M. assamenesis,* on a specific investigation two sub-species of Assamese macaque. Thus, *M. munzala* is claimed as a similar population of eastern Assamese macaque (*M. a. assmenesis*) based on tail length and morphometric closeness by Biswas et al. [5].

Sinha et al. [2] explained that adult *M. munzala* have long pelage and colour varies from dark brown to dark chocolate dorsally. The tail is reported as darker in colour and ventral part of trunk is reported lighter in colour. The upper part of the torso and the distal parts of the limbs is light brown to olivaceous in colour. Similarly, pale yellow prominent crown whorl, characteristics facial marks on the temple-forehead and pale collar hair around the neck are explained as a distinct morphological characteristics of the species. The lack of prominent cheek tufts and chin whiskers and presence of prominent crown whorl in *M. munzala* are described as distinct morphological characteristics that separated the species from *M. a. pelops* [2]. FA [6] explained that *M. assamenesis* have longer dorsal hair and lighter yellowish brown colour dorsally. The colour of tail is similar to dorsal colour. The ventral colour of the species ranges from buffy to whitish. White cheeked macaque (*Macaca leucogenys*) is described as a new species based on suite of pelage characteristics with distinct ring shaped penile morphology [7]. The tail length of the species is reported to varied from sympatric *M. mulatta, M. thibetana* and *M. assamenesis* but found similar with *M. munzala* [7]. The presence of prominent white cheeked and elongated facial hair considered as species specific characteristics of the species. Further, the molecular genetic analysis of *M. leucogenys* reveals the close phylogenetic relationship with other sinica group of species like *M. munzala* [3,4]. The influence of altitude and climatic variation has been significantly found in morphological characteristics in genus macaca [8,9]. However, a few study has been found on primate's morphometry and colour variation in eastern Himalaya region on the basis of attitudinal gradient [2,5]. Eastern Himalaya has wide altitudinal gradient and climate varied accordingly, thus influence has been reported in morphological characteristics of *M. assamensis*, Nepal [10] and *Trachypithecus geei*, Bhutan [11].

The major goal of the present study is to investigate the morphometric characteristics, colour variation and tail-body length variation of *Macaca munzala* that inhabit in high altitude cold climate (2000 m amsl). Further, a comparative study has been done with sympatric *M. assamensis pelops* that inhabit in warm and humid area of low altitude (100 m amsl). The present study, has been given emphasis in non-invasive method of photogrammetry and RGB (Red Green Blue) additive colour model to study the morphometry and colour variation between the species [12–14].

7.2. Method

7.2.1. Study site and animal

The study was conducted at Zemithang Pangchen valley of Tawang district, Arunachal Pradesh (Longitude 91°43'44.19"E; Latitude 27°42'35.05"N) and Tukreswari temple of Goalapara district (Longitude 90°37'58.38"E, Latitude 26° 2'58.81"N) (Fig. 7.1). Three troops (KZ, KS and LM troops) of *Macaca munzala* were selected in Zemithang, Pangchen valley and one troop of *Macaca assamenesis pelops* in Tukreswari of Goalapara district, Assam for the present study. The age-sex classification of the all the study troops were presented in Chapter III, Table 3.2. The morphometric measurement for *M. munzala* was conducted only from LM troop, whereas; the phenotypic characterizations were done for all the study troops.

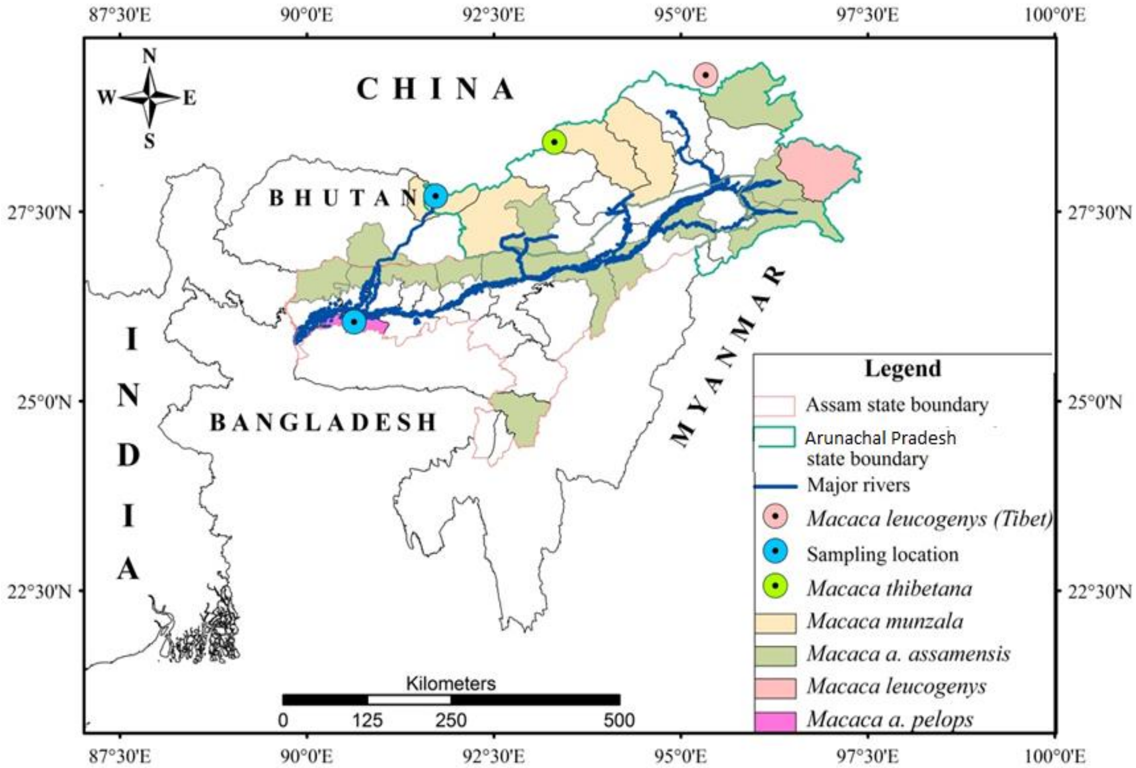

Figure 7.1. Map showing location of study area (Tawang district, Arunachal Pradesh and Goalpara district, Assam) and distribution of *sinica* group of species in Assam and Arunachal Pradesh and Bhutan

7.2.2. Climatic data

To assess the climatic difference between the study site rainfall, temperature and potential evaporation data of 10 years (1991-2002) has been downloaded (www.indiawaterportal.org/met_data) [15]. The annual mean temperature of Tawang district was found 16.54 °C ±4.68 (Standard deviation) and 23.57 °C ±3.96 for Goalpara district (Fig 4.2). The lowest temperature in Tawang district was recorded in the month of January (2.51 °C) and highest in August (25.56 °C). Similarly, lowest temperature for Goalpara district was recorded in January (10.51 °C) and highest during the month of August (30.33 °C) (Fig. 7.2). Among the selected climatic parameter, temperature was found significantly different between the study areas (df=1, F=15.74, $p<0.01$).

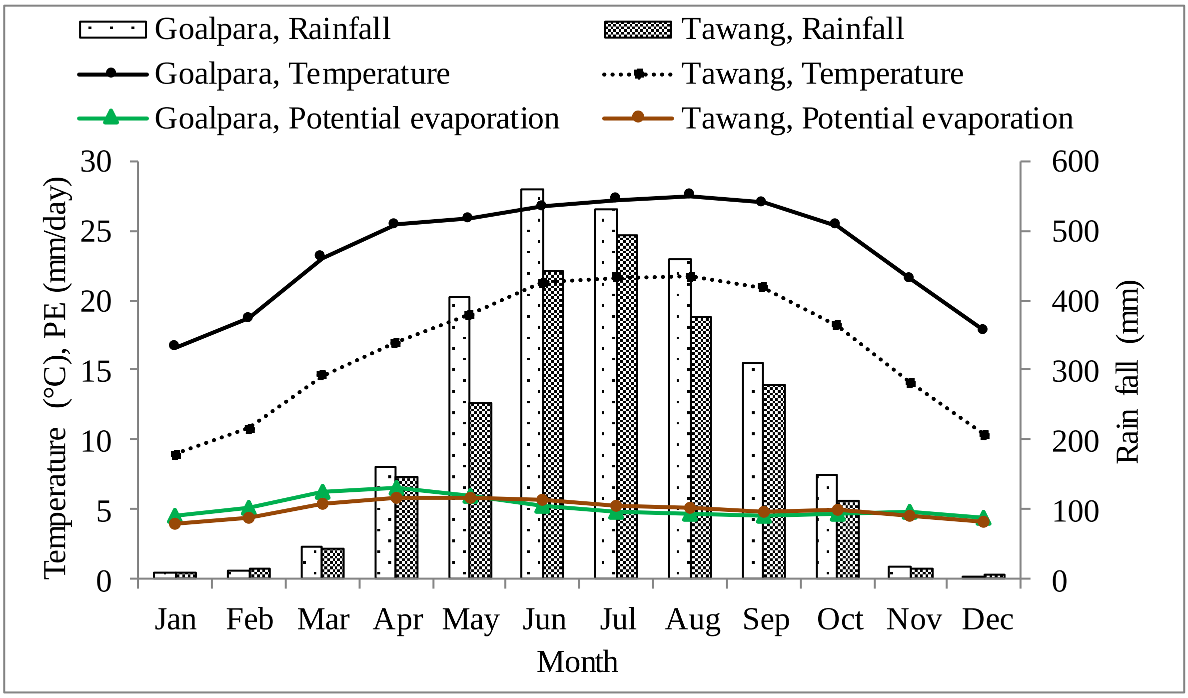

Figure 7.2. Mean monthly variation of temperature, rainfall and potential evaporation of Tawang, Arunachal Pradesh and Goalpara, Assam

7.2.3. Phenotypic characterization

Presence and absence of crown whorl, side whisker, facial and cheek hair, facial marks on the temple and head, spectacle eye appearance, glans penis appearance, etc. were studied from the photograph of *M. munzala* and *M. a. pelops* in different age/sex classes [2]. The newly discovered *M. leucogenys* was also included in the comparative study of phenotypic characteristics from the available literature [7].

