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Population structure and habitat use of golden langur *(Trachypithecus geei)* in royal manas national park, Bhutan

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Abstract
This study aims to understand population structure and habitat use of Golden langur (*Trachypithecus geei*) in Royal Manas National Park, southern Bhutan. The study was conducted using extensive and intensive surveys. Survey revealed population of 433 individuals comprising 46 groups. Six permanent transects were monitored with 12 temporal replicates which found mean group size 6.91±1.54 (*SE* = .701) in tropical; 7.82 ± 1.06 (*SE* = .483) in subtropical; and 6.80 ± 0.92 (*SE* = .416) in warm broadleaved forest. Overall group composition was 16.96% (*n* = 39) adult males, 40.17% (*n* = 96) adult females, 11.29% (*n* = 27) sub-adults, 13.39% (*n* = 32) juveniles and 15.06% (*n* = 36) infants. Average adult male –female sex ratio was 1:2.26; juveniles per adult female was 1:0.33; and infants per adult female was 1:0.37.These results suggest a healthy population status.

Keywords: Golden langur, population structure, habitat use, habitat quality

1. Introduction
The Golden Langur *(Trachypithecus geei)* is a globally endangered non-human primate that occurs only in Bhutan and in limited forest areas in Assam state of India [3, 4, 5, 20, 23]. The global distribution ranges lie between west of Manas river, east of Sunkosh river, Chamkhar river in the north and Brahmaputra river in the south. In Bhutan, it is listed as a totally protected species [6] and confined to five districts namely Zhemgang, Trongsa, Wangdiphodrang, Sarpang and Tsirang ranging from 199 m to 2,600 m above sea level [23]. It is also considered as a keystone species in Royal Manas National Park (RMNP) [15].
Very few studies have been carried out on this rare colobine monkey in Bhutan and the most recent study was known to be carried out by Wangchuk (2005). However, nothing has been known on the population structure related to the different habitat use in Bhutan and particularly in RMNP. The objective of this study is to determine the population structure in different vegetation zones and assess habitat use by Golden langur population in RMNP.
It would also generate a baseline information on group size, composition, age and sex ratio to understand the viable reproductive capacity and population status of Golden langur in the Park. The understanding of age and sex ratio in relation with the habitat condition is also expected to identify the ecological reasons for skewed age and sex ratio and ultimately help the park management to provide desired management interventions for long term conservation of endangered primate within the Park.

2. Materials and Methods
2.1. Study area
This study was conducted in Royal Manas National Park, situated in the central part of southern Bhutan (Figure 1).
The Park is rich in plant diversity with 900 species. These rich floristic zones provide home to many several charismatic mammal species which include golden langur [15].

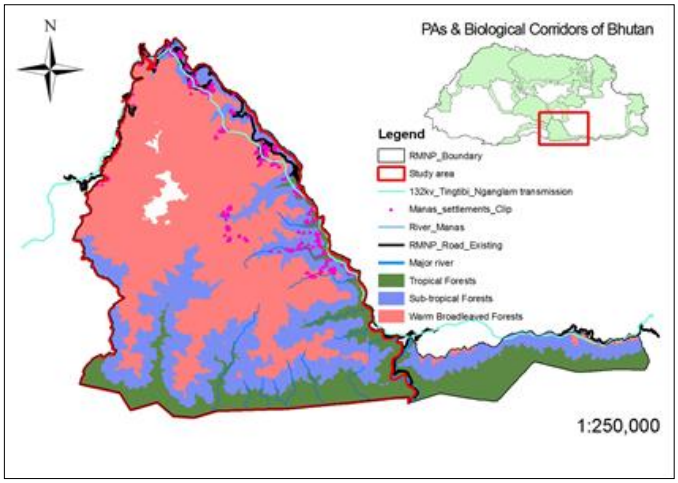

Fig 1: Map showing Golden langur study area

2.2. Sampling design

Out of an area of 1057 km² of park, potential habitats of golden langurs were estimated to 918.63 km². These potential habitats were stratified into three different vegetation zones viz. tropical (< 500 m), subtropical (500 - 1000 m), and warm broadleaved forests (1000 - 2400 m) using the software ArcGIS (10.2 version). These potential areas were further deduced to the prime habitats of 869.99 km² after excluding all unsuitable land use features covering 48.64 km². Within these prime habitats, survey was carried out in two stages involving extensive and intensive transect surveys.

2.2.1. Extensive survey Method

The extensive survey covered whole potential habitats by 52 transects comprising 383 km transect walk in a stratified random manner covering all the representative areas [2, 9, 11, 20]. This survey was designed to obtain the general population status and assess habitat quality and condition for better understanding of habitats utilization by this species.

