# How disturbed are the disturbed ones? Impacts of anthropogenic stresses on the socio-ecological interactions of Terai Gray langur (*Semnopithecus hector*) in Shivalik Hills.

**Dissertation submitted to the**
**Saurashtra University Rajkot, Gujarat**

**In partial fulfilment of**
**Master's Degree in Wildlife Science**

**By**

**Divya Dwivedi**

**Under the Supervison of**

**Dr. Bilal Habib**
**Prof. Qamar Qureshi**

**July, 2021**

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Wildlife Institute of India

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## DECLARATION

I, **Divya Dwivedi**, hereby declare that the research work entitled **"How disturbed are the disturbed ones? Impacts of anthropogenic stressors on the socio-ecological interactions of Terai Gray langur (*Semnopithecus hector*) in Shivalik Hills"**, carried out in partial fulfilment of M.Sc. (Wildlife Science) degree of Saurashtra University, Rajkot is an original piece of research work. This research work was carried out under the supervision of Dr. Bilal Habib and Prof. Qamar Qureshi, at the Wildlife Institute of India from January 2021 to July 2021. I hereby declare that this work has not been submitted for any other degree of any university.

Date: 17th August, 2021
Place: Dehradun

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XVII M.Sc. Wildlife Science

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# CERTIFICATE

This is to certify that **Ms. Divya Dwivedi** has carried out an original piece of research in partial fulfilment of Master's Degree in Wildlife Science of the Saurashtra University, Rajkot. The topic of her dissertation is **"How disturbed are the disturbed ones? Impacts of anthropogenic stressors on the socio-ecological interactions of Terai Gray langur (*Semnopithecus hector*) in Shivalik Hills".** The study was carried out under our supervision from January 2021 to July 2021. We hereby certify that this work has not been submitted for any degree to any university

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## CERTIFICATE OF PLAGIARISM CHECK

It is certified that the M.Sc thesis titled **"How disturbed are the disturbed ones? Impacts of anthropogenic stressors on the socio-ecological interactions of Terai Gray langur (*Semnopithecus hector*) in Shivalik Hills"** submitted by Ms. Divya Dwivedi has been examined by us for plagiarism check as per UGC (Promotion of Academic Integrity and Prevention of Plagiarism in Higher Educational Institutions) Regulations. The following inferences are drawn from this check:

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| | |
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| **[Dr. Bilal Habib]** | **[Prof. Qamar Qureshi]** |
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Date:

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# Summary

Animals respond to the changes in their habitats numerically and behaviourally. Alterations caused by anthropogenic stresses, like habitat degradation, fragmentation, urbanisation, changes in land use patterns, etc., changes the ecology of most species. Understanding the patterns adopted by these species to successfully survive and reproduce in such habitats is of utmost importance. This study tried to understand the impacts of human disturbance on the socio-ecology of Terai Gray langurs in Shivalik landscape, by comparing the ecology of langur troops inside the protected forest with the troops in disturbed forest. Four troops of Terai Gray langur, of comparable sizes, two in each treatment were selected.

Troops in undisturbed habitat spent more percentage of time on resting (43%) followed by feeding (19%), socialising (17%) and moving (14%) while troops in disturbed habitat reduced the percentage of time spent on resting (30%)and socialising (11%) with increasing their feeding (29%) and moving (26%) activities. The intensity of affiliative and agonistic interactions was observed using social networks. Interactions varied among different age-sex classes, between both the treatments. Troops in undisturbed habitat had high intensities of affiliative interactions and less agonistic interactions while the opposite trend was seen in troops of disturbed habitat.

The percentage of different species and their parts consumed were different in the two habitats. Out of the total plant parts consumed, troops in disturbed habitat fed on 83% of the parts while troops in undisturbed habitat fed on 68% of the total plant parts. The most important food plant in undisturbed habitat was *Holoptelea integrifolia* and with maximum feeding records while *Ehretia laevis* was a major food plant in

disturbed habitat. Impact of lopping on disturbed habitat was quantified and more than 70% of the trees lopped were diet plants of langur. The major impact of lopping was on species like *Acacia catechu*, *Anogeissus latifolia*, *Terminalia bellerica*, and *Terminalia tomentosa*.

Troops in disturbed habitat were found on lower canopy (38%) and ground (32%), for most of its activities while undisturbed troops on middle (34%) and lower canopies (32%). In addition to it, the disturbed troops used ground for movement (57%), while movement through canopy was seen more in undisturbed troops (65%). Most location records for undisturbed troops were in miscellaneous forest and Sal forest, while for disturbed troop in miscellaneous and scrub forest.

Daily distance travelled differed in these treatments, with the two troops in disturbed habitat having more mean daily distance moved of 1.45±0.07 km in winter and 2.48±0.14 km in spring while the mean daily day range of undisturbed troop was 0.9±0.1 in winter and 1.35±0.12 in spring. Home range followed a similar pattern with the troops in disturbed habitat having large home ranges of 2.98 $km^2$ and 3.42 $km^2$, and comparatively smaller home ranges of troops in undisturbed habitat 2.25 $km^2$ and 1.37 $km^2$.

# Chapter 1: Introduction

Biodiversity is increasingly lost due to a variety of factors, especially the ones arising from various anthropogenic activities, leading to a global crisis (Pimm et al. 2014). Anthropogenic stresses like urbanization, deforestation and habitat fragmentation, are among the major underlying causes for such increased crisis. Modifications in the natural habitat of animals give them a very short timescale to adapt to these disturbances (Tuomainen and Candolin 2011).Understanding these adaptations become really vital for the long term conservation and sustenance of any species. To account for the responses to different degrees of human influence, non-human primates have served as a model species for quite long (Dhawale, Kumar, and Sinha 2020).

The primate order has around 734 taxa, belonging to 469 species, in 17 families, distributed across the Neotropics, mainland Africa, Madagascar and Asia (Estrada et al. 2017). Out of the total species in this order around 60% are now threatened, and 75% have declining populations. Southeast Asian countries have a rich diversity of primates that accounts for around 22% of the global primate species (Boonratana 2014; Estrada et al. 2017; Mittermeier and Wilson 2013). India accounts for 5% of the global primate population with 34 taxa and 22 species distributed across the country (Boonratana, 2014 ; IUCN Red List).There has been a major decline in the prime habitats of several primate species in these countries, causing alterations in the biotic and abiotic environmental conditions, which in turn influence the behaviour of these species directly or indirectly (McLennan, Spagnoletti, and Hockings 2017).

Behavioural responses can vary from being the proximate changes like foraging pattern, vigilance, dispersal, migration, reproductive behaviour and social behaviour, to influencing survival rate, reproductive success and distribution of the individuals and thereby the dynamics of the population (Tuomainen and Candolin 2011).

Research at human–primate interfaces has become especially significant over the past decade, given the globally increasing significance of human–wildlife interactions and coexistence, and the shared ecology and evolutionary history of humans and primates (Fuentes and Wolfe 2002). These interactions vary in form and frequency from being neutral to visibly destructive and antagonistic. Some studies have shown mutual tolerance, provisioning and treating primates as a religious symbols (Radhakrishna 2017; Sengupta, McConkey, and Radhakrishna 2015)while others point out towards other extreme of human primate interaction, being destruction of habitat, hunting and aggression (Bryson-Morrison et al. 2017; Saraswat, Sinha, and Radhakrishna 2015).

Pressures on the habitat caused by deforestation, continued degradation of forested areas, together with ever increasing human population, have resulted in many primate species to occur in forest–agricultural mosaics. Primates inhabiting these human dominated landscapes face multiple challenges, including depletion of resources, human infrastructures such as roads or settlements, and increased encounters with people. Their long-term survival depends on the ability to adapt to these human-dominated environments, as well as people's tolerance to these adaptive behaviours (Estrada 2013; C. M. Hill and Webber 2010).

Species in the genus *Semnopithecus* are among the most widespread non-human primates across the Indian subcontinent (Nag, Pramod, and Karanth 2011; Pirta, Gadgil, and Kharshikar 1997).These old world monkeys (Family: Cercopithecidae, Subfamily: Colobinae) live in multi-male, multi-female group and are popularly known as Hanuman langur, range in a wide variety of habitats, from the arid regions of Rajasthan to rainforests of Western Ghats and northern plains to high altitudes of Himalayas (Nag, Pramod, and Karanth 2011). Most of their habitat is human altered but very less is known about their behavioural changes and adaptability in such landscapes. Furthermore, langur species (or subspecies) in the Himalayan range, *Semnopithecus ajax, Semnopithecus hector* and *Semnopithecus schistaceus*, are least studied in comparison to other species of gray langur distributed in central highlands and southern India (Chetan, Praveen, and Vasudeva 2014). There has been a lot of confusion regarding the taxonomy of gray langurs in India with several schemes to classify them as species and subspecies. Terai gray langur (*Semnopithecus hector* ) was recognised as a separate species in a few classification schemes (Groves 2001),, others have classified it as a subspecies of Himalayan langur (W. Hill 1939), while recent studies suggest that it is not a subspecies or a different species than *Semnopithecus schistaceus* (Arekar, Sathyakumar, and Karanth 2019). Terai gray langur is distributed along the foothills of Himalayas in Nepal, India and Bhutan. It lies in the elevational range of 150m to 1600m from moist deciduous forest in Shivalik hills to oak forest (Molur et al. 2005).

