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COMMUNICATION

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COMMUNICATION

Persistence of *Trachypithecus geei* (Mammalia: Primates: Cercopithecidae) in a rubber plantation in Assam, India

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Abstract: Non-human primates are highly threatened as a result of habitat destruction, agricultural expansion, industrial development, large-scale build-ups and wildlife trafficking. Nearly 60% of all primates are threatened and many are found in habitats with some form of human modifications (e.g., croplands and plantations). The adaptability of primates to survive in human-modified habitats is thus a key to determine their persistence in anthropogenic landscapes. In this study, we examined the population number and age-sex composition of the 'Endangered' Golden Langur *Trachypithecus geei* in a rubber plantation in the Kokrajhar District in Assam, India in 2016, and compared with past data of the langur population and demographics from the same location to better understand the population dynamics, demographic characters and persistence of the Golden Langurs in the rubber plantation. In 2016, we recorded six groups of Golden Langurs totaling 78 individuals with a mean group size of $13.00 \pm 4.00_{SD}$. Of the total population, 10.29% were adult males, 41.18% were adult females, 32.35% were juveniles and 16.18% were infants. The overall population growth from 1997 to 2016 was estimated to be 5.54% per year. Habitat matrices of rubber plantations with natural forest patches are important in the fragmented landscape for the persistence of Golden Langur populations. They may also act as a corridor for the langurs to move between the fragments and as food resources, highlighting the importance of such matrices for the langurs outside protected areas. Population monitoring and ecological studies in such matrices would therefore be needed for the successful implementation of targeted management strategies for the conservation of these threatened langurs.

Keywords: Anthropogenic landscape, landscape supplementation, matrix, persistence, primate.

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Author contributions: JS—conceptualisation of the study, data collection-compilation-analysis, and writing of the manuscript; JB—data collection, conceptualisation, executing the study and fundraising; SN—data collection; HNK—guiding the data compilation-analysis, writing manuscript.

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INTRODUCTION

Forest loss and habitat degradation that is primarily driven by agricultural expansion and intensification (Gibbs et al. 2010; Foley et al. 2011), are the major threats to biodiversity (Maxwell et al. 2016). This anthropogenic modification of ecosystems is globally widespread, resulting in many primate species living in human-modified landscapes (Cowlishaw 1999; Cowlishaw & Dunbar 2000; Chapman & Peres 2001) with remnant patches of natural vegetation (Prevedello & Vieira 2010; Watling et al. 2011). Non-human primates are most affected by anthropogenic habitat disturbance, partly due to their high dependence on tropical forest ecosystems (Isaac & Cowlishaw 2004). Nearly 60% of the world's primate species distributed in the Neotropics, mainland Africa, Madagascar, and Asia are threatened with extinction as a result of habitat destruction, agricultural expansion, industrial development, large-scale build-ups and wildlife trafficking (Estrada et al. 2017). In many parts of Asia, lowland dry evergreen and semi-evergreen forest and dry deciduous forests have been converted to plantations such as rubber and oil palm plantations (McKenney et al. 2004; Tordoff et al. 2005). The adaptability of primates to survive in human-modified habitats is a key to determine their persistence in anthropogenic landscapes (Ferreira et al. 2018). While some primates are known to use part of human-altered land covers (Pielke Sr. et al. 2004; Davey 2006; Wickham et al. 2012), others use degraded habitats and persist (e.g., Capped Langur *Trachypithecus pileatus*: Borah et al. 2021). But the lack of information on their ecological traits to utilize human-modified habitats greatly limits our ability to implement targeted landscape management strategies for their conservation.

