RANGING PATTERN OF GOLDEN LANGUR IN KAKOIJANA RESERVE FOREST: AN ISOLATED FOREST PATCH OF ASSAM, INDIA

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Ranging patterns and home range sizes are crucial for understanding primates' behavioral ecology and determining habitat requirements of the species. The golden langur *Trachypithecus geei* is endemic to Assam plains and eastern Himalayan region. The present study aimed to examine the home range size and day ranging pattern of this globally endangered colobine species in Kakoijana Reserve Forest (KRF), Assam, India. The study has been conducted from September, 2015 to August, 2017 through full-day focal troop monitoring and recording the locations of the existing troops in the study area. KRF is home to 45 troops of golden langur which is considered as a large population, with 489 individuals having range of 3–20 individuals/troop. Study also observed that the daily path length (DPL) was found to be varied from 95 to 441 meters (based on six study troops) with a mean distance of 235.91 ± 69.20 m in 168 full days of observations. DPL was found to be significantly different among the selected troops and also showed significant variations among seasons of the year. The home range size greatly varied among the study troops and ranges from 9.45 ha to 41.60 ha. The DPL and home range of golden langur in KRF has been highly affected by the canopy breaks and other anthropogenic disturbances. The smaller home range of the study troops with large population is an issue to be taken up urgently for the future health of the current population of golden langur in the KRF. Thus, the findings of the present study will help in opting for proper management planning for the conservation of the endangered species inhabited in isolated habitats with varying anthropogenic pressure.

Keywords: anthropogenic disturbances, colobine, daily path length, endemic, Kakoijana Reserve Forest.

INTRODUCTION

Primates, as a social animal, have a well-defined home range that they use for a variety of everyday tasks like feeding, resting, grooming, etc. (Burt, 1943). The ranging patterns of this social primate species are confined to a certain area and are significantly influenced by seasonality, the distribution of food supplies, population density, and group size (Altmann & Altmann 1970; Schaik *et al*., 1983; Zhang & Wang, 1995).

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Thus, the knowledge of ranging patterns and home range sizes is essential for comprehending the behavioral ecology of primates, identifying their habitat requirements, and assessing their vulnerability to extinction (Chapman, 1988; Singleton & Schaik, 2001).

Ranging facilitates primate for the intake and expenditure of energy through the foraging process (Smith *et al*., 2013). According to another theory (Yeager & Krikpatrick, 1998), home range sizes are primarily determined by the availability of food resources and their nutritional value. As a result, home range sizes increase when a species experiences the greatest levels of food scarcity during the course of an annual cycle (Fashing *et al*., 2007; Harvey & Clutton-Brock, 1981). Due to the fact that foliage is distributed more evenly and abundant than fruits and insects, folivorous colobine have shorter day path length and smaller home range in comparison to frugivores and insectivores. Again, folivorous colobine exhibits significant difference in home range sizes and ranging pattern within and between genera, species, and population, which is usually < 10 ha (Smith *et al.*, 2013). Anthropogenic deforestation and fragmentation compelled the primate species, in general, and colobine, in special, to adapt in altered habitat, and their survival depends on their flexibility of altered habitat utilization (Kulp & Heymann, 2015).

The golden langur *Trachypithecus geei* (Khajuria, 1956) is the globally Endangered colobine species of Asia and endemic to the Assam plains and the eastern Himalayan region (Schitwzer *et al.*, 2017). Its distribution ranges are restricted to the present Bongaigaon, Dhubri, and Kokrajhar District of Assam, bounded by the rivers Sonkosh in the west, and Manas in the east, Brahmaputra River in the south, and also in Royal Manas National Park, Bhutan (Geei, 1961).

Abound fieldwork has been done on the population, as well as activity, and feeding pattern of golden langur in its primary habitat of Assam and Bhutan (Das *et al.*, 2013), but the information related to home range study is very limited. Ghosh & Biswas (1976) had reported the home range size of the golden langur in the Bhutan part of Manas Sanctuary as a 3 × 2 km area, with an overlapping region. Biswas (2002) reported the annual home range size of golden langur between 25–58 ha along with DPL ranges between 434–513 meters in the Ultapani range of Chirang reserve forest of Assam. Chetry & Chetry (2009) also reported the annual home range between 10–58 ha for different social troops in different habitats, with a day path length of 200–700 meters in Assam, India.