Gray langurs are among the folivore primates with leaves forming a major part of their diet. Folivore primates were thought to have constrained activity patterns

assuming the non-patchiness of resources they depend on (Snaith and Chapman 2007). While this is not true for gray langurs, as they are known to show plasticity in their ecology and behaviour, having wide ranges in a variety of habitats, competing for resources, and showing changes in social structures (Sayers 2013). They can act as a perfect model to study the socioecological and behavioural changes due to a variety of anthropogenic stresses.

In the changing climatic scenario the home range of Gray langur is predicted to shift and the suitable habitat is predicted to drastically decline by 2050, causing the home ranges to lie in non-protected and human dominated landscapes (Bagaria et al. 2020). It then becomes really important to understand the changing ecology of such species for their effective management.

## 1.1 Literature Review

Activity budgets have been used as a method for understanding the life history of the species and the underlying interactions it has with its environment (Defler 1995). Furthermore, activity patterns are considered as a part of natural history of many group living species and are central to testing the short term influence of any ecological changes on that species (Dunbar 2009; Stanford 1991). Primates as a group show multiple responses to environmental disturbances but a more general adjustment response involves increasing the time for feeding, changing the dietary patterns, and minimizing energy expenditure by devoting less time to high cost behaviour or by resting more (Schoener 1971). Apart from the human disturbances causing changes in activity patterns, seasonality, group size, and other habitat variables can also lead to the changes in the time spent on different activities (Dunbar 2002).

Recent studies have shown dietary changes within human-altered environments, which include provisioning, crop-raiding, or theft of human rubbish (Bryson-Morrison et al. 2017; McKinney 2011). When primates are provisioned by human food sources which are rich in nutrient content, groups may require less travel and foraging time, have smaller ranges and travel paths, and spend much of their day resting (D. A. Hill 1999). Most species of the genus *Macaca* are known to be highly adaptable in human dominated landscapes (Thierry, Iwaniuk, and Pellis 2000). Few studies on rhesus macaques, bonnet macaques, and lion-tailed macaques have shown that when exposed to human presence, these species appear to have behaviourally adapted to anthropogenic habitats and human-provided food (Dhawale, Kumar, and Sinha 2020; Sengupta, McConkey, and Radhakrishna 2015; Sinha 2013).

On the other hand, species present in the degraded habitats, where the food resource availability was low, were seen to respond by a significant reduction in the time spent on resting, and increase in the time spent on moving, along with actively avoiding landscapes with human presence (Bryson-Morrison et al. 2017; Sayers and Norconk 2008). This response to low-quality habitat was often associated with the maintenance of a large home range and long travel paths. Species like white faced capuchins and mangabey showed a similar response, where less time was spent in resting and feeding and more time in moving with larger home ranges (Mbora et al., 2009; McKinney, 2011). Studies on folivore primates have consistently seen an increase in the daily movement range due to food scarcity or in areas with lower food availability (Snaith and Chapman 2007). Changes in dietary diversity and reliance on alternative food sources along with reduction in group size was also observed as an

outcome of altered habitat in a few primate species like Sulawesi Tonkean macaques and lion tailed macaque macaque (Riley 2007; Singh et al. 2001). Few primate species altered their activity pattern by maximizing the resting time and minimizing other energy demanding activities in disturbed habitats (Nautiyal 2015; Riley 2007). The changes in activity budget within a group due to anthropogenic factors also differed with different age sex classes.

The low availability and clumped distribution of resources, increase the feeding competition within groups. Increased competition for resource acquisition can potentially alter the social structure in many species (Lott 1984). Although the pattern of social organisation of any species results from the long evolutionary forces acting on it, environmental factors can cause some fluctuations in this social structure to effectively compensate for increased competition due to scarcity of resources (Ram, Venkatachalam, and Sinha 2003). Intraspecific competition for resources can further lead to increase in aggression, reduction in affiliative interactions, rank-related skew in food acquisition, nutritional status, fecundity, and reproductive success (Snaith and Chapman 2007).

In primates, affiliative social behaviours have many health and fitness-related benefits, and are important for maintaining group social structure, social or allo-grooming was the most commonly observed form of social affiliation. Many recent studies on rhesus macaques show flexibility in their grooming behaviour in response to the rates of human–macaque interaction to which they are exposed. More frequent the human–macaque interactions were, shorter were the grooming bouts, and more vigilance in behaviour was seen (Kaburu et al. 2019). While in bonnet macaques living

in human dominated landscape, the frequency of social affiliations was reduced especially the grooming time and the diversity of grooming partners was reduced (Balasubramaniam et al. 2020).

The changes in patterns of specific social behaviours, as a response to modified habitats, should be quantified for better understanding of the modifications in the life history strategies of any species. Network analysis has been used quite recently in the field of animal behaviour. It can be described as consisting of nodes (individuals, groups or populations) and edges (interactions between them). Social interaction networks provide a medium where social organisation of animals at the level of the individual, dyad, group or population, can be visualised for a multitude of interactions like aggression, cooperation, sexual etc. (Krause, Lusseau, and James 2009). In group living primates, understanding the consequences of these interactions, or the changes in these interactions, at multiple scales would lead to a better understanding of the fitness of an individual, group or population (Sueur et al. 2011).

# Chapter 2: Aims and objectives

The proposed study investigates the impacts of anthropogenic stresses on the socio-ecological interactions of Terai Gray langur (*Semnopithecus hector)* in the Shivalik Hills.

## 2.1 Objectives:

1. To study the behavioural ecology of Terai Gray langur in a disturbed and undisturbed habitat.

2. To study in feeding ecology of Terai Gray langur in a disturbed and undisturbed habitat.

3. To study the movement ecology of Terai Gray langur in a disturbed and undisturbed habitat.

## 2.2 Hypothesis:

- Objective 1:

  Behaviour is highly susceptible to environmental changes, so langur troops in both the treatments are expected to show a differential pattern in their major activities and social interactions.

- Objective 2:

  Dietary patterns of langur troops in disturbed habitat would be altered by the competition of resource from local communities.

- Objective 3:

  Resource being a limiting factor in disturbed habitat, langur troops in this habitat are expected to show differences in daily distance travelled and home ranges than the undisturbed troops.

## 2.3 Research questions:

For the above mentioned objectives, following research questions were asked:

Objective 1:

1. What are the variations in activity patterns of langurs in disturbed and undisturbed habitats?
2. What are the differences in affiliative and agonistic interactions, among different age-sex classes of Terai Gray langur, between the two treatments?

Objective 2:

1. What are the differences in the dietary patterns of langurs in disturbed and undisturbed habitat?
2. What is the direct impact of lopping on dietary species of langur in disturbed habitat?

Objective 3:

1. What are the variations in mean daily distance moved by langur troops between the two habitats across winter and spring?
2. What are the home range sizes of langurs in disturbed and undisturbed habitat?

# Chapter 3: Study Area

This study was carried out in a small area of Shivalik foothills forming the border of Uttrakhand and Uttar Pradesh inside Dehradun and Saharanpur district. This area lies in the lesser Himalayas and the upper Gangetic plains, and is marked by sub-tropical climate, fragile land formation with low rolling hills, bisected by gullies and seasonal streams (locally known as Rau)(Sivakumar, Sathyakumar, and Rawat 2010).

The forest type of this landscape is categorised as northern Indian moist deciduous forest and northern tropical dry deciduous forest (Champion and Seth 1968). The northern slopes of the hills receiving high annual rainfall and low sunlight are Sal *(Shorea robusta*) dominated, while southern slopes receiving low rainfall and high sunlight are predominantly miscellaneous (Harihar, Pandav, and Goyal 2009). The miscellaneous forest has combinations of Sal, plantation (*Tectona grandis*) and grassland (*Saccharum bengalense)*. Apart from Sal, *Mallotus phillipinensis* (Rohini), *Acacia catechu* (Khair), *Adina cordifolia* (Haldu), *Terminalia bellirica* (Bahera*), Ficus bengalensis* (Bar), *Dalbergia sissoo* (Shisham) etc. are also present.

High diversity of fauna is observed in landscape with species like *Elephas maximus* (Asian elephant), *Panthera tigris* (tiger), *Panthera pardus* (leopard), *Semnopithecus hector* (Terai gray langur), *Melursus ursinus* (Sloth bear), *Hyaena hyaena* (Hyaena), *Muntiacus muntjak* (Barking deer), *Axis axis* (Spotted deer), *Cervous unicolor* (Sambhar), *Sus scrofa* (Wild boar), etc., along with many bird, butterfly and reptile species(Joshi and Singh 2008).

The inviolate area of Rajaji National Park was used as a control site with no form of human disturbance. It is spread across Hardwar, Dehradun and Pauri districts of Uttarakhand state, with a core area of 820 square kilometres, and an extended area of more than 1,100 square kilometres with its buffer. It lies between the coordinates of 29°15' to 30° 31' North Latitude and 77°52' to 78°22' East Longitude (Harihar, Pandav, and Goyal 2009).

The area under Shivalik forest division (SFD) of Uttar Pradesh, which is influence by anthropogenic pressures was used as a disturbed site. The forest area under SFD is managed for forestry purposes and the local communities have access to the non-timber forest products. Gujjar community predominantly resides in these forested areas, who are nomadic pastoralists and depend heavily on the forest for grazing their large population of livestock. In recent years Gujjars have stopped their summer migration and have settled permanently in this landscape. There are many small villages, with agriculturalist and pastoralist communities, in and around SFD (Sivakumar, Sathyakumar, and Rawat 2010). Overall disturbance in the forest patches of this landscape is in the form of lopping of trees, grazing of livestock and collection of other NTFPs.

