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Feeding Ecology and Social Structure of Golden Langur (*Trachypithecus geei*) in Secondary Forests of Chakrashila Wildlife Sanctuary, Assam, India

THESIS TO BE SUBMITTED TO
MANIPAL ACADEMY OF HIGHER EDUCATION

FOR FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

DOCTOR OF PHILOSOPHY
BY

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UNDER THE GUIDANCE OF

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This is to certify that the work incorporated in this thesis "**Feeding Ecology and Social Structure of Golden Langur (*Trachypithecus geei*) in Secondary Forests of Chakrashila Wildlife Sanctuary, Assam, India**" submitted by **Mr. Joydeep Shil** was carried out under my supervision. No part of this thesis has been submitted for a degree or examination at any university. References, help and material obtained from other sources have been duly acknowledged.

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Abstract

I studied Golden langurs in altered habitats to understand the consequences of habitat conditions on social organization, ecology and ranging pattern. I selected 12 groups inhabiting forest edge and forest core of Chakrashila Wildlife Sanctuary and the adjoining rubber plantation. Three groups from the different habitats were also selected for activity budgeting and ranging data collection. Instantaneous scan sampling method was used and groups were followed from dawn to dusk. Geocoordinates of the group movements were recorded at every 30 minutes interval.

The overall group size of golden langur was $11.3 \pm 3.5_{SD}$, and ranged between 5 and 18. The mean group size in forest core, forest edge and rubber plantation differed significantly. Births occurred in all the months but peaked between May and September (82.6%). The mean number of births positively correlated with mean monthly rainfall. Diurnal activities varied significantly with highest time spent on resting followed by feeding, locomotion, monitoring and social for all the three groups. The core group, edge group and rubber group spent 27.33%, 26.83% and 25.27% time in feeding respectively. Food items consumed varied significantly across the seasons and across the groups with highest leaf consumption of leaf annually by core group (65.67%), edge group (59.39%) and rubber group (34.60%). Number of plant species consumed by core group, edge group and rubber group are 39, 41 and 40 respectively. Mean annual day path length among the three groups have significant difference ($F_{2,182}=11.08$, $p<0.001$). Home range area used by core group, edge group and rubber group are respectively 29 ha, 42.25 ha and 49.5 ha, however, the spatial use of the habitats by each group varied seasonally.

It therefore, appears that social organisation, activity budget, diet and ranging pattern are related to disturbance and environmental factors. The behavioural parameters may influence life-history traits if continuous habitat alteration persists.

Keywords: Endangered colobine, fragmented habitat, social organisation, ecology, behaviour.

CHAPTER 1

Introduction

Chapter 1
Introduction

1.1 General overview

The survival and viability of a species depend on the habitat conditions and adaptability of the species to changing environment. Deforestation and fragmentation are important causes of the alteration of habitat. Forest specialists and canopy-dependent species like Primates are more likely affected by forest degradation and fragmentation. Among the Asian Colobines, *Trachypithecus* is a highly arboreal and forest-dwelling genus. The Golden langur, also known as Gee's Golden langur *Trachypithecus geei* (Khajuria, 1956) is one of those Colobine monkeys. The species is severely threatened by habitat loss, transformation and fragmentation (Choudhury, 2002). The species is range-restricted and occurs only in a few areas in India and Bhutan (Srivastava et al., 2001b; Wangchuk et al., 2003). Limited range distribution makes the species more susceptible to threat from habitat loss and alteration (Chetry et al., 2020; Thinley et al., 2020). Life-history traits and adaptation to the changing habitat are critical questions that need to be explored to understand a species and its ecosystem.

Golden langur was first brought into the knowledge of the scientific world after photographic record by E.P. Gee from Ripu Reserved Forest (RF) in 1953 (Gee, 1955). They occur in lowland evergreen, semi-evergreen and riparian moist deciduous and sal-dominated, moist deciduous forest (Srivastava et al., 2001; Biswas, 2002; Bezbaruah, 2004) in the Brahmaputra River valley of Assam and the foothills of the Black Mountains of Bhutan (Srivastava et al., 2001). In India, its distribution is up to rivers Sankosh to the west, Manas to the east and the Brahmaputra to the south in Western Assam (Choudhury, 1992; Mukherjee, 1994). In Bhutan, its range is bound by high mountain ranges up to 3000 metres above sea level (ASL) (Saha, 1980). The estimated population in India and Bhutan were reported as 4500 individuals (Mohnot et al., 1998). However, later studies reported the estimated global population of Golden langur was $\geq$ 12000 individuals, half of which inhabits in India (Biswas et al., 2010; Wangchuk, 2005). The groups live in one-male bisexual group (Biswas, 2002). The range of Golden langur in India covers only 1500 km^2 in Western Assam (Mohnot et al., 1998). However, later Choudhury (2002) estimated that the forest habitat of Golden langur is 950 km^2. Due to habitat fragmentation and fragmentation the area of Golden langur habitat has been reduced by one-third of its past (Wangchuk et al., 2001; Choudhury, 2002). These rapid losses of habitat and habitat fragmentation became the major threats for the Golden langur in India (Srivastava, 2001b; Choudhury, 2002). In Assam, the main population resides in the Kachugaon RF, Ripu RF, Manas RF and Manas National Park (NP) with some major populations in isolated forests of Chakrashila Wildlife Sanctuary (WLS), Kakoijana RF (Horwich et al., 2013). The occurrence of Golden langur was first reported in Chakrashila WLS in 1982 (Datta, 1998) and then confirmed by the Zoological Survey of India (Mukherjee, 1994).

The reported mean group size of Golden langur in the undisturbed sal dominated Jamduar area of Ripu Reserved Forest was 12.5, (range 5–18) (Mukherjee and Saha, 1974). Later, from different areas groups were recorded with 7–40 individuals and mostly with 10–18 individuals (Mukherjee, 1994). Most groups are one-male bisexual and others are multimale bisexual and a few groups were all-male. The proportion of adult males was from 7.0% to 22.2%, adult females from 34.6% to 44.8% and juveniles and infants from 20.2% to 31.0% and 17.2% to 25.8% respectively (Mukherjee, 1994). The mean group size in the semi-evergreen forest of Chirang RF was 8.5 (Biswas, 2002). In Royal Manas NP of southern Bhutan, the mean group size was 6.91 in tropical, 7.82 in subtropical and 6.80 in the warm broadleaved forest. Overall group composition was 16.96% adult males, 40.17% adult females, 11.29% sub-adults, 13.39% juveniles and 15.06% infants. Also, there was a significant difference in mean group size between disturbed habitat (8.5) and undisturbed habitat (6.7) (Lhendup et al., 2018). In Chakrashila hills, four groups were recorded with the mean group size of 12.5, ranges 7-26. The average groups consisted of 1.22 adult males, 7.50 adult females, 3.00 juveniles and 0.75 infants (Mukherjee, 1994). Among four groups, three were one-male bisexuals and the others were two-male bisexuals (Mukherjee, 1994). In further studies, Chakrashila WLS had 64 groups (mean group size = 7.4, range = 3 to15 (Chetry et al., 2010), and the rubber plantations of Nayekgaon had three groups with the group size of 7, 19 and 26, respectively (Medhi et al., 2004).

Gee (1964) recorded newborns in August and September. Wayre (1968) suggested the breeding season between December and February. Mukherjee and Saha (1974) reported that infants are born between February and March. Mukherjee (1994) speculated that births in Golden langur occur throughout the year. From the evergreen forest of Chirang RF Biswas (2002) recorded birth from January to June with the peak in May.

Golden langurs are bimodally active in the morning and evening and during these times they feed and rest alternatively (Mukherjee, 1994). The food consisted of leaves, buds and fruits of various plants like *Eupaioriuln odoratum, Tennanalia belerica, Daphne cannabina, Lagerslroemia paniflora, Salmalia malabarica, Bridelia reiusa, Mikania scandens, Castanopsis Lribuloides, Dalbergia sissoo. Bombax ceiba, Accacia* and *Derris* sp. Their diet consists of both ripe and unripe fruits, young and mature leaves, leaf buds, flower buds, seeds, bark, and flowers. The most preferred food was however young and mature leaves (more than 60%) (Biswas, 2002). Their diet comprises of 54.72% leaves, 21.67% fruits, 10.83% shoots, 10.56% flowers and flower saps (Lhendup et al., 2018). The Golden langurs were also observed to consume soil and rocks, perhaps for balancing the mineral uptake (Gee, 1961; Gee, 1964; Lhendup et al., 2018).

Day path length of a group varies seasonally from a distance of about 500 m to 1 km (Mukherjee and Saha, 1974). Biswas (2002) recorded a range of 200-700 m day path length (DPL) and a 25-hectare area as the annual home range. The average annual activity budget has feeding 31.7%, resting 43%, locomotion 10.4%, monitoring 5.6% grooming and others 8.7% (Biswas, 2002).

Chetry et al. (2002) reported extensive anthropogenic pressure in the proximity of Chakrashila WLS, however, the population density was higher when compared to other fragmented patches (Srivastava et al., 2001). The high density of Golden langur in the sanctuary might be the absence of opportunities for their dispersal to other nearby fragments and continuous habitats (Choudhury, 2002; Biswas, 2002). The Golden langurs in the forest patches and rubber plantations at Nayekgaon are part of a population in Chakrashila WLS, but the habitat connection has been lost in the recent past (Srivastava et al., 2001; Medhi et al., 2004). Reported regular attacks by the dogs in Chakrashila WLS (Chetry et al., 2010) and organochlorine insecticide poisoning near rubber plantations adjoining to Sanctuary (Pathak, 2011), were identified as threats to Golden langur. Electrocution and roadkill were identified as threats in the population of Bhutan (Thinley et al., 2020).

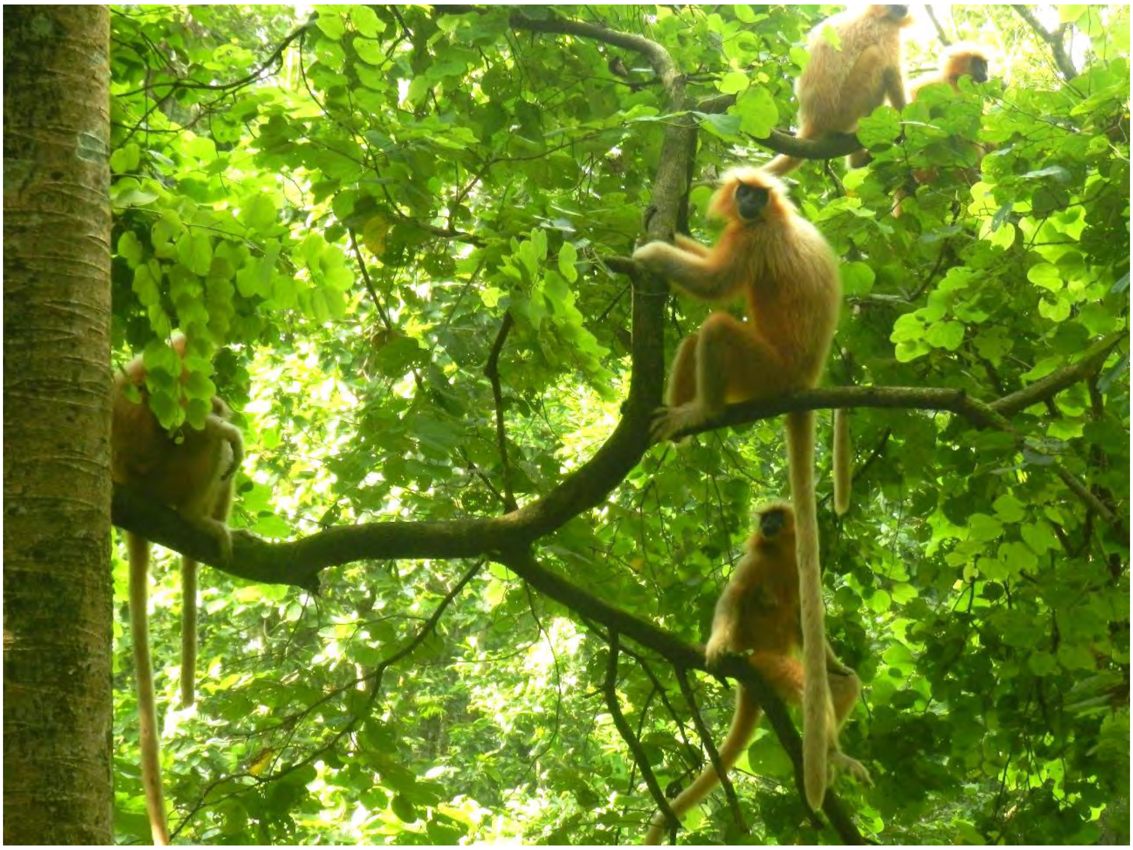
My current study on feeding ecology and social structure of Golden langur in fragmented forests and plantations would help us in understanding the social organization and consequences of resource availability on resource utilization by the species in degraded and altered habitats.

1.2 Rationale of the study

The phenomenon of group dynamics suggests that an effective mechanism must operate to maintain the stable group structures of Golden langur and to keep the stability of the socio-sexual age-sex ratio and birth rate of the group (Biswas, 2002). Habitat alteration adversely affects the life history of primates, thus affecting the species status and social organization (Hill and Bernstein, 1969). Although the behaviour and ecology of Golden langurs were done in a continuous pristine forest, understanding of the same in the fragmented secondary forest throw more light on their adaptation to altered habitat. The present study highlighted the social structure and ecological behaviours of Golden langur in secondary forests of Chakrashila WLS and its adjoining Abhaya rubber plantation (Abhaya RP). The scientific evaluation of behavioural ecology and social organisation of the species in fragmented habitats are necessary to understand the persistence of the species in degraded and altered habitats, which is useful for long-term conservation planning of the endangered species.

1.3 Legal status of the species

Golden langur is accorded the status as 'Endangered' (IUCN Red List: Das et al., 2020), endemic species inhabiting the political border areas of India and Bhutan (Choudhury, 2002; Srivastava et al., 2001; Wangchuk, 2003) (Figure 1.1). Degradation and fragmentation of Golden langur's habitat due to massive destruction (deforestation and change of land use pattern) have been a major threat to the species (Choudhury, 2002). The population of Golden langur has thus decreased (Srivastava, 2004), isolated and become vulnerable to extinction (Srivastava, 2006a). Hence the species has been legally protected by Indian Wildlife Protection Act, 1972 (Amendment 2002) and placed in Schedule-I. By international law, it is categorised as Appendix-I of CITES.



(A group of Golden langur resting on *Bauhinia* sp.)

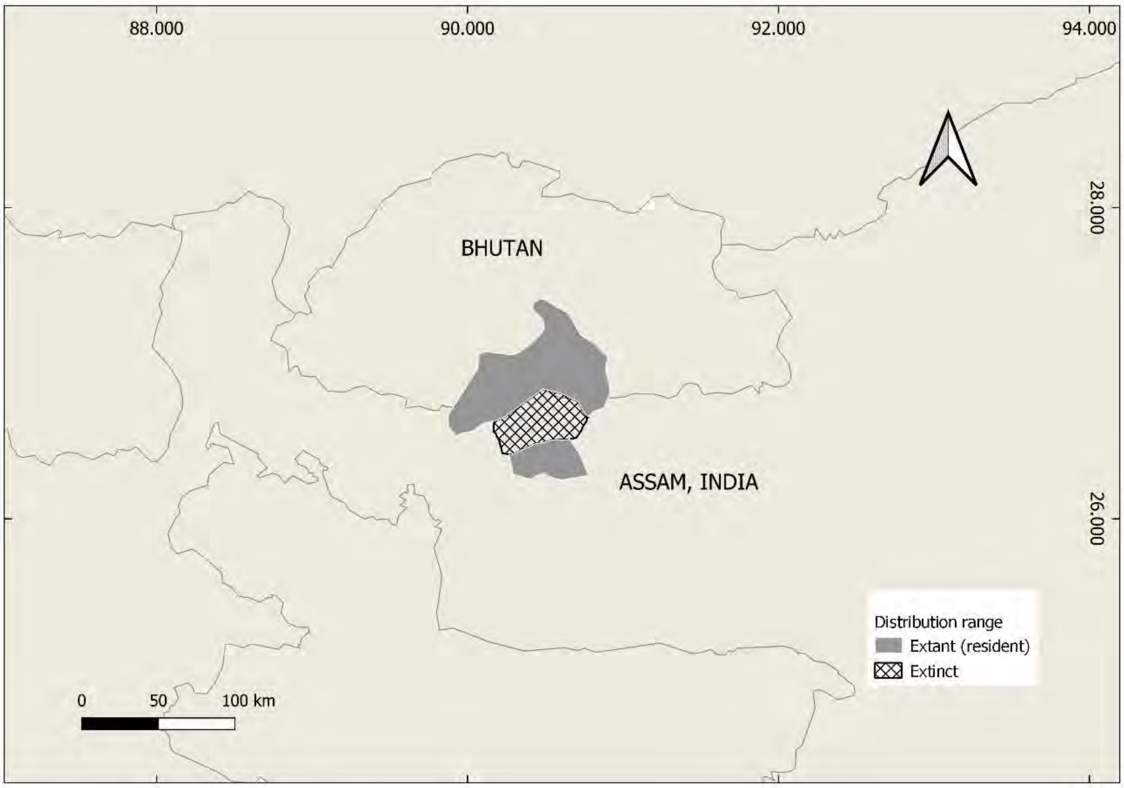


Figure 1.1 Global distribution of Golden langur (IUCN: Das et al., 2020)

1.4 Study sites

Chakrashila WLS is located in Kokrajhar district in the state of Assam in India (Figure 1.3). The sanctuary lies in the southernmost part of the range of the species. The terrain is hilly, covered with secondary forest and the forest type is 'moist deciduous forest' (Champion and Seth, 1968; Bahuguna et al., 2016). Rhesus Macaques (*Macaca mulatta*) is the only sympatric primate species with Golden langur in the area. Apart from primates, 34 species of mammals, 274 species of birds, 26 species of herpetofauna, 60 species of fishes and 43 species of butterflies are also recorded from Chakrashila WLS (Datta et al., 1998).

Abhaya RP is a private land located at Nayekgaon village in Kokrajhar district, Assam (Figure 1.3). 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 80% rubber (*Hevea brasiliensis*) and 20% natural forests with human settlements and roads (Medhi et al., 2004). Rhesus Macaques (*Macaca mulatta*) are also found along with the langurs (Medhi et al., 2004).

The area experiences subtropical monsoons, with the year which can be categorised into four seasons based on temperature and rainfall. Winter (December–February), is characterised by least rainfall and temperatures, pre-monsoon (March-May) by moderate temperature and relatively low rainfall, monsoon (June-September) by high temperature and rainfall and retreating monsoon (October and November) with moderate rainfall and moderate temperature (Borthakur, 1986) (Figure 1.2). The people inhabiting the fringes of the sanctuary and rubber plantation belong to Bodo, Rabha, Garo, Rajbanshi, Nepali and Muslim communities (Chetry et al., 2010).

Table 1.1 Area and geographical details of the study sites

	Chakrashila WLS	Abhaya RP
Geo-coordinates	26°15′ to 26°26′ N 90°15′ to 90°20′ E	26°20' to 26°23' N 90°22' to 90°24' E
Area in km^2	45.58	2.77
Altitude (m ASL)	45–454	47–60

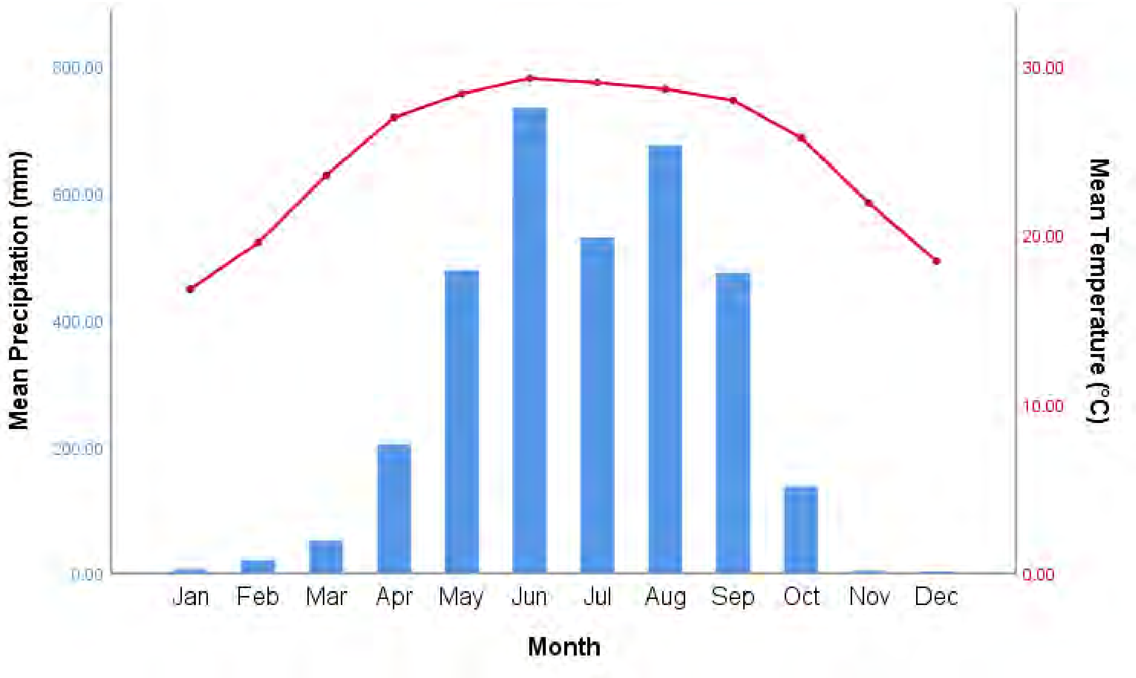


Figure 1.2 Mean monthly rainfall and temperature of the years 2013–2017 (study period). Source: https://indiawris.gov.in/wris/#/rainfall, https://power.larc.nasa.gov/data-access-viewer/ (Accessed on 28 August 2021)

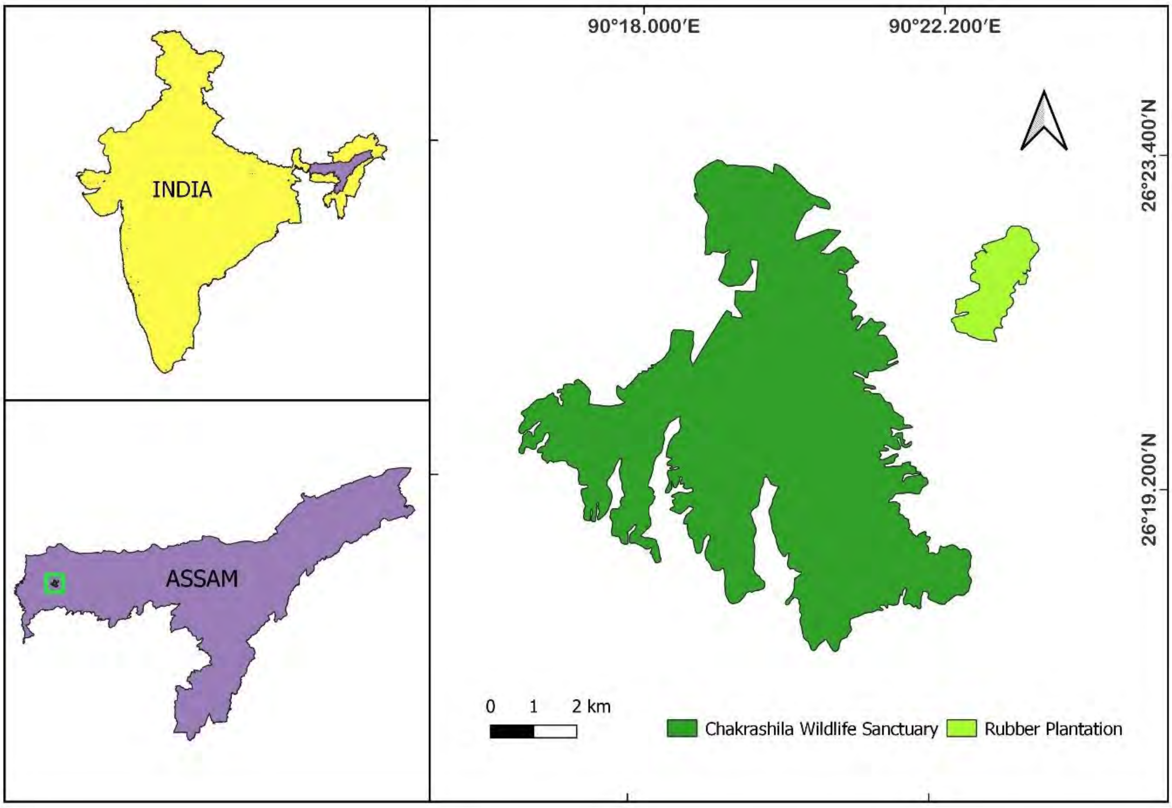


Figure 1.3 Study sites: Chakrashila WLS and Abhaya RP

(View of Chakrashila WLS)

(View of Abhaya RP)

1.5 Objectives

Objective I: To assess the social structure and group dynamics of Golden langur (*Trachypithecus geei*).