To understand the ranging behavior of golden langur troops in a small and isolated forest patch of Kakoijana Reserve Forest, the study emphasized the research hypothesis that the home range size and DPL of golden langur have showed significant differences, while they forage in human-modified feeding patches and natural habitat exists in the study area. To prove the hypothesis, two objectives set were:

- To study the daily path length (DPL) of different troops of golden langur with seasonal variations.
- To estimate the annual and seasonal home range area with range sharing if any.

MATERIAL AND METHODS

Study area

The present study was conducted in the KRF (26.22^0 N – 26.21^0 N and 90.33^0 E – 90.34^0 E), an isolated habitat patches of golden langur in the Himalayan foothills of Assam, India. It is a hilly terrain surrounded by human habitations, with area coverage of 17.19 km^2, with an altitudinal height of 41 to 321 m above SL (Fig. 1; Chakravarty *et al.*, 2020). The annual rainfall in the study area ranges from 2631 mm to 3136 mm, with an average monthly rainfall of 134.12 mm. Temperature ranges from 9°C to 10°C in winter and 33°C to 38°C in summer. The soil of the study area is composed of red coarse loams.

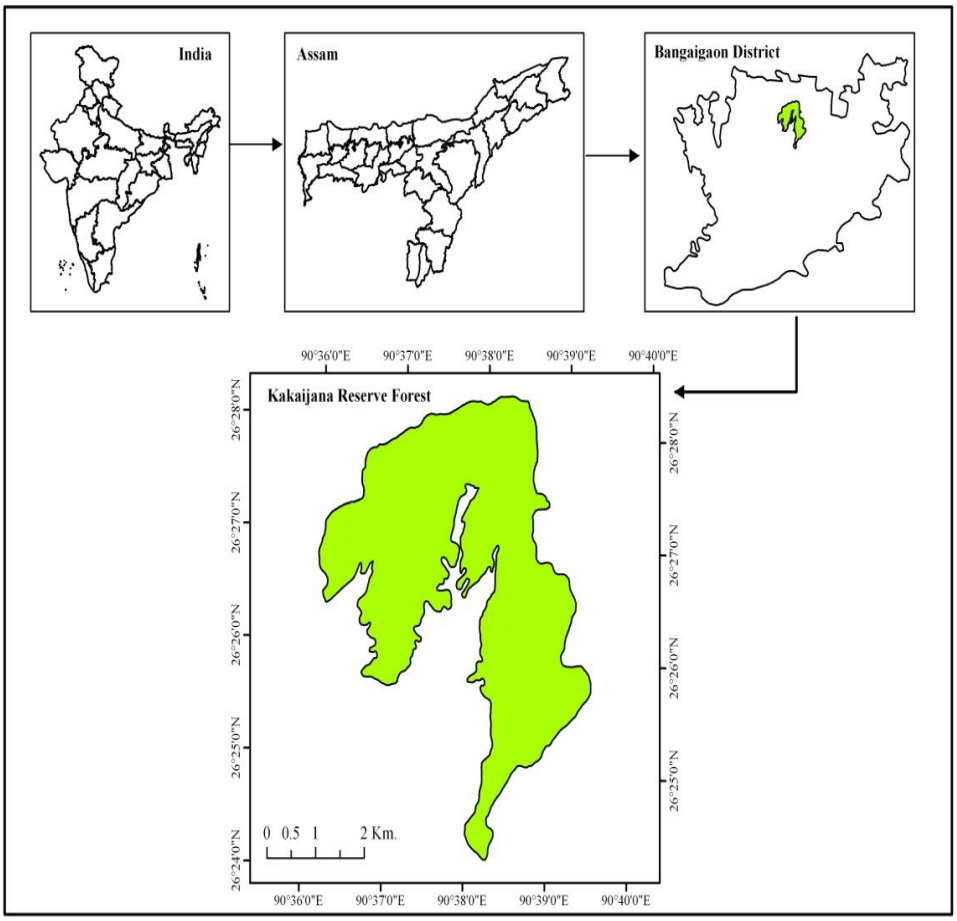

Figure 1. Kakoijana Reserve Forest, Assam, India (Chakravarty *et al*., 2020).

Study troops

A reconnaissance survey of the population and distribution of the species was done prior to the selection the study troops in KRF. Six social troops have been selected randomly out of a total of 39 forest troops (N= 415; range: 3–20 individuals/troop), and habituated for six months before started collecting home range data. The selected troops comprised 11–20 individuals and each troop were given a unique ID viz., K01, K03, K05, K32, K37, and K39 (Table 1).