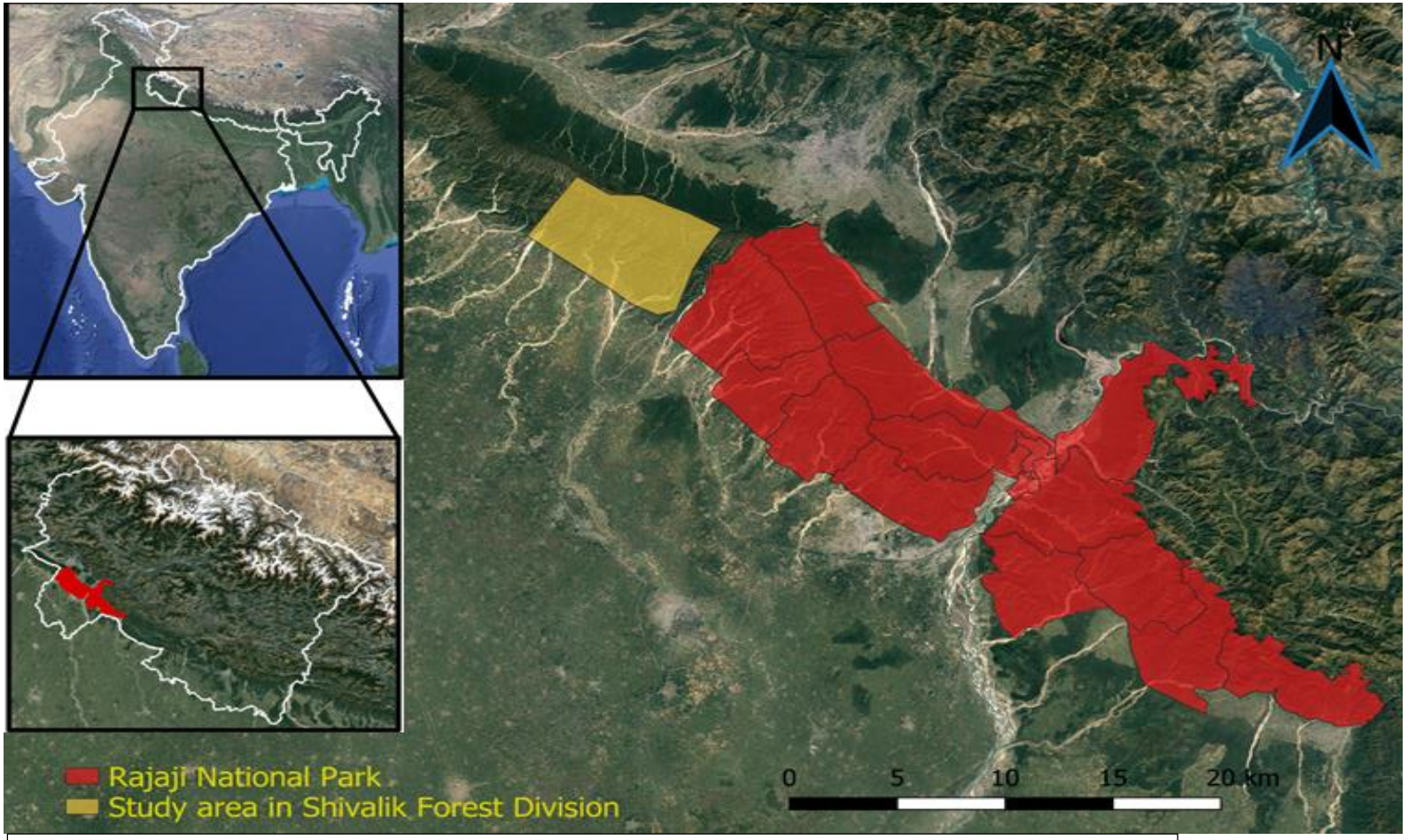


**Figure 1**: Map showing Rajaji National Park and part of Shivalik Forest Division where the current study was

# Chapter 4: Methods

## 4.1 Habituation and troop follow

The study period of four months ranged from January 2021 to April 2021. Four troops of Terai Gray langur were selected, two inside Rajaji National Park (UD1, UD2) and two inside Shivalik Forest Division (D1, D2). Selection of troops was done based on the group size, terrain features and other logistics. Selection and habituation of the troops was done initially from late December to early January. Troop D1 was present near the Gujjar settlements (local nomadic community) and D2 was present near the village of Shahjahanpur with a few Gujjar settlements. The group composition of all the troops is represented in Table 1.

Troops were followed from morning to evening between 0700 to 1700 hrs. Continuous 6 day follow represented a session for a troop before switching between troops. Troops were followed alternatively between treatments. Due to the elusive nature of langur and terrain features, full day follows were not possible for a few sessions. The troop UD1 could not be followed in spring due to Covid -19 restrictions. Overall effort for troops in disturbed area, including the number of days for habituation and sampling were 35, and 27 for undisturbed troops.

**Table 1:** Age-sex structure of all four troops followed in the study period.

| Troop Id | Adult Males (AM) | Adult Females (AF) | Sub Adult (SA) | Juveniles (Juv) | Infants (Inf) | Total |
|---|---|---|---|---|---|---|
| Disturbed Troop 1 (D1) | 6 | 14 | 11 | 8 | 6 | 45 |
| Disturbed Troop 2 (D2) | 7 | 12 | 10 | 6 | 6 | 41 |
| Undisturbed Troop 1 (UD1) | 4 | 12 | 8 | 5 | 5 | 34 |
| Undisturbed Troop 2 (UD2) | 5 | 13 | 9 | 7 | 6 | 40 |

## 4.2 Data Collection

### 4.2.1 Activity pattern

Instantaneous scan sampling (Altmann 1974) method was used for data collection. Scans of five minutes were taken after every ten minute interval using Nikon 8x42 binoculars. During a scan, age-sex class (adult male, adult female, sub-adult, juvenile, and infant) and activity of the observed individual was recorded. In this study 30 behaviour categories (Appendix 1) were selected from literature available on behaviour repertoire of Hanuman langur (Dolhinow 1978). These behaviour categories were grouped into 5 major activities as follows:

- **Feeding:** When an individual feeds on any part of the plant like leaves, ripe and unripe fruits, flowers etc., or any other food source, or actively searches for food sources.

- **Moving:** When an individual is in a state of motion (generally when the troop changes its location for feeding, socialising or resting) and the minimum distance covered is more than 3m.
- **Resting:** The period of inactivity, when an individual is either sleeping or awake without directing its attention towards any specific event or interaction.
- **Socialising:** When an individual is involved in activities that are directed towards any other member of the troop, like allo-grooming, hugging, grimace, contact calls, display, chase, threat, and playing.
- **Others:** It includes activities like auto-grooming, vigilance, urinating, defecating, vocalizing, canine grinding, suckling, etc.

Sampling effort in terms of the instantaneous scans was 9996 scan samples for troops in disturbed habitat and 7769 scan samples for troops in undisturbed habitat. The summary of sampling effort on all study troops for each season is present in Table 2.

**Table 2**: Sampling effort on all study troops of Terai Gray langur in winter and spring.

| | | Winter | | Spring | | Total | |
|---|---|---|---|---|---|---|---|
| | **Troop ID** | **Scans** | **Instantaneous Scan Samples** | **Scans** | **Instantaneous Scan Samples** | **Scans** | **Instantaneous Scan Samples** |
| **Disturbed** | D1 | 127 | 2642 | 98 | 2037 | 225 | 4679 |
| | D2 | 145 | 2901 | 111 | 2416 | 256 | 5317 |
| **Undisturbed** | UD1 | 107 | 2150 | NA | NA | 107 | 2150 |
| | UD2 | 138 | 2835 | 130 | 2784 | 268 | 5619 |

### 4.2.2 Affiliative and agonistic interactions

For all the behaviour categories of socialisation observed while taking scans, the age sex class of both actor and receiver of that activity were noted. Allogrooming was used as a surrogate for affiliative interactions while chase, displace, hand threat, face threat, and directed display, were categorised as agonistic interactions (for detailed ethogram refer to Annexure I).

### 4.2.3 Food resource

During every scan when an individual was seen feeding, the species identity along with the parts consumed was noted. The parts were categorised into young leaf, mature leaf, ripe fruit, unripe fruit, flower, bud, seed, and stem. To enumerate the impact of lopping on food resources in disturbed habitat, vegetation plots were taken in feeding patches for both the langur troops. Random 10m circular plots were laid and

the species wise number of trees lopped were noted. 19 plots were laid in the overall feeding patches of troop D1, and 16 plots in feeding patches of D2.

### 4.2.4 Strata use, ranging pattern and habitat use

During scans the strata for each observed activity except moving was also noted down. Overall, the strata was categorised into 4 levels, ground, lower canopy (<3m), middle canopy (3-6m) and top canopy (>6m). Whenever individuals were observed moving, the strata used for moving was noted down as ground or canopy. For each scan the general broad habitat characteristics were noted to determine the habitat use by Terai Gray langur. Broad habitats were characterised as miscellaneous forest, scrub forest (open forest with shrubs and a few small stunted trees), sal forest (forest dominated by dense canopy of sal tress and its associates), teak plantation (forest area dominated by teak trees of similar growth), riverine habitat (area dominated by dry river beds locally known as raus and characteristic riverine species) and human settlements (areas with close proximity to human habitations <50m, without any dominant forest type)

During each scan the geographical coordinates of an approximate centre of the troop were also recorded using GPS (Gramin etrex 10x).