7.2.4. Tail length/head-body length measurements

A wooden bar attached with a 10 m ruler was placed in the area that macaque troop frequently visit. Nikon D5200 camera (mounted with 300 mm lens) was setup on a tripod in a distance of 15 m from the bar. Macaques were lured to the bar by keeping vegetables on it and photographs were taken, when macaque walked on the bar. The macaques with forward walking only selected for morphometric measurement (Fig. 7.3). The morphometric measurement of tail length (Base to tail tip) and body length (head to base of the tail) were assessed from the photograph using ImageJ software (www.imagej.nih.gov) [12,13]. The relative tail length was estimated using the formula of tail length/head-body length ×100 [16]

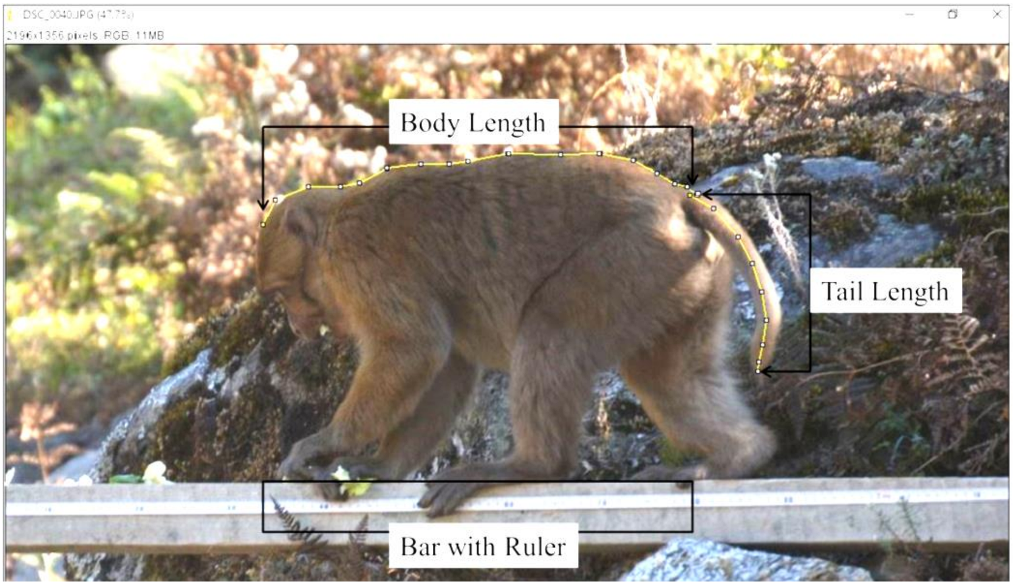

Figure 7.3. Body and tail length measurements of adult *M. munzala* using ImageJ software

7.2.5. Colour assessment

The study on colour variation in wild animal is difficult to accomplish due to constrain in getting sample and high cost instrumental requirement such as colour spectrophotometer [17]. Thus, digital photographs are increasingly found to adopt in colour variation study, which is an affordable method [12,13,18,19]. The advancement of digital camera technology is allowed to produce high resolution image (greater number of pixel) and the manual control of light intensity (Shutter speed, ISO, aperture and white balance). Light is a crucial parameter in colour composition of digital photograph and source of light influence appearance of colour [20]. In control environment (Studio) light intensity can be maintain uniformly but in outdoor environment, it is difficult to do so. The non-linearity in image greatly influences by the light that create difficult to colour comparison between images [17,18]. Therefore, the present study uses camera white balance to remove unwanted colour and recover the true colour of captured image. White balance sensor of camera targets the brightest area of an object as a reference (Warm or colder colour) that help to attain the natural colour of target object [20–22]. However, white balance also varies based on the light source.

To overcome this difficulty, a custom white balance is created using a neutral standard colour chart in a colour editing software. Later on, the photographs are treated with custom white balance to attain the linearity. The study uses RGB additive colour model to compare the image, as human perspective of colour change individual to individual. The colour display on electronic screen is proportionate composition of Red, Green and Blue colour, known as RGB additive colour model. The scale of RGB (0 to 255) provide information of intensity of Red (255, 0, 0) Green (0, 255, 0) and Blue (0, 0, 255) of an image. Subsequently, based on the RGB scale darker and lighter colour can be detected i.e., RGB value near to the "255" appear as light in colour and near to "0" darker the colour of an image.

To minimize the variation in light intensity, uniform camera settings was maintained (Camera Nikon D5200, image captured in RAW format, shutter speed 1/250 sec, aperture f/4.8, ISO- 400 and auto white balance) in every photographic sampling. A custom white balance profile was created using X-rite colour checker passport (natural colour reference with 26 patches) in Adobe Photoshop Lightroom 5.7.1 (Fig. 7.4). The photographs were synchronized with custom white balance profile and mean RGB values obtain from selected region of animal part (Dorsal coat, ventral coat, facial skin and eye orbital) using ImageJ software (Fig. 7.4). The colour analysis were carried out in HP LV1911 (HD Graphics 4000) desktop monitor with the resolution setting of 1366 × 768, refresh rate 59 Hz, Bit depth 8-bit and RGB colour format. Further, hexadecimal code and name has been used in the study using online database of www.colorhex.com [23,24].

7.2.6. Data analysis

Data was entered in Microsoft Excel spreadsheet and basic statistics were calculated in the same. Statistical analyses were performed in SPSS package (16.0). The mean of RGB value were compared using independent sample t-test between the troops RGB value and significance was set at 95% confidence interval i.e. $p<0.05$ for statistical tests. Variations were given around the mean for all results and standard error was presented with mean statistics i.e. mean ±S.E. Mean. For RGB value, standard deviation (Mean± SD) was presented with mean value i.e. mean ±SE.

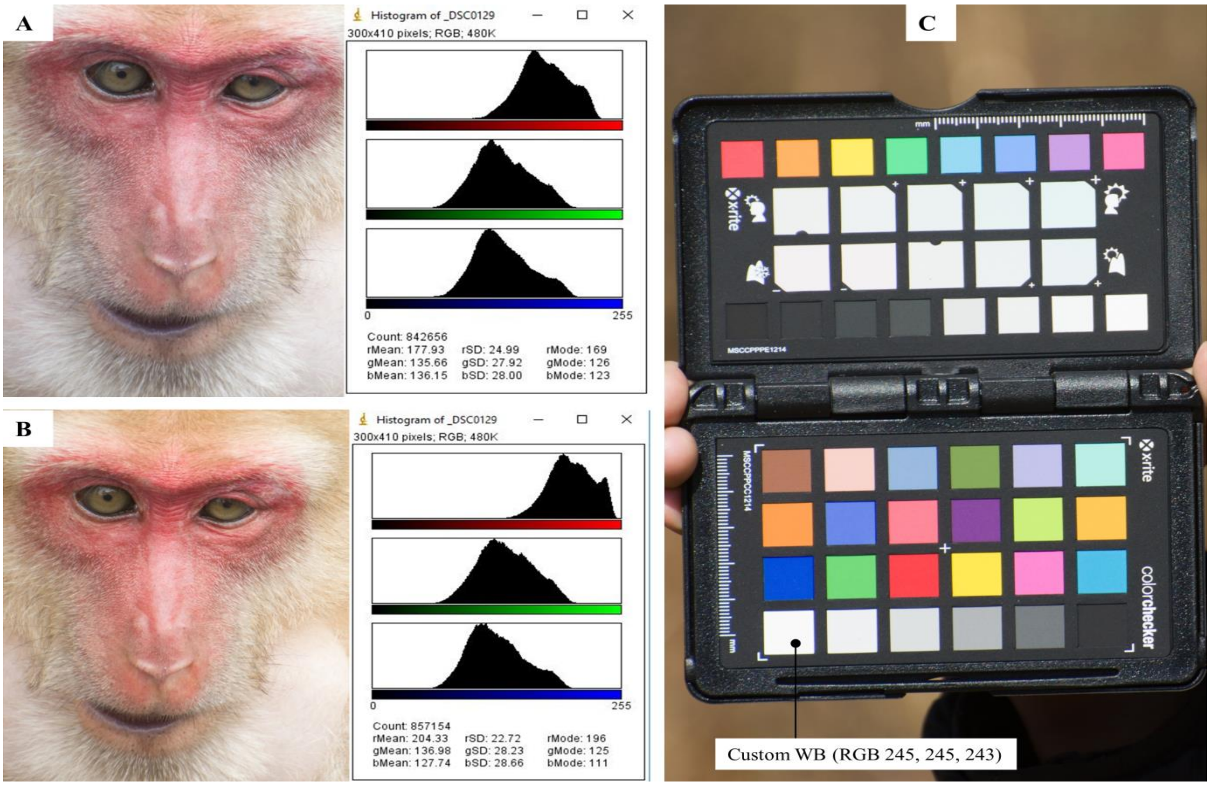

Figure 7.4. Facial colour of adult female *M. a. pelops* before treatment with custom WB (RGB 177, 135, 136) [A] and after the treatment with custom WB (RGB 204, 136, 127) [B]. Photograph of colour checker passport with selected brightest patch for custom profile [C].

7.3. Results

7.3.1. Species specific trait

The present study found that major taxonomic identification phenotypic characteristics of *M. munzala* were present in *M. a. pelops* (Table 1). However, the characteristics were more prominent in *M. munzala* than *M. a. pelops* (Fig. 7.5 and Fig. 7.6). Most of *M. munzala* individual had distinct crown whorl and dark patch of hair at receding hairline and absence of crown whorl also recorded in the species. In, adult individual of *M. a. pelops* crown whorl are not prominent but few individual had distinct crown whorl as like *M. munzala* (Fig. 7.6 A and B; Table 1). The dark patch of hair at hair line was found prominent in immature individual in both the species (Fig. 7.5). Light grey colour fur appear in sub-adult and gradually fur was found extend to the neck and lower cheek region in adult individual in both the species (Fig. 7.6). The extended cheek hair was found mostly in adult female of *M. munzala* that grows up to the muzzle area. Further, it was appeared very prominently in older female individual (Fig. 7.6 K). *M. a. pelops* exhibit similar pattern of cheek hair but shorter in length (Fig. 7.6 L). The extended patch of dark hair at temporal side of immature was found appear from upper cheek to the ear and appear as a dark stripe in both of the species (Fig. 7.5). The light pale coloured spectacle appearance in eye orbital side was prominently appear in adult male but in adult female it appears as a dark red colour (Fig. 7.6). Further, the light grey eye brow was found to be prominent characteristic in old individual of *M. munzala* and *M. a. pelops* (Fig. 7.6).