Objective II: To examine the effect of resource availability on resource utilisation by Golden langur (*Trachypithecus geei*) in a secondary forest.

The second objective has been divided into three research questions.

A. How is the resource distributed across habitats in a secondary forest?
B. How has resource availability affected the ranging pattern, habitat and resource use in a secondary forest?
C. What are the seasonal influences on the dietary requirement of Golden langur in a secondary forest?

1.6 Methods

Social structure: 12 Golden langurs groups from three different habitats viz. forest core (N=4), forest edge (N=4) and rubber plantation (N=4) were selected for observations on demography. During study period, each group was observed monthly for group size and demography. Individuals from each group were classified into adult male, adult female, juvenile and infant. Infant births in identified female were recorded during group monitoring.

The mean group size, and mean age-sex ratios for each habitat type were calculated and compared. The data on births and the number of adult females in each group were used to calculate the birth rate per group and per female for each year.

Activity budget: A total of three groups, one from each habitat type were selected at various locations (1. forest edge, 2. forest core, and 3. rubber plantation). The groups were followed from 0530 hr to 1830 hr and data were generated by following the method of scan sampling (Altmann, 1974). All diurnal activities of Golden langur *viz.*, feeding, resting, locomotion, grooming, playing, agonistic interactions and other social behaviours were recorded in every 15-minute intervals. Percentage of major food types and food plant species eaten were calculated based on total feeding scans during all the seasons and were compared.

Ranging: While following the study group, geo-coordinates of the group movements were recorded using handheld GPS at every 30 minutes interval. Day path lengths were calculated by connecting the minimum distance of the two points on a time scale.

Resource availability: The home range of the groups were selected and gridded in one-hectare grid size. Vegetations were sampled in each grid using the nested quadrat method (Mueller-Dombois and Ellenberg, 1974).

Study animal groups: Three groups were selected at different habitat types 1. forest core, 2. forest edge, and 3. rubber plantation. Details are given in Table 1.2 and Figure 1.4.

Table 1.2 Details of study groups selected for scan sampling

Area	Group name	Group Size	Location
Forest core	BST	7	N 26°18'50.9" E 90°19'38.0"
Forest edge	BPS	18	N 26°18'23.2" E 90°20'09.0"
Rubber plantation	TLC	17	N 26°21'44.5" E 90°23'06.4"

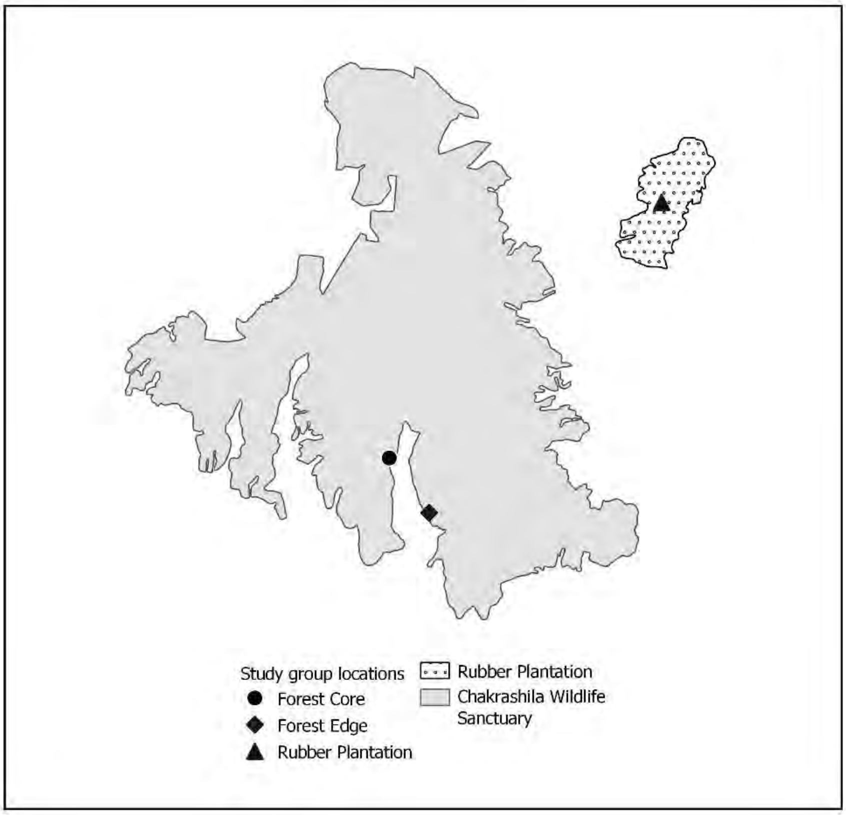


Figure 1.4 Locations of three study groups selected for scan sampling

The methods followed for data collection and analysis on different aspects are detailed in each chapter.

1.7 Organisation of the thesis

The thesis describes the social organisation and behavioural ecology of Golden langur in different habitat types. Chapter-1 of the thesis gives a general overview and motivation of the study and a description of the study area and study animal species. It is then followed by objectives and the appropriate methods applied to address them. Chapter-2 is a collection of related published literature. The literature was systematically reviewed to understand the trend and research development in the field. It also observes the acceptability of methods used to address the objectives. Chapters 3, 4, 5 and 6 are technical chapters discussing each objective and research question. Chapter-3 is an investigation of the population status of the species in the study areas using both primary data and meta data. It compares the earlier population status to understand the population growth and persistence. Chapter-4 is the exploration of the social organisation, birth pattern and dynamics of social changes of Golden langur. Chapter-5 examines how the resource is distributed and how it is consumed across the different habitat types. Chapter-6 deals with activity and ranging pattern of the Golden langur groups in different study sites. Summary of the findings and how objectives contribute to the existing knowledge of the species is described in Chapter-7.

CHAPTER 2

Literature Review

Chapter 2

Literature review

2.1 Origin and taxonomy

Old World monkeys (Family: Cercopithecidae) are divided into two subfamilies, Cercopithecinae – the monkeys with cheek pouch and Colobinae – the leaf-eating monkeys (Groves, 2001). These two subfamilies are distinguished from each other by various life-history traits, anatomy, and morphology. Dietary adaptations are different in these two subfamilies. The specialized digestive system in Colobines and buccal pouches in Cercopithecines are prime dissimilarities among many. Poorly developed or short thumb in Colobines is another such characteristic. Fossil records suggest that they diverged in Miocene from the same ancestral origin about 14 to 16 million years ago (MYA) (Delson, 1994; Raaum et al., 2005; Sterner et al., 2006). The diversion was estimated from ancestral African and Asian colobines between 10 and 13 MYA (Stewart and Disotell, 1998; Delson, 1994). Originating in Africa, Colobines reached Asia after the end of the Miocene. Molecular study shows the diversion between these two Colobine types, though relationships within these two groups are not known in detail (Disotell, 1996). It is evident from the fossil records that primitive Colobines inhabited mostly the tropical forests with high canopy rather than open forests. A European genera *Dolichopithecus* is believed to be adapted to terrestrial or cursorial movement due to its heavy body mass and lack of suitable canopy corridor in temperate forests. Several large-bodied and terrestrial colobines from Africa and Europe lineages became extinct (Ting et al., 2008). Present living Colobines are divided into two major groups *viz.* African and Asian. These two groups are further divided into three and seven genera respectively. *Colobus*, *Procolobus,* and *Piliocolobus* are the African genera. Asian includes *Nasalis*, *Pygathrix*, *Rhinopithecus*, *Simias*, *Trachypithecus, Presbytis*, and *Semnopithecus* (Groves, 1989; Groves, 2001; Davies, 1994; Disotell, 2003; Brandon-Jones et al., 2004). Classification and phylogeny of the Colobines are an unsolved puzzle and though many molecular studies were done in recent periods, the subject is still in debate. Apart from experiencing rapid adaptive radiations, Colobines are also further diverse and prevalent in various climatic environments (Davies, 1994). Their body mass varies from 4 kg in African Olive colobus (*Procolobus verus*) to 21 kg of the adult males in Proboscis monkey (*Nasalis larvatus*) in Southeast Asia. The difference in the biogeographical factors leads them to evolve and adapt unique morphological and dietary characteristics according to the habitat conditions.

2.2 Distribution and habitats

Phylogeny of Colobine monkeys have a complex evolutionary history. They evolved in several phases of radiations and inhabited in a wide range of forest and wooded habitats in tropical Africa and south and southeast Asia. Colobines are distributed over a wide habitat range, and in Asia they live in noticeably wider habitat range, from lowland to mountain ranges, than in Africa (Kirkpatrick, 2011; Fashing, 2011). In Africa, black-and-white colobus *Colobus guereza*, inhabits up to 3,300 m ASL in Ethiopian highlands (Dunbar and Dunbar, 1974) whereas in the mountains of south and central China, where a numerous species of snub-nosed monkey (*Rhinopithicus* sp.) lives. Also, several species occur in the high hill ranges of the Himalayas. Burmese snub-nosed monkey *R. strykeri* is confined to a small region in the north-eastern parts of the Himalayas (Geissmann et al., 2011). Several langurs of the genus *Trachypithecus* occur in the south-eastern parts of the Himalayas. Hanuman langurs (*Semnopithecus* sp.) are distributed widely from the Himalayas to Sri Lanka and they are adapted to dry habitats of the Indian subcontinent as well (Bennett and Davies, 1994; Roonwal and Mohnot, 1977; Unanthanna and Wickramasinghe, 2010). Most of these species range from lowland to montane areas, usually in about 2,500–3,000 m ASL. The other Colobine species of Asia like Nilgiri langur inhabits in moist deciduous to evergreen forests (Ramakrishnan and Samson, 2018). Proboscis monkey (*Nasalis larvatus*) is confined to island, riverbank, deltas comprising swamp and mangrove forest (Meijaard and Nijman, 2000). *Simias* is endemic to the evergreen forests of Mentawai Islands. *Pygathrix* is found in the forests of the Indochina region, and *Rhinopithecus* lives in coniferous montane forests in south China and Vietnam. *Rhinopithecus bietii* from China, uses ground very often (Oates et al., 1994; Long et al., 1994) and yet is an arboreal species (Kirkpatrick, 1998).

2.3 Social organisation and population dynamics

Habitat quality and variables influence the social organisation of a population. Habitat conditions also affect the group size in social animals. Colobines mostly form relatively smaller groups (Clutton-Brock and Harvey, 1977), and females exhibit dispersion from the natal group in many species (Moore, 1984; Newton, 1992). The one-male multi-female bisexual group is the stable social structure of the Asian colobines; males expelled from different natal groups make all-male groups (Struhsaker and Leland, 1987; Newton and Dunbar, 1994). In most species have both the sexes emigrates from their natal groups (Moore, 1984). Studies proposed that social factor, like infanticide risk, limits group sizes in folivores (Crockett and Janson, 2000; Isbell, 2004) and described how social relationships can be affected by sexual strategies (Sterck et al., 1997). *Colobus guereza* in the forest habitat was found with a mean group size of 7.7 individuals with 47.9% adult, 32.7% sub-adult, 11.5% young, and 7.9% infant (Ibrahim et al., 2017). The group size of proboscis monkey in the mangrove forest was 17 and 25 individuals in high vegetation cover and 6 and 10 individuals in disturbed riparian forest, 6 to 15 individuals in the forest upstream and an average of 12.3 individuals in small islands (Bismark, 2010). Capped langurs *Trachypithecus pileatus* was found in the forested areas of Satchori National Park, Bangladesh with a mean group size of 10.25 where ratio of adult males and adult females was 1:2.9, adults and young 1:0.55, adult females and infants 1:0.4. (Hasan et al., 2018). Average group size of *Trachypithecus johnii* in Silent Valley was 5.89 with 20.2% adult males, 40.1% adult females, and 26.7% of immature (Joseph and Ramachandran, 2003).

2.4 Activity and resource use

Asian Colobines usually feed on young leaves, flowers, seeds, and unripe fruit, which are patchily distributed. Though, they are also able to consume mature leaves, a non-patchily spread resource, during food scarcity because of their specialized digestive system. They have a multichambered ruminant-like stomach that can help in the fermentation of carbohydrates present in leaves with the action of foregut microbes (Chivers and Hladik, 1980, Lambert, 1998). This makes the Colobines differ from other leaf-eating primates, like sportive lemurs (*Lepilemur* spp.), gorillas (*Gorilla gorilla*) and howler monkeys (*Alouatta* spp.), who ferment their foods in the caecum. The complex behaviour of leaf-eating primates, 'the folivore paradox' is explored in studies where it is found that group sizes are smaller than expected due to competition for food resources (Moore, 1984; Janson and Goldsmith, 1995; Steenbeek and van Schaik, 2001). *Nasalis larvatus* moved an average of 500 m in mangrove forest for foraging and consumed 81.14%, 8.38% and 7.68% of leaf, fruit and flower respectively (Bismark, 2010). *Trachypithecus phayrei* group were observed to use forest strata of height from 5 to 50 m and occasionally to ground to drink water, feed on bamboo shoot and consume soil minerals. They spent 35% of their time in feeding where 46% of the diets are leaves and 35% fruits and seeds respectively (Borries et al., 2011). The species under the genus *Presbytis* also consume substantial amounts of seeds, fruits and young leaves (Bennett and Davies, 1994). *Simias concolor* was observed spending equal time feeding on young leaves, flowers and fruits. Nearly 80% of their food consists of keruing flowers (*Dipterocarpus haselthii*) during the 1997 drought (Skorupa, 1986). *Presbytis hosei* use the ground to drink water from salt springs in absence of rainwater and maximum time they utilize vertical strata in the forest (Nijman, 1997). *P. sabana* (Mitchell, 1994) and *P. canicrus* (Rodman, 1978) use middle layer of forest from 10 to 30 m. *P. hosei* was observed mainly below 20 m in the stratum and *P. canicrus* above 20 m in forest stratum. In primary forest *P. canicrus* feeds mostly on leaves and shoots (66%), fruits (28%), rest comprising of flowers, buds or insects (6%). Similarly, *P. sabana* feeds mostly on leaves (78%), fruits with seeds (19%) and flowers (3%) in primary forest. In the degraded and cleared forest, leaves and flowers proportion decreased to 60% and <1% respectively, and fruit including seeds proportion increased to 40% (Nijman, 2010). Phayre's langurs (*Trachypithecus phayrei*) were found to forage on fruits (22.2%), seeds (18.7%), buds and young leaves (41.5%) (Ma et al., 2017).

CHAPTER 3

Population Status And Persistence

Chapter 3
Population status and persistence

3.1 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 ecosystem is globally widespread, resulting in many primate species living in fragmented forest patches (Prevedello and Vieira, 2010; Watling et al., 2011) and human-modified landscapes (Cowlishaw, 1999; Cowlishaw and Dunbar, 2000; Chapman and Peres, 2001). Habitat disturbance created by anthropogenic activities affects non-human primates most since they are highly dependent on tropical forest ecosystems (Isaac and 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 forests 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 determining their persistence in anthropogenic landscapes (Ferreira et al., 2018). Degraded habitats are used by some primates (e.g., Capped Langur *Trachypithecus pileatus*: Borah et al., 2021), while some others use part of human-altered land covers (Pielke Sr. et al., 2004; Davey et al., 2006; Wickham et al., 2012). The lack of knowledge about their utilization of human-modified habitats and ecological traits restricts our ability to implement aimed landscape management approaches for their conservation.

Golden langur *Trachypithecus geei* (Khajuria, 1956) is Endangered (IUCN) (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 and 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). A few populations are restricted to isolated and fragmented forest patches (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 of 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 (Abhaya RP) and its fringe forests were once connected with the Chakrashila WLS, 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 WLS due to human settlement in adjacent forest areas (Medhi et al., 2004). In this study, I examined the population parameters of Golden langurs in Chakrashila WLS and the rubber plantation and its surrounding areas in Nayekgaon up to the year 2016. Data were compared with past data of the population and social organization from the same location to explore the population trend and persistence of the Golden langur in a fragmented forest and an isolated human-modified landscape. In Chakrashila WLS previous studies were conducted in 2006 (Chetry et al., 2010), 2008 (Ghosh, 2009), and 2016 (Chetry et al., 2020) and in the rubber plantation in 1997 (Srivastava et al., 2001a), 2002 (Medhi et al., 2004), 2008 (Ghosh, 2009) and 2016 (present study). Detailed information was not available for some of the years and hence data could be compared with only the available years. Understanding the survival possibilities of such populations in and outside their natural habitat would help in primate conservation and habitat management.

3.2 Methodology

Study Area

Chakrashila WLS with 4558 ha situated between 26°15′ to 26°26′ N and 90°15′ to 90°20′ E. Forests of Chakrashila WLS consists of moist mixed deciduous forests with sal as a dominant species. Abhaya RP and its surrounding plantation were consisting approximately 277 ha and is situated between 26°20’ to 26°23’ N and 90°22’ to 90°24’ E in Nayekgaon village. Both of the sites are in Kokrajhar district, Assam, India.

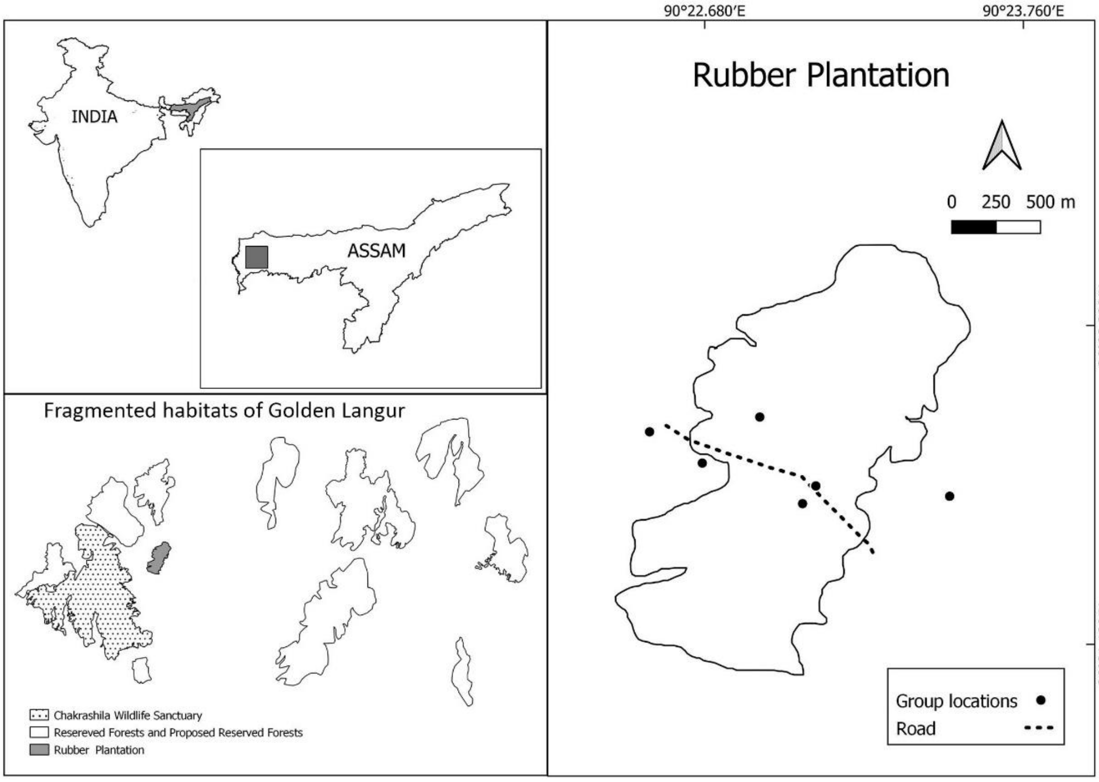


Figure 3.1 Chakrashila WLS and Abhaya RP in Nayekgaon village in the Kokrajhar district, Assam, India

Although the rubber plantations started emerging in 1985, around same time golden langurs were also documented from same regions (Medhi et al., 2004). The area is a private rubber plantation and comprises 80% rubber (*H. brasiliensis*) 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 main plant species within the natural vegetation (Medhi et al., 2004). During the study, I recorded that about 20% of the area consists natural forests (detailed in chapter 5). My interaction with the plantation manager confirms that there was no further expansion of rubber plantations after 1985. The climate conditions of the sites 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 2000- and 3000-mm. In study area rhesus macaques (*Macaca* *mulatta*) are sympatric with the golden langurs (Medhi et al., 2004). A map of study area (Figure 1) was prepared with the help of QGIS 3.16 (QGIS Development Team, 2021).

Survey

Population data on Golden langur was collected through literature review and field surveys. Secondary data of Chakrashila WLS for the years 2006 (Chetry et al., 2010), 2008 (Ghosh, 2009) and 2016 (Chetry et al., 2020) was collected. Population data of Golden langur for the rubber plantation in Nayekgaon was not available after 2008. Since the area of Abhaya RP in Nayekgaon is small, the total count was possible. I 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), and 2008 (Ghosh, 2009), i.e., block count methods (Struhsaker and Oates, 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 3.1). 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 hectares. Prior to the survey, group of volunteers and field assistants were trained to conduct population assessment including age-sex of the individuals of Golden langurs and for the recording of geo-coordinates. The teams were led by a trained person 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 hours and from 1400 to 1700 hours on three consecutive days from 26 to 28 February 2016. Each team was provided with a handheld GPS (Garmin 78S), 8×40 binocular, digital camera and Motorola wireless handset for communication to avoid duplication in counting. When langurs were encountered, the geo-coordinates of the group location were recorded and observed the group for sufficient time or until the total number, and age-sex of all the individuals in the group was recorded. 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, I 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. I 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. I calculated the mean group size, mean individual of different age-sex classification, and age-sex ratios using the data of all the groups. The age and sex of four individuals in one of the groups could not be identified, 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. I compared the data of 2006, 2008 and 2016 for Chakrashila WLS and 1997, 2002, 2008 and 2016 for the rubber plantation to check for the pattern. In some analyses, some years' data was not considered since it was not completely available. Mean group sizes were compared 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. I used statistical analysis using R version 3.6.3 (R Core Team, 2021). The rate of population growth r of two population sizes $P1$ and $P2$ between two different times $t1$ and $t2$ is calculated by the formula below and expressed as percent growth per year.

$$r = \frac{\left(\frac{P2 - P1}{P1}\right) X100}{t2 - t1}$$

Where P is the number of individuals and t is number of years.

(https://pages.uoregon.edu/rgp/PPPM613/class8a.htm Accessed on 12 March 2021).

3.3 Results

In the rubber plantation, six groups of Golden langurs were recorded with total of 78 individuals (Table 3.1) with the mean group size of $13.00 \pm 4.00_{SD}$ (Table 3.2). For group 1 there was uncertainty for identification of some of the individuals hence, its observations were truncated from the data. The age-sex composition of the population were 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 3.2). The calculated density showed 28.16 langurs/km^2.

Table 3.1 Group compositions of Golden langur 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

The number of groups recorded in 1997 was five, declined to three by 2002, increased to 12 by 2008 and then declined to six by 2016 (Table 3.2). 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=6.91, df=7, p=0.438) did not vary significantly (Table 3.2). 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.

Table 3.2 Group size, age-sex composition of Golden langur in rubber plantation in different years.

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; 7–26)	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

Population data of Golden langur in Chakrashila WLS was collected from available literature and tabulated. Total population increased from 474 in 2006 to 501 in 2008 and then 558 in 2016. Number of groups increased from 64 to 66 and then 72 in the respective years. Mean group size varied between 7.4 and 7.75 across the years.

Table 3.3 Group size, age-sex composition of Golden langur in Chakrashila WLS in different years.