Table 1

Troop size and age sex composition of six selected troops of golden langur for home range data collection

Troop ID	Sites	Troop size	Age sex class					
			AM	AF	SAM	SAF	JUV	INF
K01	MajerPahar	12	1	4	1	3	3	0
K03	MajerPahar	19 (20**)	2	5	2	4	6	1*
K05	UjanRabhapara Hill side	13	1	5	1	2	4	0
K32	Baragowali	11 (12**)	1	4	2	3	2	1*
K37	Baragowali	09 (10**)	1	4	1	2	2	1*
K39	KhoraparaRubberGarden	12	1	4	1	2	4	0

Abbreviations: AM – adult male; AF – adult female; SAM – sub/adult male; SAF – sub/adult female; JUV – juvenile; INF – infant; ** – troop size changed during the study period; * – infant born during the study period.

Methods

The survey was carried out from September, 2015 to August, 2017. The location of the focal animal was recorded with a handheld Garmin e-Trex 30 global positioning system, set to the WGS 84 grid system. During the location sample, the tree occupied by the focal animal was marked by flagging tape and subsequently relocated and mapped relative to the trail system using 30 m measuring tape and compass. The location sample of the known feeding and lodging trees were also combined with the 30 minutes location samples and the home range size was calculated using Q-GIS version 3.8.0-1 by drawing a minimum convex polygon (MCP) around the cumulative day ranges of each social troop (Sarma & Kumar, 2016). The same location point on a given day was omitted and not used for analysis. Each troop was followed 28 full days for 12 months, thus a total of 168 full days from 6.00 hrs in the morning to 6.00 hrs in the evening or till sun set. The sample size was quite comparable to the small study area of 17.19 km^2 and was found rarely for two days in continuous moving by the troops in one direction.

Analysis of the data

DPL was calculated from full-day observations (N=168 days) as the sum of the straight-line distances (in meters) between consecutive GPS points via Q-GIS version 3.8.0-1. The home range size was calculated in Q-GIS version 3.8.0-1 by drawing MCP encompassing all locations recorded in each season (seasonal home range size), and throughout the study (total home range size) (Sarma and Kumar, 2016; Zhang *et al*., 2014). Seasonal home range and Day path length were analyzed in four seasons viz., pre-monsoon (March–May), monsoon (June–August), re-treating monsoon (September–November) and winter (December–February) (Borthakur, 1986). All statistical analysis were done using SPSS version 16.0. Values are expressed as mean ± SD. One way ANOVA was used to verify the level of significance.

RESULTS AND DISCUSSIONS

Day Path Length (DPL) estimated

Study found that, the mean DPL of six studied troops was 235.91 ± 69.20 m (range: 95.00 m to 441.00 m). A one way ANOVA was performed to compare the mean DPL (Dependent Variables) and studied six troops (independent variable) and found highly significant results (one way ANOVA: $F_{(5,\ 162)} = 3.692$, $p<0.01$, N = 168) (Fig. 2; Table 2).

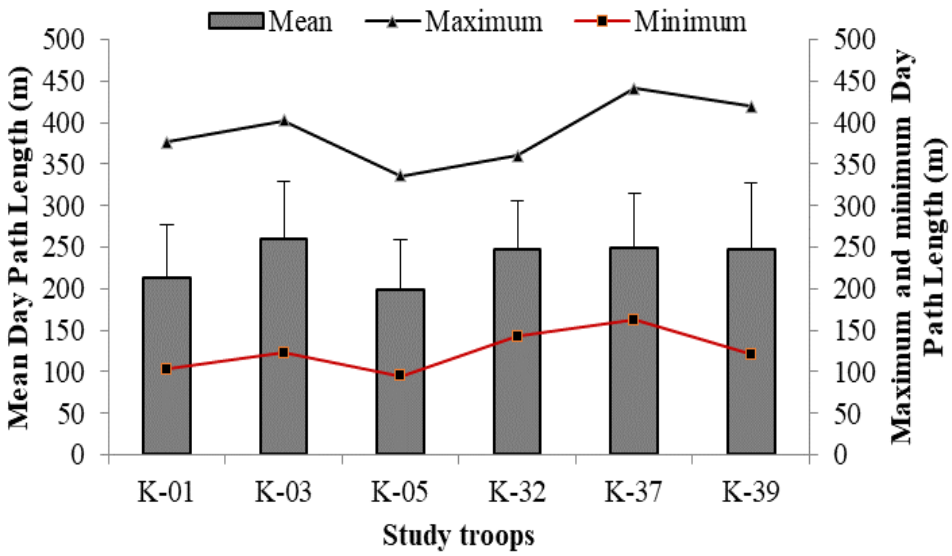

Figure 2. Mean Day Path Length of the study troops with minimum and maximum DPL.