## 4.3 Analytical methods

### 4.3.1 Activity pattern

Activity budgets were calculated by using the percentage of data points in each activity category. For winter and spring separate activity budgets were created by combining the troops in each treatment. Time activity budgets were also created for

adult males and females of all four troops. While comparing the activity patterns for adult males, adult females and differences among the two age sex classes, the seasons and troops in each treatment were clubbed. G-test of independence (Mcdonald 2009) was used to compare the differences in activity budgets.

### 4.3.2 Affiliative and agonistic interactions

For comparing the intensity of affiliative interactions (allogrooming) and agonistic interactions social networks were created using each age sex class as nodes. Separate social networks were created for both the interactions in each treatment. Networks were made in R 4.1.0 (R Core Team 2013) using the package igraph (Csardi and Nepusz 2006). Weighted directed networks were created by using an assigned score for each type of interaction as the weight of edges.

### 4.3.3 Food resource

Percentage feeding records for each plant species was calculated by number of feeding records of that species divided by the total number of feeding records for langur troops in both the treatments. Further the percentage of looping, for each of the food species consumed by Terai Gray langur, in disturbed habitat, was calculated using the number of trees lopped of that species divided by the total number of trees lopped of all species combined in all 35 plots.

### 4.3.4 Strata use, ranging pattern and habitat use

Percentage of time on a strata for all activities was calculated and compared across two treatments using the G-test of independence (Mcdonald 2009). Habitat use

was also compared by using the percentage of scans in each habitat type for the disturbed and undisturbed troops.

All the location data from each scan was imported to QGIS 3.16.7. Using this data, daily distance moved was calculated for troops in each of the treatment and season. Dot plots were created to visualise the variation in daily distance moved by ggplot2 (Wickham 2016) in R. For compare the differences in daily distance moved by the troops in disturbed and undisturbed habitat during winter and spring, Two Way Anova was done using treatments and seasons as the dependent categorical variables.

Home range was calculated by the Minimum Convex Polygon (MCP) method using package adehabitatHR (Calenge 2006) in R and QGIS 3.16.17. All location data points were used (100% MCP) for winter and spring combined of all troops, except UD1 whose spring data could not be collected, home range of UD1 was computed using the winter data points.

# Chapter 5: Results

## 5.1 Time-activity budgets

### 5.1.1 Overall activity pattern

In the entire study period, Terai Gray langur troops in the undisturbed site had resting as their major activity (43%) followed by feeding (19%) while the troops in disturbed site had almost similar distribution of time in resting (30%), feeding (29%) and moving (26%) (**Figure: 2**). There was a significant difference in the time spent by langurs in each activity between the disturbed and undisturbed habitats (G test of Independence, G = 923.49, df = 4, p-value <0.01). Undisturbed troops spent more percentage of time on socialising (17%) than disturbed troops (11%).

While comparing the seasonal differences in the activity budgets of the troops (**Figure: 3**), there was no significant difference in the time spent on each activity during winter and spring in disturbed troops (G test of Independence, G=0.297, df = 4, p-value >0.05) and undisturbed troops (G test of Independence, G= 0.40985, df = 4, p-value >0.05).

### 5.1.2 Activity pattern of adult males and adult females

For the two seasons combined, adult males of the disturbed habitat D1 and D2 spent less time in resting, and more time in feeding and moving, when compared with the adult males of the troops UD1 and UD2, who spent majority of their time in resting. Adult males of the undisturbed troops spent more time socialising than adult males of disturbed troops (**Figure: 4**). Similar trend was observed for the adult females, who spent more time in feeding and moving while less time in resting and socialising, in

the disturbed habitat for both seasons, than the adult females in undisturbed habitat (**Figure: 5**).

Comparing the activity patterns of adult males and adult females of all four troops (**Figure: 6**), there was no significant difference overall, but adult females were seen to spend less time in resting than males. Apart from resting, adult females spent more time in feeding and less time in moving than adult males. Also females engaged more in socialisation than adult males.

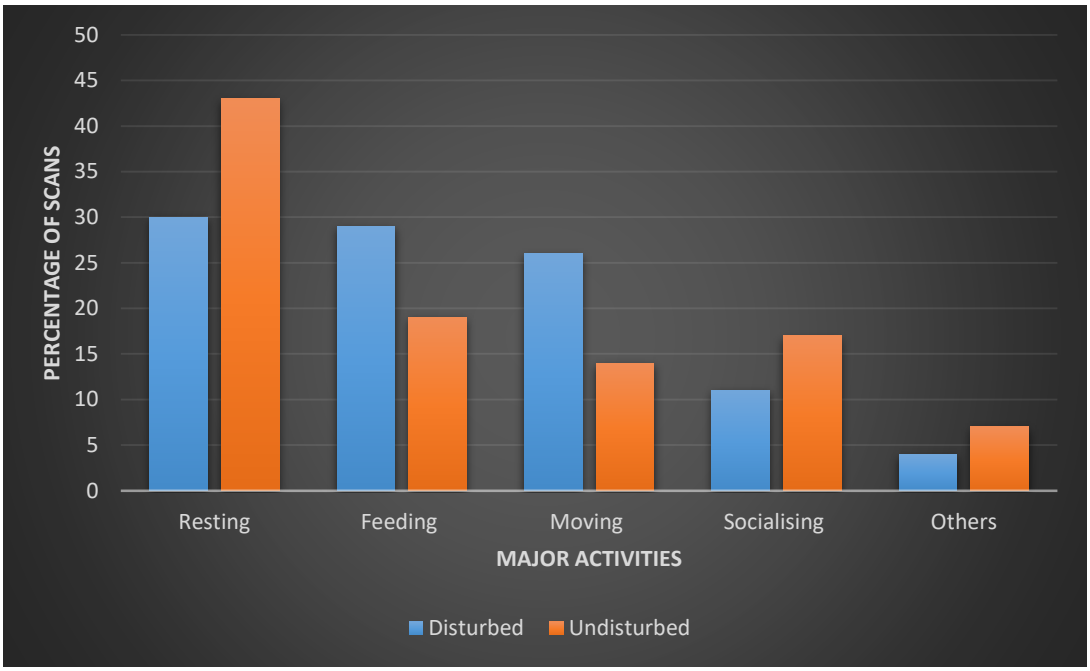


**Figure 2**: Bar graph representing overall time activity budget of Terai Gray langur in disturbed and undisturbed sites.

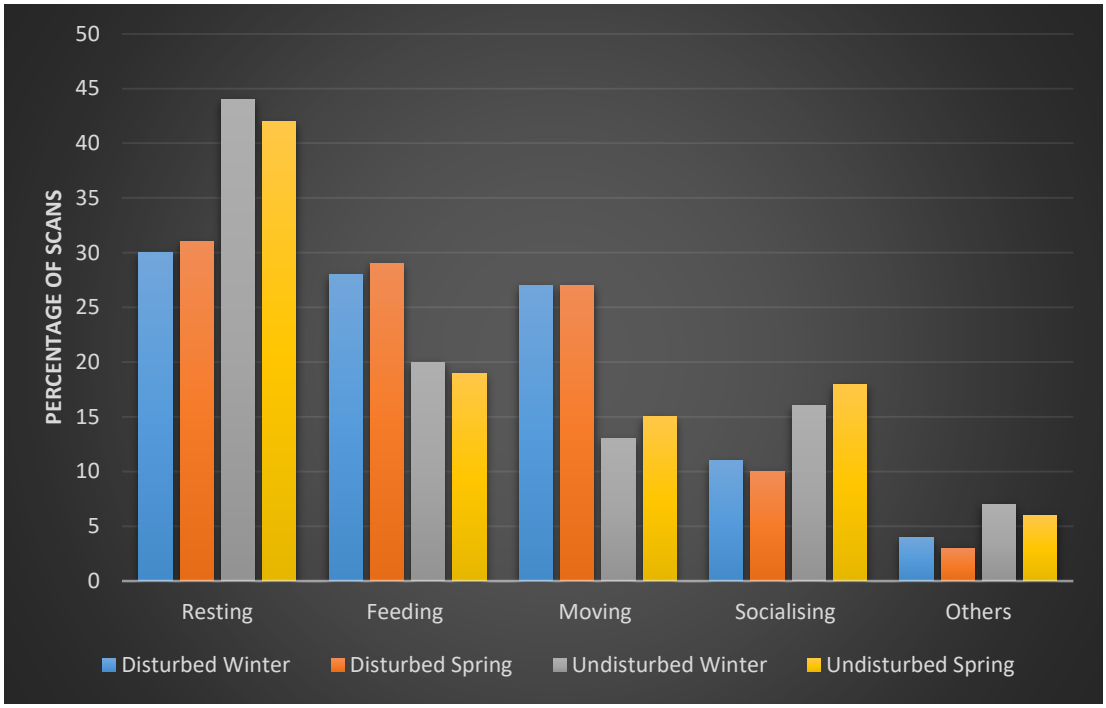


**Figure 3** Bar graph representing seasonal differences in the time activity budget of Terai Gray langur in disturbed and undisturbed sites.