Golden Langur *Trachypithecus geei* (Khajuria, 1956) is 'Endangered' (IUCN Red List; Das et al. 2020) and endemic to parts of Bhutan and the Indian state of Assam (Wangchuk 1997; Choudhury 2002). In India, the natural habitat of Golden Langur is primarily semi-evergreen and moist deciduous forests (Champion & Seth 1968; Bahuguna et al. 2016). A large part of the habitat of the Indian population of Golden Langurs has been lost in the last three decades and the population has been threatened (Srivastava 2006a). Several populations are confined to isolated forest fragments (Srivastava et al. 2001a; Choudhury 2002; Srivastava 2006b). Large-scale built-up areas and anthropogenic land-use patterns have changed the landscape and divided the Golden Langur population in India into two parts, viz., the northern and southern populations without contiguous habitats between them (Srivastava et al. 2001b). The northern population has a vast pristine area in Ripu Reserved Forest, Chirang Reserved Forest, and Manas National Park (>500 km^2) and is connected to the langur population in Bhutan. On the other hand, the southern population is confined to small habitat fragments (<50 km^2) with one subpopulation inhabiting a Rubber *Hevea brasiliensis* plantation in Nayekgaon in the Kokrajhar District in Assam, India. This rubber plantation and its fringe forests were once connected with the Chakrashila Wildlife Sanctuary, which is still a natural and protected habitat of the southern population of Golden Langurs. Over the course of time, the area lost its continuity with the Chakrashila Wildlife Sanctuary due to human settlement in adjacent forest areas (Medhi et al. 2004). In this study, we examined the population number and age-sex composition of Golden Langurs in the rubber plantation and surrounding areas in Nayekgaon in 2016, and compared with past data of the population and demographics from the same location so as to assess population trend and persistence of the Golden Langur in a small and isolated human-modified landscape. Previous studies were conducted in 1997 (Srivastava et al. 2001a), 2002 (Medhi et al. 2004), and 2008 (Ghosh et al. 2009) but detailed information was not available for the years 1997 and 2008 and hence we could only compare in detail with the 2002 data. Understanding the survival possibilities of such a population outside their natural habitat would help in primate conservation and habitat management.

METHODS

Study Area

The rubber plantation and its surrounding plantation areas consist of approximately 277 ha and is situated between 26.350–26.374 ^{0}N and 90.372–90.393 ^{0}E in Nayekgaon Village of the Kokrajhar District, Assam, India. The rubber plantations started in 1985 and Golden Langurs were also reported at the same time which indicated that the area was once the natural habitat of Golden Langurs (Medhi et al. 2004). The area is a private rubber plantation and comprises of 80% rubber plantation and 20% natural forests with human settlements and roads (Medhi et al. 2004). *Shorea robusta, Tectona grandis*, *Bauhinia purpurea*, *Bauhinia variegata*, *Mangifera indica, Dillenia pentagyna, Duabanga grandiflora, Litsea glutinosa, Terminalia bellirica, Premna bengalensis, Albizia procera, Stereospermum personatum*, and *Ficus* spp. are the