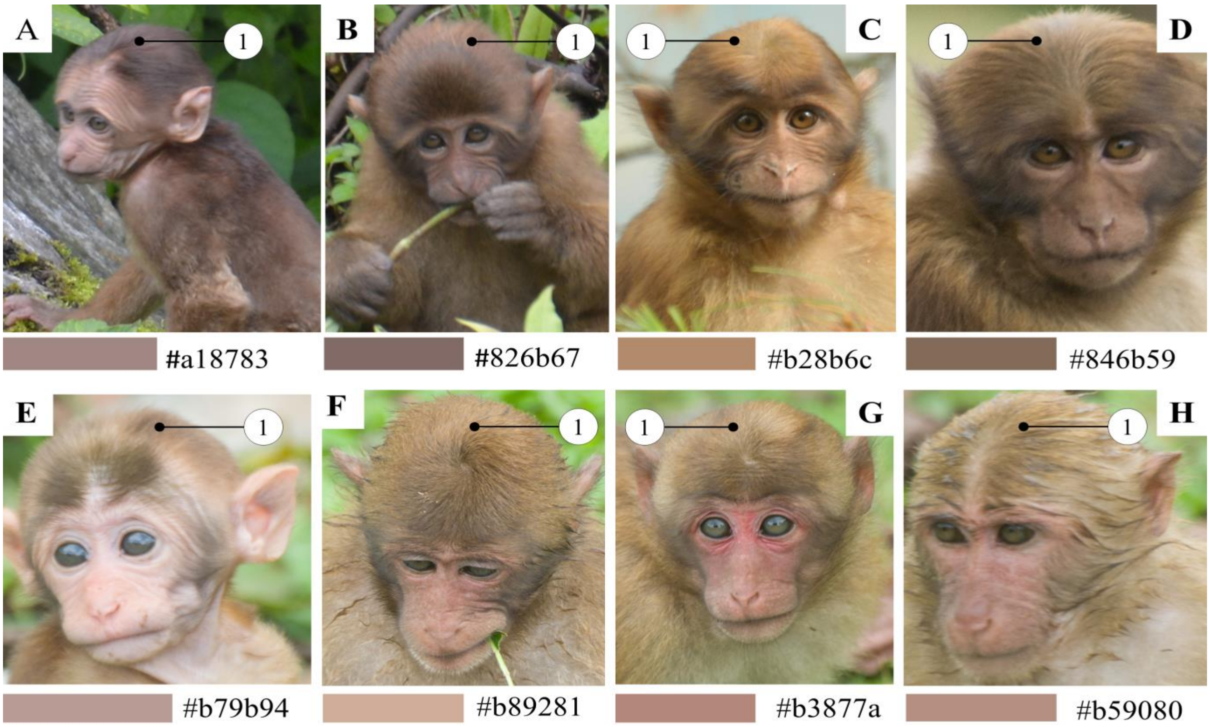

Figure 7.5. Facial skin (hcc and reference colour) and crown hair (1) in *M. munzala* (A, B, C and D) and *M. a. pelops* (E, F, G, H). Infant "Dark grayish red" and dark shaded hair line (A); Juvenile with "mostly desaturated dark orange" and dark shaded hair patch at hairline (B); Juvenile male with "mostly desaturated dark orange" face with parted hair crown (C); Sub-adult male "mostly desaturated dark orange" (D); Infant with "Grayish red" and dark patch at hair line (E); Sub-adult male with slightly desaturated red with prominent crown whorl (F); Sub-adult female with slightly desaturated red with crown whorl (G) and Sub-adult male with lightly desaturated orange with parted crown hair (H).

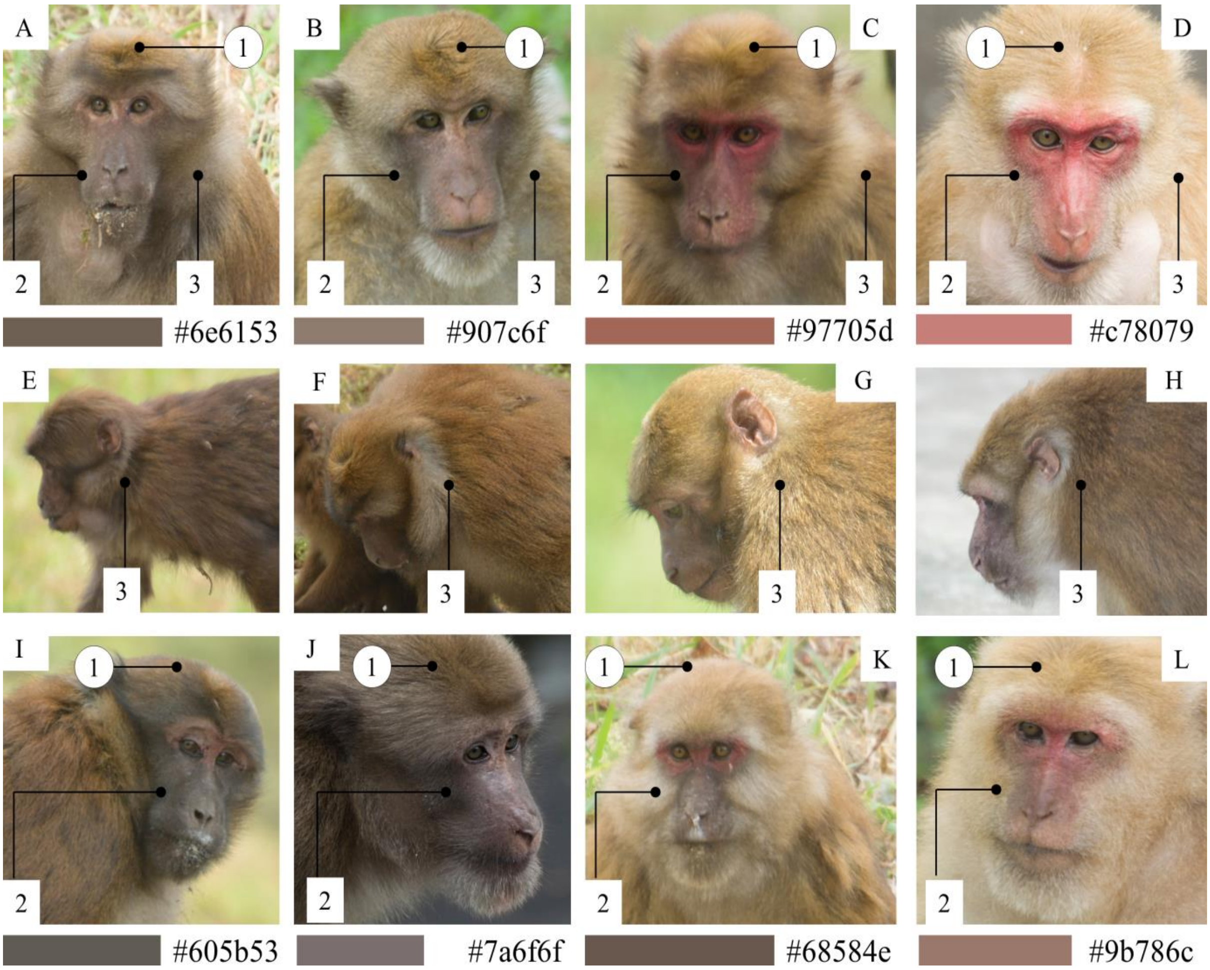

Figure 7.6. Facial skin colour (hexa decimal code and reference colour), crown whorl (1), cheek hair (2) and side-whisker (3). Adult male *M. munzala* (A) and *M. a. pelops* (B) with crown whorl and tuft appearance (1), cheek hair not prominent (2) but prominent side whisker (3); adult female *M. munzala* (C) and adult female *M. a. pelops* (D) with crown whorl presence but not prominent (1), cheek hair restricted in facial region (2) but elongated side whisker presence (3); Sub- adult *M. munzala* (E) with short side whisker (3); adult male *M. munzala* (F) with elongated side whisker (3); Sub-adult male *M. a. pelops* (G) with short side whisker; adult male *M. a. pelops* (H) with elongated side whisker (3); adult male *M. munzala* (I) and adult male *M. a. pelops* (J) without cheek hair (2) and crown whorl presence but not prominent (1); adult female *M. munzala* (K) cheek hair elongated to the muzzle region (2), crown whorl absence (1), adult female *M. a. pelops* (L) cheek hair elongated to muzzle area and crown whorl presence but not prominent (1).

Table 1. Comparative assessment of phenotype characteristics of *M. munzala*, *M. a. assamenesis* and *M. leucogenys*

Phenotypic characteristics	*M. munzala* Sinha et al. [2]	**Present study**		*M. leucogenys* Li et al. [7]
		M. munzala	*M. a. pelops*	
1.Tail appearance				
Infant	Not explain	**Hairless,** Whip-like, tapering distally and slightly bent inward at end (n=6) **Colour:** Light grayish red (hcc #fadadd)	**Hairless,** Whip-like, tapering distally and slightly bent inward at end (n=4) **Colour:** Grayish orange (hcc #cebfba)	#Hairless, tapering to the end, with the root of tail thicker than the distal end, the end of tail bends toward the ground in some individuals
Juvenile	Hairless, Whip-like, tapering distally to a narrow tip	Hairless, Whip-like, tapering distally to a narrow tip and slightly bent inward at end (n=18) **Colour:** Very dark grayish orange (hcc #60594c)	Hair less, Whip-like, tapering distally to a narrow tip and slightly bent inward at end (n=8) **Colour:** Dark grayish pink (hcc #a89ca2)	
Sub-adult	Not explain	Short hair covered, distal end and slightly bent inward at the end of tail (n=20)	Short hair covered, distal end and slightly bent inward at the end of tail (n=10)	

		Colour: Mostly desaturated dark orange (hcc #a18c6d)	**Colour:** Grayish orange (hcc #bcae94)	
Adult	Dark colour tail, Whip-like, tapering distally to a narrow tip	Longer hair, distal tail end or tapering end (n=35) **Colour:** Mostly desaturated dark orange (hcc #736853)	Longer hair, distal tail end (n=6) or tapering end (n=12) **Colour:** Mostly desaturated dark orange (hcc #a18c6d)	
Old adult	Not explain	Distal end stocky tail and curve to inward (n=10) **Colour:** Very dark grayish orange (hcc #635b4e)	Distal end stocky tail and curve to inward (n=5, N=5) **Colour:** Mostly desaturated dark orange (hcc #a38e6e)	
2. Facial hair				
Infant	Not explain	Not observed	Not observed	Dark hairs on their face
Juvenile	Not explain	Not observed	Not observed	Not explain
Sub-adult	Not explain	Not observed	Not observed	Not explain
Adult	Not explain	Presence only in lower region of face in **male** (n=15) but longer grown in **female** (n=20)	Not observed	Adults exhibit virtually no dark hairs on their face