Group parameters	2006 (Chetry et al., 2010)	2008 (Ghosh, 2009)	2016 (Chetry et al., 2020)
Total groups (mean group size±SD; range)	64 (7.4, 3–15)	66 (7.59, 6–9)	72 (7.75, 3–18)

Total AM (mean±SD; range)	85	88	82
Total AF (mean±SD; range)	127	201	169
Adult unidentified (mean±SD; range)	24		97
Total IM (mean±SD; range)	238	212	210
AM:AF	1:1.53	1:2.28	1:2.06
AD:IM	1:1.02	1:0.65	1:0.6
AF:IN	1:0.62	1:0.7	1:0.5
Total individuals	474	501	558

Population growth in the rubber plantation between 1997 and 2016 was found to be 5.54 % and in Chakrashila WLS it was found to be 1.47% between 2006 and 2016 (Table 3.4).

Table 3.4 Population growth rate of Golden langur in different habitats

Rubber plantation		Chakrashila WLS	
Period	Annual growth rate %	Period	Annual growth rate %
1997–2002	7.37		
2002–2008	19.23	2006–2008	2.85
2008–2016	-3.79	2008–2016	1.42
1997–2016	5.54	2006–2016	1.47

To calculate annual growth rate, data used from current study and literatures (refer table 3.2 and table 3.3).

3.4 Discussion

I examined the population numbers and age-sex ratio of the Golden langur (*Trachypithecus geei*) in Chakrashila WLS and in a rubber (*Hevea brasiliensis*) plantation in Assam, India between 1997 and 2016. Population growth in Chakrashila WLS shows an increasing trend without much fluctuation. Mean group size across the years was also found similar which shows that as a habitat of Golden langur, Chakrashila WLS is likely to support in maintaining a stable and viable population. Although the reasons for the differences in the number of groups and the mean group size between the study period in the rubber plantation 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 mean group size in 2002 with a few groups and the smaller mean group size in 2008 with more 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, 2002). 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. The absence of a 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 WLS, the group size of Golden langur ranged from 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). However, my study 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 WLS (12.40 langurs/km^2) (Chetry et al., 2020). The annual population growth from 1997 to 2016 was much higher (5.54%) in rubber plantation than in the natural habitat of Chakrashila WLS i.e., 1.47% annual growth from 2006 to 2016. (Chetry et al., 2010, Chetry et al., 2020) (Table 3.4). 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 to the Golden langur population. This could affect the population dynamics and age-sex composition since the population of Golden langur is small. But during the survey and behavioural study period (2013-2016), I 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 WLS (detailed in chapter 4). 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. Monocultures like rubber plantation can deliver passage for the Golden langurs between fragmented habitats since canopy continuity lowers the vulnerability of primates to predators (Oliveira and Dietz, 2011; Cassano et al., 2014; Coleman and Hill, 2014).

Primates may be pushed to use modified landscapes of a matrix composition regularly for foraging and daily activities where their natural habitat is declined (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 and Nagarajan, 2018) and dry rubber seeds by Golden langurs (Medhi et al., 2004; Roy and Nagarajan, 2018) and use of rubber trees for sleeping (Roy and Nagarajan, 2018) highlight an adaptive behaviour 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 maybe because they can 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 (*P. thomasi*), Long-tailed Macaque (*M. fascicularis fascicularis*), Southern Pig-tailed Macaque (*M. nemestrina*), Lar Gibbon (*Hylobates lar*), and Griffith's Silver Langur (*T. villosus*) 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 was resilient to habitat changes (Boonratana, 2013). But the decline in critical habitats and restrictions of movement between fragments have made the species persist only at lowered population size and densities, and probably with changes to their behaviour and ecology (Boonratana, 2013). The emigration rate from habitat also had a strong predicted impact on the extinction threshold; the higher the rate of emigration, the more habitat is required 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 kilometres from the nearest forest fragments. Agricultural habitats, such as perennial plantations (coconut, mango, and cashew nut) were also used by colobus as corridors (Anderson et al., 2007a). Although the initial decline in the population was observed, Golden langurs have shown an 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 the Nicobar Islands (Velankar et al., 2016), Lion-tailed Macaque (*M. silenus*) in the Western Ghats (Umapathy et al., 2011), Guerezas (*C. guereza*) and Blue Monkey (*Cercopithecus mitis*) in Kakamega forests in Kenya (Mammides et al., 2009). 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 a 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 Golden langur.

(Golden langur group foraging in rubber plantation)

CHAPTER 4

Social Organisation

And

Birth Pattern

Chapter 4
Social organisation and birth pattern

4.1 Introduction

Habitat loss and fragmentation are among the primary causes of biodiversity loss worldwide (McGarigal and Cushman, 2002; Hanski, 2011). As deforestation and habitat fragmentation continue at alarming rates throughout the world, perhaps the survival of many forest species largely depends on their ability to cope with such changes (Robinson and Ramirez, 1982; Marsh et al., 1987; Noss and Csuti, 1994). Primates are one among the highly threatened taxa in the world (Mittermeier and Oates, 1985; Rylands et al., 2008; Schipper et al., 2008) and they commonly occur in landscapes subjected to a high degree of habitat modification (Schipper et al., 2008; Marsh et al., 2013). Different primate species respond differently to habitat loss and fragmentation (Bicca-Marques, 2003; Chapman et al., 2006, 2007; Anderson et al., 2007a,b; Bicca-Marques et al., 2009; Boyle and Smith 2010; Arroyo-Rodriguez et al., 2013). The higher densities of a species were reported in small fragments compared to large, while some studies reported the opposite (Goncalves et al., 2003; Wieczkowski, 2004; Wagner et al., 2009; Carretero-Pinzo´n, 2013).

Species respond differentially to habitat fragmentation or loss due to differences in life-history traits and behavioural characteristics (Henle et al., 2004; Ewers and Didham, 2006). Such responses of a species are an important driver in conservation priorities (Henle et al., 2004; Thornton et al., 2011; Vetter et al., 2011). Life history processes are concerned with the rates at which animals give birth, die and migrate (Dunbar, 1980). Demographic structures are the age-sex composition of a social group or a population (Gray, 1985) which is determined by ecological and phylogenetic factors. These factors dictate general grouping patterns and reproductive capacities of a social group (Clutton-Brock and Janson, 2012; Strier 2018; Vigilant and Guschanski, 2009). The demographic structure varies due to environmental and social variables that directly affect the birth and death rates (Dunbar, 1980). The group size and age-sex structure of the population is also affected by the group fission (where a single group divides into two or more new groups), fusion (where two or more groups merged to form a single group) and migration (whereby individuals or groups leave their ranging area either to join a neighbouring group or to set up a new ranging area elsewhere) (van Schaik, 1999).

Life-history traits are known to be related to environmental changes, which determine the socio-ecological behaviour of a species e.g., landscape change (Irwin, 2008; Boyle and Smith, 2010), loss of habitat and isolation of habitat (Anzures-Dadda and Manson, 2007; Pyritz et al., 2010; Arroyo-Rodriguez et al., 2013; Benchimol and Peres, 2013). Such changes may occur due to selective logging or clear felling (Mittermeier et al., 2006); hunting, persecution for the pet and exploitation for biomedical markets (Marsh et al., 2013). Impact on primate habitats affects the abundance and distribution of their food resources influence the changes in group size and composition, reproductive patterns or social relationships (e.g., langurs: Sterck, 1999; tana river colobus *Cercocebus galeritus*: Mbora et al., 2009; red colobus: Gogarten et al., 2015; muriquis, *Brachyteles hypoxanthus*: Strier and Mendes, 2012). The habitat fragmentations, disturbances, or degradations altered ranging patterns, activity budgets, and the diet of primates (Wong et al., 2006; Pebsworth et al., 2012; Mekonnen et al., 2017; McLennan et al., 2017). *Colobus guereza* (Onderdonk and Chapman, 2000) and *Colobus vellerosus* (*C. guereza*; Grimes and Paterson, 2000) consumed non-native species in human-altered environments or fragments. Such changes in the social structure and group sizes in a habitat could be considered as indicators of the changes in the habitat conditions (Chapman and Rothman, 2009; Boyle and Smith, 2010).

Primates show a high degree of variability in birth seasonality, ranging from strictly seasonal breeding species, such as macaques, to species in which females give birth throughout the year, such as baboons (*Papio* spp.; Janson and Verdolin, 2005). Primate females may adjust their breeding behaviour by reproducing during favourable times e.g., yellow baboons (*P. cynocephalus*) in Kenya breed throughout the year, but females are less likely to conceive after periods of extreme heat (Beehner et al., 2006). Temperature and rainfall influenced the phenological pattern of plants and was correlated with the overall availability of young and mature leaves (Li and Rogers, 2006), thus they have been considered as determinant environmental factors. E.g., *Aotus azarai* females conceive on the onset of high rainfall, which triggers the production of important food sources (Fernandez-Duque et al., 2002). Nutrition conditions strongly impact the seasonality of mating, and life-history traits like age at first birth, gestation period and the interbirth interval (Borries et al., 2001). Colobines are social primates and their social organization and life-history traits in changing habitat are likely governed by the habitat factors and anthropogenic influences. Among the colobines of north-east India, Golden langur (*Trachypithecus geei*)

(Khajuria, 1956) is endemic to Bhutan and the Indian state of Assam (Wangchuk, 1995; Choudhury, 2002), having a group size of 12.5 (ranged: 5-18) in some forests like undisturbed sal dominated Ripu Reserved Forest (Mukherjee and Saha, 1974). While Chakrashila WLS had 64 groups with a mean group size of 7.4 which ranged between 3 to15 (Chetry et al., 2010), and the rubber plantations of Nayekgaon had three groups with the group size of 7, 19 and 29 (Medhi et al., 2004). A large part of its habitat is lost in the recent past (Choudhury, 2002), and the population has drastically decreased (Srivastava, 2006a) and isolated (Srivastava, 2006b) thus confined to small forest fragments (Srivastava et al., 2001). I studied Golden langur in fragmented and altered habitats to understand the consequences of habitat conditions on group size, social organisation, and birth seasonality.

4.2 Methods

Data collection

The Golden langur groups live in a single-male/multi-female group which is the most stable social system (Biswas, 2002). Due to their small geographic range, fragmented population and population decline golden langurs are categorised as Endangered in IUCN red list (Das et al., 2020). To understand the group structure, dynamics and birth pattern of Golden langur, I selected 12 groups inhabiting forest edge and forest core of Chakrashila WLS and adjoining Abhaya RP (Figure 4.1). Chakrashila WLS (45.58 km^2; 26°15′ to 26°26′N and 90°15′ to 90°20′E) is situated in Kokrajhar district, Assam, India. The sanctuary is hilly, covered with a secondary forest of moist deciduous type (Champion and Seth, 1968). The Abhaya rubber (*Hevea brasiliensis*) plantations and their surrounding areas (2.77 km^2) is small, isolated, private land located at Nayekgaon village.

Four groups in each habitat were named as TPD, BPN, IMK and BST in forest core, BPS, TPB, JNE and SLB in forest edge and TLC, CTS, OFC and GDW in a rubber plantation. Each group was visited every month from May 2013 to September 2016 and I recorded the age-sex of individuals in the group. Individuals were classified into different age/sex classes as adult male (larger body size with a longer tail, cheek hair and prominent canine), adult female (presence of elongated nipples), juvenile (smaller size than an adult, post-weaning stage and sexually differentiated based on genitals) and infant (dependent on their mother). The groups and individuals were distinguished using ranging location, group composition data and the physical characteristics of some individuals. In each habitat type, individuals in select groups were identified based on markings on the body and face, and tail characteristics. While monitoring the groups, the births were recorded with the individual identity of females in five focal groups. The monthly rainfall data for the study sites were collected for four years (2013-2016) (www.indiarainfall.com accessed on 16th April 2019).

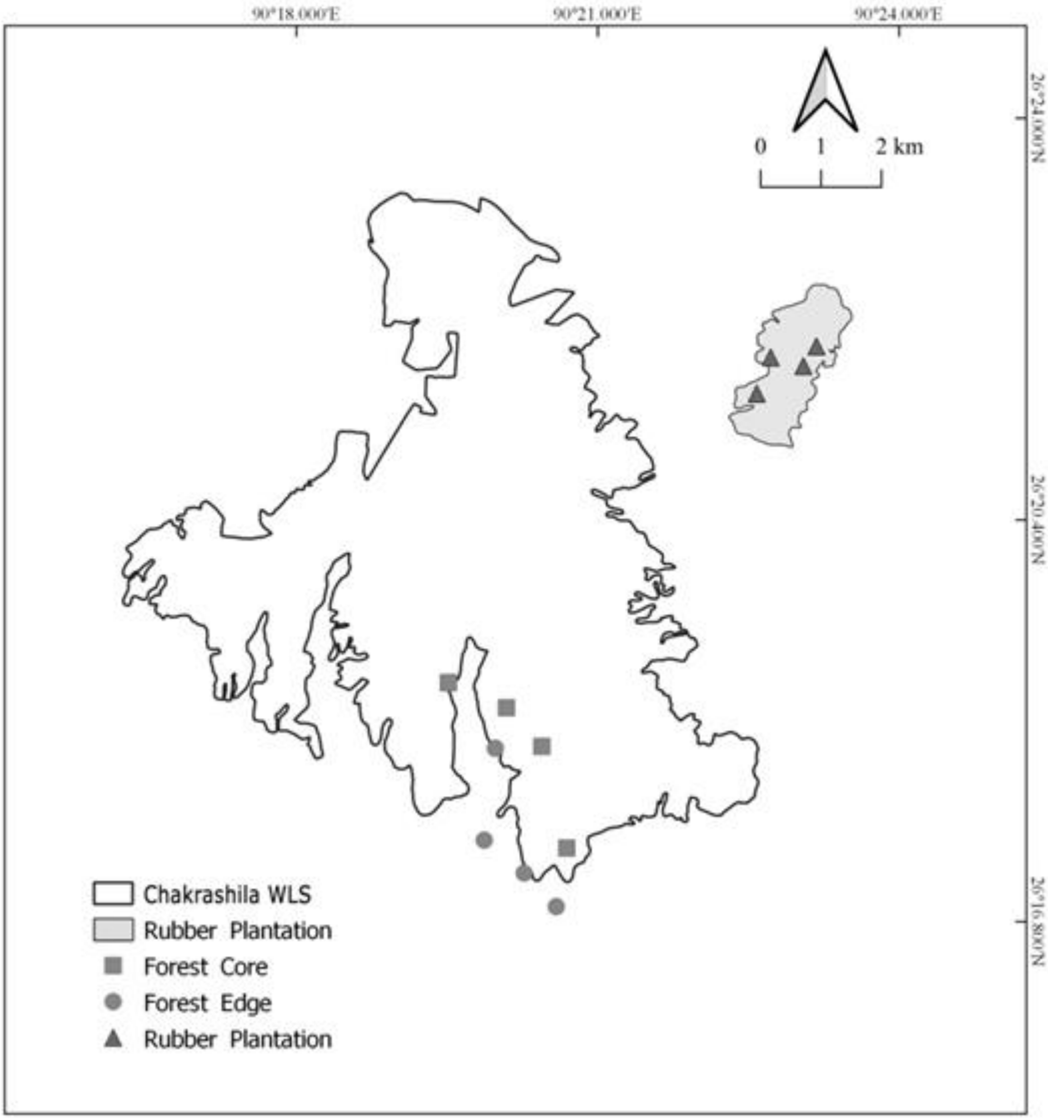


Figure 4.1 Location of study groups of Golden langurs

Data analysis

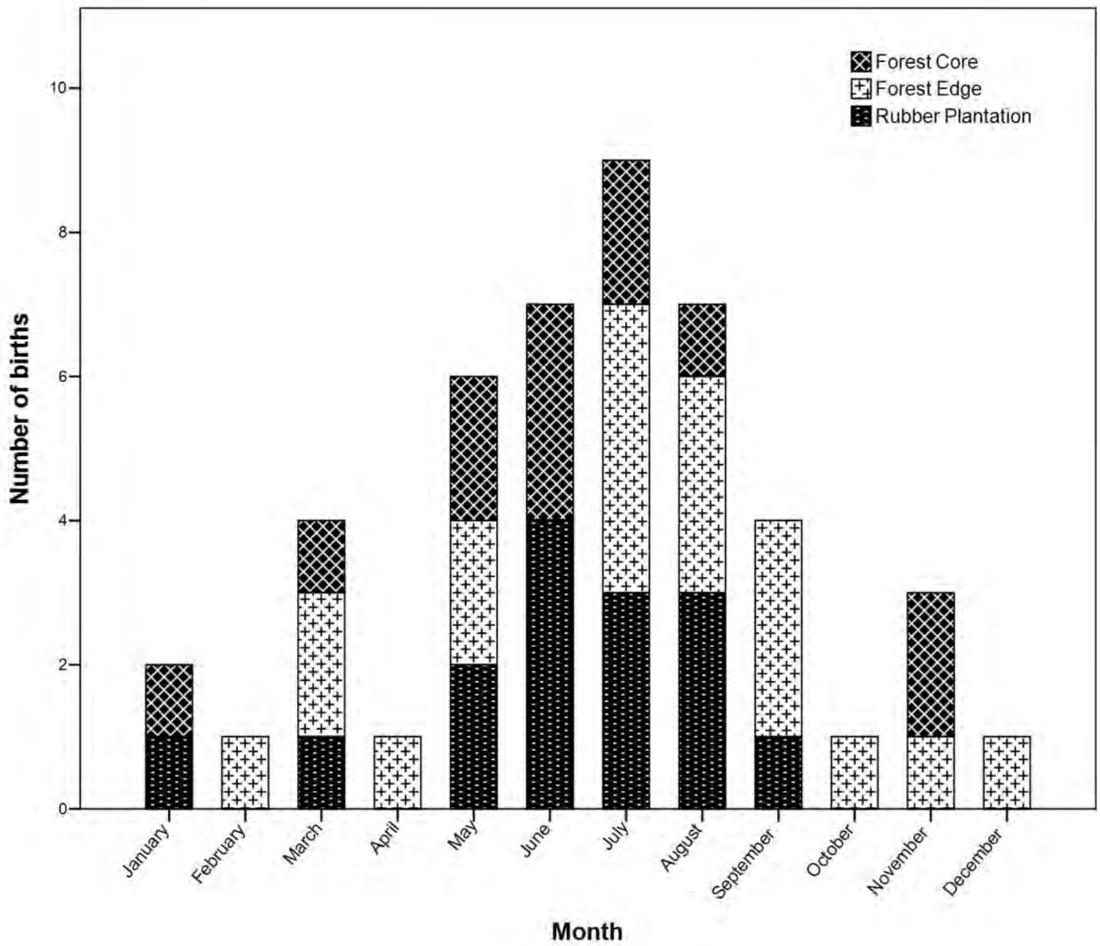
I tabulated the data on age-sex of the individuals in each group from the monthly monitoring data as adult male (AM), adult female (AF), infant (INF) and immature (IMM-consisting of infant and juvenile together) for each study group. The data of adult male and adult females were combined to represent adults (AD) to compute the age-sex ratios. I computed the mean group size, mean age-sex individuals and mean age-sex ratios for each habitat type. Analysis of variance (ANOVA) was used to compare all the means. The data on births and the number of adult females in each group were used to calculate the birth-rate per group and female for each year. I calculated the mean birth rate per adult female and group size. The immature survival rate was estimated as the proportion of immature surviving annually out of the total number of immatures present each year in each group. I considered all immature individuals within our observation period until they attain the adult stage to calculate the immature survival rate. The interbirth interval was calculated from data collected from eight known adult individual females in five focal groups. I could not record consecutive births by the identified females during our observation period, and thus reported only one Inter Birth Interval (IBI) for each female. Infant loss before weaning was not observed in these females. The mean monthly rainfall of each month was calculated from the rainfall data of four years (2013-2016). Pearson's product-moment correlation test was performed to check the relation between monthly births and mean rainfall data. All statistical analyses were done using software SPSS 23 (IBM Corp., 2015).

4.3 Results

The mean group size of Golden langur was $11.3 \pm 3.5_{SD}$ and ranged between 5 and 18. The mean group size in forest core ($7.4 \pm 1.7_{SD}$), forest edge ($12.7 \pm 2.2_{SD}$) and rubber plantation ($13.9 \pm 2.3_{SD}$) differed significantly ($F_{2,45}=42.434$, $P<0.001$). The mean number of age-sex individuals were significantly varied between the groups in different habitats, especially the groups in forest core had lesser than in the other two habitats (Table 4.1). The number of adult females to adult males did not differ between the habitats ($F_{2,45}=0.910$, $P=0.410$), however, immature to adults, immature to adult females and infant to adult females were highly varied between the habitats (Table 4.1, Supplementary Table 1).

I recorded a total of 46 births in twelve groups across the three different habitats (Table 1). The birth-rate per adult female ($F_{2,45}=0.261$, $P=0.771$) and birth-rate per group ($F_{2,45}=0.412$, $P=0.665$) did not differ between the habitats. The number of infants correlates positively with adult females ($r=0.634$, $N=48$, $P<0.001$) and group size ($r=0.813$, $N=48$, $P<0.001$) across all the twelve groups for all the years. The births were not recorded in some of the habitats in some months, but the pooled data show that the number of births that occurred in all the months varied significantly between the months (N = 46) (χ^2=22.870, df=11, P<0.05) (Supplementary Table 1). Births occurred in all the months but peaked between May and September (82.6%; Figure 4.2). The mean number of birth was positively correlated with mean monthly rainfall (r=0.858, N=12, P<0.001) (Figure 4.3). The mean immature survival rate was $0.97 \pm 0.05_{SD}$ which varied between 0.86 and 1 in different groups (Table 4.2). The mean inter-birth interval for all the eight known females was $24.5 \pm 1.6_{SD}$ months (N = 8) (Table 4.3).