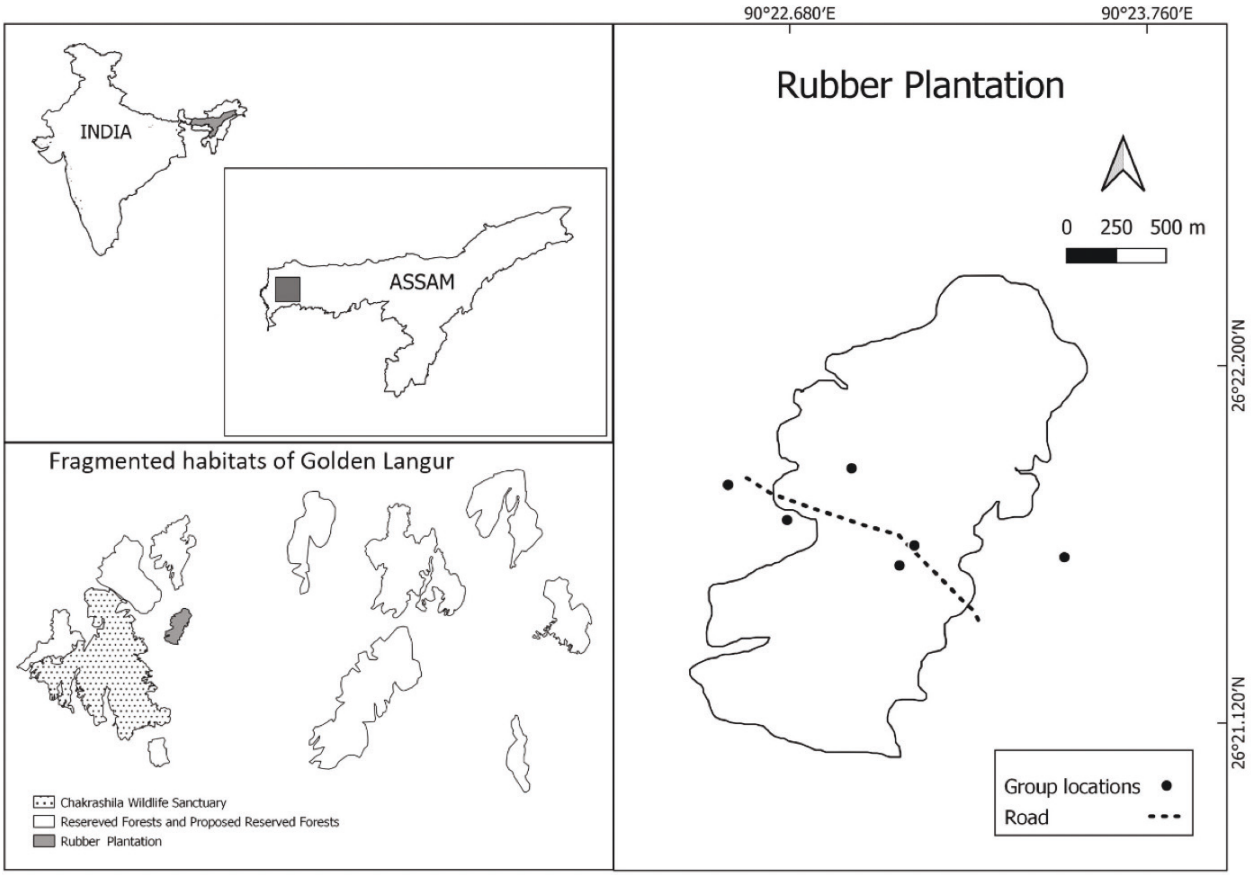

Figure 1. Abhaya rubber plantation in Nayekgaon Village of the Kokrajhar District, Assam, India

Image 1. Golden Langur in the rubber plantation. © Joydeep Shil.

Image 2. Golden Langur in the rubber plantation. © Joydeep Shil.

main species within the natural vegetation (Medhi et al. 2004). During our study, we also recorded roughly 20% of the area consisting of natural forests. Our interaction with the plantation manager confirms that there was no further expansion of rubber plantation after 1985. Climatic conditions of the area are humid with moderate temperature with high rainfall during monsoon and dry with low temperature during winter (Barthakur 1986). The annual rainfall of the area is between 2,000 and 3,000 mm. Rhesus Macaques *Macaca mulatta* are sympatric with the langurs (Medhi et al. 2004). A study area map (Figure 1) was created using QGIS 3.16.

Survey

Since the area of Nayekgaon rubber plantation is small, total count was possible. We followed the same field protocol as the previous population assessment in the same location in 1997 (Srivastava et al. 2001a, 2002; Medhi et al. 2004, 2008; Ghosh et al. 2009), i.e., block count methods (Struhsaker 1975; Burnham et al. 1980; NRC 1981) for a total count of the population. The area was demarcated into two blocks by taking the road as a landmark (Figure 1). The road passes from east to west through the rubber plantation and divides the area almost equally. Each block was further divided into sub-blocks of 12 to 15 ha. Prior to the survey, a one-day training workshop was conducted for the recording of geo-coordinates and population assessment including age-sex of the individuals of Golden Langurs. The teams were led by a trained biologist who was able to differentiate the age and sex of individuals of Golden Langurs. The assessment was conducted by 12 teams consisting of two people in each team. Each sub-block was surveyed by a team of two people either in the morning or in the evening. All the teams walked in parallel maintaining at least 200 m distance between each team from 0600 to 1100 h and from 1400 to 1700 h on three consecutive days from 26 to 28 February 2016. Each team was provided with a handheld GPS (Garmin 78S), 8×4 binocular, digital camera and Motorola wireless handset for communication to avoid duplication in counting. When langurs were encountered, we recorded the geo-coordinates of the location of the group, and observed the group for sufficient time or until we could record the total number, and age-sex of all the individuals in the group. The data on age and sex were considered as adult male (AM), adult female (AF), juvenile (JU), and infant (IN). Visibility was high in the rubber plantation so there were no difficulties in locating the animals. The langurs were habituated to human presence since they regularly came into contact with plantation workers and researchers.