Old adult	Not explain	Very prominent in **female** individual grows up to muzzle area (n=10)*	Presence in female but short (n=4)*	old individuals, white to pale hairs grow on the muzzle
3. Crown whorl				
Infant	Not explain	Absent*	Absent*	Not explain
Juvenile	Not explain	Present (n=20)*	Present (n=4)*	Not explain
Sub-adult	Not explain	Present (n=12)		
Adult	Present (whorl of hairs)	Present adult (n=20)*	Present (n=6)*	Not explain
4. Dark pelage patch at the hair line and extends to outer area of crown whorl				
Juvenile	Not explain	Presence (n=4)*	Present (n=4)*	Not explain
Sub-adult	Not explain	Presence (n=30)*	Present (n=4)*	
Adult	Pale yellow patch with central group of dark hair	Presence (n=25)*	Present (n=4)*	
5. Erect tuft crown whorl				
Infant	Absent	Absent*	Absent*	Absent
Juvenile	Absent	Absent*	Absent*	

Sub-adult	Absent	Absent*	Absent*	
Adult	Observed in adult individual	Present (n=9)*	Present (n=1)*	
Old adult		Present (n=3)	Absent	
6. Facial mark				
Infant	Not explain	Present (n=8)*	Present (n=4)*	Not explain
Juvenile	Not explain	Present (n=18) *	Present (n=8)	
Sub-adult	Not explain	Present (n=20) *	Present (n=4)*	
Adult	Characteristic facial marks on the temple and forehead	Present (n=20) *	Present (n=3)	
7. Side whisker				
Infant	Not explain	Absent*****	Absent*****	Lack pale side-whiskers**#**
Juvenile	Not explain	Slightly appear at ear side (n=15)	Not observed prominently (n=8)	Prominent white side-whiskers which extended from cheek to ears

Sub-adult	Not explain	Prominent at ear side (n=25)*	Present (n=6)*	Prominent white side-whiskers extended from cheek to ears#
Adult	Pale collar of hair around the neck	Present and elongated to the lower region of cheek (n=30)*	Present and elongated (n=6)*	Prominent white side-whiskers extended from cheek to ears#
8. Prognathous head with broader muzzle				
Adult male	Prognathous head with broader than the muzzle	Prognathous head and flaring shape nose* (n=15)	Prognathous head and flaring shape nose* (n=4)	Not explain
Adult female		Prognathous head and flaring shape nose* (n=20)	Prognathous head and flaring shape nose* (n=2)	
Older female	Round appearance	Round appearance* (n=6)	Round appearance* (n=4)	Round appearance#
9. Patch of dark hair at temporal side and extended to upper cheek to the ear				
Infant	Dark patch on either temple (Stripe extends from the outer corner of the eye or the upper cheek to the ear.)*	Present (n=3)*	Present (n=2)*	Not explain
Juvenile		Present (n=10)*	Present (n=8)*	
Sub-adult		Present (n=20)*	Present (n=7)*	
Adult		Not prominent (n=35)*	Present but covered by cheek and side whisker (n=2)*	

Adult Glans penis	Explain as sagitate shape	Glans penis sagitate in shape (n=12) and also appear as a round shape, when glans retract to the shaft (n=8)*	Glans penis sagitate in shape (n=5) and also appear as a round shape, when glans retract to the shaft (n=4)*	No inflection between the glans penis and shaft and the glans looks like a ring (Li et al., 2015)
10. Light grey eye brow (hcc #d3d3d3)				
Infant	Not explain	Absent *	Absent*	Not explain
Juvenile		Absent *	Absent*	
Sub-adult		Absent *	Absent*	
Adult		Present but not prominent (n=20)*	Present but not prominent (n=8)*	
Old-adult		Prominently present (n=13)*	Prominently present (n=4)	

*****Common in *M. munzala* and *M. a. pelops*; **#** Common in *M. munzala* and *M. leucogenys*, n=No. of individual

The pattern of tail appearance was found similar between the *M. munzala* and *M. a. pelops* (Fig. 7.7). Infant had hairless tapering end tail and slightly bent inward at the end (Fig. 7.7 A. *M. munzala* and F. *M. a. pelops*); sub-adult had tapering end tail and slightly bent inward at the end (Fig. 7.7 B. *M. munzala* and G. *M. a. pelops*). The adult individual had tapering end with slightly bent inward end (Fig. 7.7 D. *M. munzala* and I. *M. a. pelops*) and distal end tail with slightly bent inward (Fig. 7.7 C. *M. munzala* and H. and J. *M. a. pelops*). The old individual of *M. munzala* and *M. a. pelops* were found to have stocky distal end tail that curve to inward (Fig. 7.7 E) and sometime dark shaded fur at the end (Fig. 7.7 H, J).

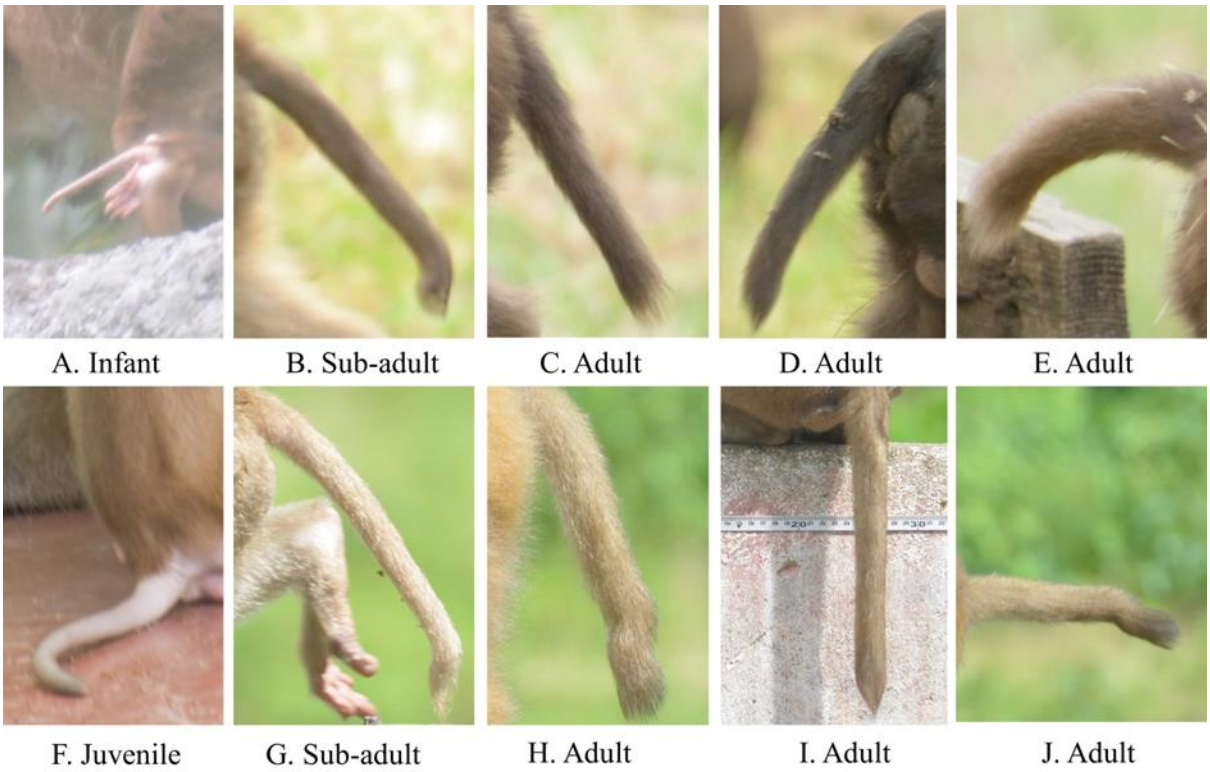

Figure 7.7. Tail shape and pattern in *M. munzala* (A, B, C, D) and *M. a. pelops* (F, G, H, I, J)

7.3.2. Penile morphology

The glans penis was found sagittate shape for both of the species (Fig. 7.8). In immature, shaft was found more exposed to outward but in adult foreskin cover the maximum of shaft. But, in some adult individual head of glans retract to the foreskin and appear as round or ring shape in both the species (Fig. 7.8. C and F).

Figure 7.8. Glans penis appearance in adult of *M. munzala* (A, B, C) and *M. a. pelops* (D, E, F)

7.3.3. Tail and body length variation (adult individual)

A total of 11 adult individuals of *Macaca munzala* and *Macaca assamenesis pelops* were selected (Photographs) for the morphometric measurement. The mean tail length for *M. munzala* was found 0.24 m ±0.005 (mean ±SE) and *M. a. pelops* tail length was 0.32 m ±0.01. The relative tail length of *M. a. pelops* was found higher (60.56% ±4.37) than the *M. munzala* (43.04% ±3.28) (Table 2). The ratio between tail and body length in *M. munzala* was found to be 0.59:1.37 and 1.02:1.68 for *M. a. pelops* (Fig. 7.9). The length of tail, head to tail, relative tail length and ratio of tail and body were found significantly differ between *M. munzala* and *M. leucogenys* (Table 2).