Figure 4.2 Distribution of births in each month in different habitat conditions (N =46) in Golden langur groups



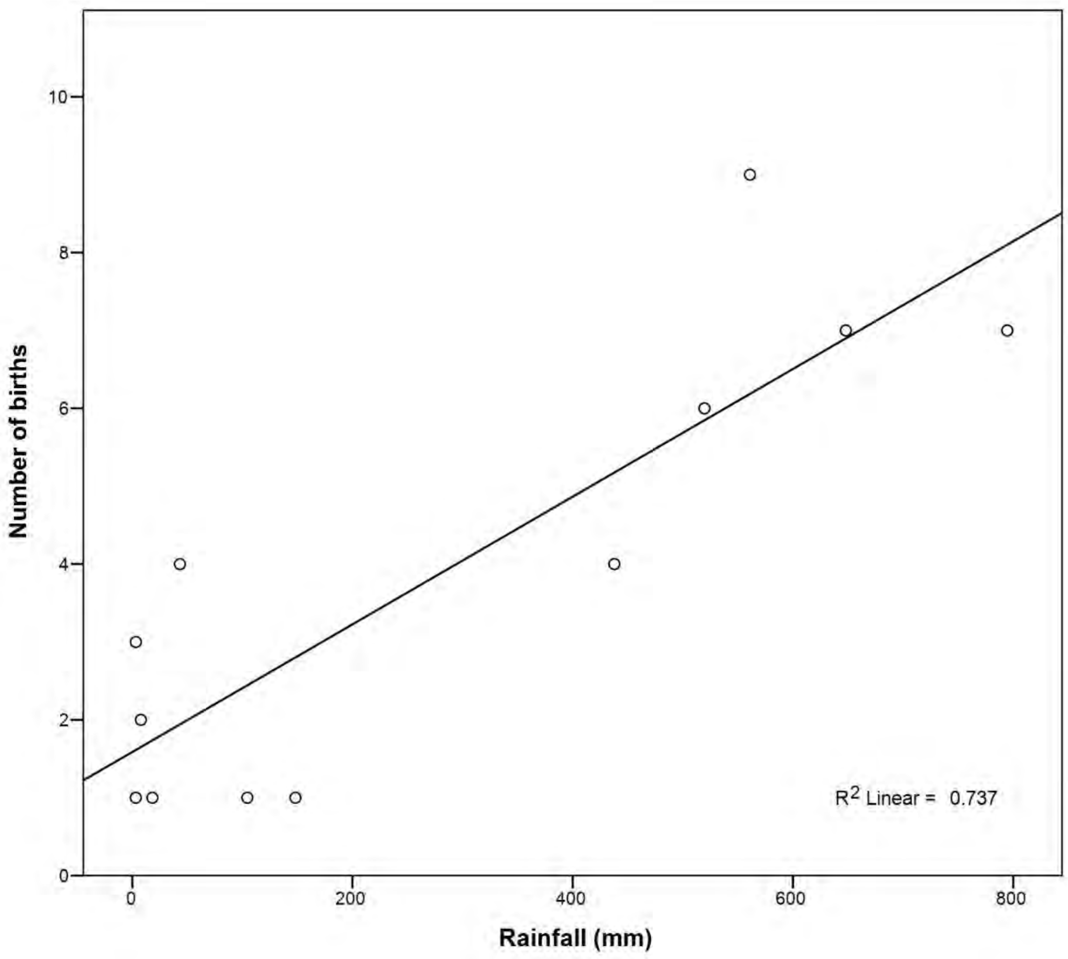


Figure 4.3 Relation between mean monthly rainfall and number of births in Golden langurs

Table 4.1 Comparison of mean and ANOVA of different demographic parameters of Golden langurs in different habitats

Parameters	Forest core	Forest edge	Rubber plantation	Overall	ANOVA
Mean group size ±SD, range	7.4±1.7, 5-11	12.7±2.2, 10-18	13.9±2.3, 9-16	11.3±3.5, 5-18	$F_{2,45}$=42.434, P<0.001
Mean no. of males ±SD, range	1.1±0.3, 1-2	1.5±0.5, 1-2	1.7±0.8, 1-3	1.4±0.6, 1-3	$F_{2,45}$=5.152, P<0.05
Mean no. of females±SD, range	3.7±1.1, 2-5	5.5±1.3, 3-9	5.8±1.2, 4-7	5.0±1.5, 2-9	$F_{2,45}$=13.730, P<0.001
Mean no. of infants ±SD, range	1.2±0.8, 0-2	2.6±1.2, 0-5	3.6±0.8, 1-4	2.5±1.4, 0-5	$F_{2,45}$=24.458, P<0.001
Mean no. of immature ±SD, range	2.7±0.9, 1-4	5.7±1.4, 3-8	6.4±1.4, 3-8	4.9±2.04, 1-8	$F_{2,45}$=40.035, P<0.001
Mean AM:AF±SD, range	3.5±1.1, 2-5	4.0±1.4, 2.5-6	4.3±2.4, 2-7	4.0±1.7, 2-7	$F_{2,45}$=0.910, P=0.410
Mean AD:IMM±SD, range	0.6±0.2, 0.2-1	0.9±0.4, 0.4-2	0.9±0.2, 0.5-1.1	0.8±0.3, 0.2-2	$F_{2,45}$=5.878, P<0.01
Mean AF:IMM±SD, range	0.8±0.3, 0.25-1.5	1.1±0.5, .6-2.7	1.1±0.2, 0.8-1.6	1.0±0.4, 0.3-2.7	$F_{2,45}$=4.286, P<0.05
Mean AF:INF±SD, range	0.4±0.3, 0-1	0.5±0.2, 0-0.8	0.6±0.1, 0.3-0.8	0.5±0.2, 0-1	$F_{2,45}$=5.105, P<0.05
Total births	12	19	15	46	
Mean birth rate/female ±SD, range	0.2±0.3, 0-1	0.2±0.2, 0-0.7	0.2±0.3, 0-0.8	0.2±0.2, 0-1	$F_{2,45}$=0.261, P=0.771
Mean birth rate/group ±SD, range	0.1±0.1, 0-0.4	0.1±0.1, 0-0.3	0.1±0.1, 0-0.3	0.1±0.1, 0-0.4	$F_{2,45}$=0.412, P=0.665

Table 4.2 Immature survival rate in each group (N=12) of Golden langur

Group ID	Years monitored	Total animals in the period	Deaths or disappearances	Annual survival
TPD	4	11	0	1.00
BPN	4	14	1	0.93
IMK	4	10	1	0.90
BST	4	8	0	1.00
BPS	4	21	1	0.95
TPB	4	22	0	1.00
JNE	4	26	0	1.00
SLB	4	21	3	0.86
TLC	4	30	0	1.00
CTS	4	18	0	1.00
OFC	4	29	1	0.97
GDW	4	26	0	1.00
Average (±SD)				0.97±0.05

Table 4.3 Inter-birth interval for identified females in different groups of Golden langurs

Female ID	Inter-birth interval (in months)	Birth status
BPS 1	23	Uniparous
BPS 2	22	Multiparous
TPB 1	26	Multiparous
SLB 1	25	Multiparous
BPN 1	26	Unknown
TLC 1	23	Multiparous
TLC 2	25	Uniparous
TLC 3	26	Multiparous
Mean (±SD)	For all the females (N=8) 24.5±1.6 Months	
Mean (±SD)	Female excluding 2 uniparous and 1 unknown female (N=5) 24.4±1.8 Months	

4.4 Discussion

The ecology and evolutionary history of a species play a key role in determining the group size and age-sex ratios (Chapman and Rothman, 2009). The undisturbed continuous forests may hold a relatively different group size and age-sex composition than in the habitat that is undergoing a change that would keep altering the group size and age-sex ratios of the species (Singh et al., 2016). The group size and age-sex ratio of Golden langur in undisturbed and continuous habitat (Mukherjee and Saha, 1974) are similar to findings of this study. However, ratio of adult female to adult male reported earlier (Chetry et al., 2010) is less than in the current study. It is evident that the larger Golden langur groups were in forest edge and rubber plantation than in the forest core. Larger groups travel more to compensate for their feeding cost by eating more of the same foods or switch their diet if access to the preferred food was compromised (Steenbeek and van Schaik, 2001). Competition for food is expected to limit the primate group size since larger groups deplete patches faster, forcing increased travel (Wrangham et al., 1993; Chapman and Chapman, 2000). However, since leaves do not appear to be limited in distribution, thus the competition for food within folivore groups was inconsequential and may not be limited by the availability of food (Isbell, 1991; Borries, 1993). Therefore, folivores are theoretically free to form large groups, yet many folivores live in small groups. Steenbeek and van Schaik (2001) described this clear inconsistency as the folivore paradox. In forest edges and degraded patches, food was likely not evenly distributed and scramble competition would be high for preferred food. Thus, Golden langurs may have formed larger groups than making many smaller groups to avoid inter-group conflicts.

Group size did not negatively affect the birth rate, which would have been expected if females in larger groups were suffering from competition for food (van Schaik and van Noordwijk, 1988). Populations of a species may exhibit a mixture of group types e.g., one-male and multi-male groups (Yoshiba, 1968). Large groups of Golden langurs mostly form with two or more adult males whereas small groups had single adult males, thus the age-sex ratios are maintained. Age-sex ratios did not vary between the habitats which are similar to *Semnopithecus hypoleucos* and *S. priam* (Singh et al., 2016), *Trachypithecus crepusculus* (Pengfei et al., 2014), *T. phayrei* (Koenig et al., 2004a), *T. auratus* (Tsuji et al., 2013), *T. delacouri* (Workman, 2010). It, therefore, appears that group size is sensitive to forest type (Singh et al. 2016) and food availability (Snaith and Chapman, 2007).

Although births in the Golden langur peak during the high rainfall months but recorded in all the months, which indicates that the Golden langurs are non-seasonal breeders. Temporal variation in food abundance is one of the main factors suspected to determine the timing of reproduction (Janson and Verdolin, 2005; Carnegie et al., 2011). For example, capuchin monkeys in Santa Rosa give birth throughout the year but do so mostly during the period of highest fruit abundance (Carnegie et al., 2011). Thus, if temporal variation in food availability changes, some primates may shift their birth peak. The selection of birth peak is when food resources are abundant since it can compensate for the incurred energy loss during pregnancy. Thus, there is considerable evidence that the rainy season is the most favourable time of the year for female langurs to build up resources to support conception (Huang et al., 2003; Li and Rogers, 2006). A similar pattern of conception during periods of peak food availability in *Semnopithecus entellus* (Koenig et al., 1997), *T. vetulus* at Polonnaruwa (Rudran, 1973) and *T. phayrei* (Borries et al., 2010) (Table 4.4).

No record of infanticide cases in pre-weaning or less than one year of age infants and speculate post-weaning immature deaths are only caused by electrocution or attacked by domestic dogs as reported by the local people. Thus, the infant survivorship in the pre-weaning stage or up to one year of age (100%) appears to be higher in Golden langur than in *Trachypithecus cristatus* 70% (12/40) (Wolf, 1984), *Trachypithecus leucocephalus* 85% (20/133) (Jin et al., 2009), *Trachypithecus phayrei* 84% (8/53) (Borries et al., 2008), *Presbytis thomasi* 52.4% (50/105) (Wich et al., 2007), *Semnopithecus spp.* 66% (49/144) (Rajpurohit and Sommer, 1991).

The interval between successive births defines the inter-birth interval of a species and performs an essential role in the reproductive rate. The recorded inter-birth interval in the current study for Golden langur (24.5 months) (Table 4.3) did not show much difference from other colobines e.g., capped langurs in Arunachal Pradesh (23 months) (Solanki et al., 2007) and in Bangladesh (24 months) (Stanford, 1991), 22–25 months in *T. vetulus* (Rudran, 1973), 24 months in *Colobus polykomos* (Dasilva, 1989), 20-24 months in *S. schistaceus* (Bishop, 1979), 24.1 months in *T. leucocephalus* (Yin et al., 2013), 25 months in *T. poliocephalus* (Jin et al., 2009), 24 months in *T. shortridgei* (Li et al., 2015). Long-term

Table 4.4 Group size, age-sex ratio and birth parameters of colobines

Species	Mean group size	AM:AF	AF: In	Ad: Imm	Habitat	Source	Inter-birth interval	Birth seasonality	Source
Colobus guereza	10.1					Onderdonk and Chapman 2000	25.2		Struhsaker and Leland 1987
Colobus polykomos							24		Dasilva 1989
Colobus satanas	12.1					White 1994			
Presbytis thomasi							26.8 (n=28)		Wich et al. 2007
Pygathrix nemaeus							22.0 (n=27)		Lippold, 1989
Rhinopithecus bieti					Captivity	Cui et al. 2006	23.2 (n=12)	Dec-June	Cui et al. 2006
Rhinopithecus roxellana							23.3 (n=36)	Mar-May	Qi et al. 2007 2008
Semnopithecus hypoleucos in	9.3±4.2	1:3.4±1.4		1:0.6	Wet forest	Singh et al. 2016			
Semnopithecus hypoleucos	18.5±7.0	1:5.5±2.6		1:0.9	Dry forest	Singh et al. 2016			
Semnopithecus priam	12±3.7	1:2.8±0.7		1:0.5	Wet forest	Singh et al. 2016			
Semnopithecus priam	19.5±10.7	1:4.2±2.0		1:0.8	Dry forest	Singh et al. 2016			
Semnopithecus schistaceus							20-24	Feb-Apr	Bishop 1979
Trachypithecus auratus	24	1:14	1:0.07	1:0.7		Tsuji et al. 2013			
Trachypithecus crepusculus	90-91	1:3	1:0.7	1:1.3	Evergreen broadleaf	Fan et al. 2014			
Trachypithecus cristatus							15.3 (n=45)		Shelmidine et al. 2009
Trachypithecus delacouri	10.8	1:5.4	1:0.7	1:0.7	Limestone karst	Workman 2010			

Trachypithecus francoisi	9	1:5	1:0.6	1:0.5	Limestone karst	Huang et al. 2007	16.3 (n=12)		Gibson and Chu 1992
Trachypithecus geei	12.5±4.1	1:3.8	1:0.6	1:0.7	Moist deciduous	Mukherjee and Saha 1974			
Trachypithecus geei	8.5	1:2.2	1:0.5	1:0.6	Semi evergreen	Biswas 2002		January-June	Biswas 2002
Trachypithecus geei	17.3	1:3.2	1:1.5	1:2.6	Rubber plantation-	Medhi et al. 2004			
Trachypithecus geei	7.4	1:1.5	1:0.6	1:1.01	Moist deciduous	Chetry et al. 2010			
Trachypithecus geei	11.3±3.5	1:3.5	1:0.5	1:0.8	Moist deciduous	Present study	24.5 (22-26; n=8)	Throughout the year /	Present study
Trachypithecus johnii	9.2±3.2	1:6.1		1:0.3	Wet forest	Singh et al. 2016	20	May-June (peak)	Poirier 1970
Trachypithecus leucocephalus	9.7 (5-14;10)	1:4.9	1:0.3	1:0.4	Disturbed and natural	Li and Rogers 2004	24.1 (n=6)		Yin et al. 2013
Trachypithecus obscurus	18	1:5	1:0.2	1:2		Md Zain and Ch'ng 2011			
Trachypithecus phayrei	9	1:4	1:0.8	1:0.3	Evergreen forest	Koenig et al. 2004b	22.3 (n=40)	December-April	Borries et al. 2008 2010
Trachypithecus pileatus	8.3 (7-9; 3)	1:4.7	1:0.14	1:0.5	Evergreen-moist	Solanki et al. 2007	23.3	December-April	Solanki et al. 2007
Trachypithecus poliocephalus							25.0 (n=23)		Jin et al. 2009
Trachypithecus shortridgei	8 (7-9, 5)	1:2.9	1:0.5	1:1.2		Li et al. 2015	24	March-July	Li et al. 2015
Trachypithecus vetulus	11	1:6		1:0.6			23.5 (n=4)	May-August	Rudran 1973

data on reproduction in colobine species are relatively scarce (Kirkpatrick, 2007; Newton and Dunbar, 1994). The limited information available indicates that most Asian and African colobines are not strictly seasonal breeders but have distinct birth peaks during the year. In general, gestation typically lasts 6–7 months in colobines and inter-birth intervals are approximately two years (Table 4.4). The time the species takes for weaning of their young and gestation length are important factors in determining birth interval (Lee et al., 1991). Gestation period can be an important characteristic to assess the reproductive capacity of a species. The variability in the gestation length between the species is enormous (Lee et al., 1991). The longer gestation period and slow foetal growth rates are evident in poor nutritional conditions in two different populations of *Semnopithecus entellus* (Borries et al., 2001). Lee (1986) and Borries et al. (2001) reported that prolonged lactation is a result of low net energy intake in poor quality environments which leads to longer weaning time. The nutritional regime had a significant influence on the first parturition for provisioned populations compared to wild ones (Leigh, 1994; Borries et al., 2001). An increase in birth rate by 0.76% in altered habitat comprises 80% rubber plantation (*Hevea brasiliensis*) and 20% natural forest (Medhi et al., 2004) suggests that provisioned or altered food has implications on the Golden langur population. It is evident in my study that the number of infants per female in edge and rubber plantation is much smaller than in other habitats.

In higher primates' inter-birth interval and infant, survivorship is the most important determinant of reproductive success (Fedigan and Rose, 1995). Poor nutritional conditions result in elongating inter-birth intervals which reduce female reproductive rates (Borries et al., 2001). Especially in endangered species, these reproductive parameters are critical for developing models examining population viability and adequate conservation measures (Di Bitetti and Janson, 2001). Golden langur's habitat has already fragmented and has been continuously degrading. The behavioural parameters may further influence life-history traits if continuous habitat alteration persists.

CHAPTER 5

Resource Availability And Feeding

Chapter 5

Resource availability and feeding

5.1 Introduction

Plant species composition and richness are the defining factors of a forest ecosystem. Heterogeneity and diversity of species are essential attributes of moist forests in tropics and subtropics (Mishra et al., 2005). Forest floral community can be described specifically with importance value index. The importance values of plants are determined by the presence of their number, size, and dispersion (Newton, 2007). Trees with high importance value may possess a high effect on the community or it may be otherwise. The vegetation composition regulates the presence of animals and their ecology (Lombardi et al., 2007). For example, animals like squirrels, blue jays and wild turkeys are expected to be more abundant in nut-producing oak-hickory forests (Kricher, 1988). Tropical and subtropical forests are the primary habitats of primates, especially forest specialist species. Among primates, diet varies with taxa and their habitats. African and Asian colobines like *Colobus* and *Presbytis* genera eat leaves in a considerable proportion in their diet (Oates, 1994; Yeager and Kirkpatrick, 1998). A substantial quantity of leaves in the diet of colobines are necessary to maintain a forestomach environment for proper digestion of plant parts (Waterman et al., 1988). However, they also consume fruits and seeds in significant amounts (Stanford, 1991; Boonratana and Le, 1994). In the wide spectrum of diet, preferred food can be defined as those foods which are of high quality and are consumed comparatively more than other food items which may be abundant. Whereas fallback foods are those which are of poorer quality than preferred foods and are consumed when preferred food availability is less. Primates are threatened worldwide (Rylands et al., 2008; Schipper et al., 2008) due to habitat fragmentation and alteration (Schipper et al. 2008; Marsh et al. 2013). Patch size and habitat characteristics such as food availability affect differently to abundance of different species of primates (Chapman et al. 2006; Baranga et al. 2013). Colobines like endangered Golden langur (*Trachypithecus geei*) are threatened by habitat degradation and fragmentation. It is highly dependent on tree canopies for food, lodging, travel and other daily activities. Its habitat in Assam, India is mostly mixed moist deciduous forest and semi-evergreen forest. The feeding ecology of the species in different habitat conditions will be crucial information that is required to understand their response to the habitat alteration.

5.2 Methodology

Study area: Chakrashila WLS (45.58 km^2; 26°15′ to 26°26′N and 90°15′ to 90°20′E) is situated in Kokrajhar district, Assam, India. Dominant vegetation in the sanctuary is secondary moist deciduous, forest covering its undulating terrain (Champion and Seth, 1968; Bahuguna et al., 2016). The area experiences by subtropical monsoons, with four distinct seasons based on annual fluctuations in temperature and rainfall. The seasons are namely pre-monsoon, monsoon, retreating monsoon and winter (detailed in chapter 1).

Resource availability: Three Golden langur groups were selected at different habitat conditions (1. forest core, 2. forest edge, and 3. rubber plantation) and their home range areas were estimated (detailed in chapter 6). The home range of the groups was overlaid with the one-hectare grid cells. The grids which are used more than 1% were selected for vegetation sampling using the nested quadrat method (Mueller-Dombois and Ellenberg, 1974). In each grid two quadrats of (10X10 m) were established. Within these plots, the trees (>30 cm Girth at Breast Height = GBH) and saplings (>10 cm GBH) were measured for the GBH, species identification. Shrubs and lianas (<10 cm GBH) were assessed in 3x3 m plots within each plot. All the shrubs and lianas were identified and counted. The dominance of woody food plant species has been quantified by using ‘Importance Value Index or IVI’ (Smith and Smith, 2001). The following formulas are used to calculate IVI.

$$Basal\ area = \frac{GBH^2}{4\pi}$$

$$Dominance = \frac{Total\ basal\ area\ of\ given\ species}{Total\ area\ sampled}$$

$$Relative\ dominance = \frac{Total\ basal\ area\ of\ given\ species}{Total\ basal\ area\ of\ all\ species}\ X\ 100$$

$$Density = \frac{Total\ number\ of\ individual\ of\ a\ given\ species}{Total\ number\ of\ quadrats\ sampled}$$

$$Relative\ density = \frac{Total\ number\ of\ individual\ of\ a\ given\ species}{Sum\ of\ all\ individuals\ of\ all\ species}\ X\ 100$$

$$Frequency\ \% = \frac{Number\ of\ quadrats\ in\ which\ species\ occured}{Total\ number\ of\ quadrats\ studied}\ X\ 100$$

$$Relative\ frequency = \frac{Number\ of\ quadrats\ in\ which\ species\ occured}{Total\ number\ of\ quadrats\ occupied\ by\ all\ species}\ X\ 100$$

$$IVI\ =\ Relative\ dominance\ +\ Relative\ density\ +\ Relative\ frequency$$

Simpson's index (*D*) to find heterogeneity is calculated using the formula (Simpson, 1949)

$$D = \frac{1}{\sum_{i=1}^{s}(p_i)^2}$$

where p_i is the proportion of species *i* in the community and *s* is the number of species in the community.

Shannon and Wiener's diversity index (H') is calculated using the formula (Shannon and Wiener, 1948)

$$H' = -\sum P_i \ln P_i$$

Where P_i is the proportional abundance of *i* species. $P_i = (n_i/N)$ where, n_i = IVI; N = total IVI of all species.

Feeding behaviour: Three Golden langur groups at different locations was selected for data collection and followed from dawn to dusk between 0530 hr. and 1830 hr. While following of the group, the instantaneous scan based on ethogram were recorded as per (Altmann, 1974). All diurnal activities of Golden langur *viz.*, feeding, resting, locomotion, grooming, playing, agonistic interactions were recorded in every 15-minute intervals for 4 to 6 days in for each group. Data of the forest core group in the monsoon season was not collected due to heavy rain and extremely difficult terrain with dense ground vegetation and slippery mud. From the total activities scan data, feeding scans were extracted and time spent on the feeding of particular food items was calculated. If they were seen feeding, food plant species, plant parts viz. mature leaves, young leaves, leaf buds, petioles, flowers, fruits, seeds, bark, stem, and whole plants were recorded and the food plants were identified at least up to genus level. Scan data for feeding on different resources were compared seasonally and annually for different habitats. Clutton-Brock (1975) method was adopted in the present study to quantify diet composition of Golden langur by "measurement of the proportion of feeding time spent on different foods". In this study, the relative time expended in eating or handling or foraging on a particular food item was taken as the measurement of the feeding efforts of the groups rather than actual food intake (Stanford, 1991; Struhsaker, 1975; Oates, 1977). The proportion of food items is calculated by using the formula

$$Feeding\ \% = \frac{Feeding\ scan\ of\ particular\ food\ item}{Total\ feeding\ scan}\ X\ 100$$

The proportion of different food resources consumed within groups was compared using the chi-square test to check significant differences within the food resources. Food resources consumed across the groups were tested for significance using the G-test of proportion. Various food resources consumed within a group was tested using the chi-square (χ^2) test for the three groups. All the statistical tests were performed using R 4.1.2 (R Core Team, 2021). Food plant preference was presented as Forage Ratio (Krueger, 1972; Jacobs, 1974; Cock, 1978) using the formula

$$\bar{P}_i = \sum_{k=1}^{n} \frac{D_{ik}}{RA_{ik}} / n$$

where $\bar{P}_i$ is the mean preference ratio in *n* trials. D_i is the proportion of species *i* in the diet, and RA_i is the proportion of species *i* available in vegetation. IVI was used to calculate the percentage of species available. Food plant similarity was computed and presented using Bray-Curtis similarity index in Biodiversity Pro 2.0 (McAleece et al., 1997).

5.3 Results

Scan sampling was performed for three Golden langur groups situated in the forest core, edge, and rubber plantation. From the estimated home range of the groups 0.38 ha, 0.52 ha, and 0.46 ha were sampled to assess vegetation structure. Details of vegetation structure are given in Table 5.1.

Table 5.1 Summary of vegetation structure in different habitats

Parameters	Forest core	Forest edge	Rubber plantation
Total basal area m^2/ha	37.68	54.94	48.94
Density (stems/ ha)	1088	1621	588
Simpson (D)	0.928	0.944	0.890
Shannon-Wiener (H')	3.182	3.53	2.944
Number of species recorded	82	106	56
Number of food plant species	39	41	40

Quantity of food resources in diet:

Total 70429 number of scans from the three groups were collected in 1955 hours. Out of the total feeding scans from forest core (N= 2703), forest edge (N= 7847) and rubber plantation (N= 7907) were collected. Details are given in Table 5.2 – Table 5.4.