The survey was carried out from January 2017 to March 2017. A modification of the line transect method by following along the existing animal trails and paths [1,13] was used. A straight line transect was found not feasible in rugged terrain in Bhutan [12, 23]. The survey team of three to eight people walked the transects covering an average length of eight to ten kilometers daily at 1.5 km per hour from morning at 0800 hours to evening 1630 hours. Whenever the Golden langurs were sighted a minimum of 15 minutes were spent to estimate the group size and composition, age and sex structure.

The vegetation sampling from the transect walk was carried out at every 500 m interval and at every Golden langur sighting points. The trees above 12 cm diameter at breast height (DBH), canopy cover and ground cover were estimated in 10 m radius circular plot; shrubs in 5 m radius; and regenerations in 1 x 1 m quadrat.

2.2.2. Intensive survey Method

The intensive survey involved 12 temporal replicates with a total transect walk of 313 km in the six-permanent selected transects (average 4 km) for monitoring based on the extensive survey. It was intended to estimate the complete counts of the group size and composition, age and sex structure of the Golden langurs in three different habitats of tropical, subtropical and warm broadleaved vegetation zones covering both disturbed and undisturbed habitat type. The forests which were encountered with high evidences of timber cuttings were classified as disturbed habitats and with no evidences of timber cutting as undisturbed habitats. The survey started at 0800 hours in the morning and terminated at 1630 hours in the evening. The speed of 1.5 km/hour was maintained to observe the target species in three dimensional directions. Whenever the target animals were sighted at least 15 minutes were spent to count the group size, individual number, age and sex.

2.3. Instrument used

The field equipment such as topo-sheet of the study areas, GPS (Garmin *etrex* vista), Compass (SUNTO), Clinometer (SUNTO), Altimeter, measuring tape and Binocular Bushnell make (10 x 45), and Laser Range finder were used for recording data during the survey.

2.4. Data Analysis

The data analysis on group size, composition, age and sex ratio were done in Microsoft Excel spreadsheet 2016. The differences on group size and composition at three vegetation zones of tropical, subtropical and warm broadleaved forests encompassing both disturbed and undisturbed habitats were also analyzed using SPSS (23 Version) software. Analysis of Variance (One-way ANOVA) was used to test the mean differences between three vegetation zones.

The absolute density of the trees and shrubs were calculated per hectare by using the circular plot formula [8].

$D = n / a * 10,000$

Where D = density of plant species, n = number of trees/ shrubs, and a = area of the plot in m^2 (circular). The diversity of tree species was calculated using the Shannon diversity (*H*), $H = \Sigma Pi \ln Pi$. Where $Pi = ni / N$, ni = the abundance of the species *i*, N= total number of all individuals, and *Pi* = the relative abundance of each species. The canopy cover was estimated using "Plant Cramming" method of Ocular estimation [8].

3. Results and Discussion

3.1. Golden langur Distribution status

The Golden langur sightings with 433 individuals in 46 groups were recorded from the entire extensive survey (Figure 2).

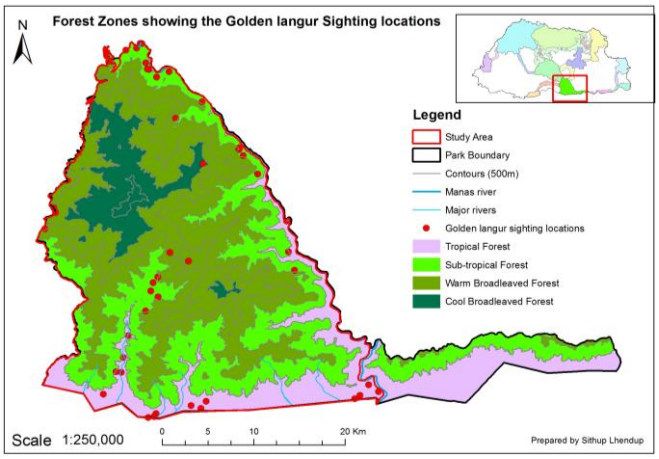

Fig 2: Map showing 46 Golden langur groups sighting locations

These sighting locations revealed that the golden langurs are distributed contiguously throughout the park areas. The highest elevation range of Golden langur sighting was

recorded at 1714 m in the north (Kharila) and lowest at 112 m in the south (Manas). It was confirmed that Golden langurs are not distributed beyond the east of Manas River [4, 23]. No sightings were recorded towards western region between Kanamakura and Taraythang. However, very rare sightings have been reported between these locations in the past [16].

Further, two groups sightings of approximately 10-15 individuals were sighted along Gelephu-Sarpang highway at mixed plantation area below domestic airport. Occasional sightings (n = 2) were also recorded in Gelephu municipal area in 2009 and 2013 (personal observation). Although, the habitat connectivity between RMNP and Phibsoo Wildlife Sanctuary (PWS) is known to be highly disturbed by human settlements and roads, the Reserved Forests in Indian side seems to provide the habitat contiguity toward PWS.