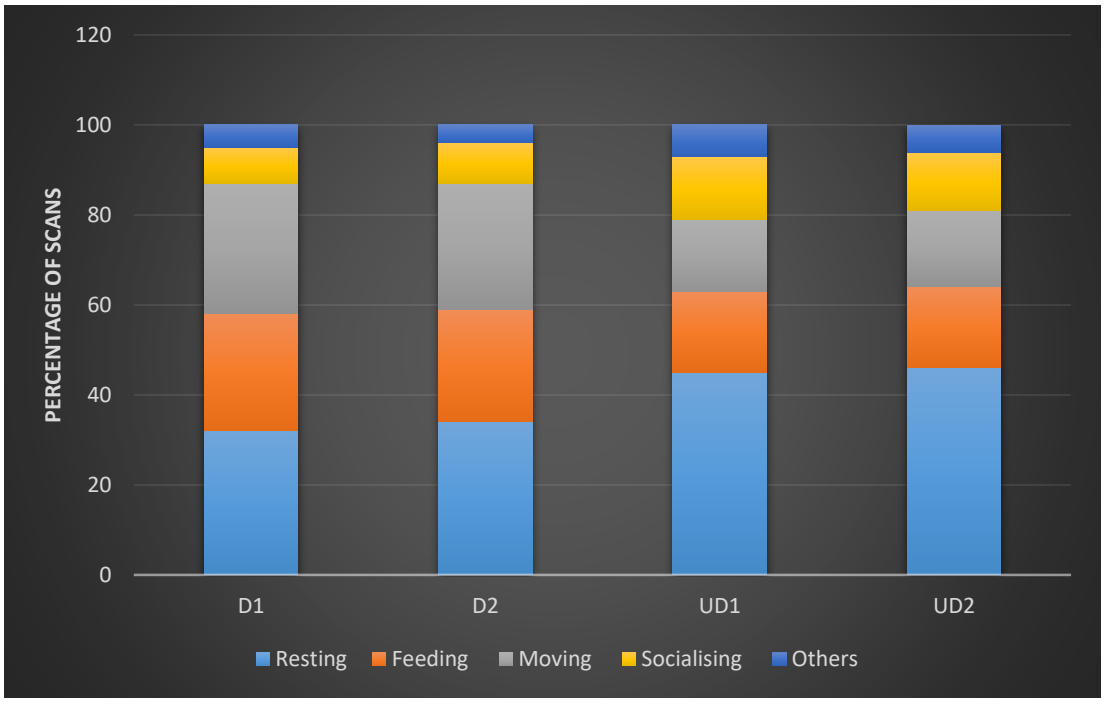


**Figure 4**: Bar graph representing the time-activity budgets of adult males in all four langur troops (D1, D2, UD1 and UD2) for the two seasons combined.

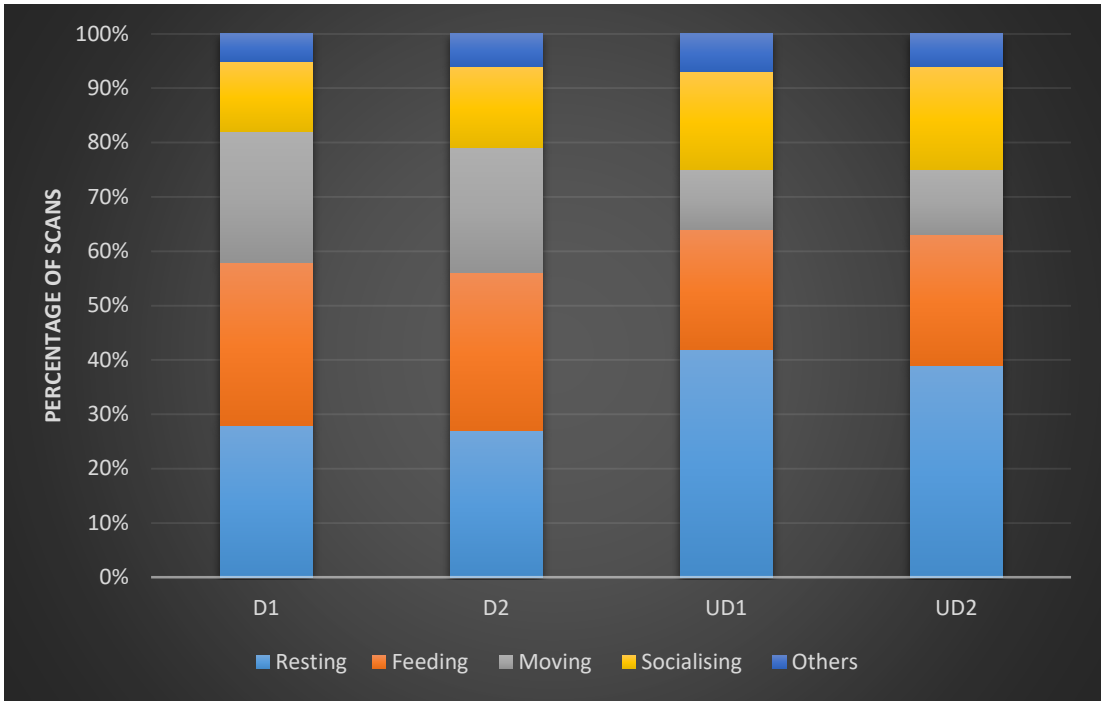


**Figure 5**: Bar graph representing the time-activity budgets of adult females in all four langur troops (D1, D2, UD1 and UD2) for the two seasons combined.

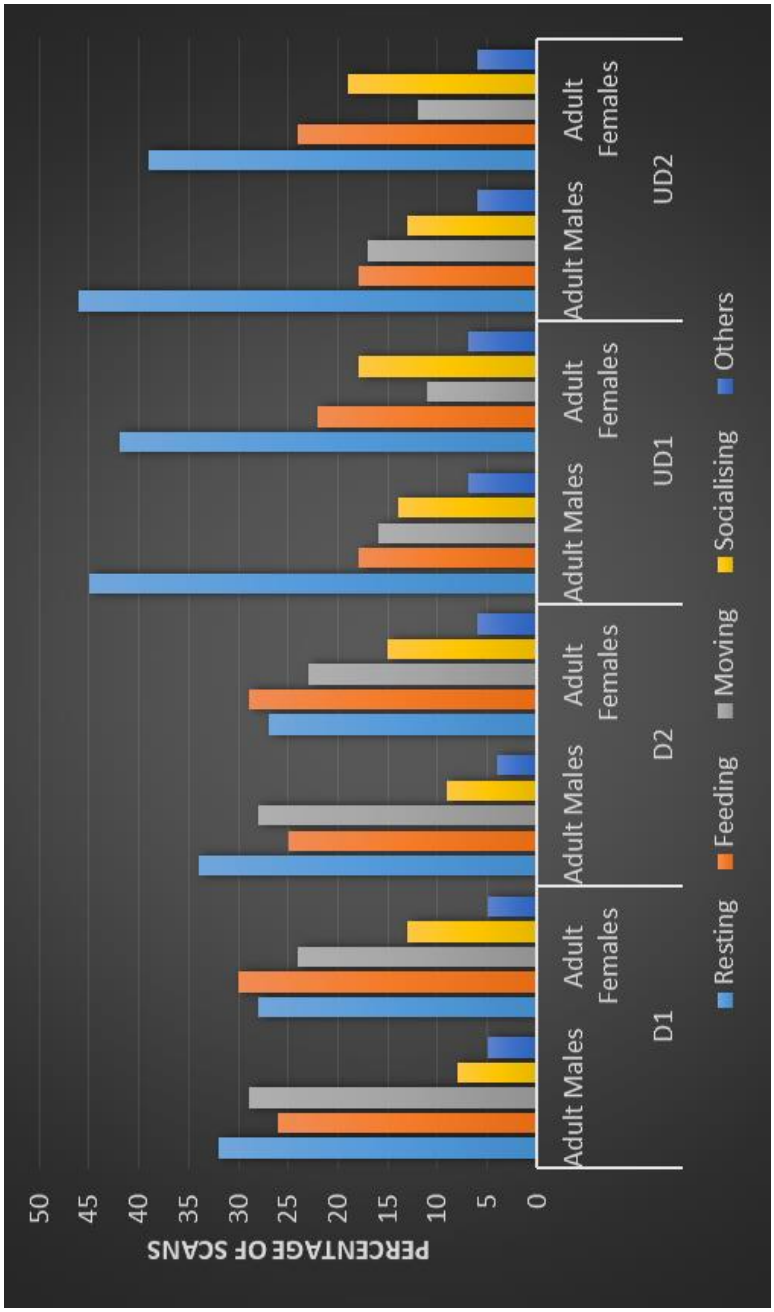


**Figure 6**: Bar graph comparing the of time-activity budgets of adult males and adult females in all four langur troops (D1, D2, UD1 and UD2) for the two seasons combined.

## 5.2 Differences in aggressive and affiliative interactions

### 5.2.1 Social Networks for grooming interactions

Social networks were created for grooming interactions of different age sex classes in disturbed (Figure: 7) and undisturbed habitat (Figure: 8). Each of the two weighted directed networks, have nodes representing different age sex classes, edges

represent grooming interactions, width of edges represent intensity of interactions with the arrow head towards receiver. Loop in a node represent the grooming interaction of an age sex class with itself. The weights for intensity of grooming interactions are mentioned in Table 3.