Data analysis

The groups were differentiated and identified using the time, location, and group composition of adjacent groups. Since the area was small, we adapted the total count method, and the sum of the number of individuals in each identified group was considered as the number of individuals in the study area. We calculated the density as a total number of individuals in the total area.

The data of adult males and adult females were combined to represent adults (AD) and the same was done for infant and juvenile, represented as immature (IM), to compute the age-sex ratios. We calculated the mean group size, mean individual of different age-sex classification, and age-sex ratios using the data of all the groups. We could not identify the age and sex of four of the individuals in one of the groups, thus that group was not considered in the calculation for the mean age-sex compositions but was considered for the total count and mean group size. We compared the data of 2002 and 2016 to check for any significant differences. We did not consider other year's data since it was not completely available. We compared the mean group sizes using the Mann-Whitney U test, the proportions of different age-sex compositions using the Chi-square test, and the ratios of different age-sex using Paired Wilcoxon Signed Rank test. The density of langur was calculated as a total number of individuals divided by the total area of the survey (~277 ha). We used statistical analysis using R version 3.6.3. The rate of population growth, r, between two-time points, t1 and t2, is calculated as a rate of growth, expressed in percentage units per year:

$$r = \frac{\left(\frac{P2 - P1}{P1}\right) x100}{t2 - t1}$$

Where P1 and P2 are the number of individuals at times t1 and t2 respectively and the time interval (t2-t1) is expressed in years (https://pages.uoregon.edu/rgp/PPPM613/class8a.htm Accessed on 12 March 2021).

RESULTS

We recorded six groups of Golden Langurs totaling 78 individuals (Table 1, Image 1&2) with the mean group size of $13.00 \pm 4.00_{SD}$ (Table 2). By excluding the data from Group 1 where we were unsure of the demographics of some of the individuals, the age-sex composition of the population was 10.29% (N= 7) adult males, 41.18% (N= 28) adult females, 32.35% (N= 22) juveniles and 16.18% (N= 11) infants. Of the six groups, three groups had two adult males. The ratio of adult male to adult female was 1:4.00; adult to immature was 1:0.94; and adult female to infant was 1:0.39 (Table 2). The calculated density showed 28.16 langurs/km^2.

The number of groups recorded in 1997 was five, declined to three by 2002 (Medhi et al. 2004), increased to 12 by 2008 and then declined to six by 2016 (Table 2). The mean group size between 2002 and 2016 did not vary significantly (M-W U test, U= 12.0, p= 0.517). Proportion of adult males, adult females and immature per group in 2002 and 2016 (adult males: χ^2= 2.88, df= 7, p= 0.896; adult females: χ^2= 10.34, df= 7, p= 0.17; immature: χ^2=

Table 1. Group compositions of *Trachypithecus geei* in rubber plantation in 2016.

Group #	Adult male	Adult female	Juvenile male	Juvenile female	Infant	Unidentified/ Doubtful	Total
1	2	2	1	1	0	4	10
2	1	6	1	2	2	-	12
3	1	4	2	2	0	-	9
4	2	8	2	1	5	-	18
5	2	6	4	4	2	-	18
6	1	4	1	3	2	-	11
All total							78

Table 2. Group size, age-sex composition of *Trachypithecus geei* in rubber plantation in different studies.