Table 5.2 The proportion of the seasonal diet of forest core group (all total scan N = 9891, total feeding scan N = 2703)

Feeding component	Pre monsoon N= 1003	Retreating monsoon N=658	Winter N=1042	Annual N=2703
Leaf	76.32	60.79	58.41	65.67
Petiole	0.88	0.33	0.62	0.63
Shoot	3.4	4.78	1.38	2.92
Flower	3.52	27.86	19.57	15.61
Fruit	12.68	4.81	13.24	10.99
Seed	2.81	1.02	5.62	3.48
Stem	0.39	0.41	1.16	0.70

Table 5.3 The proportion of seasonal diet of forest edge group (all total scan N = 29249, total feeding scan N = 7847)

Feeding component	Pre monsoon N= 1721	Monsoon N= 2433	Retreating monsoon N= 1708	Winter N= 1985	Annual N= 7847
Leaf	80.32	55.61	56.27	48.57	59.39
Petiole	1.74	0	0	0.74	0.57
Shoot	2.15	26.91	12.65	7.36	13.43
Flower	1.52	0.28	24.26	16.2	9.80
Fruit	10.68	16.36	5.67	16.75	12.90
Seed	3.59	0	0.76	8.22	3.03
Stem	0	0.84	0.39	2.16	0.88

Table 5.4 The proportion of seasonal diet of rubber plantation group (all total scan N = 31289, total feeding scan N = 7907)

Feeding component	Pre monsoon N= 1495	Monsoon N= 2634	Retreating monsoon N= 1730	Winter N= 2048	Annual N= 7907
Leaf	55.01	20.55	12.78	56.26	34.60
Petiole	2.17	2.69	26.7	27.26	14.20
Shoot	2.11	10.19	7.29	4.6	6.58
Flower	1.77	0	0.21	0	0.39
Fruit	38.31	41.33	14.21	7.93	26.19
Seed	0	0	8.65	1.85	2.36
Stem	0.63	7.68	5.53	2.09	4.43
Dry seed (rubber)	0	17.56	24.63	0	11.24

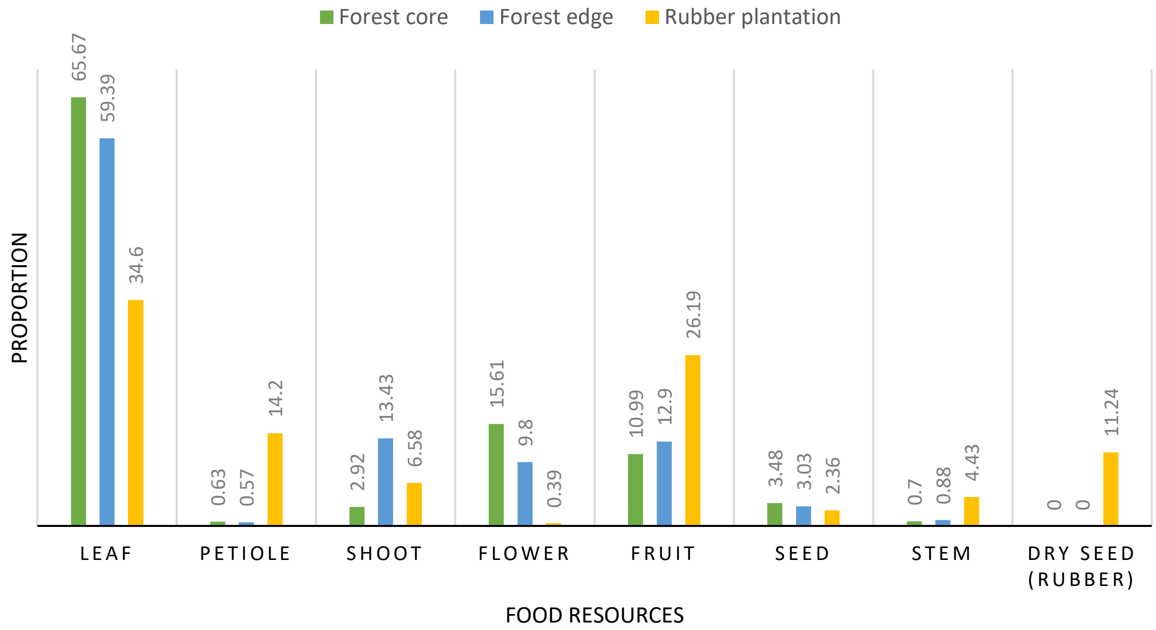


Figure 5.1 The proportion of annual diet of three different study groups.

The proportion of food plant species consumed seasonally by the three groups is detailed in Table 5.5 – 5.8.

Table 5.5 The proportion of food plant species consumed by forest core group

Species name	Annual N= 2703	Pre monsoon N= 1003	Retreating monsoon N= 658	Winter N= 1042
Abroma augusta	0.11	0.23	0.11	
Acacia himalayensis	0.02			0.04
Albizia lebbeck	4.88	4.80	0.53	7.71
Alstonia scholaris	0.06	0.17		
Artocarpus lacucha	6.24	16.82		
Bauhinia variegata	14.18	13.74	17.38	12.58
Butea painflava	1.88	1.67	4.92	0.17
Callicarpa arborea	0.30	0.57	0.36	
Cassia fistula	0.18		0.73	
Croton sparsiflorus	4.21		11.25	3.81
Dendrocalamus hamiltonii	9.80	7.49	16.71	7.65
Dysoxylum binectariferum	0.19	0.34	0.26	
Ficus carica	0.18	0.08	0.62	
Ficus hispida	0.24	0.64		
Ficus nervosa	0.17	0.17		0.27
Ficus racemose	0.42	1.12		
Ficus sp.	0.06	0.17		
Heteropanax fragrans	0.35	0.25		0.68
Holarrhena pubescens	0.91	0.3	3.27	
Holmskoldia sanguinea	5.23		6.56	9.43
Lannea coromandelica	0.32	0.14		0.70
Litsea glutinosa	1.37	1.34	2.59	0.63
Litsea monopetala	14.62	34.57	1.32	3.81
Mallotus phillipinensis	1.89	0.84	1.92	2.89
Mikania micrantha	0.43		0.63	0.71
Oroxylum indicum	12.22	3.24	14.57	19.38
Paederia scandens	0.88	0.26	0.26	1.88
Phlogacanthus thyrsiformis	0.15	0.41		
Protium serratum	1.44	1.03		2.74
Schima wallichii	0.39	0.94	0.17	
Scoparia dulcis	0.59	1.38	0.31	
Spondias pinnata	0.19			0.49
Sterculia bilosa	0.95	0.37	0.41	1.84
Stereospermum chelonoides	1.87		2.66	3.16
Terminalia belerica	5.45	6.80	1.87	6.42
Terminalia chebula	2.05		1.02	4.68

Thunbergia sp.	5.53		9.57	8.30
Toona ciliata	0.01			0.03
Unidentified	0.04	0.12		

Table 5.6 The proportion of food plant species consumed by forest edge group

Species name	Annual N=7847	Pre monsoon N=1721	Monsoon N=2433	Retreating monsoon N=1708	Winter N=1985
Acacia himalayensis	0.18		0.58		
Albizia lebbeck	1.87	2.91			4.89
Alstonia scholaris	0.01	0.06			
Artocarpus lacucha	4.83	12.03	7.07		
Averrhoa carambola	1.95		2.06	6.03	
Bambusa tulda	15.55	3.49	25.81	20.32	9.32
Bauhhinia acuminata	16.82	4.53	3.45	39.87	24.03
Butea painflava	2.77	0.29	7.89	1.17	
Calliearpa arborea	0.66		2.14		
Cassia fistula	0.27		0.86		
Croton sparsiflorus	2.55			8.14	3.07
Dalbergia sissoo	2.23	9.59	0.41		
Ficus nervosa	1.25		4.03		
Ficus racemosa	0.70	2.67	0.37		
Gmelina arborea	12.82	33.24	3.86	1.11	16.17
Gmelina hainanensis	0.54			2.46	
Heteropanax fragrans	0.04				0.15
Holmskoldia sanguinea	1.90			2.40	5.44
Kydia calycina	0.52		1.69		
Litsea glutinosa	4.87	0.06	15.66	0.94	
Litsea monopetala	5.21	21.38	0.21		1.01
Mallotus phillipinensis	0.09	0.41			
Micromelen pubecens	0.01				0.05
Mikania micrantha	0.23		0.08	0.94	
Oroxylum indicum	7.51	1.51	4.77	9.31	14.51
Paederia scandens	1.16		1.97		2.17
Protium serratum	0.68	0.41	0.62		1.56
Schima wallichii	0.10		0.33		

Scoparia dulcis	0.13	0.58			
Smilax zeylanica	0.01	0.06			
Spondias pinnata	0.60		1.44		0.60
Stereospermum	3.91		11.22	0.29	1.46
Tectona grandis	0.01		0.04		
Terminalia belerica	1.54	5.69			1.16
Thunbergia sp.	3.82		3.04	6.56	5.74
Toona ciliata	0.01				0.05
Ficus hispida	0.18	0.81			
Unidentified	0.06	0.29			
Unidentified	0.10		0.33		
Unidentified	0.03		0.08		
Unidentified	2.28			0.47	8.61

Table 5.7 The proportion of food plant species consumed by rubber plantation group

Species name	Annual N= 7907	Pre monsoon N= 1495	Monsoon N= 2634	Retreating monsoon N= 1730	Winter N= 2048
Acacia himalayensis	2.02				7.81
Acacia sp.	0.27	1.40			
Albizia lebbeck	0.58	1.27			1.32
Albizia lucida	1.54	3.27	2.77		
Areca catechu	2.95	0.27	3.42	3.29	4.00
Artocarpus lacucha	0.33			1.50	
Bambusa tulda	6.10	3.41	7.52	7.28	5.22
Bauhhinia variegata	1.82	4.48	0.87	1.45	1.42
Callicarpa arborea	1.35		0.57	3.93	1.17
Croton sparsiflorus	0.40		0.53	1.04	
Dysoxylum	1.48	7.83			
Elaeocarpus floribundus	0.05				0.20
Eucalyptus sp.	0.15				0.59
Ficus hispida	0.10			0.46	
Ficus sp.	0.01		0.04		
Garcinia cowa	0.04		0.11		
Gmelina arborea	0.76	2.34		1.45	
Grewia nervosa	0.18		0.53		

Hevea brasiliensis	54.57	43.34	60.78	63.12	47.56
Holarrhena pubescens	0.05			0.23	
Kydia calycina	3.12	0.40	6.72	3.70	
Lannea coromandelica	0.66	2.61		0.75	
Litsea glutinosa	2.43	1.47			8.30
Litsea monopetala	4.06	3.34		0.87	12.50
Lorenthus sp.	0.82	4.35			
Mallotus phillipinensis	1.34	7.09			
Micromelen pubecens	1.95				7.52
Mikania micrantha	0.59	1.47	0.27	0.98	0.05
Schima wallichii	0.14		0.15	0.40	
Smilax zeylanica	0.06		0.11	0.12	
Stereospermum	0.32		0.46	0.75	
Swietenia mahagoni	4.40	1.67	6.95	5.32	2.34
Syzygium cuminii	1.77	2.41	3.04	1.39	
Syzygium	0.58	1.87		1.04	
Syzygium sp.	0.97	5.15			
Terminalia belerica	0.09			0.40	
Toona ciliata	0.16		0.49		
Unidentified	1.50		4.52		
Unidentified	0.15	0.54	0.15		
Unidentified	0.11			0.52	

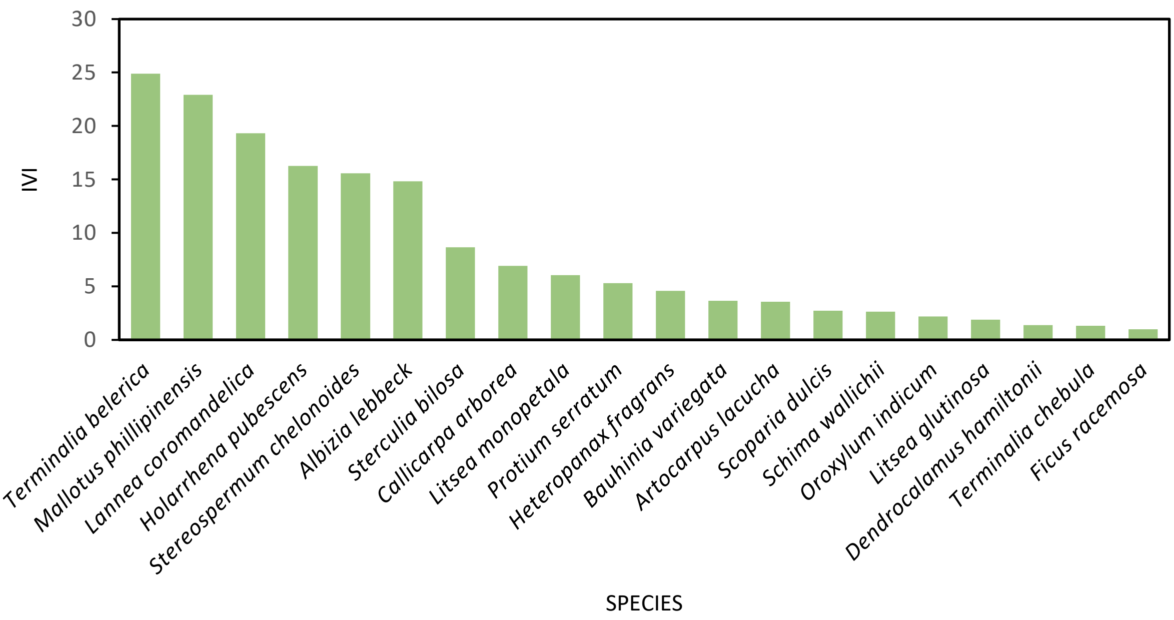


Figure 5.2 IVI of top 20 food plant species used by forest core group.

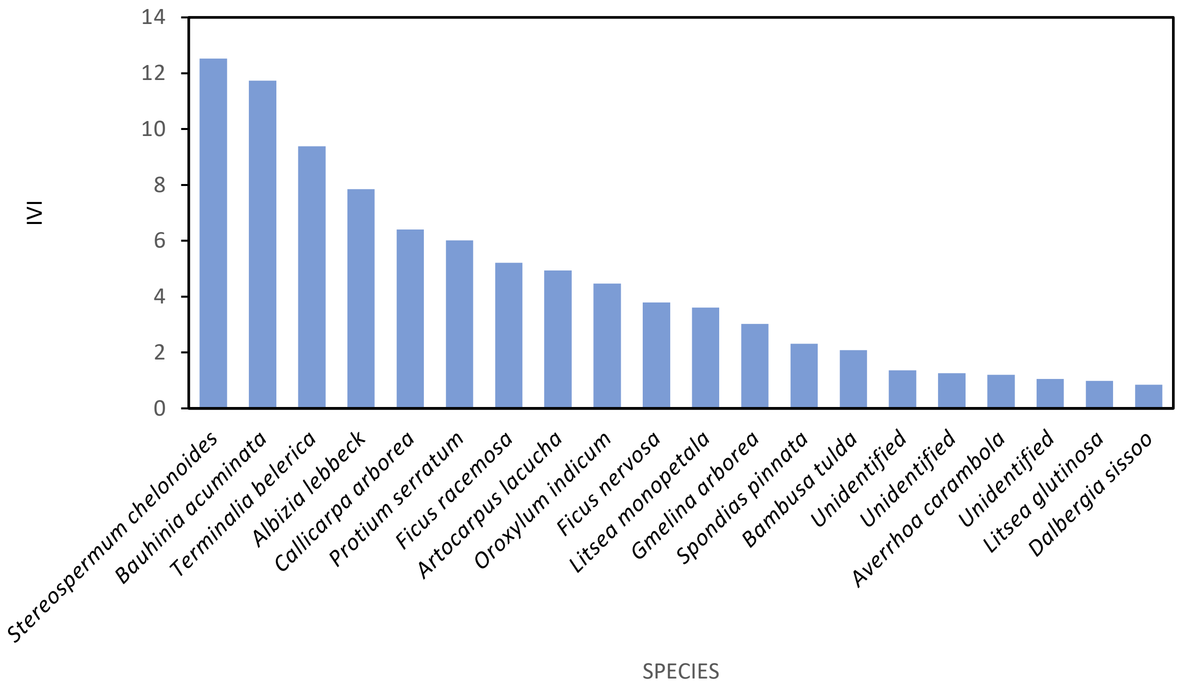


Figure 5.3 IVI of top 20 food plant species used by forest edge group.

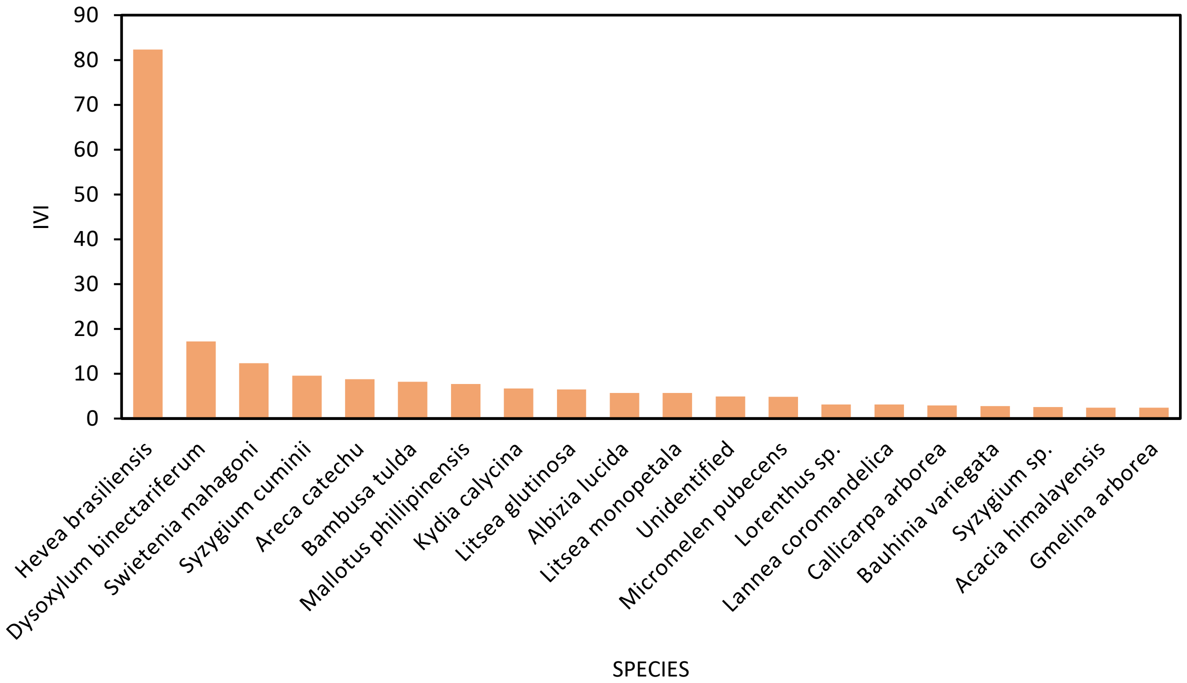


Figure 5.4 IVI of top 20 food plant species used by rubber plantation group.

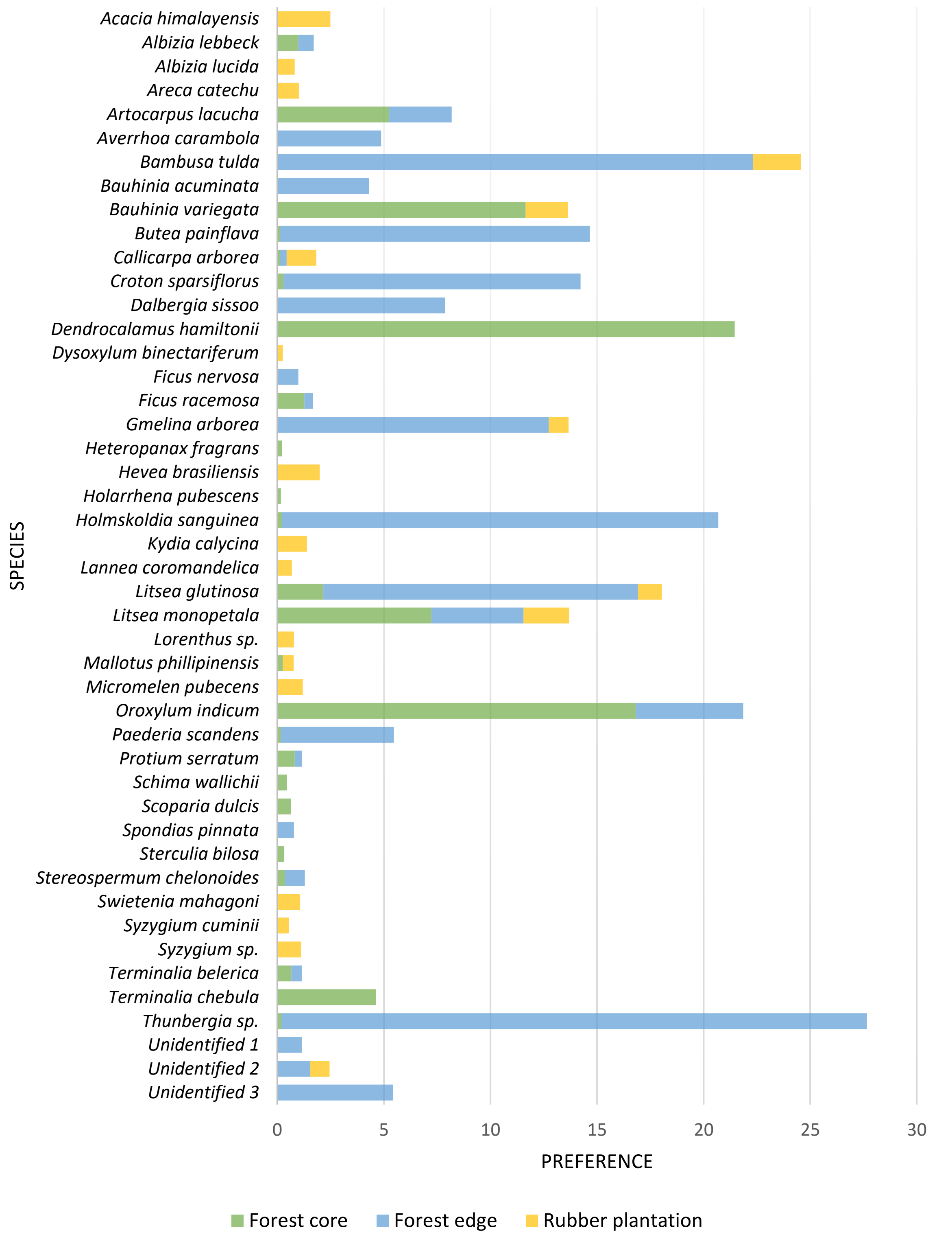


Figure 5.5 Forage ratio indicating selection preference of top 20 food plant species from each in three different habitats.

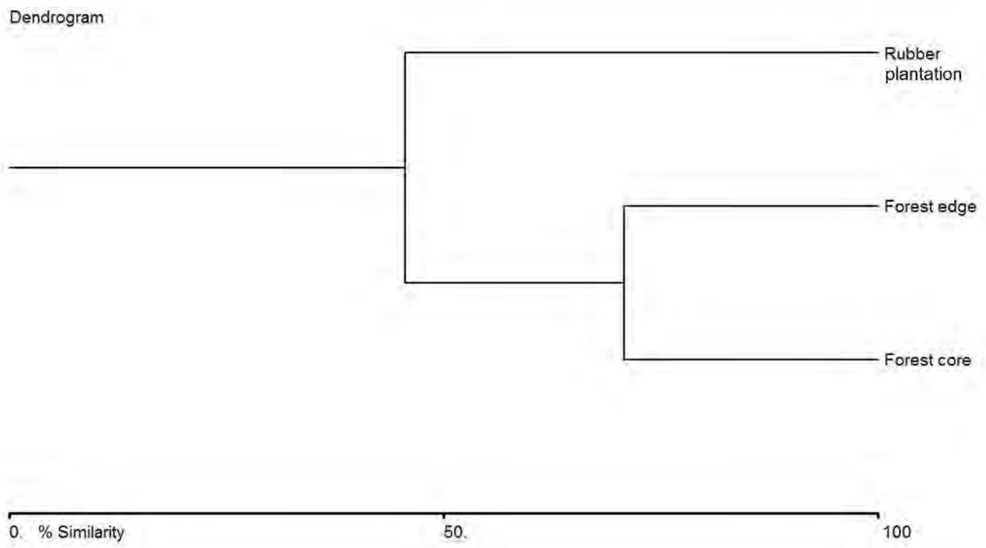


Figure 5.6 Dendrogram showing similarities of food plant species consumed by three different groups of Golden langurs.