Table 2

Mean DPL (±SD) of the six study troops of golden langurs in KRF

Troop ID	Daily Path Length (in meter)		
	Mean±SD	Minimum	Maximum
K01	212.29 ±65.21	103.00	376.00
K03	260.32 ± 69.19	123.00	402.00
K05	199.32 ± 59.11	95.00	336.00
K32	247.71 ± 57.38	142.00	360.00
K37	248.75 ± 65.01	162.00	441.00
K39	247.07 ± 80.85	121.00	419.00
Total	**235.91 ± 69.20**	**95.00**	**441.00**

A one way ANOVA was also performed to compare the effect of seasonal variation on mean Day Path Length of golden langur in KRF which shows statistically significant difference of mean DPL in different seasons of the year (One way ANOVA: $F_{(3, 164)} = 3.65$, $p<0.01$). The mean DPL of the study troops, in different seasons, were recorded highest in retreating monsoon (DPL: 259.45 ± 63.20), followed by pre-monsoon (DPL: 238.65 ± 66.95) and winter season (DPL: 234.31 ± 75.91). However, the lowest DPL was recorded in the monsoon season (DPL: 210.56 ± 63.51). Amongst the troops, the DPL of K-01 (DPL: 267.29 ± 65.90), K-03 (DPL: 269.86 ± 50.60), K-05 (DPL: 254.00 ± 60.65) and K-39 (DPL: 305.00 ± 91.81) was highest in Retreating monsoon season, whereas, K-32 (DPL: 264.71 ± 67.20) has highest DPL in pre-monsoon and K-37 (DPL: 328.57 ± 62.85) has highest in the winter season. Moreover, K-01(DPL: 182.43 ± 56.03), K-05 (DPL: 176.67 ± 58.01) and K-32 (DPL: 206.29 ± 37.04) troops have lowest DPL on the monsoon season and K-03 (DPL: 243.43 ± 49.15) and K-39 (DPL: 206.14 ± 52.72) has lowest DPL in the winter season, whereas, K-37 (DPL: 198.86 ± 25.84) has lowest DPL in retreating monsoon season (Table 3).

DPL also showed significant differences among the months of the year (One-way ANOVA: $F_{11,156}= 3.34$, $P= 0.000$). Tukey's Post-Hoc test confirmed that the significant difference was mainly found between pairs January–July, May–July, June–July and July–October (Tukeys Test; January *vs.* July: $p<0.05$; May *vs.* July: $p<0.05$; June *vs.* July: $p<0.05$ and July *vs.* October: $p<0.01$; Table 4).

The analysis of Pearson Correlation between mean DPL and weather data conclude a significant negative correlation between them (Pearson Correlation: $r = -0.184$, $N = 168$, $p<0.05$), however, temperature has not been found significantly correlated with DPL of the troops (Pearson Correlation: $r = –0.076$, $N = 168$, $p>0.05$) and rainfall (Pearson Correlation: $r = –0.145$, $N = 168$, $p>0.05$).

Table 3

Mean DPL (±SD) of the six study troops of golden langurs across different seasons in KRF

Troop ID	DPL (m) ± SD			
	Winter	**Pre-Monsoon**	**Monsoon**	**Retreating Monsoon**
K01	192.29 ± 70.07	207.14 ± 39.19	182.43 ± 56.03	267.29 ± 65.90
K03	243.43 ± 49.15	269.00 ± 87.70	259.00 ± 91.36	269.86 ± 50.60
K05	177.29 ± 41.37	187.75 ± 48.84	176.67 ± 58.01	254.00 ± 60.65
K32	258.14 ± 74.58	264.71 ± 67.20	206.29 ± 37.04	261.71 ± 25.97
K37	328.57 ± 62.85	246.43 ± 51.82	221.14 ± 21.94	198.86 ± 25.84
K39	206.14 ± 52.72	264.14 ± 69.70	213.00 ± 76.04	305.00 ± 91.81
Total	**234.31 ± 75.91**	**238.65 ± 66.95**	**210.56 ± 63.51**	**259.45 ± 63.20**

Table 4

Mean DPL of golden langur in different months of the year in KRF

Month	No. of days followed	DPL (m)		
		Mean ± SD	**Minimum**	**Maximum**
January	18	243.28 ± 75.24	95.00	441.00
February	12	238.33 ± 93.74	103.00	359.00
March	12	248.92± 69.39	140.00	360.00
April	18	224.22 ± 71.33	121.00	360.00
May	12	254.00 ± 59.31	19.000	402.00
June	12	253.92 ± 49.50	191.00	355.00
July	18	170.06 ± 44.88	106.00	238.00
August	12	226.33 ± 64.30	154.00	361.00
September	12	230.67 ± 55.69	176.00	318.00
October	18	291.17± 61.70	213.00	419.00
November	12	240.67 ± 54.49	162.00	376.00
December	12	216.83 ± 58.82	112.00	303.00
Total	**168**	**235.91± 69.20**	**95.00**	**441.00**