Group parameters	1997 (Srivastava et al. 2001a)	2002 (Medhi et al. 2004)	2008 (Ghosh 2009)	2016 (current study)
Total groups (mean group size±SD; range)	5 (7.6)	3 (17.33±9.61; 7–29)	12 (9.3)	6 (13.00±4.00; 9–18)
Total AM (mean±SD; range)	-	5 (1.67±0.58; 1–2)	-	7 (1.40±0.55; 1–2)
Total AF (mean±SD; range)	-	17 (5.67±3.21; 2–8)	-	28 (5.60±1.67; 4–8)
Total IM (mean±SD; range)	-	30 (10.00±6.00; 4–16)	-	33 (6.60±2.41; 4–10)
AM:AF	-	1:3.40	1:2.25	1:4.00
AD:IM	-	1:1.36	-	1:0.94
AF:IN	-	1:0.76	-	1:0.39
Total individuals	38	52	112	78

Table 3. Population growth rate of *Trachypithecus geei* in rubber plantation.

Period	Annual Growth rate %
1997–2002	7.37
2002–2008	19.23
2008–2016	-3.79
1997–2016	5.54

6.91, df= 7, p= 0.438) did not vary significantly (Table 2). Although, the number of females per male in 2002 (3.40) was less than in 2016 (4.00) the difference was not significant (t= -1.313, df= 6, p= 0.237). Similarly, the number of immatures per adult (in 2002: 1.36 and in 2016: 0.94; t= -0.844; df= 6, p= 0.431), and number of infants per adult female (2002: 0.76 and 2016: 0.39; t= 2.144; df= 6, p= 0.076) did not differ significantly. The population growth between 1997 and 2016 was found to be 5.54 % (Table 3).

DISCUSSION

We examined the population numbers and demographics of the Golden Langur in a rubber plantation in Assam, India between 1997 and 2016. Although the reasons for the differences in the number of groups and the mean group size between the study period were not well understood due to the lack of continuous monitoring, the fluctuations in the population size could be tracked during certain periods. The large group size in 2002 and the small group size in 2008 with many groups indicated that the population might be exhibiting fusion and fission of the groups. Fusion and fission of groups are social traits in primates, and also reported in Golden Langur (Biswas 2004). Group size influences feeding time (Doran 1997; Sakura 1994), suggests that fission-fusion may serve as a mechanism to reduce within-group feeding competition and help to overcome the negative consequences of group living. Absence of the significant difference in age-sex ratios between 2002 and 2016 suggests that though the population size fluctuated, the demographical structures remained stable despite changes in vegetation structure and species composition in the habitat. Within the natural habitat of Chakrashila Wildlife Sanctuary, the group size of Golden Langur ranged 3–15 individuals, with a mean size of 7.4 and the age structure of the population comprised 49.8% adults, 33.5% juveniles and 16.7% infants (Chetry et al. 2010). Our study, however, shows

that the density of Golden Langur in a rubber plantation (28.16 langurs/km^2) is much higher than in the natural habitat of Chakrashila Wildlife Sanctuary (12.40 langurs/km^2) (Chetry et al. 2020). The annual population growth from 1997 and 2016 (Table 3) was much higher (5.54%) than in the natural habitat of Chakrashila Wildlife Sanctuary i.e., 1.5% annual growth from 2006 (Chetry et al. 2010) to 2016 (Chetry et al. 2020). In the rubber plantation, deaths of three adult female Golden Langurs due to electrocution in 2001–2002 were reported by Medhi et al. (2004). Medhi et al. (2004) also mentioned domestic dogs as a possible threat for the Golden Langur population. This could affect the population dynamics and age-sex composition since the population of Golden Langur is small. But during this survey and our behavioral study period (2013-2016) we did not record any incident of electrocution or dog attack. The birth rate and immature survival rate were not different between the rubber plantation and adjacent natural forests of Chakrashila Wildlife Sanctuary (Shil et al. 2020). Since the birth and immature survival rate cannot be a factor of population fluctuation in the rubber plantation, therefore migration of animals could be the possible reason. Furthermore, the high nucleotide diversity of the langur population at Nayekgaon's rubber plantation (Ram et al. 2016) indicated that gene flow between the populations of other nearby fragments was probably still present. Rubber monocultures can provide corridors for the movement of Golden Langurs between fragmented habitats as canopy connectivity reduces the exposure of primates to predators (Oliveira & Dietz 2011; Cassano et al. 2014; Coleman & Hill 2014).