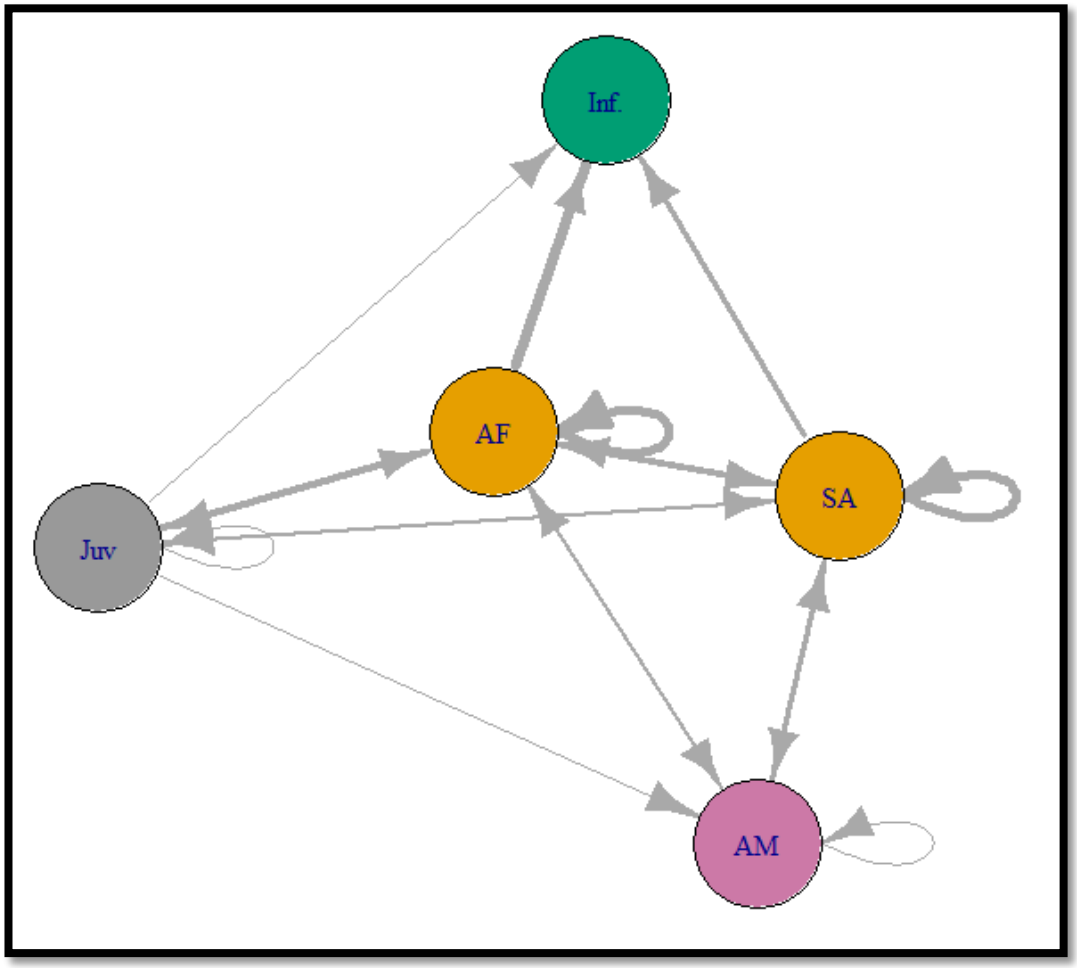


**Figure 7**: Figure representing social network for grooming interactions of different age-sex classes in langur troops of disturbed habitat (AM: Adult Male, AF: Adult Female, SA: Sub-adults, Juv: Juveniles, Inf: Infants).

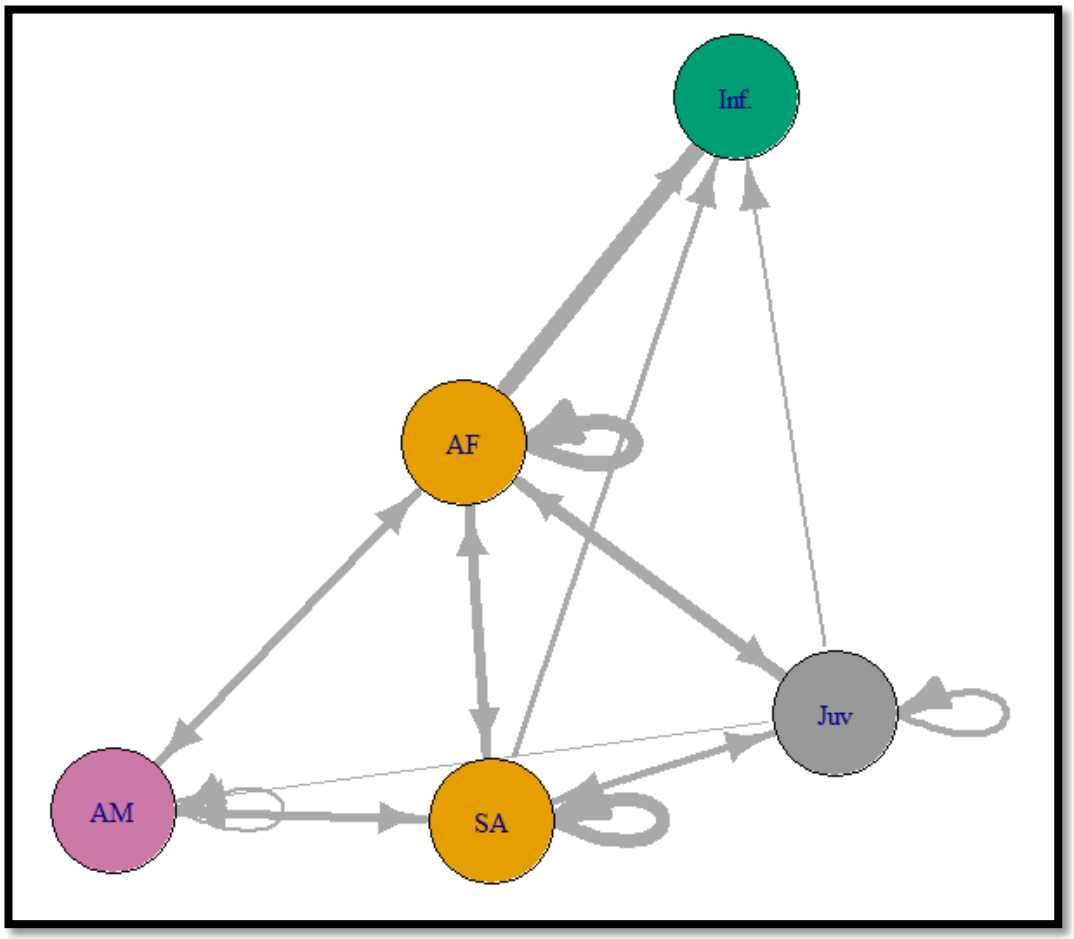


**Figure 8**: Figure representing social network for grooming interactions of different age-sex classes in langur troops of undisturbed habitat (AM: Adult Male, AF: Adult Female, SA: Sub-adults, Juv: Juveniles, Inf: Infants).

Overall the intensity of grooming interactions is high for troops in undisturbed site, which is represented by the heavily weighted edges. Adult females in undisturbed habitat showed high grooming intensity towards infants, sub-adults and other adult females when compared to grooming intensity of adult females in disturbed habitat. Adult males in undisturbed habitat received a higher intensity of grooming interactions from adult females and sub-adults than the adult males in disturbed habitat.

**Table 3:** The weights of edges for grooming interaction for each pair of actor and receiver in all age sex classes.

| Actor | Receiver | Weights | |
|---|---|---|---|
| | | Disturbed | Undisturbed |
| AM | AM | 7 | 15 |
| AM | AF | 10 | 21 |
| AM | SA | 7 | 19 |
| AF | AM | 15 | 31 |
| AF | AF | 35 | 55 |
| AF | SA | 18 | 35 |
| AF | Juv | 29 | 45 |
| AF | Inf | 41 | 60 |
| SA | AM | 19 | 35 |
| SA | AF | 22 | 40 |
| SA | SA | 31 | 51 |
| SA | Juv | 12 | 29 |
| SA | Inf | 19 | 23 |
| Juv | AM | 4 | 10 |
| Juv | AF | 6 | 12 |
| Juv | SA | 4 | 25 |
| Juv | Juv | 11 | 27 |
| Juv | Inf | 5 | 15 |

### 5.2.2 Social Networks for agonistic interactions

Social networks were created for agonistic interactions of different age sex classes in disturbed (Figure: 9) and undisturbed habitat (Figure: 10). Each of the two weighted directed networks, have nodes representing different age sex classes, edges represent agonistic interactions, width of edges represent intensity of interactions with the arrow head towards receiver. Loop in a node represent the agonistic interaction of an age sex class with itself. The weights for intensity of agonistic interactions are mentioned in Table 4.