3.2. Group size and composition

The intensive study revealed with 239 individuals in 32 groups from a total of 213 km transect walk (Table 1). The mean group size was estimated 6.91±1.54 (SE = .701) in tropical; 7.82 ± 1.06 (SE = .483) in subtropical; and 6.80 ± 0.92 (SE = .416) in warm broadleaved forests. The overall mean group size estimated was 7.19 ± 0.45 (SE = .023). The mean group size of seven individuals in Bhutan [23]. The Chakrashila Wildlife Sanctuary, Assam state of India also estimated the group size of 7.4 individuals [2]. However, the mean group size in Assam state of India revealed high with 9.8 individuals [20]. The low group size in the warm broadleaved as compared to the tropical and the subtropical zones was known to be due to increase in altitude with the low temperature influencing on the decrease of the number of individual [10].

Table 1: Group size and composition from intensive survey

Habitats	Adult male	Adult female	Unknown adult	Sub-adult	Juveniles	Infants	Total groups	Total individuals	Average group size
Disturbed	21	44	4	15	15	20	14	119	8.5
Undisturbed	18	52	5	12	17	16	18	120	6.7

There was significance difference between the mean group size of disturbed habitats (M = 7.67, SE=.410) and mean group size of undisturbed habitats (M = 6.76, SE = .202); t (30) = 2.04, p < .05. These results truly revealed that degraded habitats contain more number of group size [20]. The larger group sizes were found in the disturbed habitats of tropical forests. This suggests that the tropical forests are under degradation from high frequency of illegal wood cutting that occurs along the southern foothills, by people from across the international border [4, 14, 15].

The overall group composition was 16.96% (n = 39) adult males, 40.17% (n = 96) adult females, 11.29% (n = 27) sub-adults, 13.39% (n = 32) juveniles, and 15.06% (n = 36) infants. The disturbed habitats revealed high in adult males (17.65%, n= 21), sub-adults (12.6%, n = 15) and infants (16.81, n = 20) as compared to undisturbed habitats which revealed high in adult females (43.3%, n = 52) and juveniles (14.17%, n = 17). These results suggest that the population structure is in healthy habitat condition either with growing or stable population of juveniles and infants.

3.3. Age and Sex Structure

The age and sex ratio denote the status of the population whether increasing, decreasing or stable. The different recruitment classes with young individuals in a population indicates a healthy population in contrast to more adults indicating poor reproduction capacity [17]. The average adult sex ratio was 1:2.26 (1.5 – 3); immature per adult was 1:1.98; juveniles per adult female was 1:0.33; and infants per adult female was 1:0.37. This shows that the population is either growing or in stable condition. The undisturbed habitats revealed with high adult sex ratio (1:2.9) as compared to disturbed habitats (1:2.09). Although, most of the groups were observed with a single adult male / multi–females (78.13%, n = 25), the multi–males/multi–female groups (21.87%, n = 7) were observed all in the disturbed habitats. The juvenile ratio (1:0.34) and infant ratio (1:0.45) per adult female were found high in the disturbed habitats than the undisturbed habitats (Table 2). This suggests that quality of the habitats can have affect on the population structure and as well as population growth.

Table 2: Sex ratio at disturbed and undisturbed forests

Habitats	No. of groups	Adult Male: Adult Female	Adult: Immature*	Adult Female: Juveniles	Adult female: Infant
Disturbed	14	21:44 (1:2.09)	35:65 (1:1.86)	44:15 (1:0.34)	44:20 (1:0.45)
Undisturbed	18	18:52 (1:2.90)	33:70 (1:2.12)	52:17 (1:0.33)	52:16 (1:0.31)
* Includes Juveniles and Infants					

3.4. Habitat Condition

The main reason for assessing the habitat quality and use was to provide a general picture on the potential habitat use as the animals usually depend on quality habitats through spatial or temporal movements [17]. A total of 200 vegetation sampling plots were laid in three different habitats (tropical, subtropical and warn broadleaved forest), of which 46 (23%) plots covered in Golden langur sighted and 154 (73%) in unsighted locations. The Shannon diversity estimated also showed with high diversity in the warm broadleaved forests (H'= 3.24) and low in tropical forests (H'= 2.92). Similar finding also reported that there was high diversity in the warm broadleaved forest and low in the disturbed tropical forests in the south [22]. The absolute tree density was also high in warm broadleaved forests (320.89/ha) as compared with the subtropical (193.74/ha) and tropical forests (195.26/ha). However, regeneration capacity was high in the tropical forests (61.43%) and low in the warm broadleaved forests (33.33%). The regeneration capacity in the broadleaved forests was poor [23]. However, the regeneration of preferred forage species was high in the subtropical forests (73.81%) as compared to the tropical forests (18.18%) and the warm broadleaved forests (66.67%). The areas disturbed from forest grazing also showed with poor regeneration capacity.