Home range size

Annual home range size

The study showed that, among all the studied golden langur troops' home range, the maximum home range was estimated in case of K39 troop (41.6 ha), followed by troop K03 (23.68 ha), troop K32 (17.96 ha), troop K05 (15.37 ha), and troop K01 (12.35 ha), whereas, the lowest home range was estimated in case of

troop K37 (9.45 ha). The mean annual home range of golden langur in KRF was estimated 20.07 ± 11.62 ha (±SD); (Fig. 3).

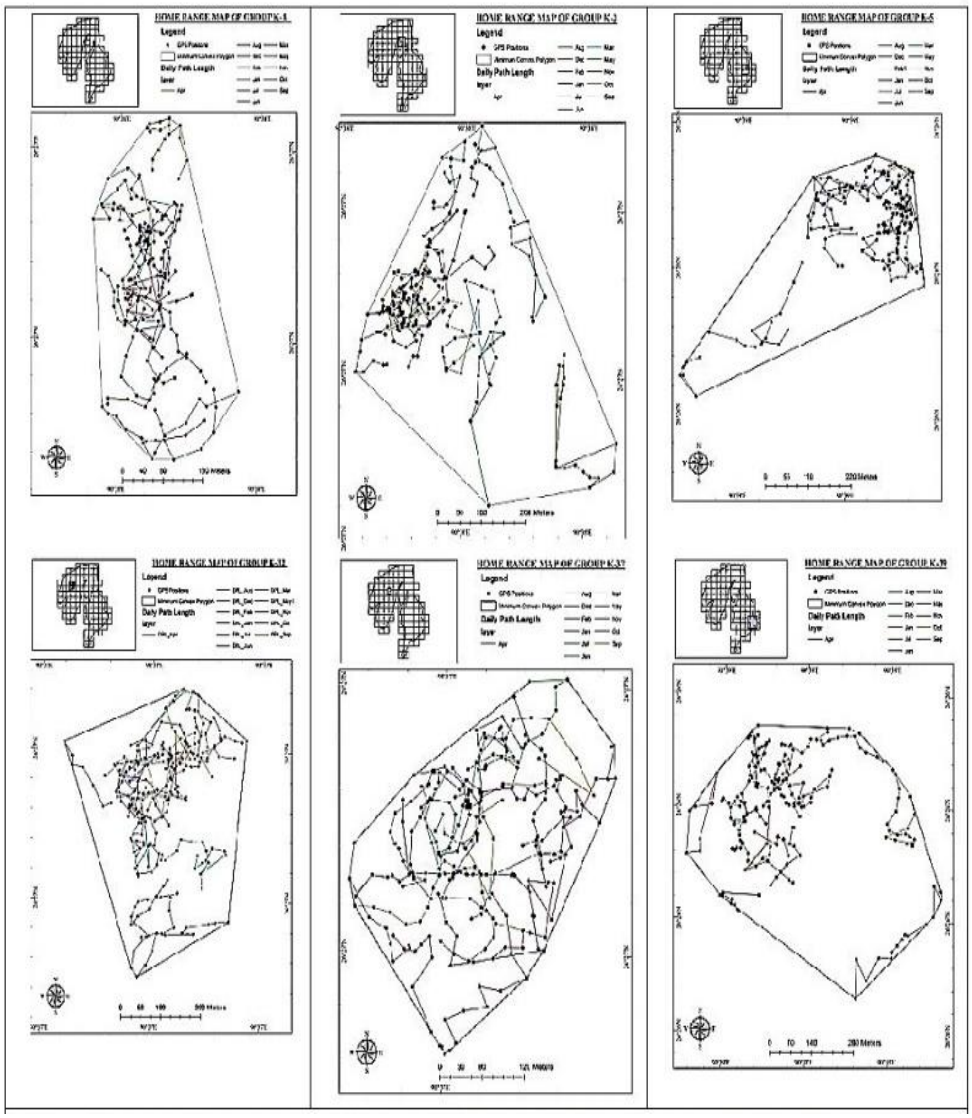

Figure 3. Annual home range of study troops in Kakoijana Reserve Forest.