Table 2. Morphometric measurement of *Macaca munzala* and *Macaca assamenesis pelops;* statistics shows independent sample t-test

Measurement (in m)	*M. munzala* (mean ± SE)	Range	*M. a. pelops* (mean ± SE)	Range	Equal variance, t-test
Tail length	0.24±0.005**	0.20-0.26	0.32±0.01**	0.28-0.34	10.21
Head to tail	0.78±0.02*	0.69-0.87	0.84±0.01*	0.74-0.90	2.20
Body length	0.55±0.02^{ns}	0.49-0.63	0.52±0.01^{ns}	0.45-0.56	1.55
Relative tail length	43.04%±0.99**	36.89-47.45	60.56%±1.32**	52.74-67.92	10.63
Mean Tail/Body ratio	0.43±0.009	0.37-0.47	0.60±0.04	0.53-0.68	
Tail/Body	0.59:1.37**		1.02:1.68**		10.72

*p<0.05; **p<0.01, ^{ns} (not significant)

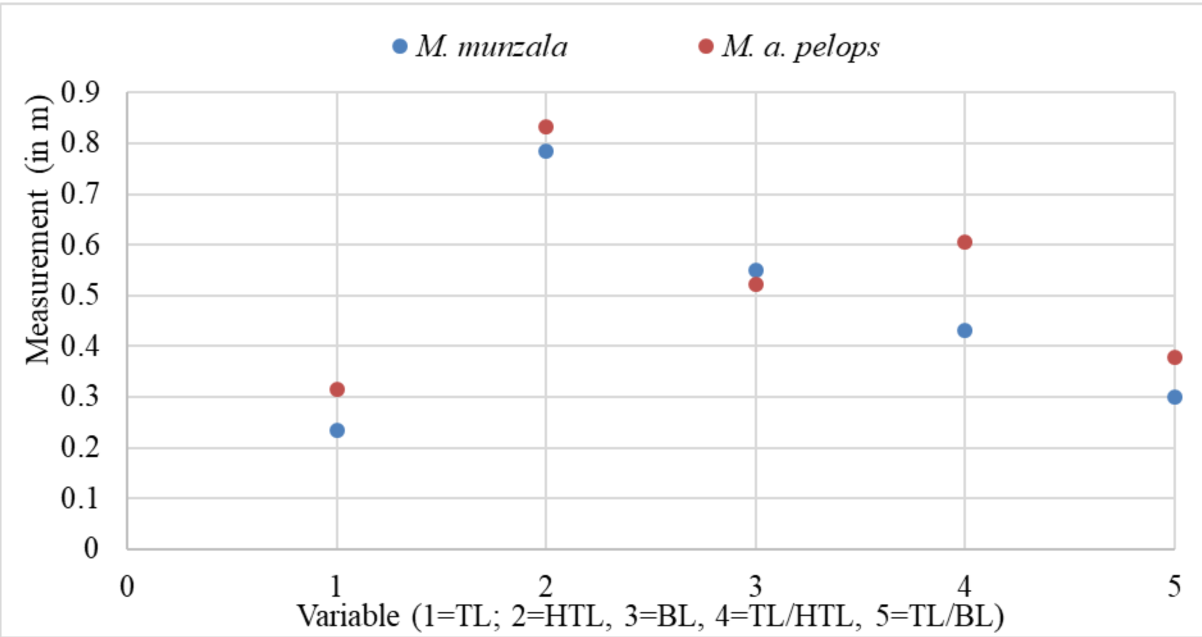

Figure 7.9. Morphometric measurement of *M. munzala* and *M. a. pelops;* (TL=Tail length; HTL=Head to tail length, BL=Body length)

7.3.4. Coat colour

Overall, the mean value of coat colour was found highest for Red (137.26±6.20) followed by Green (115.94±5.49) and Blue colour (90.31±4.05). The coat colour appearance was found orange but it exhibits in different shades i.e., saturated, desaturated, light, dark and very dark orange (Table 3 and 4).

The coat colour of *M. munzala* were change gradually from "Very dark grayish red" (n=1, hcc #463a36; R 70, G 58, B 54) in infant to "desaturated dark orange" in sub-adult (hcc #977e61; n=7, R 151±19.95, G 126±16.39, B 97±12.29) and adult (hcc #947b5e; n=7, R 148±11.51, G 123±11.82, B 94±10.32) (Fig. 7.10 and Fig. 7.11). Exceptionally, "very dark grayish orange" coloured of older individual (hcc #534844; n=2, R 83±15.55, G 71±15.55, B 57±14.84) were also found within the troops (Fig. 7.10. C and D; Fig. 7.11. E and F).

Infant of *M. a. pelops* had dark moderate orange colour (hcc #856849; n=1, R 133, G 104, B 73) and "slightly desaturated orange" colour in sub-adult (hcc #b7a37e, n=3, R 183±2.94, G 163±2.70, B 126±4.03) and adult (hcc #b89d75, n=6, R 184±4.66, G 157±4.36, B 117±9.55). The ventral coat colour of *M. munzala* were found "grayish orange" (hcc #bfb5a4; n=7, R 191±11.14, G 181±11.94, B 164±13.37) and "mostly desaturated dark orange (hcc #94805f; n=4, R148 ±9.83, 128 ±9.74, 95 ±11.50). But, *M. a. pelops* individual had mostly "grayish orange" (hcc #bfb5a4; n=6, RGB 191, 181, 164) ventral coat colour.

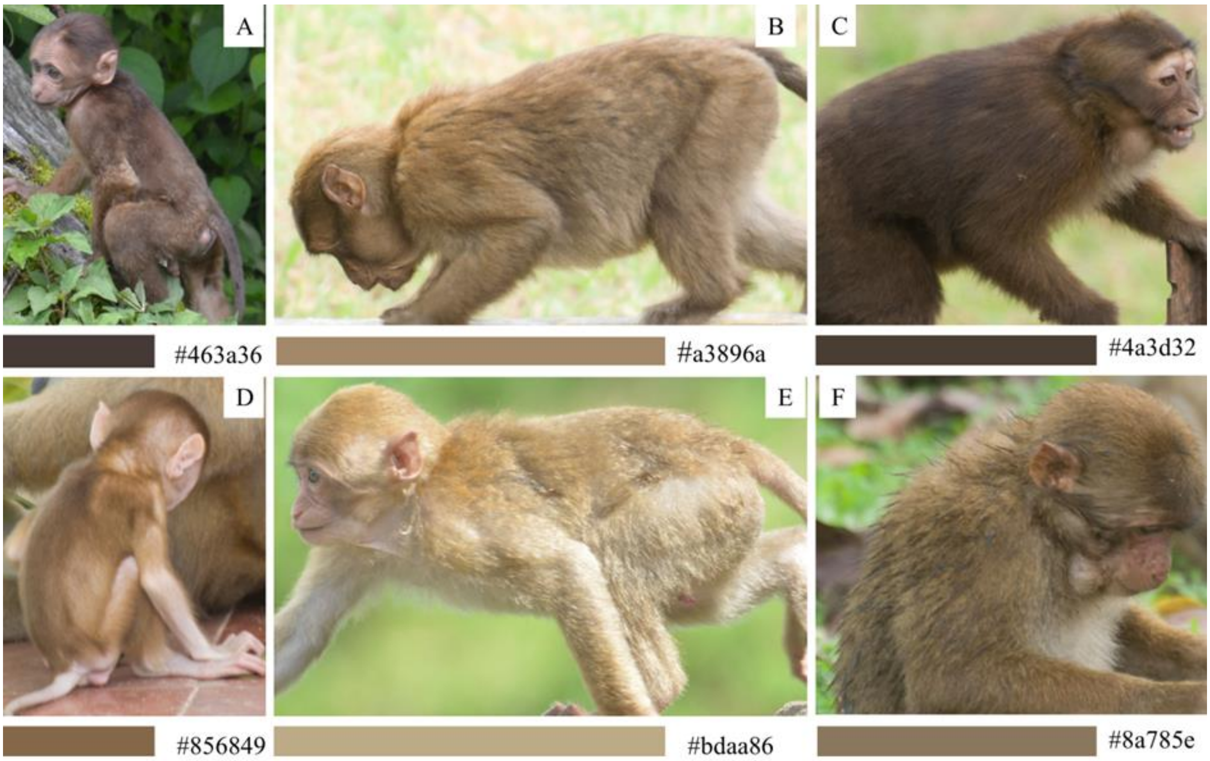

Figure 7.10. Coat colour of *M. munzala*. Infant dark grayish red (A); Mostly desaturated dark orange coat (B); Sub adult with “very dark grayish orange” (C); *M. a. pelops* infant with “dark moderate orange” (D); Sub-adult with “slightly desaturated orange” (E) and Sub-adult with “mostly desaturated dark orange” coat (F).

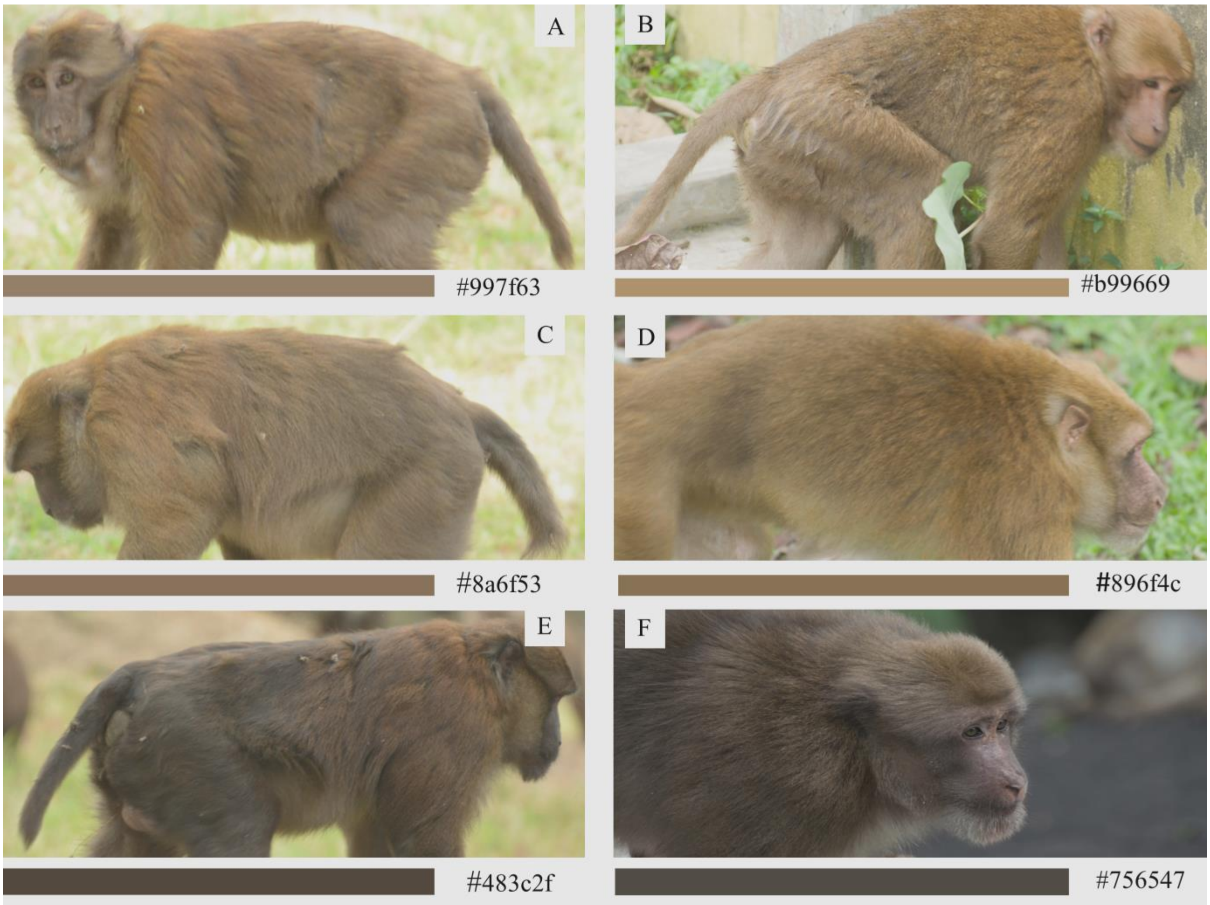

Figure 7.11. Coat colour of adult *M. munzala*. Mostly desaturated dark orange (A); Mostly desaturated dark orange (C); Very dark grayish orange (E) and *M. a. pelops* Slightly desaturated orange (B); Mostly desaturated dark orange (D) and Very dark grayish orange (F).