The preferred forage tree species richness was high in subtropical (41.38%, n = 24), as compared to tropical forests

(34.92%, *n* = 22) and warm Broadleaved forests (32.73%, *n* = 18) (Figure 3).

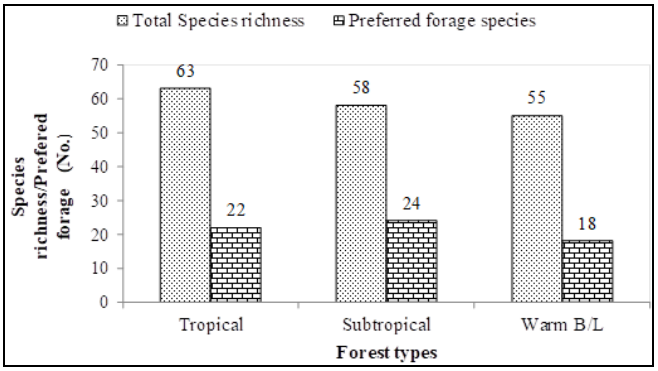

Fig 3*:* Species richness in different habitats

The unsighted locations revealed with canopy cover mostly above 75% in the warm broadleaved forests as compared to the tropical and subtropical forests with canopy cover between 51-75%. This result shows that the overall Golden langur habitat under RMNP are in good canopy conditions.

3.5. Habitat Use

The habitat use assessment was carried out from the 46-golden langur sighted locations. The habitat use generally covers food, cover, water and space [17], but here the canopy cover, canopy height, forage species (food) and space (suitable habitats) were considered as habitat use components for golden langur study. The results showed with the maximum occupancy over canopy cover above 76% in tropical and canopy cover between 51-75% in subtropical and warm broadleaved zones. The average canopy cover occupancy showed mostly between 51–75% as compared to other classes of canopy cover (Table 3). This suggests that canopy cover is very important for the survival of this species. The most preference over the middle canopy due to more availability of foliage species as a main diet [7].

Table 3: Percent of sightings with indicated levels of canopy cover

Habitat Use	Tropical	Subtropical	Warm B/L	Total Average
No. of sightings (groups)	17	21	8	46
No canopy cover/ground	0	14.29	0	4.76
Canopy cover1-5%	0	0	0	0
Canopy cover 6-25%	11.76	9.52	12.5	11.26
Canopy cover 26-50%	5.88	9.52	25	13.47
Canopy cover 51-75%	29.42	42.86	37.5	36.59
Canopy cover 76-100%	52.94	23.81	25	33.92

The occupancy of canopy height also showed with the occupancy of all levels of canopy height, but mostly the top canopy (>15 – 20 m). It was also reported the use of all the three layers with most frequently the upper canopy height [23]. The terminal and top canopy due to more availability of forage species and to escape from large terrestrial carnivores from predation [18]. This could be same in the Park due to the presence of high number of large carnivores such as tigers and leopards [21] and due to the presence of poachers and illegal wood cutters along the foothills [14, 15].

The foraging activity comprises mostly the leaves (54.72%) followed by fruits (21.67%), shoots (10.83%), flowers and flower saps (10.56%). Apart from the forage species the Golden langurs were also observed to use rock minerals from the steep rocky areas (Table 4).

Table 4: Percent of sightings with indicated level of foraging preferences.

Forage preferences	Tropical	Subtropical	Warm B/L	Total average
No. of sightings (groups)	17	21	8	46
Leave	37.50	60.00	66.67	54.72
Fruit	25.00	6.67	33.33	21.67
shoot	12.50	20	0.00	10.83
Flowers	25.00	6.67	0.00	10.56
Rock minerals	0.00	6.66	0.00	2.22

This was true that *Trachypithecus* species mostly forage on young leaves and with least preference on flowers, mainly due to high containing of proteins which makes easy for their hindguts fermentation [13]. However, feeding on insects and invertebrates were not known unlike in the *Presbytis* monkeys [10].

4. Conclusions

Although there is contiguous habitat for golden langur in the Park, its occupancy is not extensively covered in the Park. However, RMNP provides largest habitat of golden langur in the country. The conservation and management of subtropical forests along with its foraging species is essential to maintain viable population of this primate. Meanwhile, a separate population survey is required in all seasons to help understand distribution pattern of Golden langur. Understanding home range can also help the park management for intensive management of this important primate species.

5. Acknowledgement

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