The vegetation structure in the three habitats showed the highest basal area in forest edge (54.94 m^2/ha) followed by rubber plantation (48.94 m^2/ha) and forest core (37.68 m^2/ha). Though surprisingly stem density in forest core was found second-highest and more than rubber plantation. The three Golden langur groups *viz.* forest core group, forest edge group and rubber plantation group spent 27.33%, 26.83% and 25.27% time in feeding respectively. The forest core, forest edge and rubber plantation groups were recorded to feed on 39, 41 and 40 plant species respectively. In total sampled plant species, food plant species comprised 47.56% in forest core, 38.68% in forest edge and 71.43% in the rubber plantation. Among the top 25 feeding plant species, there were 20 woody plants, one liana, three climbers and one shrub species present in forest core and forest edge but absent in rubber plantation. The food items consumed by Golden langur include leaf, petiole, shoot, flower, fruit, seed, stem and fallen dry seed from the forest, village and plantations. Highest annual consumption of leaf by forest core group (65.67%), forest edge group (59.39%) and rubber plantation group (34.60%). The major food resources consumed by the forest core group annually with leaf (65.67%), flower (15.61%), fruit (10.99%) where leaf consumption is highest (76.32%) in pre monsoon season (details in Table 5.2). Major food resources consumed by forest edge group annually with leaf (59.39%), shoot (13.43%), fruit (12.9%), flower (9.8%) where leaf consumption is highest (80.32%) in pre monsoon season (details in Table 5.3). In the rubber plantation group major food resources consumed annually by Golden langur with leaf (34.6%), fruit (26.19%), petiole (14.2%), dry seed (11.24%) where leaf consumption is highest (55.01%) in pre monsoon season (details in Table 5.4). In rubber plantations consumption of dry seed is unique which is missing in the other two habitats. Petiole, stem and fruit consumption was also found much higher than the other two habitats, whereas flower consumption was found very less. Plant resources consumed throughout the year varied significantly across the resources in forest core group (χ^2 = 276.340, df= 12, P<0.001), forest edge group (χ^2 = 2036.260, df = 18, P<0.001) and rubber plantation group (χ^2 = 3850.780, df = 21, P<0.001). Plant resources consumed annually varied across the groups for leaf (G=671.384, df=3, P<0.001), petiole (G=1486.840, df=3, P<0.001), shoot (G=356.292, df=3, P<0.001), flower (G=1151.913, df=3, P<0.001), fruit (G=469.109, df=3, P<0.001), seed (G=11.229, df=3, P<0.01), stem (G=253.146, df=3, P<0.001) and dry seed (G=1507.202, df=3, P<0.001) (Figure 5.1). Forest edge group consumed 49.37% of its annual diet from trees which are exclusively available only in fringe villages of the forest. Some dominant plant species within the top 10 ranking in IVI are found in the three habitats those are not used by Golden langur for feeding but used for resting and travel. Among them, *Shorea robusta* shows maximum IVI in both forest edge (32.46) and forest core (30.84). In the rubber plantations, *Shorea robusta* has second-highest IVI (55.72) after the rubber plant (*Hevea brasiliensis*). *Careya arborea* is another species that has IVI in the top 10 ranked plant species in forest core with 20.04 and forest edge with 7.46 IVI.

5.4 Discussion

Golden langurs in fragments usually start their daily activity early in the morning for feeding and generally roost near food patches, so that in the next morning, they can easily procure the food. In the three different habitat types of Golden langur, the tree cover and species composition were different. Forest edge and forest core had more similarities than the rubber plantation. Basal area in forest core was found less because of less abundance of matured trees since the area is disturbed to some degree by selective logging (Ghosh and Ramesh, 2010). On the other hand, forest edge includes many plots which are anthropogenically managed for timber and other resources resulting in densely distributed moderately matured trees. Rubber plantation has more basal area compared to the tree density since rubber is the predominant species planted uniformly and around 90% of the trees sampled had more than 45 cm GBH. Shannon-Wiener indices found in Chakrashila forest core and forest edge were similar to other studies conducted in moist mixed deciduous forests in Lumding RF, but species richness and basal area was higher than the estimated from core and edge of Chakrashila forest (Dutta and Devi, 2017). Resource distributions are not the same for the three Golden langur group locations, although the groups are in the same or nearly close landscape. Depending on such attributes of habitat at home-range level, dietary requirement and food preference are also influenced.

To maintain the microbial environment for food fermentation in the forestomach, colobines need to eat a considerable amount of leaves (Davies, 1984). Forest core group and edge group consumed leaf in high quantity during pre-monsoon season when new foliage is usually more abundant in moist deciduous forests. Overall annual consumption of proportion of leaves resembles with the earlier study in the pristine evergreen forest where leaves, leaf buds and petioles together consist of 59% and 63% in the annual diet of two different groups (Biswas, 2002). Whereas, in fragmented and degraded habitats 70.7% leaf consumption was recorded (Biswas, 2002). Biswas (2002) reported fruit consumption by Golden langurs were 20% and 8.5% in the same pristine forest for two different groups and 10% in disturbed fragmented habitat. The present study also shows that the difference among food resources proportions for similar and different kinds of habitats. From the earlier and the present studies, it is apparent that consumption of food resources varies between the groups both within habitats and between habitats.

Feeding is generally accomplished with foraging and feeding of preferred food available interrupted by searching of new food patches, not explored for last few days within their home range. For that, they sometimes visit the periphery of their home range and sometimes come to the village gardens and once a "food patch" has been completely exploited, they move to another food patch for feeding. The Golden langur group in rubber plantation consumed less proportion of leaf compared to the other two groups but consumed more fruits including seeds. The major proportion of annual consumption of leaf, fruit and dry seeds (54.57%) was from rubber plants (*Hevea brasiliensis*). Consumption of resources from rubber plants increased in monsoon (60.78%) and retreating monsoon (63.12%) when it is a fruiting season. But from the forage ratio of rubber (1.99) it does not seem a highly preferred food resource. Unavailability or less availability of other plant resources drive the Golden langur group of rubber plantations to consume more rubber plant resources. Rubber (*H. brasiliensis*) is an exotic plant species used for commercial rubber production and not a natural diet of Golden langur. Long-term effect of consumption of rubber on the health of the Golden langur is not known. Nevertheless, the present study suggests that secondary vegetation and vegetable plant species in altered habitats may be an important food source of Golden langur as found in other folivore primates (Chiarello, 2003; Cristobal-Azkarate et al., 2005; Lovejoy et al., 1986).

(Juvenile Golden langurs in playing activity)

CHAPTER 6

Activity

And

Ranging Pattern

Chapter 6
Activity and ranging pattern

6.1 Introduction

The behavioural plasticity of a species to varying resource availability in fragmented and altered habitats is an essential component of their adaptive strategy. The amount of time spends in each day by an animal for its various activities depends on the environment in which they live (Campos and Fedigan, 2009; Dunbar et al., 2009; Guan et al., 2018). Accordingly, they allot their time to perform their vital activities like feeding, resting, travel, vigilance, grooming, playing and other social activities. For a better understanding of behavioural aspects, activity budgets have been studied for a wide range of species: ranging from birds (Stock and Hofeditz, 1996) to antelope (Maher, 1997), squirrels (Wauters et al., 1992), otters (Ostfeld et al., 1989), bats (Charle-Dominique, 1991) and dolphins (Neumann, 2001). The studies on primates connected changes in activity budgets to habitat alteration (Isbell and Young, 1993; Defler, 1996), food resource (Adeyemo, 1997), predation risk (van Schaik et al., 1983), and age-sex compositions (Baldellou and Adan, 1997). In primates, feeding and behavioural flexibility have been extensively studied (Chaves and Bicca-Marques, 2013; Struhsaker, 2010). Comparison of the behaviours and diet of a particular species living in an intact pristine habitat and degraded fragmented habitat has received more attention (Onderdonk and Chapman, 2000; Milich et al., 2014). Food is an important survival factor in the environment that restrict foraging behaviour which has always been prioritised over others in activity budget (Menon and Poirier, 1996; O'Brien and Kinnaird, 1997). In many instances, populations living in the fragments change their behaviour and feeding habit by increasing or decreasing day path length, increasing feeding time, an increasing number of food patches accessed per day relative to populations inhabiting in dense forests (Milich et al., 2014; Wong et al., 2006). For example, *Colobus vellerosus* living in patches outside the protected area in Ghana ate more lianas and other tree species not consumed by groups residing in the protected area (Wong et al., 2006). Generally, folivorous primates are known to rest more and spend less time on movement and feeding than frugivorous primates (Bach et al., 2017; Ruppert et al., 2018; Yap et al., 2019). Compared to fruits, fibre rich leaves, which is a lower energy food that takes a long fermentation time (Richard, 1985; Huang, 2002).

Home range is identified as "*the area traversed by the individual in its normal activities: of food gathering, mating, and caring for young. The size of the home range may vary with sex, possibly age, and season. Population density may also influence the size of the home range and cause it to coincide more closely with the size of the territory*" (Burt, 1943, p.351). Primates have to move around to obtain preferred food and to perform normal activities (Burt, 1943). Most primates are very well organized in their spatial distribution and show at least some element of territorial behaviour. Patterns of ranging behaviour and territoriality have been studied in most of the leaf-eating *Colobine* monkeys like *Trachypithecus pileatus* (Stanford, 1991); *Semnopithecus entellus* (Newton, 1986); *Presbytis senex* (Rudran, 1973); *Presbytis johnii* (Poirier, 1970). They budget their active time depending on their requirement priorities.

The folivore primates like Golden langur, which consume a larger amount of leaves need much time to digest these plant materials for usable energy, so they are more sedentary in habit than the frugivore primates. Time-activity budget is good indicator of how a population is affected by alterations in habitat quality, food availability, and other environmental parameters. In the continuous primary habitat of Ultapani in Chirang RF Golden langur group spent 43% time on resting, 29.8% on feeding, 10% on locomotion, 7% on monitoring, 4.5% on playing, 2% on social grooming and 3% on other activities (Biswas, 2002). In the fragmented secondary habitat of Kakoijana RF, the Golden langur group spent 42.4 % time on resting, 30.4 % on feeding, 12.7 % on locomotion, 8.6 % on monitoring and surveillance, 1.6 % on playing, 1.9 % on social grooming and 2 % on other activities (Biswas, 2002). Biswas (2002) reported the home range size of Golden langurs as 25 ha and 58 ha for two groups with 434 m and 513.5 m of day path length. I studied the activity patterns and ranging patterns of three Golden langur groups in three different habitats *viz.*, forest core, forest edge and in a rubber plantation. I aimed to compare data on their ecology and behaviour to highlight complex questions related to their adaptation to altered habitat.

6.2 Methodology

Study area: Chakrashila WLS and adjoining Abhaya RP. Chakrashila WLS (45.58 km^2; 26°15′ to 26°26′N and 90°15′ to 90°20′E) is situated in Kokrajhar district, Assam, India. The sanctuary has hilly terrain covered with secondary moist deciduous forest (Champion and Seth, 1968; Bahuguna et al., 2016). The region receives subtropical monsoons, and has four distinct seasons namely pre monsoon, monsoon, retreating monsoon and winter based on monthly variations in temperature and rainfall (detailed in chapter 1).

Activity budget: Three selected Golden langur groups were followed for 4 to 6 days in a month from dawn to dusk between 0530 hr. and 1830 hr. During the group follows, the instantaneous scans were recorded (Altmann, 1974). All the diurnal activities of Golden langurs were recorded for fine minutes for every 15-minute interval. An ethogram of different activities was prepared and broadly categorized in (a) feeding, (b) resting, (c) locomotion/travel and (d) monitoring (Table 6.1). The other behaviours include all the remaining behaviour viz. a) grooming, b) vocalization, c) playing, d) sexual activity, e) aggression, f) vocalization and g) social activities. The activity budget was estimated using the frequency method (Oates, 1977), in which the contribution of each behavioural category was estimated by the number of occurrences in each scan. The proportion of activity records is calculated using the formula and expressed in percentage

$$I = \frac{n_i}{N} X\ 100$$

where n_i = number of activity records collected for behaviour i, N = total activity records collected during the study.

Proportions of behaviours were compared across seasons and across groups using G test of proportion.

Table 6.1 Description of ethogram of the major behaviours of the Golden langurs recorded during study period.

Activity	Description
Resting	This comprises of sleeping or sitting.
Feeding	Feeding on plants or any other resources. This includes food possession, processing and feeding.
Locomotion	Travel or movement for food resource access, lodging site selection and territory defence. Includes both horizontal and vertical movements.

Monitor	Individuals watching for potential threats or being vigilant after noticing other group in the vicinity.
Social	Behaviours comprising of grooming, play, courtship and mating and agonistic interactions with other group members.

Ranging: While following the study group, geocoordinates of the visually approximated group center were recorded using handheld GPS at 30 minutes interval. Day path lengths were calculated by connecting the minimum distance of the two points on a time scale. The data from complete follows from dawn to dusk were used to estimate the day path length. The normality test was performed for the day path length data using the Shapiro-Wilk test. Mean day path length was compared across the seasons and groups using one way ANOVA with Tukey's post-hoc correction. Taking the maximum limit of the group spread into consideration, 50x50 m grid cells were laid on the home-range areas of each group. Home range area were estimated as the number of grid cells covered by all the location points. Location points gathered in each grid cell was counted as a measure of the intensity of home range use. The intensity was expressed as proportions for each season and for annual using the formula.

$$Grid\ use\ proportion = \frac{Number\ of\ points\ in\ a\ given\ grid\ cell}{Total\ number\ of\ points\ recorded}\ X\ 100$$

Comparative assessment between seasons and across groups was performed to identify spatio-temporal variation in the data.

6.3 Results

A total of 70429 activity records were collected from the three groups together in 1955 hours of observation between September 2013 and June 2017. Data of the forest core group in the monsoon season was not collected due to heavy rain and extremely difficult terrain with dense ground vegetation and slippery mud. The total effort and details of the data is shown in Table 6.2.

Table 6.2 Details of effort given for scan sampling for each study group

Forest core group				
Season	Hours	Instance	Total activity records	Activity records per instance
Pre monsoon	169.5	678	3612	5.33
Retreating monsoon	119	476	2492	5.24
Winter	164	656	3787	5.77
Annual	452.5	1810	9891	5.46
Forest edge group				
Season	Hours	Instance	Total activity records	Activity records per instance
Pre monsoon	194	776	6783	8.74
Monsoon	265	1060	9211	8.69
Retreating monsoon	167.5	670	6160	9.19
Winter	162.5	650	7095	10.92
Annual	789	3156	29249	9.27
Rubber plantation group				
Season	Hours	Instance	Total activity records	Activity records per instance
Pre monsoon	157	628	6360	10.13
Monsoon	217	868	9792	11.28
Retreating monsoon	156.5	626	6931	11.07
Winter	183	732	8206	11.21
Annual	713.5	2854	31289	10.96

Table 6.3 Proportion of seasonal activity budget of forest core group

Activities	Pre monsoon N= 3612	Retreating monsoon N= 2492	Winter N= 3787	G-test of proportions
Rest	50.69	50.12	51.89	G=1.03, df=3, P=0.794
Feed	27.77	26.40	27.52	G=1.09, df=3, P=0.779
Locomotion	13.73	15.01	12.49	G=7.084, df=3, P=0.069
Monitoring	2.85	3.49	3.06	G=1.936, df=3, P=0.586
Social	4.96	4.98	5.04	G=0.031, df=3, P=0.999

A total 9891 activity records were collected in 452.5 hours of observation of the forest core group. The highest proportion of time spent was on resting (51.01%) followed by feeding (27.33%), locomotion (13.58%), social (4.99%) and monitoring (3.09%). The proportion of time spent on the same activity did not vary significantly across the seasons (Table 6.3).

A total of 29249 activity records were collected in 789 hours of observation for the forest edge group. The proportion of time spent by the group on resting was 50.55%, feeding was 26.83%, locomotion was 13.04%, monitoring was 4.73% and social was 4.85%. The proportion of time spent on the same activity varied significantly between the seasons (Table 6.4).

Table 6.4 Proportion of seasonal activity budget of forest edge group

Activities	Pre monsoon N=6783	Monsoon N=9211	Retreating monsoon N=6160	Winter N=7095	G-test of proportions
Rest	53.97	48.83	48.78	51.05	G=25.017,df=4,P<0.001
Feeding	25.37	26.41	27.73	27.98	G=11.331,df=4,P<0.050
Locomotion	11.18	13.26	14.34	13.4	G=27.729,df=4,P<0.001
Monitoring	5.23	6.68	3.18	3.06	G=152.154,df=4,P<0.00
Social	4.25	4.82	5.97	4.51	G=22.009,df=4,P<0.001

In 713.5 hours of observations in rubber plantations, a total of 31289 activity records were collected. The proportion of time spent on resting was 43.81%, feeding was 25.27%, locomotion was 17.60%, monitoring was 5.39% and social was 7.93%. The proportion of time spent on the same activity varied significantly across the seasons (Table 6.5).

Table 6.5 Proportion seasonal activity budget of rubber plantation group

Activities	Pre monsoon N=6360	Monsoon N=9792	Retreating monsoon N=6931	Winter N=8206	G-test of proportions
Rest	45.82	44.87	41.26	43.14	G=19.579,df=4,P<0.001
Feeding	23.5	26.9	24.96	24.95	G=18.676,df=4,P<0.001
Locomotion	15.19	16.29	19.94	19.06	G=62.175,df=4,P<0.001
Monitoring	6.59	5.83	4.65	4.57	G=37.528,df=4,P<0.001
Social	8.9	6.11	9.19	8.28	G=66.263,df=4,P<0.001

The proportion of time spent by groups in forest core and forest edge were similar except monitoring which is more in forest edge group compared to forest core group. On the other hand, the group in rubber plantation were found less resting and feeding over locomotion and social activities. Proportion of time spent annually on same activity varied significantly across the habitats for resting (G=173.005, df=3, P<0.001), feeding (G=19.539, df=3, P<0.001), locomotion (G=225.106, df=3, P<0.001), monitoring (G=90.964, df=3, P<0.001) and social activities (G=255.063, df=3, P<0.001).

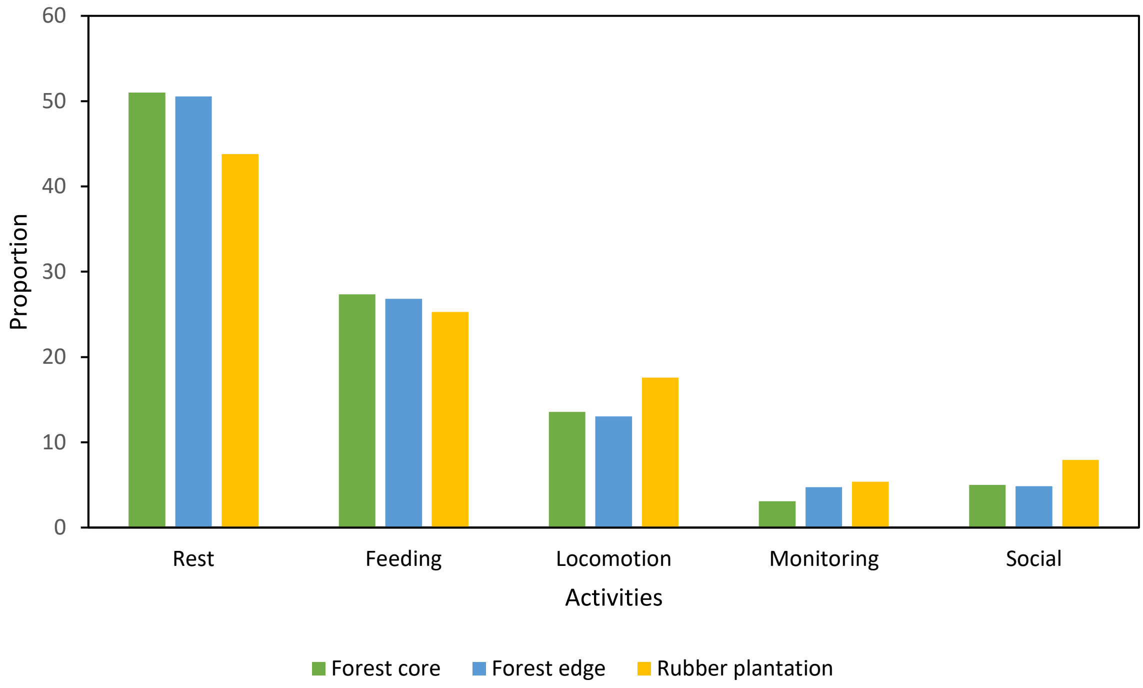


Figure 6.1 The percent annual activity budget of three study groups

The day path length of the three Golden langur groups was tested using the Shapiro-Wilk test which showed that the data is not normally distributed for forest core group (W=0.861, P<0.001, Skewness=1.504), forest edge group (W=0.901, P<0.001, Skewness=1.222) and rubber plantation group (W=0.936, P<0.01, Skewness=0.957). The skewness value for the three groups lay between -1.96 to 1.96 which is the acceptable range and hence I have performed the parametric test to compare the data on day path length. Day follows with >8 h of data were not statistically different from full (>10 to 12 h) days for forest core group (N=45) (*t*=-0.917, df=43, *p*=0.364), forest edge group (N=73) (*t*=-1.593, df=71, *p*=0.116) and rubber plantation group (N=67) (*t*= -0.882, df= 65, *p*= 0.381). In the forest core group, total observation was 466 hours with an average of 10.36 hours per day, ranging from 8–12.5 hours per day. The day path length ranged from 137.27 m to 912.82 m, with 80% falling between 191.57 m and 554.31 m. In the forest edge group, total observation was 803.5 hours with an average of 11.01 hours per day, ranging from 8–13 hours per day. The day path length ranged from 129.21 to 1047.35 m, with 80% falling between 233.24 and 664.18 m. In the rubber plantation group, total observation was 720 hours with an average of 10.75 hours per day, ranging from 8–12.5 hours per day. The day path length ranged from 171.75 m to 1297.01 m, with 80% falling between 237.76 and 889.05 m.

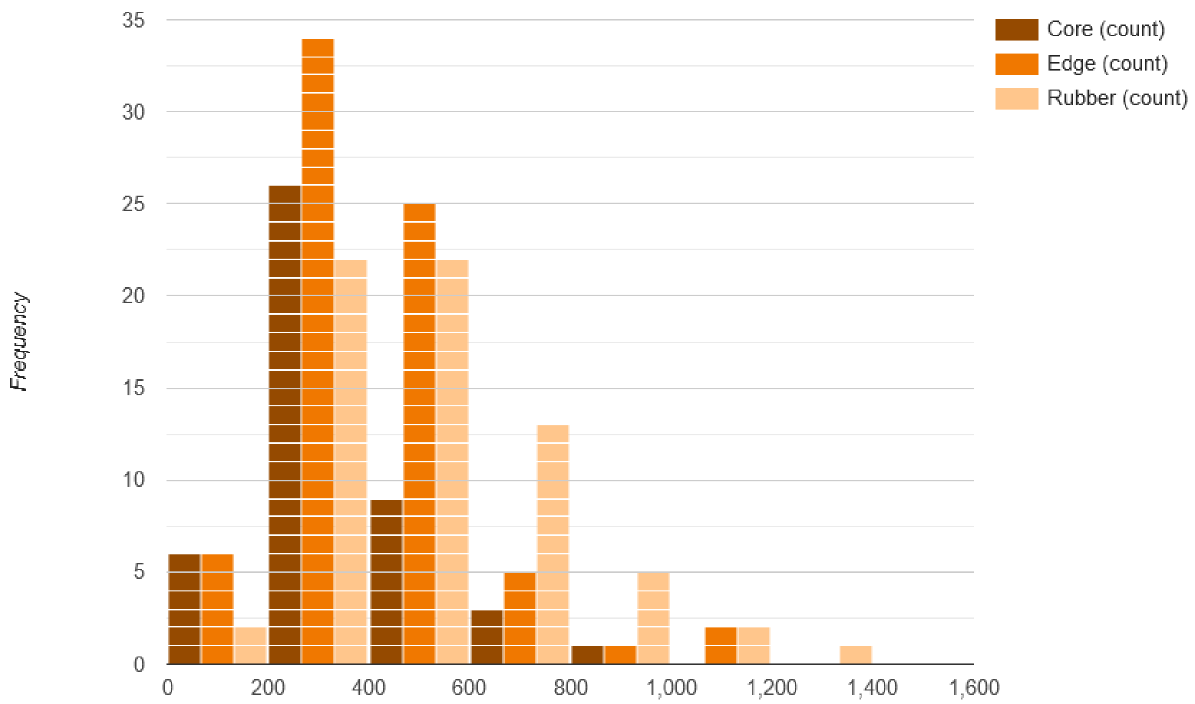


Figure 6.2 Frequency histogram of day path length of Golden langur groups in different habitats.

The mean annual day path length of forest core group was $339.11 \pm 167.67_{SD}$ m (Table 6.6) which did not vary significantly across the seasons (ANOVA, $F_{2,42}= 1.251$, $P= 0.297$).

Table 6.6 Day path length of forest core group in metre

Group	N	Mean	Median	SD	SE	Range
Pre monsoon	16	324.91	257.25	159.49	39.87	157.64 - 726.12
Retreating monsoon	11	407.29	361.67	216.57	65.29	191.57 - 912.82
Winter	18	310.06	267.95	136.51	32.18	137.27 - 687.66
Annual	45	339.11	281.17	167.67	24.99	137.27 - 912.82

The mean annual day path length of the forest edge group was $416.57 \pm 184.87_{SD}$ m (Table 6.7) which did not vary significantly across the seasons (ANOVA, $F_{3,69}$= 1.744, P= 0.166).