RGB value of coat colour of *M. munzala* and *M. a. pelops* differ significantly i.e., R ($t=4.92$, $p<0.01$), G ($t=4.84$, $p<0.01$) and B ($t=3.48$, $p<0.01$). *M. munzala* coat colour was found darker (RGB) than the *M. a. pelops* (RGB) based on RGB scale (0-255) (Fig. 7.12).

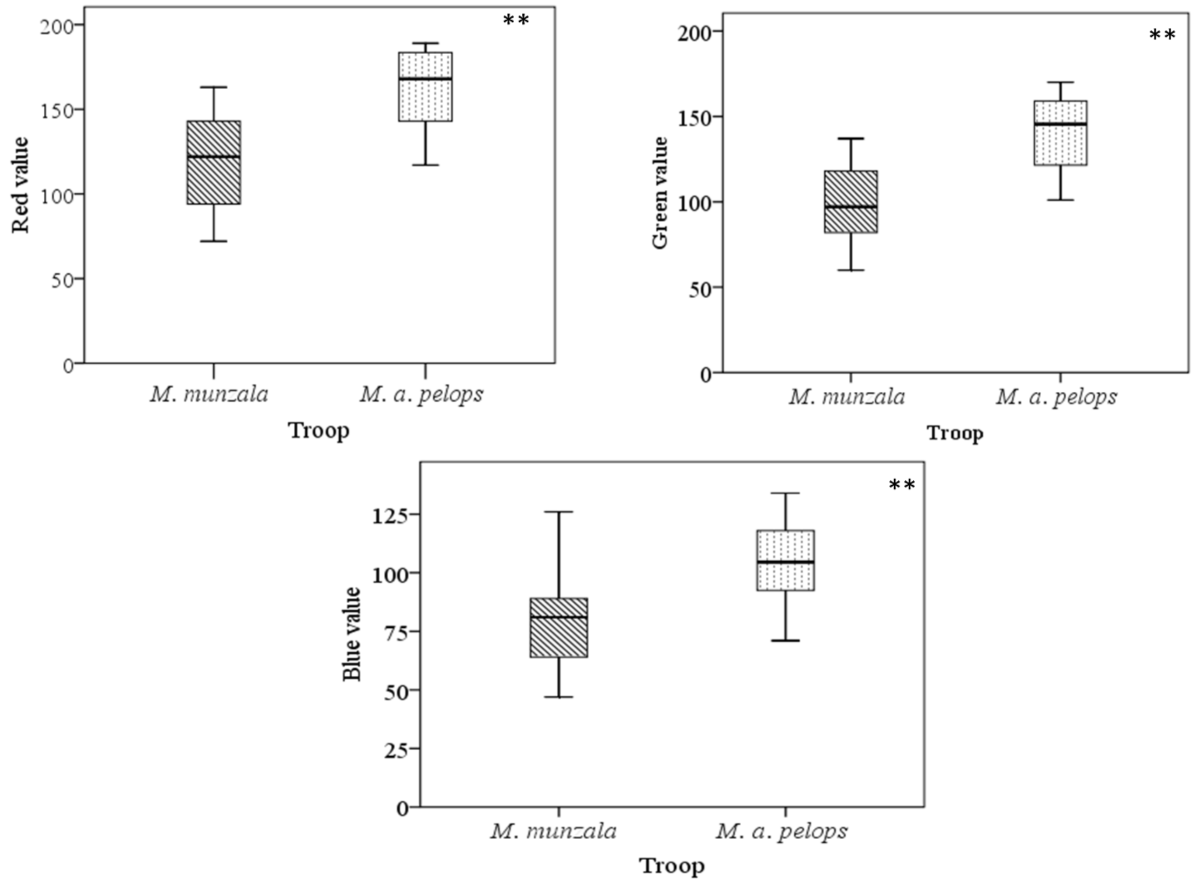

Figure 7.12. RGB value of adult individual coat colour of *M. munzala* and *M. a. pelops*

Table 3. Colour assessment of different part of *Macaca munzala*

Part	**Age/ Sex**	**Colour name**	**RGB value**	**Hex code**	**Colour**
	I	Dark grayish orange	120, 99, 92	#78635c	
	I	Very dark grayish red	70, 58, 54	#463a36	
	SAF	Mostly desaturated dark orange	163, 137, 106	#a3896a	
	SAF	Mostly desaturated dark orange	129, 110, 89	#816e59	
	SAF	Mostly desaturated dark orange	143, 118, 89	#8f7659	

SAF	Very dark desaturated orange	99, 84, 62	#63543e	
SA	Mostly desaturated dark orange	144, 124, 99	#907c63	
SA	Mostly desaturated dark orange	131, 106, 80	#836a50	
SA	Slightly desaturated orange	184, 151, 114	#b89772	
SA	Mostly desaturated dark orange	164, 138, 108	#a48a6c	
SAM	Very dark grayish orange	74, 61, 50	#4a3d32	
SAM	Very dark desaturated orange	96, 75, 52	#604b34	
AF	Mostly desaturated dark orange	155, 133, 105	#9b8569	
AF	Mostly desaturated dark orange	138, 111, 83	#8a6f53	
AF	Mostly desaturated dark orange	133, 108, 81	#856c51	
AF	Mostly desaturated dark orange	148, 122, 94	947a5e	
A	Mostly desaturated dark orange	142, 121, 94	#8e795e	
AM	Mostly desaturated dark orange	153, 127, 99	#997f63	
AM	Mostly desaturated dark orange	125, 99, 70	#7d6346	
AM	Mostly desaturated dark orange	122, 97, 69	#7a6145	
A	Mostly desaturated dark orange	153, 125, 92	#997d5c	

	A	Mostly desaturated dark orange	167, 142, 109	#a78e6d	
	AF	Very dark grayish red	75, 64, 64	#4b4040	
	OA	Mostly desaturated dark orange	139, 115, 86	#8b7356	
	AF	Very dark grayish red	93, 82, 86	#5d5254	
	AM	Dark grayish orange	152, 135, 126	#98877e	
	OAM	Very dark grayish orange	72, 60, 47	#483c2f	
	AM	Very dark grayish orange	107, 93, 77	#6b5d4d	
	AM	Very dark grayish orange	94, 82, 68	#5e5244	
Ventral	I	Grayish orange	192, 181, 162	#c0b5a2	
	SAF	Dark grayish yellow	160, 157, 140	#a09d8c	
	SAM	Dark grayish orange	175, 165, 146	#afa592	
	SAM	Grayish orange	185, 174, 152	#b9ae98	
	SAM	Grayish orange	207, 196, 178	#cfc4b2	
	AF	Grayish orange	203, 198, 184	#cbc6b8	
	AF	Grayish orange	193, 180, 162	#c1b4a2	
	AF	Grayish orange	184, 175, 165	#b8afa5	
	AF	Mostly desaturated dark orange	151, 124, 88	#977c58	
	AF	Mostly desaturated dark orange	150, 127, 91	#967f5b	

	AF	Mostly desaturated dark orange	134, 118, 91	#86765b	
	OF	Mostly desaturated dark orange	173, 149, 118	#ad9576	
	AM	Grayish yellow	158, 158, 143	#c7c4bb	
	AM	Mostly desaturated dark orange	157, 141, 112	#9d8d70	
	AM	Very dark grayish orange	113, 103, 84	#716754	
	AM	Grayish yellow	198, 193, 176	#c6c1b0	
	I	Dark grayish red	161, 135, 131	#a18783	
	SAF	Mostly desaturated dark orange	178, 139, 108	#b28b6c	
	SAF	Mostly desaturated dark orange	158, 123, 94	#9e7b5e	
	SAF	Mostly desaturated dark orange	117, 94, 72	#755e48	
	SAM/F	Mostly desaturated dark orange	132, 107, 89	#846b59	
	SAM	Mostly desaturated dark orange	125, 109, 93	#7d6d5d	
	SAM	Mostly desaturated dark orange	143, 121, 101	#8f7965	
	AF	Grayish orange	186, 156, 144	#ba9c90	
	AF	Mostly desaturated dark red	160, 118, 108	#a0766c	
	AF	Mostly desaturated dark orange	151, 112, 93	#97705d	
	OF	Mostly desaturated dark orange	157, 122, 110	#9d7a6e	
Facial	OF	Mostly desaturated dark orange	147, 117, 99	#937563	

	AF	Mostly desaturated dark orange	175, 137, 116	#af8974	
	OAF	Mostly desaturated dark orange	150, 125, 105	#967d69	
	OAF	Very dark desaturated orange	101, 77, 62	#654d3e	
	OAF	Dark grayish orange	132, 115, 100	#847364	
	OAF	Very dark grayish orange	104, 88, 78	#68584e	
	AM	Mostly desaturated dark orange	137, 116, 81	#897451	
	AM	Very dark grayish orange	110, 97, 83	#6e6153	
	OAM	Mostly desaturated dark orange	115, 100, 85	#736455	
	OAM	Very dark grayish orange	109, 94, 80	#6d5e50	
	OAM	Dark grayish orange	127, 112, 98	#7f7062	
	OAM	Very dark grayish orange	96, 91, 83	#605b53	
Eye orbital	SAF	Grayish orange	197, 169, 155	#c5a99b	
	SAM	Mostly desaturated dark orange	143, 116, 100	#8f7464	
	AF	Mostly desaturated dark red	177, 122, 111	#b17a6f	
	AF	Mostly desaturated dark red	128, 93, 82	#805d52	
	OAF	Very dark desaturated orange	97, 62, 47	#613e2f	