Seasonal home range size

The troop K05 (7.64 ha; 49.73% of annual home range area), K32 (11.58 ha; 64.48%) and K37 (6.28 ha; 66.47%) have the highest seasonal home range in the winter season, whereas, K01 (7.01 ha; 56.80%), K03 (21.69 ha; 91.61%) and K39

(33.43 ha; 80.35%) troops have the highest home range in retreating monsoon, monsoon, and pre-monsoon season, respectively. Moreover, the lowest home range was found in troop number K03 (4.53 ha; 19.14%) and K39 (6.25 ha; 15.03%) during the winter season, whereas, K01 (4.84 ha; 39.22%) and K32 (3.38 ha; 18.80%) troops have the lowest home range in pre-monsoon season, and K05 (3.88 ha; 25.26%) and K37 (3.65 ha; 38.63%) have lowest in monsoon, and retreating monsoon respectively (Fig. 4; Table 5).

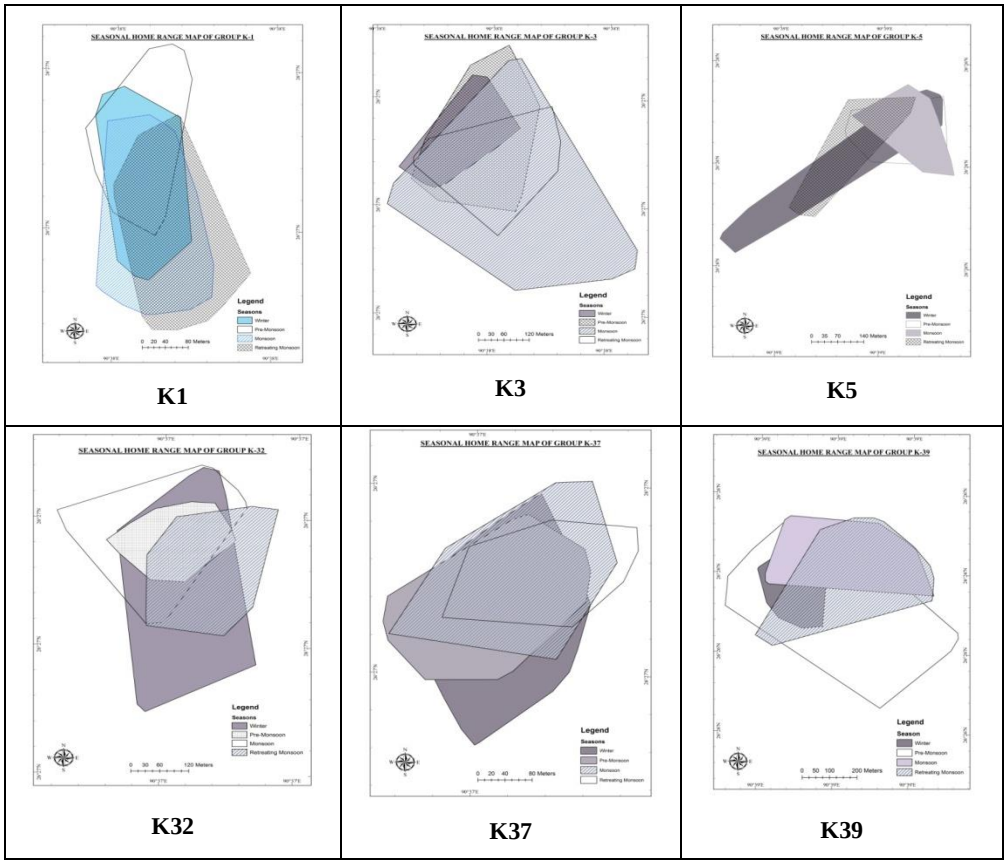

Figure 4. Home range of different troops shows seasonal home range sizes in KRF.

The study showed that the mean seasonal home range sizes of the study troops were significantly different among the troops with maximum 33.43 ha area in troop K39 (18.06 ± 11.47) and minimum 3.38 ha (7.44 ± 3.43) in troop K32. All troops' lowest mean seasonal home range was estimated in troop K05 (5.24 ± 1.66). All troops' mean seasonal home range area was recorded 8.79 (ha) ± 6.96 (One way ANOVA: $F_{5, 18} = 2.90$; $p < 0.05$; N = 24; Table 6).