Table 6.7 Day path length of forest edge group in metre

Group	N	Mean	Median	SD	SE	Range
Pre monsoon	18	485.00	340.68	192.52	45.38	238.26 – 1005.91
Monsoon	24	412.94	358.91	211.17	43.10	129.21 – 1047.35
Retreating monsoon	15	419.66	385.11	115.06	29.70	275.84 – 713.56
Winter	16	342.14	328.54	172.49	43.12	177.34 – 813.91
Annual	73	416.57	383.91	184.87	21.64	129.21 – 1047.35

The mean annual day path length of the rubber plantation group was $519.58 \pm 241.27_{SD}$ m (Table 6.8) which varied significantly across the seasons (ANOVA, $F_{3,63}$= 3.183, P< 0.05).

Table 6.8 Day path length of rubber plantation group in metre

Group	N	Mean	Median	SD	SE	Range
Pre monsoon	14	523.04	520.11	217.09	58.02	204.10 – 993.24
Monsoon	19	397.04	371.23	149.38	34.27	181.55 – 678.00
Retreating monsoon	15	636.72	555.22	228.00	58.87	367.69 – 1069.20
Winter	19	547.11	470.92	297.60	68.27	171.75 – 1297.01
Annual	67	519.58	463.16	241.27	29.48	171.75 – 1297.01

One-way Analysis of Variance (ANOVA) shows that mean annual day path length among the three groups have significant difference ($F_{2,182}$= 11.0787, P<0.001) and Post Tukey's Honest Significant Difference (HSD) shows difference between forest edge – rubber plantation group (P<0.01) and forest core – rubber plantation group (P<0.001).

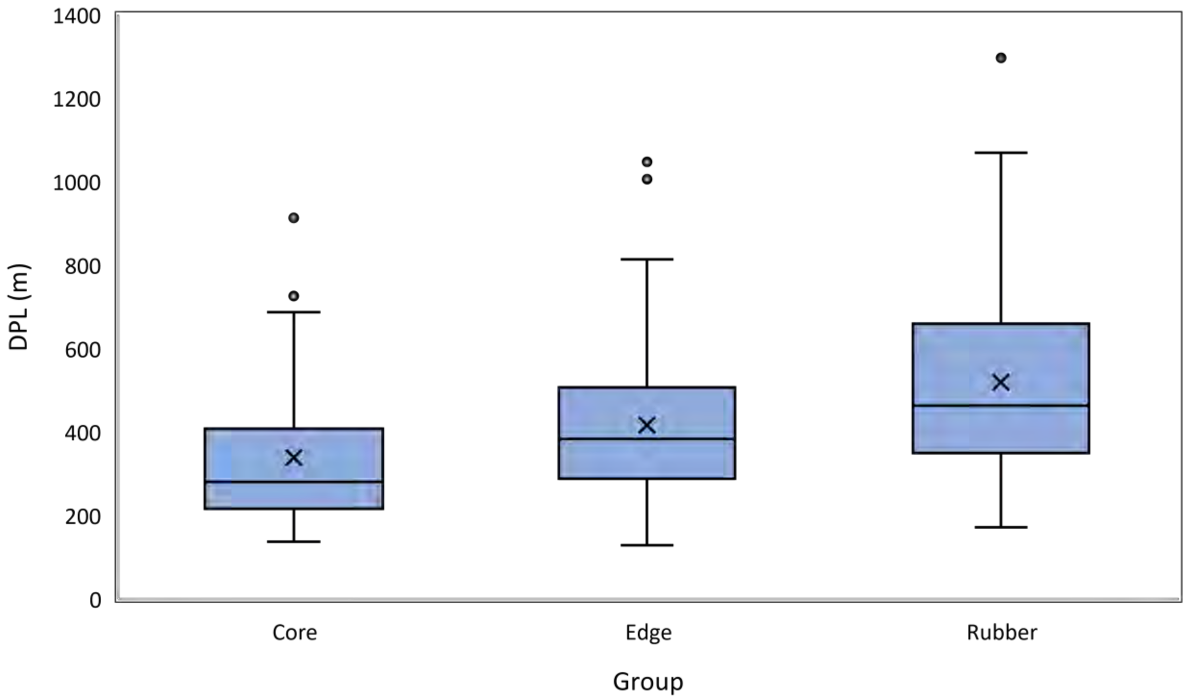


Figure 6.3 Day path length of the Golden langur groups in different habitats.

The Pearson correlation shows a negative relationship between mean monthly rainfall and day path length of forest core group (r= -0.289, p= 0.487), forest edge group (r= -0.005, p= 0.987) and rubber plantation group (r= -0.391, p= 0.209), however, the relationship was not significant. Relationship between mean monthly temperature and day path length was also found insignificant for forest core group (r= 0.210, p= 0.620), forest edge group (r= 0.250, p= 0.430) and rubber plantation group (r= -0.360, p= 0.240).

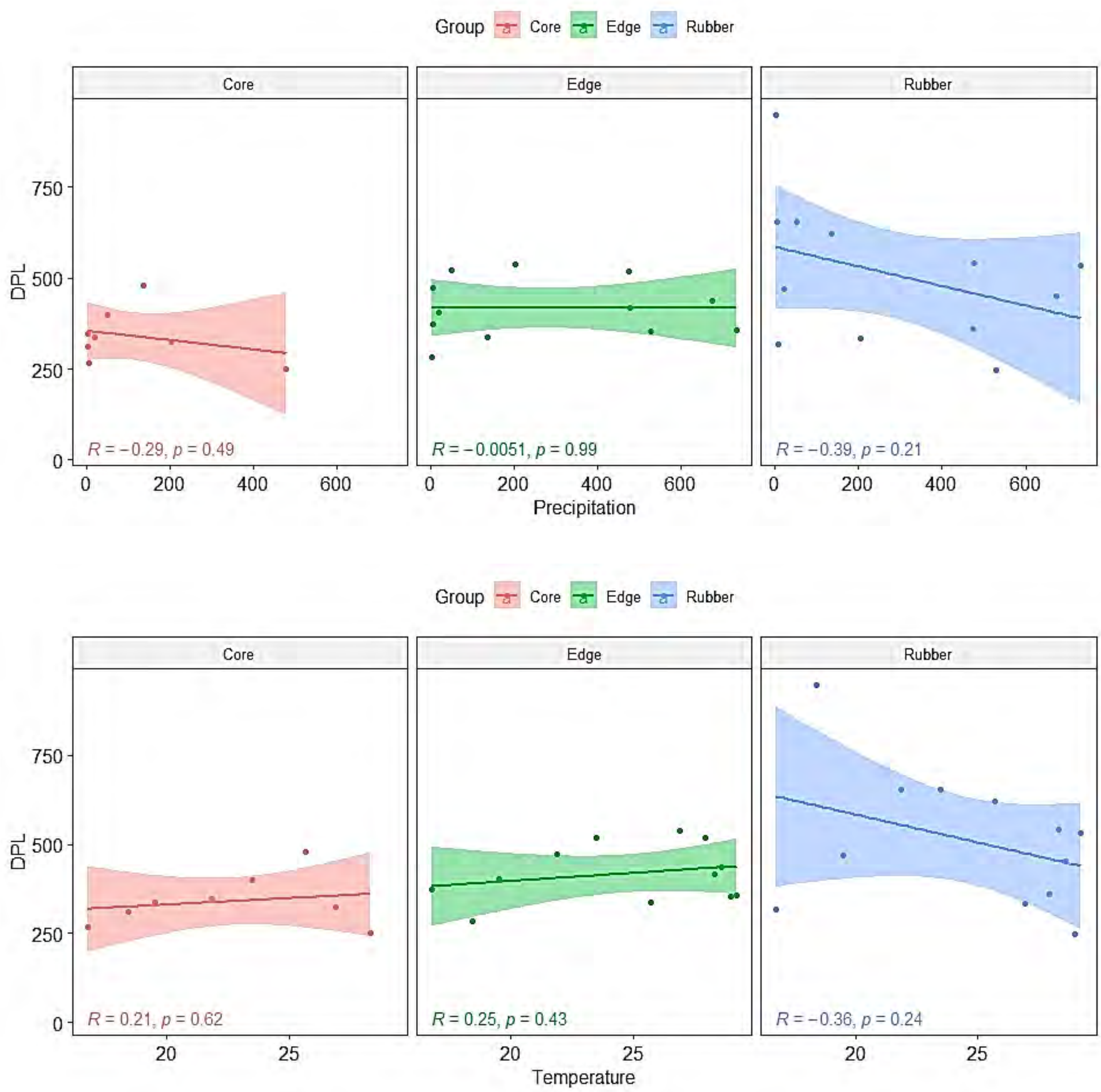


Figure 6.4 Pearson correlation between mean monthly precipitation and day path length and temperature day path length

A total of 4152 group locations of the three study groups were collected in 2076 hours. Grid cell used by forest core group was 116, forest edge group was 169 and rubber plantation group was 198. Home range area used by forest core group, forest edge group and rubber plantation group are respectively 29.00 ha, 42.25 ha and 49.50 ha, however, the spatial use of the habitat by each group seasonally varied (Table 6.9 – 6.11).

Table 6.9 Home-range details of forest core group

Season	Tracking time (in hours)	Total group locations	Number of grids	Home-range size (Ha)
Pre monsoon	195.0	390	67	16.75
Retreating monsoon	113.5	227	59	14.25
Winter	165.0	330	53	13.25
Annual	473.5	947	116	29.00

Table 6.10 Home-range details of forest edge group

Season	Tracking time (in hours)	Total group locations	Number of grids	Home-range size (Ha)
Pre monsoon	198.0	396	100	25.00
Monsoon	264.0	528	77	19.25
Retreating monsoon	247.0	494	84	21.00
Winter	157.5	315	72	18.00
Annual	866.5	1733	169	42.25

Table 6.11 Home-range details of rubber plantation group

Season	Tracking time (in hours)	Total group locations	Number of grids	Home-range size (Ha)
Pre monsoon	151.0	302	101	25.25
Monsoon	198.5	397	72	18.00
Retreating monsoon	212.0	424	111	27.75
Winter	174.5	349	115	28.75
Annual	736.0	1472	198	49.50

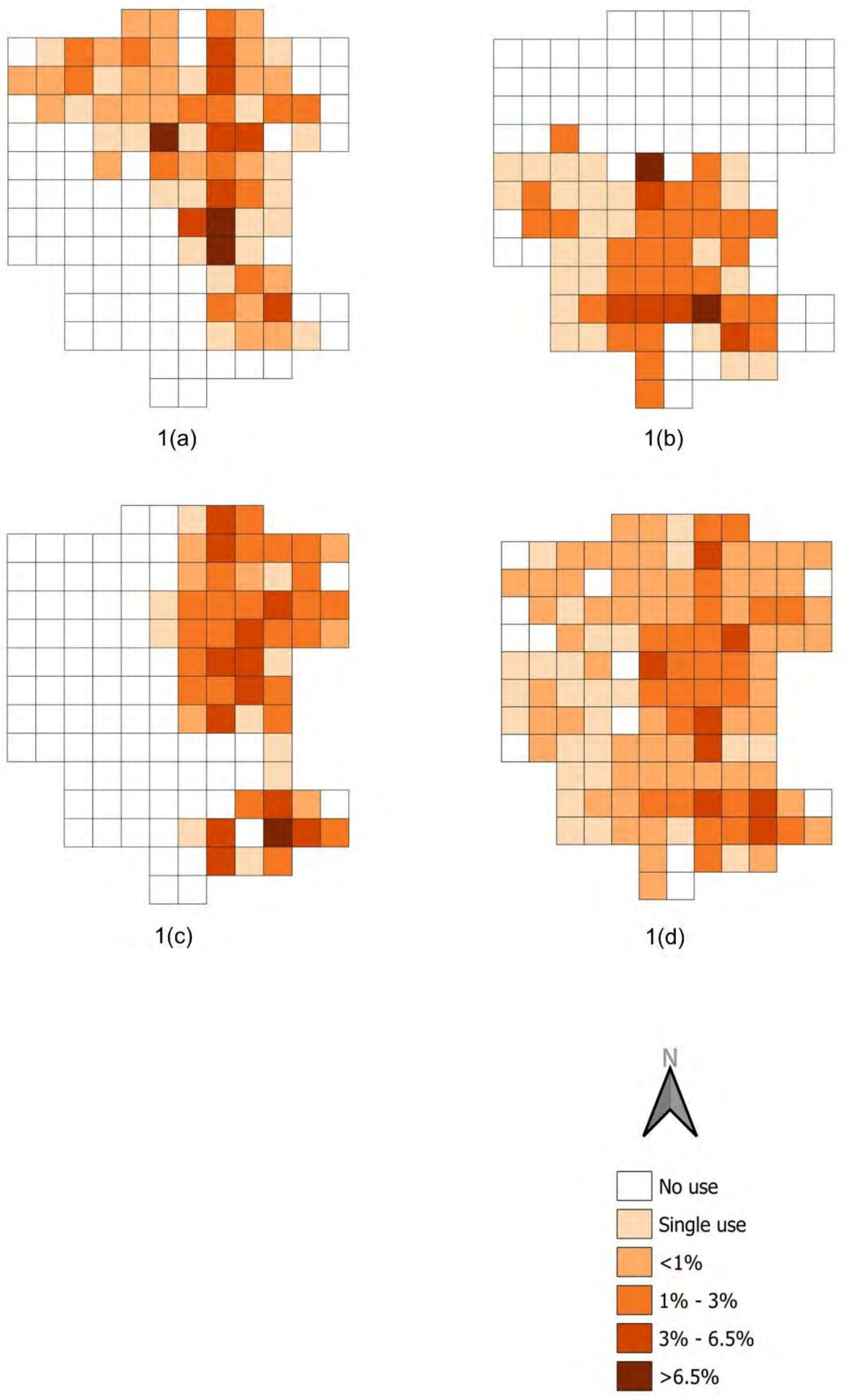


Figure 6.5 Grid use intensity of 1. forest core group (a) pre monsoon, (b) retreating monsoon, (c) winter, (d) annual. Each cell size is 50x50 m (0.25 Ha).

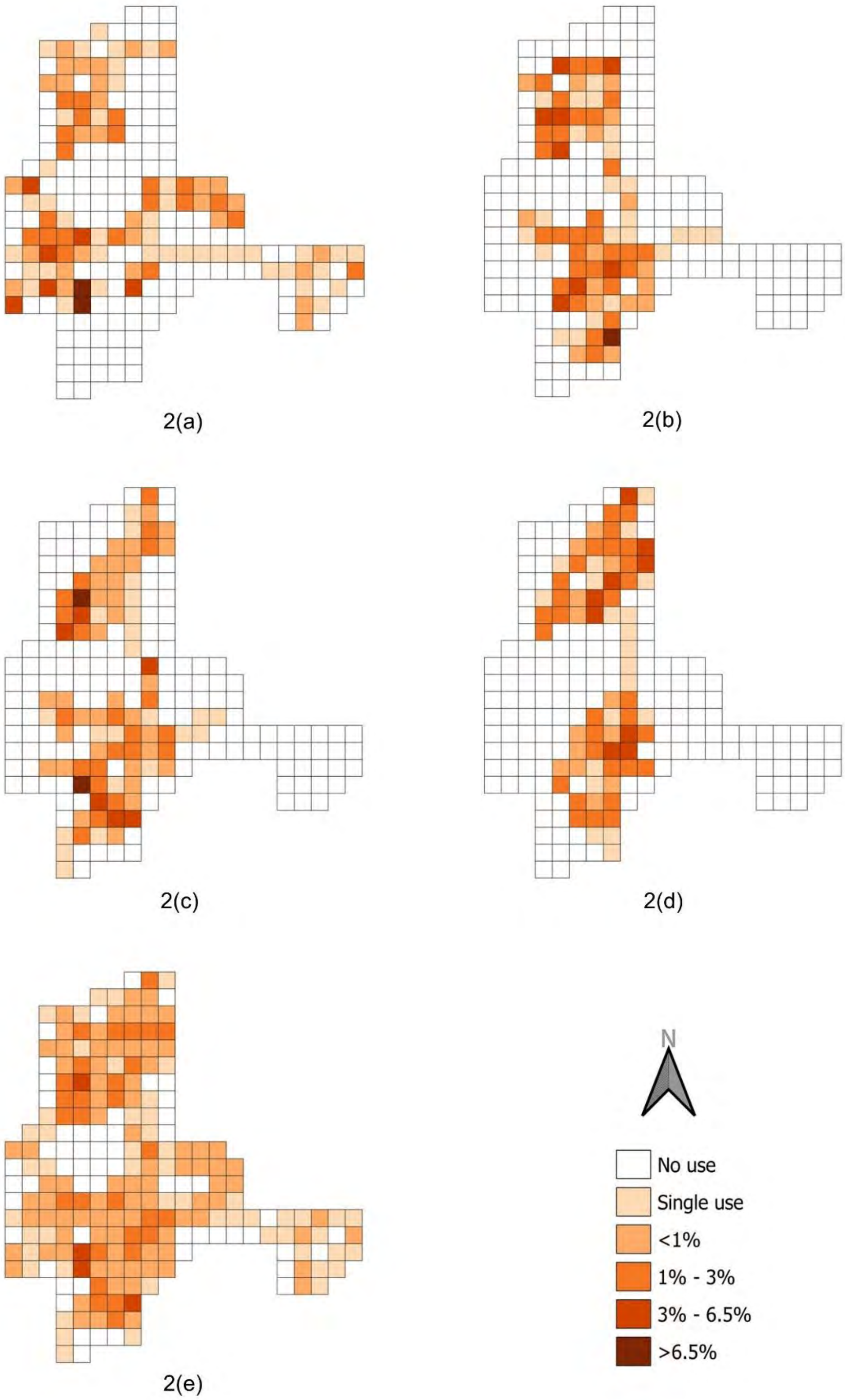


Figure 6.6 Grid use intensity of 2. forest edge group (a) pre monsoon, (b) monsoon, (c) retreating monsoon, (d) winter, (e) annual. Each cell size is 50x50 m (0.25 Ha).

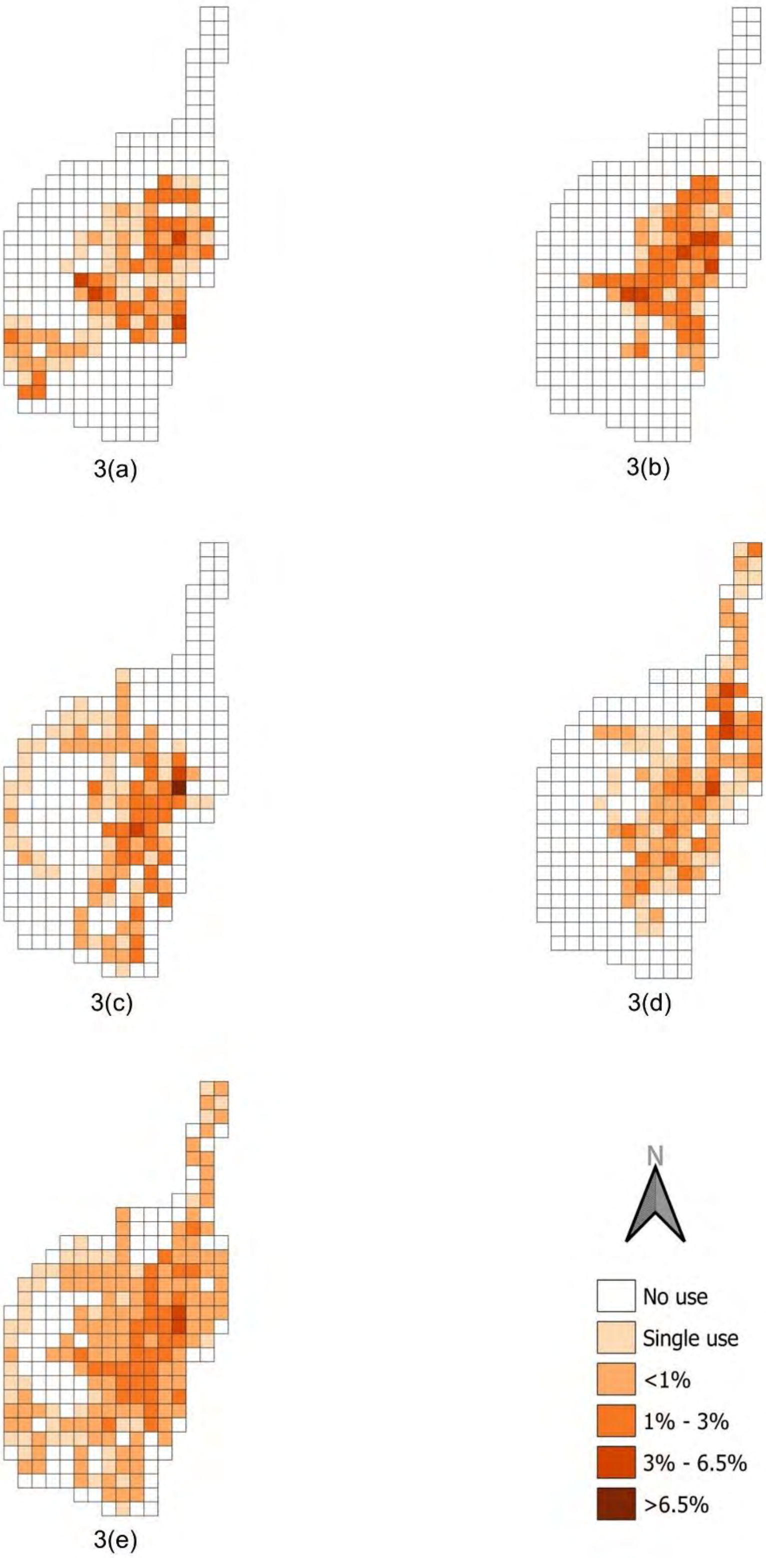


Figure 6.7 Grid use intensity of 3.Rubber plantation group (a)pre monsoon, (b)monsoon, (c)retreating monsoon, (d)winter, (e)annual. Each cell size is 50x50 m (0.25 Ha).

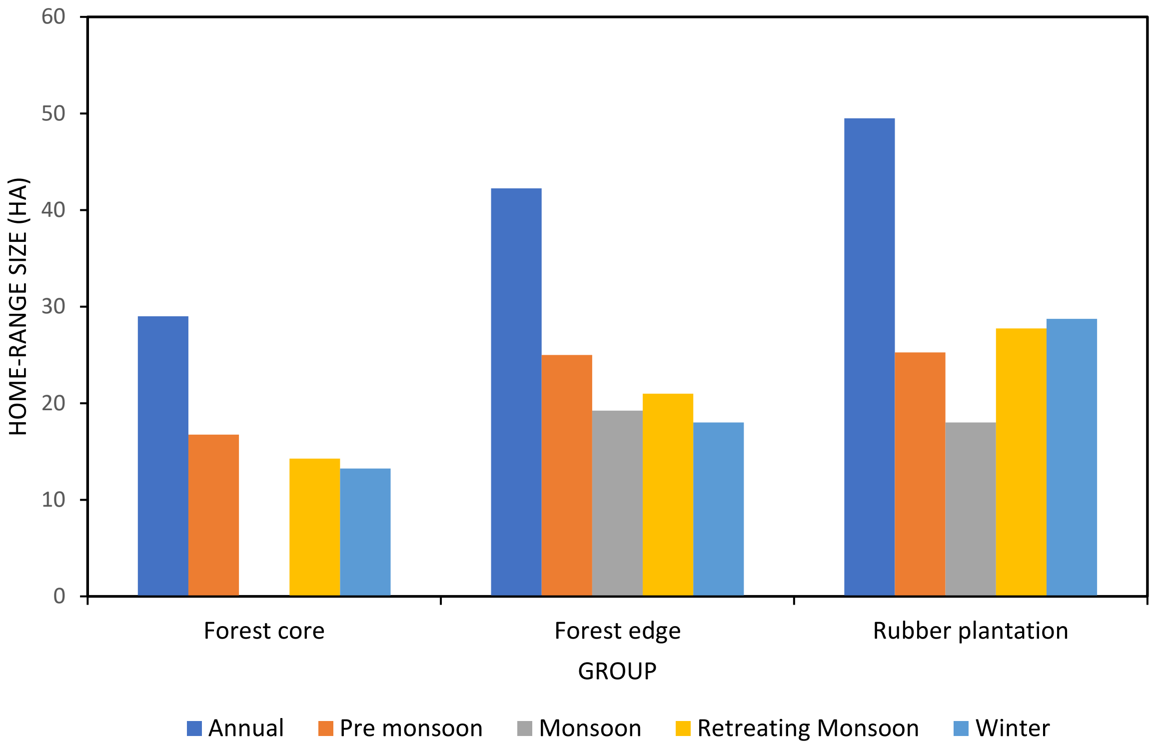


Figure 6.8 Annual home range sizes of Golden langur groups in different habitats.