	OAF	Mostly desaturated dark red	156, 95, 93	#9c5f5d	
	AF	Mostly desaturated dark red	123, 81, 73	#7b5149	
	AF	Dark moderate red	162, 103, 88	#a26758	
	OAM	Mostly desaturated dark orange	148, 120, 100	#947864	
	OAM	Mostly desaturated dark orange	130, 105, 88	#826958	
Tail	JUV	Very dark grayish red	111, 102, 103	#6f6667	
	JUV	Very dark grayish orange	84, 73, 65	#544941	
	SAF	Mostly desaturated dark orange	141, 121, 100	#8d7a64	
	SAM	Dark grayish orange	163, 143, 124	#a38f7c	
	AF	Mostly desaturated dark orange	143, 128, 107	#8f8068	
	AF	Mostly desaturated dark orange	135, 114, 89	#877259	
	AM	Mostly desaturated dark orange	162, 140, 118	#a28c76	
	AM	Mostly desaturated dark orange	145, 126, 106	#917e6a	
	AM	Dark grayish orange	115, 103, 88	#736758	

Note: I (Infant); JUV (Juvenile), SAM (Sub-adult male), SAF (Sub-adult female), AM (Adult male), AF (Adult female), OAM (Older male), OAF (Olader female)

Table 4. Colour assessment of different parts of *M. a. pelops*

Part	Age/Sex	Colour name	RGB value	Hex code	Colour view
Coat	I	Dark moderate orange	133, 104, 73	#856849	
	SAM	Mostly desaturated dark orange	182, 120, 94	#8a785e	
	SAF	Slightly desaturated orange	138, 170, 134	#bdaa86	
	AF	Slightly desaturated orange	187, 163, 132	#bba384	
	AF	Slightly desaturated orange	182, 156, 123	#b69c7b	
	AF	Slightly desaturated orange	189, 159, 115	#bd9f73	
	AF	Slightly desaturated orange	185, 150, 105	#b99669	
	AF	Slightly desaturated orange	189, 159, 111	#bd9f6f	
	AF	Mostly desaturated dark orange	136, 109, 79	#886d4f	
	AF	Mostly desaturated dark orange	117, 101, 71	#756547	
	AF	Mostly desaturated dark orange	177, 159, 121	#b19f79	
	AM	Mostly desaturated dark orange	156, 128, 97	#9c8061	
	AM	Mostly desaturated dark orange	148, 123, 91	#947b5b	
	AM	Mostly desaturated dark orange	167, 137, 103	#a78967	
	AM	Mostly desaturated dark orange	166, 146, 104	#a69268	

	AM	Mostly desaturated dark orange	169, 145, 114	#a99172	
	AM	Very dark grayish orange	69, 63, 54	#453f36	
	I	Grayish orange	192, 181, 162	#c0b5a2	
	SAF	Dark grayish yellow	160, 157, 140	#a09d8c	
	SAM	Dark grayish orange	175, 165, 146	#afa592	
	SAM	Grayish orange	185, 174, 152	#b9ae98	
	SAM	Grayish orange	207, 196, 178	#cfc4b2	
	AF	Grayish orange	203, 198, 184	#cbc6b8	
	AF	Grayish orange	193, 180, 162	#c1b4a2	
	AF	Grayish orange	184, 175, 165	#b8afa5	
	AM	Grayish yellow	158, 158, 143	#c7c4bb	
Ventral	AM	Dark grayish yellow	148, 147, 129	#949381	
	I	Grayish red	183, 155, 148	#b79b94	
	SAF	Slightly desaturated red	182, 135, 123	#b6877b	
	SAF	Slightly desaturated red	179, 135, 122	#b3877a	
	SAM	Mostly desaturated dark orange	151, 127, 112	#977f70	
	SAM	Slightly desaturated orange	181, 144, 128	#b59080	
	SAM	Slightly desaturated orange	184, 146, 129	#b89281	
Facial	SAM	Slightly desaturated orange	208, 173, 154	#d0ad9a	

	AF	Very soft red	221, 163, 154	#dda39a	
	AF	Slightly desaturated red	201, 147, 136	#c99388	
	AF	Slightly desaturated red	199, 128, 121	#c78079	
	OAF	Mostly desaturated dark orange	155, 120, 108	#9b786c	
	AF	Slightly desaturated orange	205, 168, 148	#cda894	
	AF	Mostly desaturated dark orange	172, 138, 23	#ac8a7b	
	AM	Mostly desaturated dark orange	130, 107, 91	#826b5b	
	AM	Mostly desaturated dark orange	138, 113, 99	#8a7163	
	AM	Mostly desaturated dark orange	115, 96, 82	#736052	
	AM	Slightly desaturated orange	179, 140, 118	#b38c76	
	AM	Dark grayish orange	139, 118, 107	#8b766b	
	AM	Dark grayish orange	115, 101, 90	#73655a	
	AM	Dark grayish red	144, 124, 111	#7a6f6f	
Eye orbital	I	Light grayish red	219, 195, 190	#dbc3be	
	SAF	Slightly desaturated orange	194, 151, 127	#c2977f	
	SAF	Mostly desaturated dark orange	162, 128, 113	#a28071	
	SAF	Mostly desaturated dark red	172, 121, 112	#ac7970	

	SAM	Grayish orange	195, 167, 149	#c3a795	
	SAM	Mostly desaturated dark orange	168, 130, 117	#a88275	
	AF	Slightly desaturated red	202, 157, 146	#ca9d92	
	AF	Slightly desaturated red	185, 105, 99	#b96963	
	AF	Slightly desaturated red	211, 130, 127	#d3827f	
	AM	Mostly desaturated dark orange	136, 113, 96	#887160	
	AM	Mostly desaturated dark orange.	135, 111, 97	#876f61	
	I	Grayish orange	205, 198, 187	#cdc6bb	
	SAF	Grayish orange	180, 163, 136	#b4a388	
	SAF	Dark grayish orange	149, 139, 120	#958b78	
	SAM	Dark grayish orange	177, 165, 135	#b1a587	
	AF	Slightly desaturated orange	184, 157, 125	#b89d7d	
	AF	Grayish orange	183, 169, 147	#b7a993	
	AM	Slightly desaturated orange	191, 169, 142	#bfa98e	
Tail	AM	Mostly desaturated dark orange	167, 145, 113	#a79171	

Note: I (Infant); IM (Immature), SAM (Sub-adult male), SAF (Sub-adult female), AM (Adult male), AF (Adult female), OAM (Old male), OAF (Old female)

7.3.5. Facial skin colour

The immature individual (infant and Juvenile) of *M. munzala* facial skin colour was found “dark grayish red” (hcc #a18783; n=1, RGB 161, 135, 131); “mostly desaturated dark orange” colour in sub-adult male (hcc #9c7b61; n=3, mean RGB 156, 123, 97) and female (hcc #9c7b61; n=3, mean RGB 156, 123, 97) (Fig. 7.5 and Fig.7.6). The adult female of *M. munzala* facial colour was “desaturated dark red” (hcc #855f54; n=3, mean RGB 133, 95, 84) and “mostly desaturated dark orange” (hcc #7e6d58; n=3, mean RGB 126, 109, 88) in adult male. The older individual of female facial skin was found “desaturated dark orange” (hcc #927969; n=3; mean RGB 146, 121, 105) and old adult male individual skin colour was “very dark grayish orange” (hcc #695e52; n=3, mean RGB 105, 94, 82) (Fig. 7.6 and Table 3).

The juvenile of *M. a. pelops* facial colour was found “grayish red” (hcc #b79b94; n=1; RGB 183, 155, 148); “slightly desaturated red” (hcc #b5877a; n=2, mean RGB 181, 135) in sub-adult female, “mostly desaturated dark orange” in colour (hcc #b59382, n=4, mean RGB 181, 147, 130) in sub-adult male. Similarly, adult female of *M. a. pelops* facial skin was found slightly desaturated red (hcc #cf9289; n=3, mean RGB 207, 146, 137) and dark grayish orange (hcc #8b766b; n=3, mean RGB 139, 118, 107) in adult male. The old adult individual skin colour was “very dark grayish orange” (hcc #695e52; n=3, mean RGB 105, 94, 82). The eye orbital skin colour was found “desaturated dark red” (hcc #885754; n=3, mean RGB 136, 87, 84) in adult female individual of *M. munzala* and *M. a. pelops* (Fig. 7.5 and Table 4).

The RGB value of facial skin colour in adult male and female was not significantly different in *M. munzala* but in *M. a. pelops*, Red ($t=4.96$, $p<0.01$) and green colour ($t=3.71$, $p<0.01$) value was found to be significantly different in male and female. The RGB value of facial skin in adult male of *M. munzala* and *M. a. pelops* did not varied significantly but Red colour value ($t=3.31$, $p<0.05$) was found significantly differ between adult female individual (Fig. 7.13 and Fig. 7.14). The RGB value of adult male and female of *M. munzala* has shown lower value than *M. a. pelops* that depicted darker colour concentration in facial skin of *M. munzala* (Fig. 7.13 and Fig. 7.14).