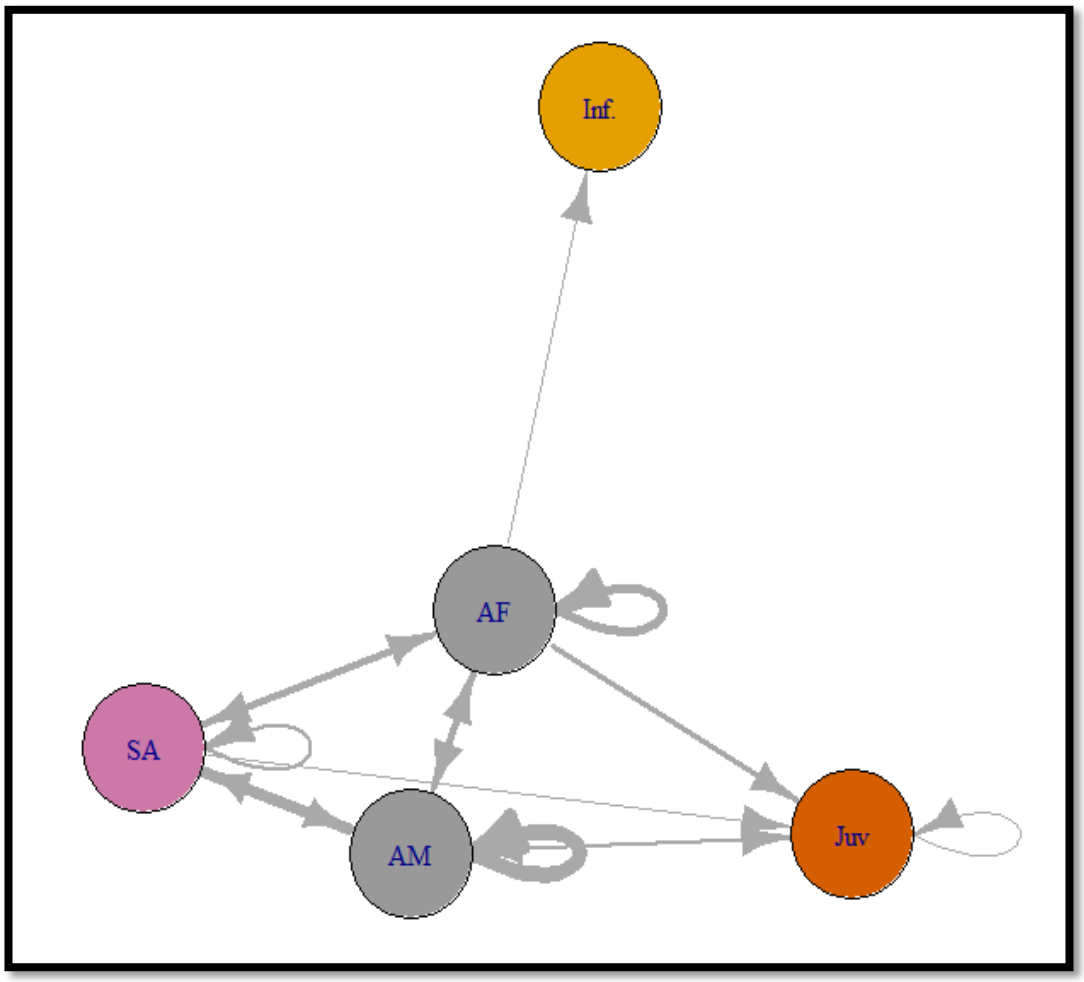


**Figure 9**: Figure representing social network for agonistic interactions of different age-sex classes in langur troops of disturbed habitat (AM: Adult Male, AF: Adult Female, SA: Sub-adults, Juv: Juveniles, Inf: Infants).

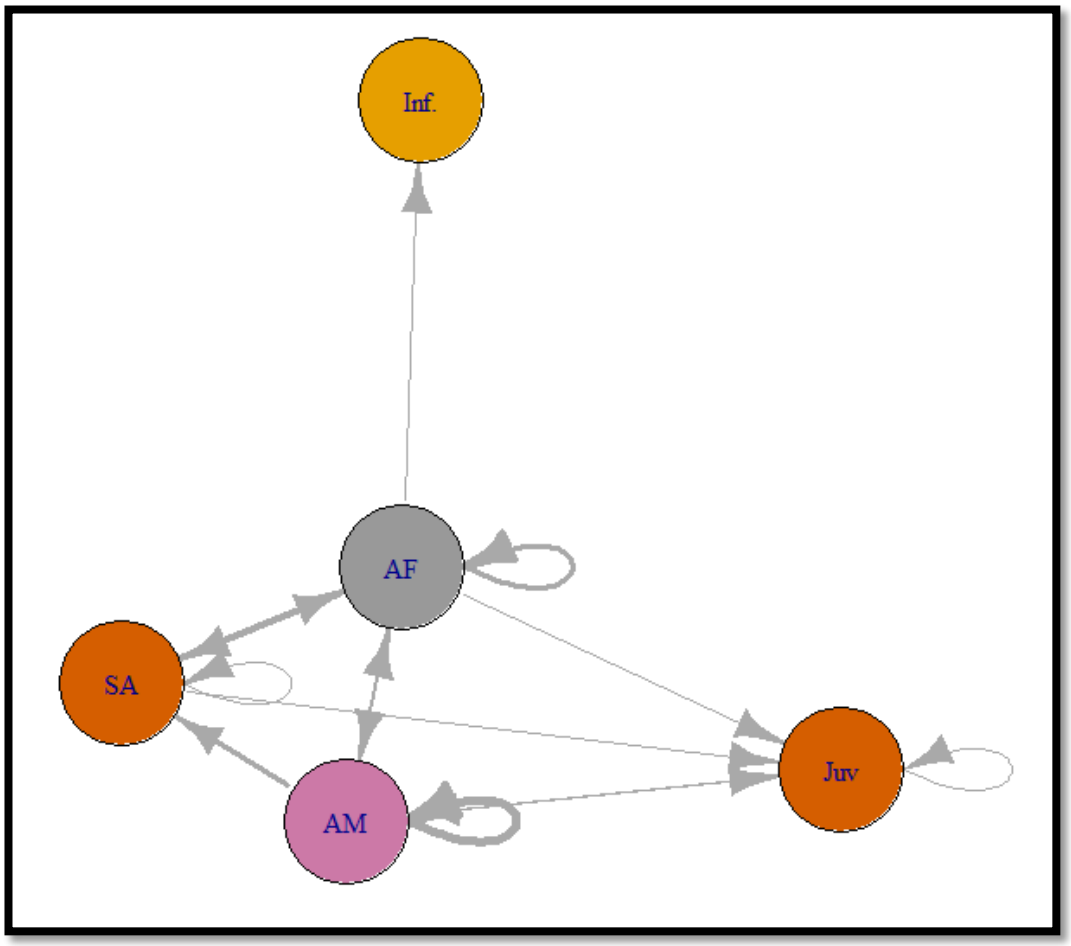


**Figure 10**: Figure representing social network for agonistic interactions of different age-sex classes in langur troops of undisturbed habitat (AM: Adult Male, AF: Adult Female, SA: Sub-adults, Juv: Juveniles, Inf: Infants).

The intensity of agonistic interactions among different age classes in disturbed habitat was higher compared to undisturbed habitat. Apart from the overall increase in agonistic interactions, the intensity of agonistic interactions of adult males towards other adult males of disturbed troop was significantly higher (more edge width) than in undisturbed habitat.

**Table 4**: The weights of edges for agonistic interactions for each pair of actor and receiver in all age sex classes.

| Actor | Receiver | Weights | |
|---|---|---|---|
| | | Disturbed | Undisturbed |
| AM | AM | 36 | 21 |
| AM | AF | 17 | 9 |
| AM | SA | 29 | 15 |
| AM | Juv | 10 | 5 |
| AF | AM | 6 | 1 |
| AF | AF | 22 | 15 |
| AF | SA | 19 | 17 |
| AF | Juv | 12 | 6 |
| AF | Inf | 5 | 3 |
| SA | AM | 2 | 0 |
| SA | AF | 4 | 5 |
| SA | SA | 11 | 7 |
| SA | Juv | 6 | 3 |
| Juv | AM | 1 | 0 |
| Juv | Juv | 2 | 0 |

## 5.3 Diet

### 5.3.1 Species Consumed

During the overall study period a total of 41 species were consumed by the Terai Gray langur (Table 1), out of which 31 species were consumed by troops in disturbed habitat and 32 species were consumed by troops in undisturbed habitat. 65% of the total plant species were common between the troops in both the habitats. Species that accounted for more than 1% of the feeding scans were considered as food plants. Out of the 31 species fed by disturbed troop, 21 species were consumed during winter and 28 species during spring. For undisturbed troops out of 32 species, 18 species were consumed during winter and 25 species during spring.

For both seasons combined, 7 plant species namely *Ehretia laevis, Acacia catechu, Sterculia velosa, Lantana camara, Carissa opaca, Dalbergia sisso* and *Bombax ceiba* accounted for more than 60% of the diet of disturbed troops. Species namely *Holoptelea integrifolia, Ehretia laevis, Syzygium cumini, Bombax ceiba, Sterculia velosa, Acacia catechu* and *Terminalia bellerica* formed more than 60% of the diet of undisturbed troops. *Ehretia laevis* was the dominant feeding species for disturbed troops in both the seasons while *Holoptelea integrifolia* remained a major food plant for undisturbed troops in winter as well as spring.