Table 5

Seasonal home range of the study troops and their percentage contribution to the annual home range in KRF (S – season; W – winter; PM – pre-monsoon; M – monsoon; RM – retreating monsoon; HR – Home Range; ha – hectare)

S	K01		K03		K05		K32		K37		K39	
	HR (ha)	% of total HR	HR (ha)	% of total HR	HR (ha)	% of total HR	HR (ha)	% of total HR	HR (ha)	% of total HR	HR (ha)	% of total HR
W	5.05	40.89	4.53	19.14	7.64	49.73	11.58	64.48	6.28	66.47	6.25	15.03
PM	4.84	39.22	9.29	39.25	4.50	29.31	3.38	18.80	5.43	57.42	33.43	80.35
M	6.84	55.38	21.69	91.61	3.88	25.26	8.34	46.43	5.90	62.44	13.78	33.11
RM	7.01	56.80	7.48	31.61	4.92	32.02	6.47	36.00	3.65	38.63	18.78	45.15

Table 6

Mean seasonal home range size of the study troops in KRF

Troop ID	Home Range Size (ha)		
	Mean ± SD	Minimum	Maximum
K01	5.94 ± 1.15	4.84	7.01
K03	10.75 ± 7.55	4.53	21.69
K05	5.24 ± 1.66	3.88	7.64
K32	7.44 ± 3.43	3.38	11.58
K37	5.32 ±1.16	3.65	6.28
K39	18.06 ± 11.47	6.25	33.43
Total	**8.79 ± 6.96**	**3.38**	**33.43**

The K01 has shared 6.23% (0.77 ha) of its home range with troop K03, whereas, K03 has shared 3.25% (0.77 ha) of its home range with K01 troop. Again, the troop K32 has shared 4.73% (0.85 ha) of its home range with K37 troop, while troop K37 has shared an 8.49% (0.85 ha) home range with troop number K37 (Fig. 5).

As a social folivorous colobine species, golden langur troops also have a definite home range and ranging pattern. Annual home range size and ranging behavior of golden langur at KRF followed the typical pattern of small home range size with short day path length. The DPL of the study troops in KRF is comparatively shorter and smaller than the DPL studied in other habitat areas (as studied by Biswas (2002) in Ultapani range, Chirang Reserve Forest and Chetry & Chetry (2009) in different golden langur habitats in Assam). Shorter DPL may be due to patchy vegetation resources in the habitat along with high anthropogenic pressure. Trees and climbers used by the species as food resources and roosting place were mainly distributed near springs inside the forest and also found in

abundant in human habitation areas, hence golden langur troops in KRF confined themselves in those areas. A wide variety of plant species (trees, shrubs, climbers, etc.; n = 134), used by the troops as food, helped to fulfill their dietary requirements within a short day range (Chakravarty & Saikia, 2023). Fire wood collection and sound of logging with increased human presence in the forest before and after the monsoon months is another cause of increased DPL both in open and dense area of the forest. Reduction in energy spent in food procurement by shortening day path length, can utilize by primates for population growth (Zhou *et al*., 2011) may be the fact of high population of golden langur (n = 489 individuals in 45 troops; area: 1719 ha) in KRF area (Chakravarty *et al*., 2020). Similarly, the overall DPL in pre-monsoon and winter season as long as the leaf consumption is high in these two seasons due to the unavailability of the fruits. It has also been opined by other researchers that, when food is scarce, the distance of daily movement may be increased (Bennett, 1986). Hence, the long daily movement distance is influenced by the presence of fruit-bearing trees (Zhang & Wang, 1995; Fashing, 2001; Zhang *et al*., 2014). The present study also opined that the golden langurs used densely vegetated areas significantly more often in the winter season, which could lead to increase DPL during such resource-scarce winter season as there was no plan for energy conservation in dense vegetation in particular. In contrast, dense forest troops spent less travel time (DPL) in monsoon season. Differences in seasonal home range may also reflect troop's foraging site with anthropogenic pressure on them. Findings from the present study support the previous findings that overall food abundance did not accurately reflect the situation experienced by the animals (Chapman, 1988).