In areas where natural habitats have declined, primates may be forced to use altered landscapes of a matrix composition more frequently for feeding and traveling (Galán-Acedo et al. 2019). Rubber agroforests that retain some degree of natural forests support a subset of forest biodiversity in landscapes (Warren-Thomas et al. 2015). The encounter rate of Spider Monkeys *Ateles geoffroyi* increased with matrix functionality in the more disturbed region (Galán-Acedo et al. 2019). Feeding on young leaves and fruits of rubber (Roy & Nagarajan 2018) and dry rubber seeds by Golden Langurs (Medhi et al. 2004; Roy & Nagarajan 2018) and use of rubber trees for sleeping (Roy & Nagarajan 2018) highlight an adaptive behavior of the langurs. In Sumatra, Rizaldi et al. (2019) reported six out of nine groups of East Sumatran Banded Langur *Presbytis percura* adapting to feed on non-native rubber trees which were introduced into their habitat nearly 100 years ago. At least 86 primate species (17% of all primates) are actively obtaining food resources from the anthropogenic landscape, highlighting their importance for primate conservation (Asensio et al. 2009; Arroyo-Rodríguez et al. 2017). Among forest-specialised primates, which represent 70% of the studied species, the results suggest that the reason for the persistence of their population in the altered habitat may be because they are able to supplement their diet by foraging in the modified landscape (Dunning et al. 1992). In Batang Serangan in northern Sumatra, a small population of the Sumatran Orangutan *Pongo abelii*, Thomas's Langur *Presbytis thomasi*, Long-tailed Macaque *M. fascicularis fascicularis*, Southern Pig-tailed Macaque *M. nemestrina*, Lar Gibbon *Hylobates lar*, and Silvered Langur *T. cristatus* have been reported living for several decades in a mixed agroforest system composed of Oil Palm *Elaeis guineensis*, rubber trees, and remnant forest (Campbell-Smith et al. 2010). The continued presence of Proboscis Monkey *Nasalis larvatus* for more than two decades in the cocoa and oil palm plantation in Lower Kinabatangan Floodplain suggests that the species is resilient to habitat changes (Boonratana 2013). But the loss of critical habitats and the inability to access other nearby fragments have allowed the species to persist only at lowered population size and densities, and with likely changes to their behavior and ecology (Boonratana 2013). The rate of emigration from habitat also had a very strong predicted effect on the extinction threshold; the higher the rate of emigration, the more habitat was needed for persistence (Fahrig 2001). Angolan Colobus *Colobus angolensis palliatus* frequently travelled and foraged in indigenous matrix vegetation (such as mangrove, wooded shrubland, and shrubland) up to four kilometers from the nearest forest fragments. Agricultural habitats, such as perennial plantation (coconut, mango and cashew nut) was also used by colobus as corridor (Anderson et al. 2007). Although initial decline in the population was observed, Golden Langurs have shown increase in the population size over the period. A similar pattern was also seen with other primates e.g., Nicobar Long-tailed Macaque *M. f. umbrosus* in Nicobar Islands (Velankar et al. 2016), Lion-tailed Macaque *M. silenus* in Western Ghats (Umapathy et al. 2011), Guerezas *Colobus guereza* and Blue Monkey *Cercopithecus mitis* in Kakamega forests in Kenya (Mammides et al. 2008). Thus, the persistence of Golden Langur in a relatively high density in the rubber plantation could be due to continued gene flow between nearby populations and the value of the rubber plantation as food resource and habitat corridor amid a disturbed, anthropogenic landscape outside of protected areas. Continuous population monitoring and ecological

studies in such matrices would help in understanding their adaptability for the conservation of the threatened Golden Langur.

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