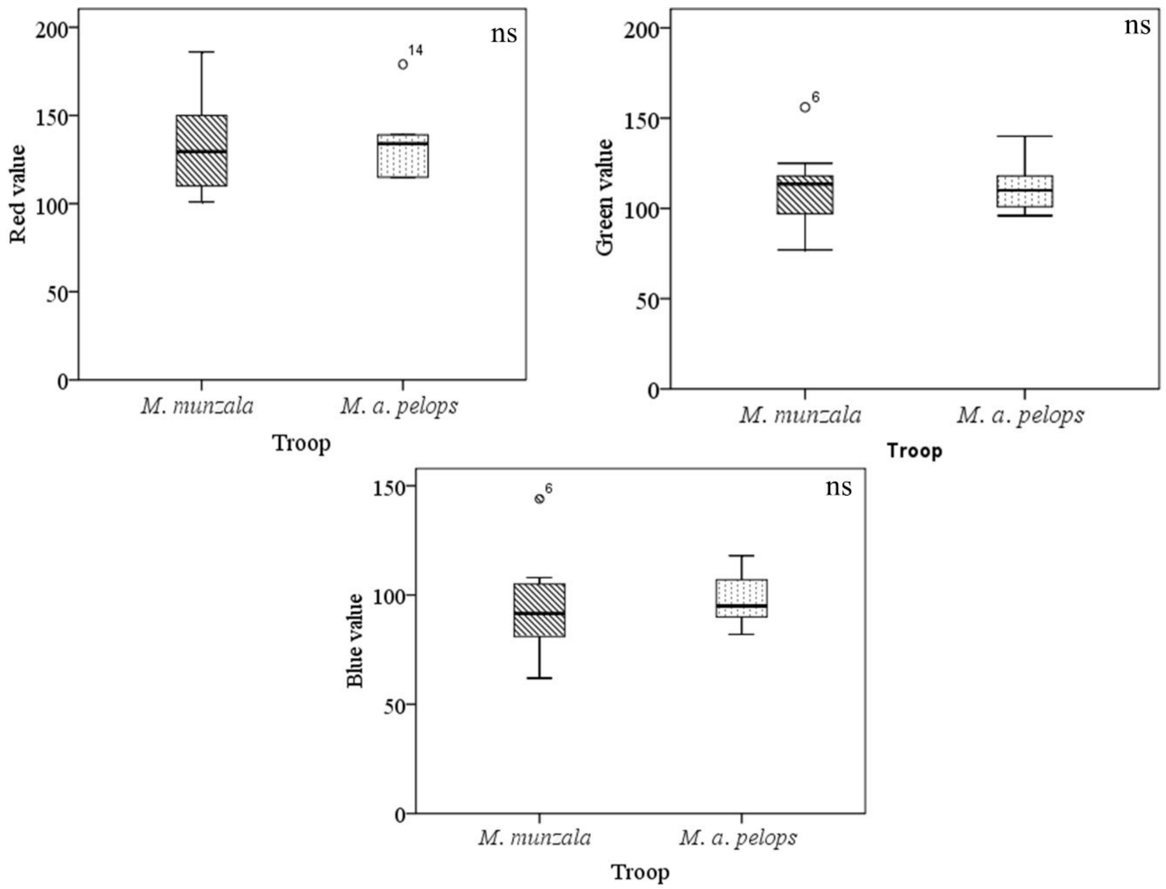

Figure 7.13. Facial skin colour of adult male of *M. munzala* and *M.a. pelops* (^{ns} not significant)

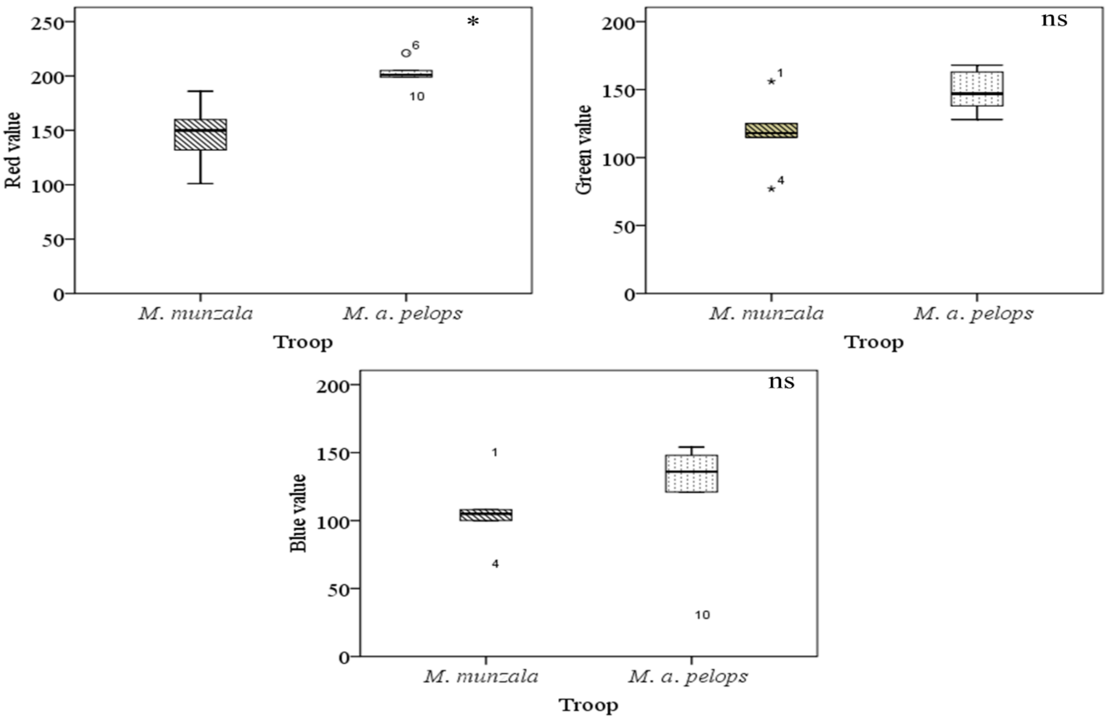

Figure 7.14. Facial skin colour of adult female of *M. munzala* and *M.a. pelops*

7.4. Discussion

The species specific characteristics of *Macaca munzala* such as distinctive facial mark on the temple and head, prognathous head, prominent chin and cheek whisker, dark patch on the crown are also found in *Macaca assamensis pelops*. The pattern of crown whorl hair was found to be significantly similar in both the species. However, crown colour and occurance in *M. munzala* did not found vary seasonally as explained by Sinha et al. [2]. But, it varied according to the age i.e., adult individual has prominent crown whorl than the immatruare individual. Moreover, chin and cheek whisker are found very prominent in older aged individual of *M. munzala*. *M. a. pelops* have cheek and side whisker but less prominent than the *M. munzala*. The side whisker in *M. munzala* gradually elongated from immature to adult and it appears as very dense in older age. Further, study did not found any significant variation in pattern of tail appearance between *M. munzala* and *M. a. pelops*. The evidence of common morphological characteristics might be the reason of similar ancestral origin in both of the species [3] and few extents of variation might be the reason of climatic adaptation. Rakotonirina et al. [25] reported that primate's inhabitant in cold environment and living in larger group, exhibit longer hair compared to the ones inhabitant in warm area. Similarly, Villano et al.

[26] reported that morphological characteristics of Long Tailed Macaques (*Macaca fascicularis*) such as prominent crown crest appearance differ with geographical variation. Further, white-pale side whisker and white cheeked-round facial appearance, bending, short, hairless tail with end tapering of *M. leucogenys* morphological characteristics were found resembles with *M. munzala* [7]. The penile morphology for both the studied species was sagittate in shape and glans head were slightly expose outward. Exceptionally, in some of adult individual glans heads were retract in foreskin and appear as round ring shape that resembles with *M. leucogenys* penile morphology [7].

The present study has shown that absolute tail length decreases with increase in altitudinal gradient but relative tail length decrease with increasing altitude. Both the relative tail length and tail to head body ratio in *M. munzala* was found to be lower than that of *M. a. pelops*. These might be due to the altitudinal variation in the distribution of these two study troops. Moreover, the shorter relative tail length in *M. munzala* is in conformation with Allen's rule that closely related species have shorter appendages in cold climate than warmer climate as it is evident that the species is found in cold climate in Zemithang Valley [27]. The absolute length and relative tail length of *M. munzala* and *M. a. pelops* are found within the range that has been reported in previous studies on both the species [2,5]. Further, the fact that head to tail ratio of *M. munzala* was much closer to *M. a. assmenesis* in comparison to that of *M. a. pelops* is also supported by Biswas et al. [5]. Weinstein [8] reported that limb of macaca species in higher latitude and elevation have shorter than the low latitudes and elevation. Thus, *M. munzala* inhabited in higher elevation in colder climate might influence the morphometric of these species within *sincia* group.

The present study on colour variation has shown that R (red) value was dominant over G (green) and B (blue) and form different shades of orange colour in both the species. Sumner and Mollon [28] also mentioned that the orange colour of pelage was found to display by the platyrrhine and strepsirhine species. The higher RGB value in *M. a. pelops* has shown lighter colouration of pelage and facial skin than *M. munzala* as explained by Sinha et al. [2]. Subsequently, RGB value for dorsal coat has shown significance difference between the species. A very profound intraspecific variation in colour has been observed in both the species. R (red) value has shown as a significance factor in colour appearance of male and female facial skin for both the species. The pelage colour variation within the similar species has been found in colour quantification study in terms of Lightness (L), which concludes as an environmental adaptation [26]. Primate interspecific variation in coat colour is proportional to actual evapotranspiration (AET) and latitude that support the Gloger's rule [16,26,29,30]. But, the result of the present study is contradictory to the Goggler rule. The result of the present study has shown lighter colour appearance in warm and humid region, and dark colour appearance in colder region as reported. Thus, temperature and altitudinal variation might have greater influence in colour pigmentation than the rain fall and evapotranspiration. The study has found that exposure to higher solar radiation develop dark pelage colour in primates of tropics that protect skin from negative effect from UV radiation [31]. Solar UV radiation increases with altitude, thus, it might have significant influence in darker colour formation in high altitude primates [32,33]. *Macaca thibetana* and *Macaca leucogenys* of Tibet are found to have darker coat colour and facial skin [7,9]. Susequently, higher UV radiation was reported from Tibetan plateau [33]. The study has been suggested that black fur of *Rhinopithecus bieti* is a result of higher exposure to solar radiation [33–34]. Furthermore, Assamese macaque (*M. asamensis*) of high altitude area of Nepal is reported to have darker pelage than the low altitude population [10,36]. Golden langur (*Trachypithecus geei*) of high altitude region of northern Bhutan (1000-7000 m amsl) have darker pelage colour than southern range of Bhutan and Assam, India (40-900 m amsl) [11]. Thus, temperature, altitude and solar radiation might have greater influence in primate coat colouration in terms of climatic adaptation. However, to conclude the phenomenon further extensive study id required.

The present study established that coat colour of non-human primate differ according to altitudinal gradient, where, temperature, altitude and solar UV radiation might have significant influence. The presence of morphometric characteristics among the three species of s*inica* group is supported by the genetic closeness [3,4]. However, taxonomic identity based on colour and morphological characteristics are not found relevant among geographically closer *sinica* group species. Moreover, the result of present study has shown non-invasive photogrammetry method is reliable for morphometric measurement and colour variation study of primates. The photogrammetry method is simple and less costly than other methods that are being used in colour variation study [35,37]. Similarly, RGB additive colour model and post process "custom white balance" method has potential in colour assessment study of primates.

7.5 References

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