The Golden langur groups in three different habitats used their total home range with a spatiotemporal variation. Different grid cells were used in different seasons depending on diet preference, availability of food resources and lodging trees in the particular grid at a particular time. Some grids are exclusively used in a particular season whereas others are used throughout the years. Grid use intensity also varied seasonally and annually among the grids for the three groups. The number of grid cell use and intensity of use has been shown in colour gradient maps (Figure 6.5 – Figure 6.7).

6.4 Discussion

Activity budget is an analytical tool to know, how a particular primate species prioritises its daily activity over time to maximize its net energy gain. It is also instrumental in characterising their lifestyle and develop understanding of interdependence of ecology and ethology (Struhsaker and Leland, 1979). Golden langurs spent most of their active time resting than feeding and travelling, which is typical to folivorous primates (Stanford, 1991) as described for some other Colobine species. Like other primates, there are several advantages for the Golden langur to remain in a circumscribed area. The group may develop cognition of the distribution and phenophases of food plants, shelter location, water holes and direct route between the resources (Dunbar, 1988). The rubber plantation group spent more time on locomotion to access the scarcely distributed patches of food resources by minimising resting time compared to the other two groups. Home range estimations focus on what habitats are essential for a species and how it might respond to environmental variation (Mitani et al., 2010; Powell and Mitchell, 2012). The dispersion and abundance of food influenced the daily activity pattern including ranging behaviour. Comparison of seasonal and annual mean day path length and home range size of Golden langur in three different habitat conditions suggest an increased day path length and home range size in the more disturbed area. The relationship of day path length with rainfall and temperature is insignificant for the three groups. Group size is also another factor that influences the space used to gather more resources by increasing travel time for foraging to reach the patchily distributed isolated food resources. The adjustment of annual and seasonal budget and daily activity patterns of Golden langurs in different habitats with variable size and disturbance gradient suggested that fragment size and habitat characteristics influence the activity and ranging pattern.

The availability of more leaves in monsoon and more flowers and fruits in dry seasons affect the seasonal activity budget and range size (Hendershott et al., 2018). When high-calorie foods were ample feeding time decreases (Hanya, 2004). As folivory is inversely proportional to travel time and day path length for colobines, increase in their home range has been observed with decrease in folivory (González Monge, 2016; Grueter et al., 2013). A similar pattern was observed with Golden langurs in this study. The results also suggest that the activity budget of Golden langurs is directly related to the food availability in the habitat. The comparative study of Golden langur inhibiting in different habitat conditions revealed that a marked constancy of feeding time and patterns throughout the study, relative to resting and feeding emphasised uniform trend of activity pattern. They spent more time resting than feeding in habitats with high food value. They were observed to feed and forage more often than rest in habitat with less food value, possibly to maintain the balance demand and supply of energy for different activities.

Abbreviations

ASL	Above sea level
DPL	Day path length
GBH	Girth at breast height
MYA	Million years ago
NP	National Park
RF	Reserved Forest
RP	Rubber Plantation
WLS	Wildlife Sanctuary

Appendices

Supplementary Table 1: Demographic parameters of Golden langurs in different groups and year

Group habitat	Group ID	Year	Group size	AM	AF	IMM	INF	AM:AF	AD:IMM	AF:IMM	AF:INF	No. of births	Birth rate (per female)	Birth rate (per group size)
Forest core	TPD	2013	6	1	3	2	0	3.00	0.50	0.67	0.00	0	0.00	0.00
Forest core	TPD	2014	7	1	3	3	1	3.00	0.75	1.00	0.33	1	0.33	0.14
Forest core	TPD	2015	8	1	4	3	2	4.00	0.60	0.75	0.50	1	0.25	0.13
Forest core	TPD	2016	8	1	4	3	1	4.00	0.60	0.75	0.25	0	0.00	0.00
Forest core	BPN	2013	11	2	5	4	2	2.50	0.57	0.80	0.40	2	0.40	0.18
Forest core	BPN	2014	9	1	5	3	2	5.00	0.50	0.60	0.40	2	0.40	0.22
Forest core	BPN	2015	9	1	5	3	0	5.00	0.50	0.60	0.00	0	0.00	0.00
Forest core	BPN	2016	10	1	5	4	1	5.00	0.67	0.80	0.20	1	0.20	0.10
Forest core	IMK	2013	6	1	3	2	1	3.00	0.50	0.67	0.33	0	0.00	0.00
Forest core	IMK	2014	5	1	2	2	1	2.00	0.67	1.00	0.50	2	1.00	0.40
Forest core	IMK	2015	6	1	2	3	2	2.00	1.00	1.50	1.00	1	0.50	0.17
Forest core	IMK	2016	6	1	2	3	2	2.00	1.00	1.50	1.00	0	0.00	0.00
Forest core	BST	2013	6	1	4	1	0	4.00	0.20	0.25	0.00	0	0.00	0.00
Forest core	BST	2014	6	1	4	1	0	4.00	0.20	0.25	0.00	0	0.00	0.00
Forest core	BST	2015	8	1	4	3	2	4.00	0.60	0.75	0.50	1	0.25	0.13
Forest core	BST	2016	8	1	4	3	2	4.00	0.60	0.75	0.50	1	0.25	0.13
Forest edge	BPS	2013	10	2	5	3	0	2.50	0.43	0.60	0.00	0	0.00	0.00
Forest edge	BPS	2014	13	2	6	5	4	3.00	0.63	0.83	0.67	4	0.67	0.31
Forest edge	BPS	2015	14	2	6	6	5	3.00	0.75	1.00	0.83	1	0.17	0.07
Forest edge	BPS	2016	18	2	9	7	3	4.50	0.64	0.78	0.33	2	0.22	0.11
Forest edge	TPB	2013	11	1	4	6	2	4.00	1.20	1.50	0.50	1	0.25	0.09
Forest edge	TPB	2014	13	1	6	6	2	6.00	0.86	1.00	0.33	2	0.33	0.15
Forest edge	TPB	2015	13	1	6	6	3	6.00	0.86	1.00	0.50	2	0.33	0.15

Forest edge	TPB	2016	11	1	6	4	3	6.00	0.57	0.67	0.50	0	0.00	0.00
Forest edge	JNE	2013	13	2	5	6	3	2.50	0.86	1.20	0.60	0	0.00	0.00
Forest edge	JNE	2014	14	2	5	7	3	2.50	1.00	1.40	0.60	1	0.20	0.07
Forest edge	JNE	2015	14	2	5	7	3	2.50	1.00	1.40	0.60	2	0.40	0.14
Forest edge	JNE	2016	16	2	7	7	4	3.50	0.78	1.00	0.57	1	0.14	0.06
Forest edge	SLB	2013	12	1	3	8	2	3.00	2.00	2.67	0.67	1	0.33	0.08
Forest edge	SLB	2014	10	1	5	4	1	5.00	0.67	0.80	0.20	0	0.00	0.00
Forest edge	SLB	2015	10	1	5	4	2	5.00	0.67	0.80	0.40	1	0.20	0.10
Forest edge	SLB	2016	11	1	5	5	2	5.00	0.83	1.00	0.40	1	0.20	0.09
Rubber plantation	TLC	2013	12	1	5	6	4	5.00	1.00	1.20	0.80	4	0.80	0.33
Rubber plantation	TLC	2014	15	1	6	8	4	6.00	1.14	1.33	0.67	3	0.50	0.20
Rubber plantation	TLC	2015	16	1	7	8	4	7.00	1.00	1.14	0.57	3	0.43	0.19
Rubber plantation	TLC	2016	16	1	7	8	4	7.00	1.00	1.14	0.57	0	0.00	0.00
Rubber plantation	CTS	2013	9	2	4	3	1	2.00	0.50	0.75	0.25	0	0.00	0.00
Rubber plantation	CTS	2014	11	2	4	5	3	2.00	0.83	1.25	0.75	2	0.50	0.18
Rubber plantation	CTS	2015	11	2	4	5	3	2.00	0.83	1.25	0.75	0	0.00	0.00
Rubber plantation	CTS	2016	11	2	4	5	3	2.00	0.83	1.25	0.75	0	0.00	0.00
Rubber plantation	OFC	2013	15	2	5	8	3	2.50	1.14	1.60	0.60	0	0.00	0.00
Rubber plantation	OFC	2014	16	3	6	7	4	2.00	0.78	1.17	0.67	1	0.17	0.06
Rubber plantation	OFC	2015	16	3	6	7	4	2.00	0.78	1.17	0.67	0	0.00	0.00
Rubber plantation	OFC	2016	16	3	6	7	4	2.00	0.78	1.17	0.67	0	0.00	0.00
Rubber plantation	GDW	2013	14	1	7	6	4	7.00	0.75	0.86	0.57	1	0.14	0.07
Rubber plantation	GDW	2014	14	1	7	6	4	7.00	0.75	0.86	0.57	0	0.00	0.00
Rubber plantation	GDW	2015	15	1	7	7	4	7.00	0.88	1.00	0.57	1	0.14	0.07
Rubber plantation	GDW	2016	15	1	7	7	4	7.00	0.88	1.00	0.57	0	0.00	0.00

Primates
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ORIGINAL ARTICLE

Influence of habitat conditions on group size, social organization, and birth pattern of golden langur (*Trachypithecus geei*)

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Abstract
We studied endangered golden langurs in fragmented and altered habitats to understand the consequences of habitat conditions on group size, social organization, and birth seasonality. We selected 12 groups inhabiting forest edge and forest core of Chakrashila Wildlife Sanctuary (henceforth Chakrashila WLS) and adjoining the Abhaya rubber plantation. Each group was monitored every month from May 2013 to September 2016 and recorded the age–sex of individuals in the group. The births were recorded with the individual identity of females in five focal groups. The overall group size of golden langur was $11.3 \pm 3.5_{SD}$, and ranged between 5 and 18. The mean group size in forest core, forest edge, and rubber plantation differed significantly. We recorded a total of 46 births in 12 groups across the three different habitats. The number of infants correlates positively with adult females and group size across all the 12 groups for all the years. The number of births that occurred in all the months varied significantly across the months. Births occurred in all the months but peaked between May and September (82.6%). The mean number of births positively correlated with mean monthly rainfall. Mean inter-birth interval was $24.5 \pm 1.6_{SD}$ months that did not vary between the females. It therefore appears that group size is sensitive to forest type, and births are positively related to social and environmental factors. The behavioral parameters may influence life-history traits if continuous habitat alteration persists.

Keywords Endangered colobine · Habitat alteration · Social structure · Birth seasonality · Birth interval

Introduction

Habitat loss and fragmentation are among the primary causes of biodiversity loss worldwide (McGarigal and Cushman 2002; Hanski 2011). As deforestation and habitat fragmentation continue at alarming rates throughout the world, perhaps the survival of many forest species largely depends on their ability to cope with such changes (Robinson and Ramirez 1982; Marsh et al. 1987; Noss and Csuti 1994). Primates are among the world's most threatened taxa (Mittermeier and Oates 1985; Rylands et al. 2008; Schipper et al. 2008) and they commonly occur in landscapes subjected to a high degree of habitat modification (Schipper et al. 2008; Marsh et al. 2013). Different primate species respond differently to habitat loss and fragmentation (Bicca-Marques 2003; Chapman et al. 2006, 2007; Anderson et al. 2007a,b; Bicca-Marques et al. 2009; Boyle and Smith 2010; Arroyo-Rodriguez et al. 2013). The higher densities of a species were reported in small fragments compared to large, while some studies reported the opposite (Goncalves et al. 2003;

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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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Habitat utilization and ranging pattern of Endangered Golden langur *Trachypithecus geei* in Chakrashila WLS, Assam, India

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Golden langur, *Trachypithecus geei* (Khajuria, 1956) also known as golden leaf monkey is an arboreal, canopy-dependent colobine monkey (Khajuria, 1978). It is an endangered (IUCN, 2008), endemic species inhabiting the political border areas of India and Bhutan (Choudhury, 2002; Srivastava et. al., 2001; Wangchuk, 2003). The study was carried out in a fragmented secondary forest of Chakrashila WLS to understand the effect of resource availability on resource utilization on peripheral population of golden langur in a secondary forest. One Golden langur troop (n = 11) from southern edge of the Chakrashilla WLS was selected for this study. Data was collected by Scan sampling method (Altman, 1974) from September 2013 to August 2015 for feeding, ranging and other behavior. The golden langur troop used an annual home range of 50.3 ha (MCP 95%). Seasonal home range at 95% MCP varied significantly $t=6.0165$, $df=3$, $P=0.0092 <0.05$. The troop showed folivory behavior with 58.7% leaf in their annual diet. Seasonal leaf consumption varied significantly $t=8.3551$, $df=3$, $P=0.0036 <0.05$ with high consumption in pre monsoon season n=79.5%. A simple regression equation was found $F(1,2)=84.75$, $P<0.05$ with $R^2=0.9769$. Use of habitat area was high with increased leaf consumption. Home range used was found higher in disturbed habitat as compared to the pristine forest (Biswas, 2002) and it depended on food availability.

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ABSTRACT NO. - 039

Habitat impact on social organization and birth pattern of golden langur *Trachypithecus geei*

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We studied golden langurs in fragmented and altered habitats to understand the consequences of habitat conditions on group size, social organization, and birth seasonality. We selected 12 troops inhabiting forest edge and forest core of Chakrashila Wildlife Sanctuary and adjoining Abhaya rubber plantation. Each group was monitored every month from May 2013 to September 2016 and recorded the age-sex of individuals in the group. The births were recorded with individual identity of females in five focal groups. The overall group size of golden langur was $11.3\pm3.5_{SD}$, and ranged between 5 and 18. The mean group size in forest core ($7.4\pm1.7_{SD}$), forest edge ($12.7\pm2.2_{SD}$) and rubber plantation ($13.9\pm2.3_{SD}$) differed significantly ($F_{2,45}=42.434$, $P<0.001$). We recorded a total of 46 births in twelve groups across the three different habitats. Number of infants correlates positively with adult females ($r=0.634$, $N=48$, $P<0.001$) and group size ($r=0.813$, $N=48$, $P<0.001$) across all the twelve groups for all the years. The number of births occurred in all the months varied significantly across the months ($N = 46$) ($\chi^2=22.870$, $df=11$, $P<0.05$). Births occurred in all the months but peaked between May and September (82.6%). Mean number of births was positively correlated with mean monthly rainfall ($r=0.858$, $N=12$, $P<0.001$). Mean inter-birth interval was $24.5\pm1.6_{SD}$ months that did not vary between the females ($N = 8$) ($\chi^2=0.735$, $df=7$, $P=0.998$). It therefore appears that group size is sensitive to forest type in golden langurs and birth is positively related with social and environmental factors. The behavioural parameters may further influence life history traits if continuous habitat alteration persist.

Keywords: Habitat alteration, social structure, birth seasonality, birth interval.

Conclusion

- The mean group sizes were significantly varied between the groups in different habitats, especially the groups in forest core had lesser than in other two habitats. In forest edges and degraded patches, food was likely not evenly distributed and scramble competition would be high for preferred food. Thus, golden langurs may have formed larger groups than making many smaller groups to avoid inter-group conflicts.
- Births occurred in all the months but peaked in monsoon season. Temporal variation in food abundance is one of the main factors suspected to determine the timing of reproduction. In a moist deciduous forest, leaves are more abundant during monsoon season, thus they can manage and reproduce even in the monsoon.
- The mean immature survival rate was 0.97±0.05SD which varied between 0.86 and 1 in different groups. Survival rate is high, since infanticide is not common in golden langurs and these fragments also has less predators.
- Food items consumed varied significantly across the seasons and across the groups with highest leaf consumption of leaf annually by all the three groups. Number of plant species consumed by Chakrashila core group, Chakrashila edge group and Nayekgaon rubber group are 39, 41 and 40 respectively. Food plant species are more different in rubber plantation than forest edge and forest core. Forest edge group can access the plants in the village which adds some other food plant species in their diet. This shows explosive foraging behaviour of golden langur.
- Mean annual day path length and seasonal day path length of golden langur in altered habitat (rubber plantation) varied significantly with the forest edge and forest core groups. Home-range use was found highest in rubber plantation group followed by forest edge and forest core group. Seasonal variation in size and space of home-range is observed in all the three groups. Larger groups travel more to compensate for their feeding cost or by eating more of the same foods or switch their diet if access to the preferred food was compromised. Also, the habitat condition and food availability affect their ranging pattern. In rubber plantation food plant availability is less and patchily distributed, which forces the golden langurs to travel more and expand their home-range over other two groups.

Summary

Summary

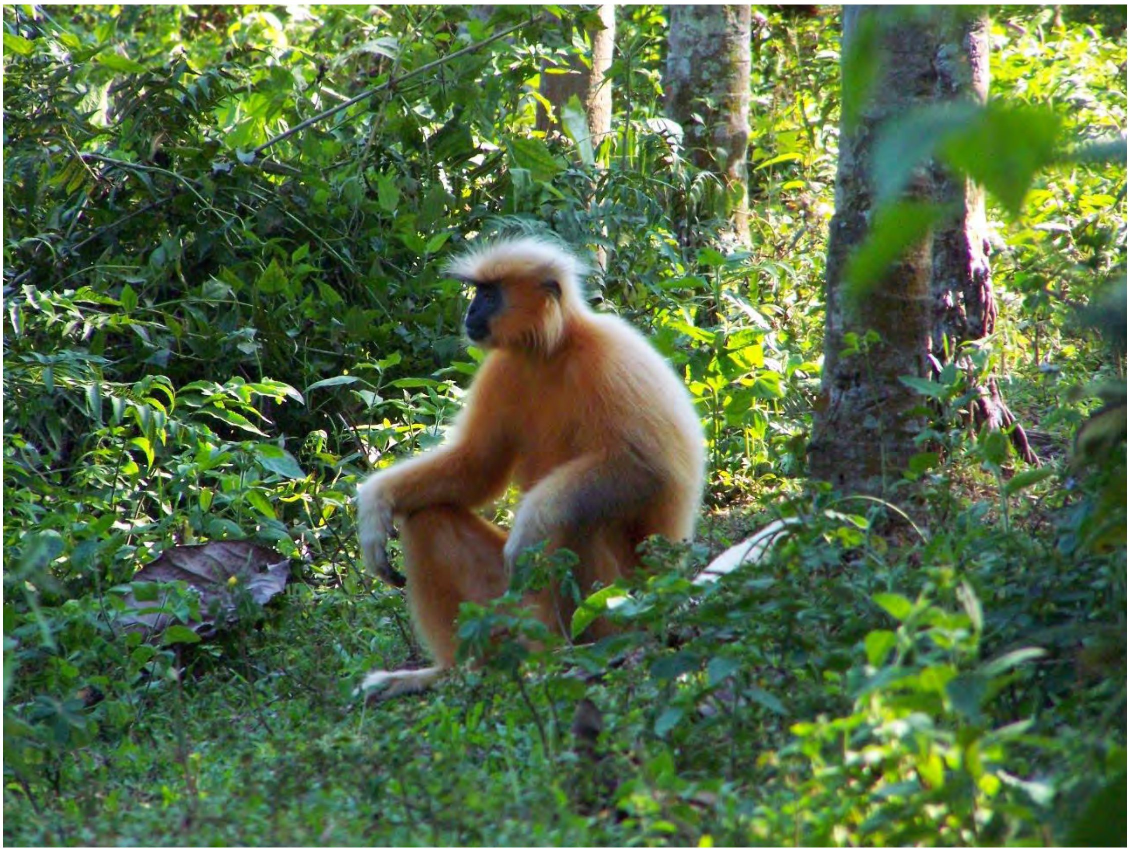
Golden langur (*Trachypithecus geei*) is an endangered and endemic leaf-eating monkey of Eastern Himalaya. The distribution of the southern population of India is restricted to small, isolated fragments. The langur is a forest specialist yet shows some extent of behavioural plasticity which helped them to continue to exist in degraded and altered habitats. Anthropogenic activities like logging, agriculture, human settlements, road and railway networks and other infrastructure built-ups resulted in habitat loss and fragmentation of its habitat that has pushed the species to explore human habitation, rubber plantation and other matrix patches which eventually make them vulnerable to threats like electrocution, dog attack and poaching. Though these negative impacts prevail, still the Golden langur persists in the forests of Chakrashila WLS and Abhaya RP. Chakrashila WLS retain a relatively stable population and also shows slow growth than in rubber plantation where a high fluctuation of population density has been observed over the few decades. Rubber plantations are an important part in connecting fragments and providing corridors for the Golden langur. These plantations are the preferred corridor and refuge of the langurs because of their tall height and continuous canopy cover which provide protection and keep the area at a lower temperature.

The group size of Golden langur depends on habitat conditions and resource availability. Forest core groups had a smaller mean group size than forest edge and rubber plantation groups. In forest edge, the group had the option to access more diverse food plants since edges are ecotones where diversity is always expected to be higher than either core inside or completely outside. The Golden langur group could access both forest plant species and species which are cultivated or grown in the home garden. To explore such diverse food plant species, nearby groups also look for the opportunity to get access to the resources. To defend territory from conspecific, groups in edges are expected to be larger. Larger group sizes are also benefitted during vigilance due to more individuals. On the other hand, groups in the rubber plantation maintained larger group sizes due to high population density to avoid intergroup conflicts by forming a few larger groups than many smaller groups. In forest core areas folivores like Golden langurs can form larger groups since leaves are evenly distributed and food cannot be a factor to limit group size. Yet in a habitat where

there is no choice to access exotic food plant species or scrambled competition is not required, group sizes are small, as small groups are more socially stable and less prone to intragroup conflicts. Golden langurs give births throughout the years but maximum in monsoon. In a moist and mixed deciduous forest, leaves are more abundant during monsoon, which can provide calory requirement during gestation period or compensate for the energy loss in the post gestation period. The immature survival rate was high since infanticide is not common in Golden langurs and these fragments also have fewer predators.

In the three habitat types of Golden langur, the tree cover and species composition were different. Forest edge and forest core had more similarities than the rubber plantation. Basal area in forest core was found less because of less abundance of matured trees since the area is disturbed to some degree by selective logging. On the other hand, forest edge includes many cultivated plant resources resulting in densely distributed moderately matured trees. Rubber plantation has more basal area compared to the tree density since rubber is the predominant species planted uniformly and have more girths. The number of plant species consumed by forest core group, forest edge group and rubber plantation group are not very different in species number but species composition. Food plant species are different in the rubber plantation than forest edge and forest core. The forest edge group can access the plants in the village which adds some other food plant species to their diet. To maintain the microbial environment for food fermentation in the forestomach, colobines need to eat a substantial quantity of leaves. Forest core group and edge group consumed leaf in high quantity during pre-monsoon season when new foliage is usually more abundant. For fermentation of the leaves, they also need more resting time than travelling. The group in rubber plantations spent more time on locomotion to access the scarcely distributed patches of food resources by minimising resting time compared to the other two groups. The dispersion and abundance of food influenced the daily activity pattern including ranging behaviour. Comparison of seasonal and annual mean day path length and home range size of Golden langur in three different habitat conditions suggest an increased day path length and home range size in the more disturbed area. Home-range use was highest in the rubber plantation group followed by forest edge and forest core group. Seasonal variation in size and space of home range is observed in the three groups. The habitat condition and food availability affect their ranging pattern. In the rubber plantation, food plant availability is less and patchily distributed, which forces the Golden langurs to travel more and expand their home range over the other two groups.

The social organisation and ecology of Golden langurs is dependent on food resources and roosting trees available in the habitat and continuity of the forest patches in the habitat. The comparative study of Golden langur shows the relationship between habitat type and activity and ranging pattern. Group size is another factor that influences the space used to access more resources by increasing travel time for foraging to reach the patchily distributed isolated food resources. The adjustment of annual and seasonal budget and daily activity patterns of Golden langurs in different habitats with variable size and disturbance gradient suggests that fragment size and habitat characteristics influence the activity and ranging pattern. Though the species has some degree of plasticity to adapt in degraded and altered habitat, for the persistence of viable population the remaining natural habitats need to be protected. As a long-term conservation strategy, the fragments need to be connected through the regeneration of required plant resources for effective migration and gene flow.



(Male Golden langur monitoring from the ground)

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