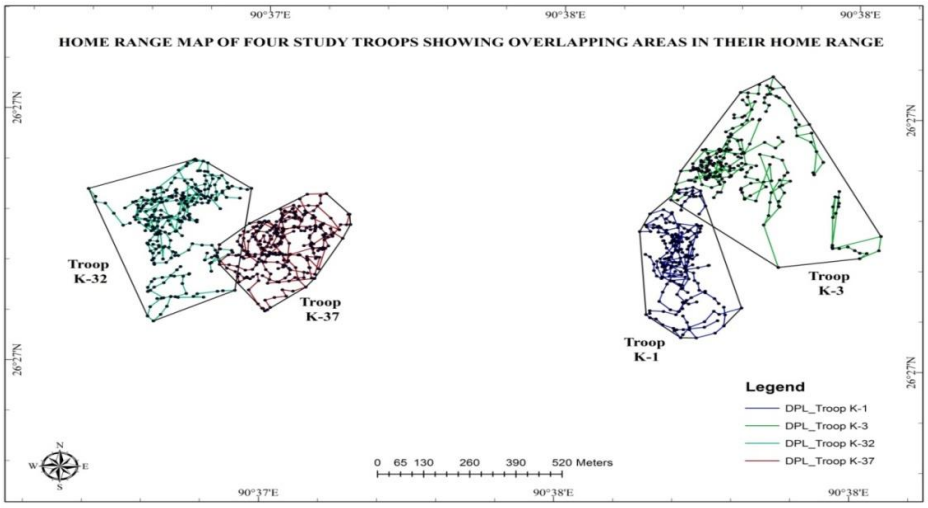

Figure 5. Range sharing/range overlapping of the study troops in the study area.

Present study shows substantial negative correlation with temperature which supported by significant correlation of temperature variation and day path length as studied by Biswas (2002). This difference may be due to the fact that present study takes more than one year as large number of study groups. A significant negative correlation with weather is probably an adaptation to cope up with adverse weather in open forest with less canopy cover and tall trees.

Annual home range of the present study troops were found within the range of the previous studies done in different primary as well as isolated habitats of the species (Table 7).

Table 7

Summary of information of golden langur day path length (DPL) and home range size (range and mean values)

Species	Study site	Sample size		Day path length (DPL) (m)	Annual Home range (ha)	Source
		No. of troops studied	Duration of study			
Trachypithecus geei	Kakoijana Reserve Forest	06	January, 2015 – August, 2017)	235.91± 69.20 (SD) (range: 95– 441)	20.07± 11.62 (SD) (range: 9.45–41.6)	Present study
	Ultapani Range Chirang Reserve Forest	02	December, 1998 – November, 1999	Range: 434–513	25 ha and 58 ha	Biswas, 2002
	Bhutan part of Manas WLS	01	–	–	3 × 2 km^2	Ghosh & Biswas, 1976
	Chakrashila	02	–	–	10–21	Chetry & Chetry, 2009
	Ripu-Chirang	01	–	–	25	-Do-
	Nayakgaon	01	–	–	10	-Do-
	Sreegram	01	–	–	25	-Do-

The result of the present study depicted that, the home range size increased in the pre-monsoon and monsoon seasons as troops foraged more to enjoyed sprouting leaves along with ripe fruits in these seasons. This result also in support of the fact that colobines generally increase home range size when they eat fewer leaves, as leaf consumption is inversely proportional to travel time and day range length (Clutton-Brock, 1975; Harvey & Clutton-Brock, 1981; Bennett, 1986; Newton, 1992; Decker, 1994; Li *et al*., 2000; Grueter *et al*., 2013; Smith *et al*., 2013).

Comparison on annual and seasonal home range suggested that, seasonal ranging was much smaller than the annual range in all the troops except two troops, showing 91.61% and 80.35% of total home range area in pre-monsoon and monsoon season respectively similar with previous study (Biswas, 2002). Exception may due to anthropogenic activities and feeding requirements.

The area of KRF is very small and the occurrence of a high population of golden langur in the reserve is a major concern. Home range overlapping was also recorded in previous studies (Biswas, 2002) as we have found in the present study. Overlapping is very negligible in the present study. The overlapping in the home range among the six study troops was found very minimal in the present study which signifies that troops are restricted themselves in very small areas. Probably this is an eco-behavioral requirement of a group living organisms in densely populated areas to reduce inter- troop encounter as well as encounter with rhesus macaque, another primate species coexist in the habitat. That also evokes serious questions on the availability of resources in terms of food and cover for the species in such an isolated forest patch.

CONCLUSIONS

From this study, it can be concluded that the day path length and home range of study troops showed flexibility to overcome unpredictable anthropogenic constraints in the form of logging and grazing. The forest is severely under the anthropogenic pressure and focal species adopted in the patchy vegetation of the habitat to live in. Again, it was seen that the species likely to respond to the availability of food plants and as an adaptive measure includes more climber species that grow easily near the water sources. The smaller home range of the species in comparison to that of reported for species from other areas is another issue to be taken up urgently for the future health of the current population of golden langur in the KRF. High population density, monoculture plantation in the forest area, illegal logging, landlocked condition, road killing, and electrocution are some of the major threats to golden langur in the present study area to be resolved with the findings of the present study.

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