**Table 5:** List of major food plants consumed by the study troops in disturbed and undisturbed habitat along with the parts and their phenology.

| **Species** | **Disturbed** | | **Undisturbed** | |
|---|---|---|---|---|
| | **Parts eaten[a]** | **% F** | **Part eaten[a]** | **% F** |
| *Acacia catechu* | ML, S | 10.5 | ML, S | 5.1 |
| *Adhatoda vasica* | UF,RF | 2.4 | | |
| *Aegle marmelos* | ML | 0.4 | ML | 1.1 |
| *Albizia lebbeck* | ML,YL | 1.5 | YL | 0.7 |
| *Anogeissus latifolia* | ML,ST,YL | 1 | ST,YL | 3.3 |
| *Bauhinia vahlii* | | | FLB | 0.3 |
| *Bombax ceiba* | YL,ST,UF,RF, FL | 4.9 | YL,ST,UF,RF, FL | 9 |
| *Butea monosperma* | | | FLB | 0.8 |
| *Carissa opaca* | ML,YL | 6.3 | YL | 1.9 |
| *Cordia dichotoma* | ST,NL | 0.8 | YL | 0.2 |
| *Crateva religiosa* | | | FLB | 0.1 |

| | | | | |
|---|---|---|---|---|
| *Dalbergia sisso* | YL,ML | 5.8 | YL | 2.5 |
| *Diospyros montana* | | | ML | 5 |
| *Ehretia laevis* | ML,ST,YL,FLB,FL,UF | 17.6 | ML,ST,YL,FLB,FL | 12.3 |
| *Ficus bengalensis* | YL,RF | 3.7 | YL,RF | 4.9 |
| *Ficus racemosa* | YL,RF | 1.2 | YL,RF | 3.6 |
| *Flacourtia indica* | ML,YL | 2 | YL | 0.6 |
| *Garuga pinnata* | YL,ST | 0.7 | YL | 0.3 |
| *Holoptelea integrifolia* | ML,YL,S | | ML,YL,S | 14.5 |
| *Holorina antidysenterica* | YL | 1.1 | | |
| *Lagerstoemia parviflora* | ML,YL,ST | 1.6 | YL | 0.5 |
| *Lannea coromandelica* | FLB,FL,UF | 0.9 | FLB,FL,UF | 1.4 |
| *Lantana camara* | YL | 7.8 | YL | 0.2 |
| *Mallotus philippinensis* | ST,UF | 2.1 | UF | 3 |
| *Milusa velutina* | | | ST | 0.9 |
| *Mitragyna parvifolia* | ST | 1.3 | | |
| *Naringi crenulata* | YL | 4.7 | | |
| *Phyllanthus emblica* | | | UF,RF | 0.7 |
| *Premna latifolia* | ML | 0.2 | ML | 0.5 |
| *Shorea robusta* | UF,RF | | UF,RF | 4.2 |
| *Sida cordifolia* | YL | 1.8 | | |
| *Sterculia velosa* | FLB,FL,UF | 8 | FLB,FL,UF | 5.6 |
| *Syzygium cumini* | ML,YL | 3.7 | YL | 9.1 |
| *Terminalia bellerica* | RF,ST | 4 | RF,ST | 5.1 |

| | | | | |
|---|---|---|---|---|
| *Terminalia tomentosa* | ST | 1.2 | | |
| *Trevia nudiflora* | ST | 0.1 | | |
| *Woodforlia fruticosa* | ML | 0.6 | | |
| *Wrightia tomentosa* | | | UF,RF | 0.6 |
| *Zizyphus mauritiana* | | | ML | 0.3 |
| *Zizyphus xylopyra* | ML | 1.5 | ML | 0.7 |
| *Unknown* | | 0.6 | | 1 |

**Parts eaten[a]:** ML: Mature Leaf, YL: Young Leaf, RF: Ripe Fruit, UF: Unripe Fruit, FLB: Flower Bud, FL: Flower, ST: Stem, S: Seed

### 5.3.2 Looped species in disturbed habitat

Out of the total 31 species consumed by langur troops in disturbed area, lopping was observed in 52% of these plants species. Species wise looping percentage was calculated (Table: 2) for both the disturbed troops combined. Species namely *Terminalia bellerica, Terminalia tomentosa, Anogeissus latifolia, Flacourtia indica, Acacia catechu* and *Garuga pinnata* were among the highly lopped species. Out of the total plants lopped, 74% were the food plants of Terai Gray langur.

**Table 6**: List of species lopped with the frequency of lopping observed in study area for disturbed troops.

| **Species** | **Frequency % of lopping** |
|---|---|
| *Acacia catechu* | 8.7 |
| *Anogeissus latifolia* | 9 |
| *Cordia dichotoma* | 2.6 |
| *Dalbergia sisso* | 8 |
| *Flacourtia indica* | 6.8 |
| *Garuga pinnata* | 3.7 |
| *Holoptelea integrifolia* | 4.1 |
| *Lannea coromandelica* | 0.4 |

| | |
|---|---|
| *Mitragyna parvifolia* | 2.9 |
| *Sterculia velosa* | 0.8 |
| *Syzygium cumini* | 4.4 |
| *Terminalia bellerica* | 10.4 |
| *Terminalia tomentosa* | 8.4 |
| *Zizyphus xylopyra* | 1.1 |
| *Mallotus philippinensis* | 2.8 |

## 5.4 Spatial use

### 5.4.1 Strata usage

There was a significant difference in the height category of strata used by langur troops in disturbed and undisturbed sites for both seasons combined (G test of independence, df=3, $p<0.05$). Troops in disturbed habitat were observed to use lower canopy, followed by ground and middle canopy respectively, for majority of their activities while the troops in undisturbed habitat were observed to prefer middle canopy, followed by lower canopy and top canopy (Figure: 11).

The differences in substrate used for moving in disturbed and undisturbed habitat can be seen in figure 12, where troop individuals in disturbed habitat were observed to move more via ground than canopy. More moving scans via canopy were observed for langur troops in undisturbed habitat.

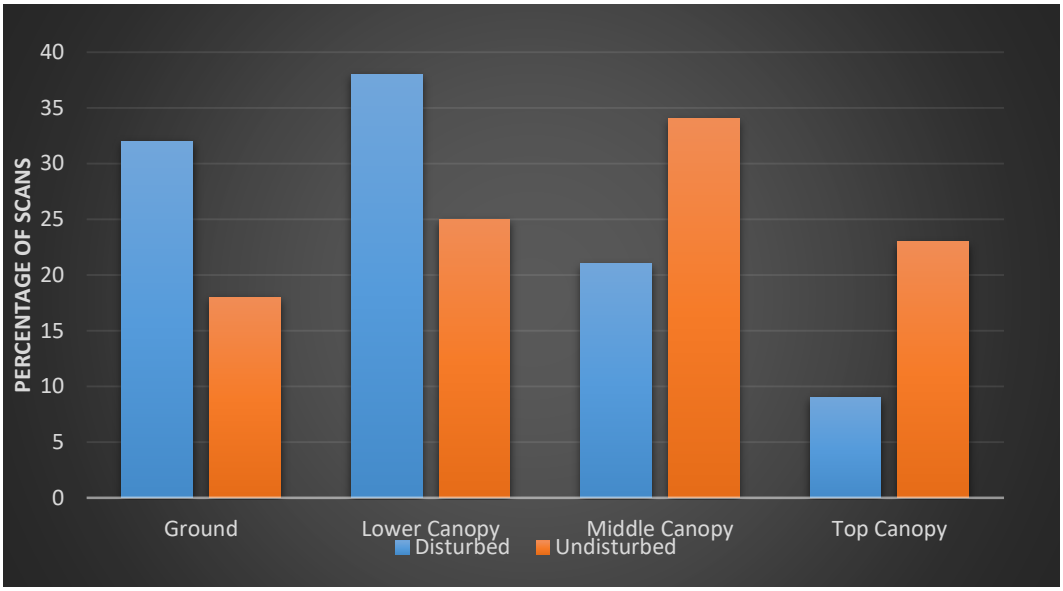


**Figure 11**: Bar graphs representing different height category of strata used by individuals in disturbed and undisturbed habitat for major activities (Lower canopy <3m, Middle canopy<3-6m, Top canopy>6m).

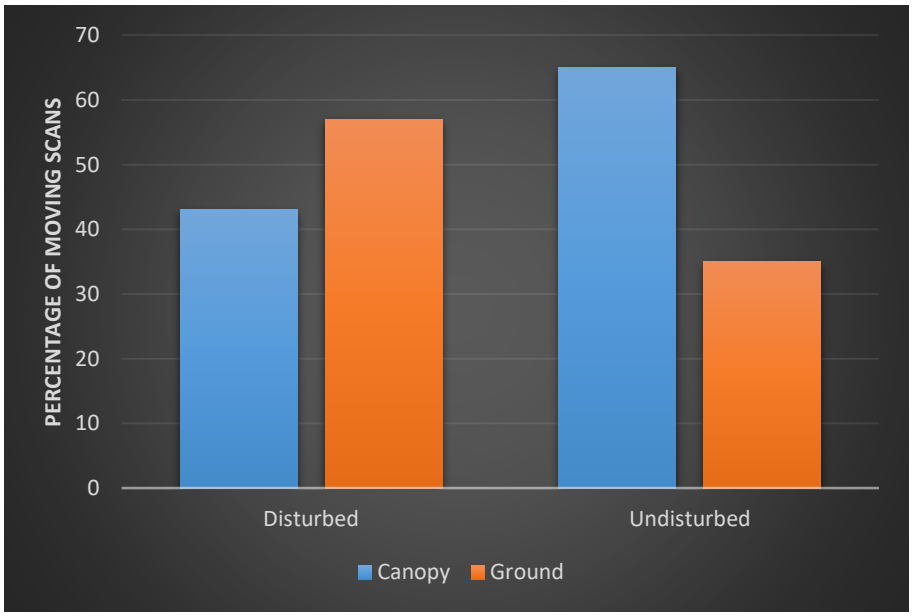


**Figure 12**: Bar graph representing the strata used while moving, by the troop individuals, of disturbed and undisturbed habitat.

## 5.4.2 Habitat Type

Out of the 6 habitat categories, langur troops present in each category for the study period is shown in figure 13. For troops in both the sites, maximum location records were seen in miscellaneous forest. Followed by misc. forest, the troops in disturbed site were seen in scrub forest (23%) and teak plantation (19%), while the undisturbed troops were seen in sal forest (17%) and riverine habitat (11%). There was a significant difference between the records in different habitat category observed for disturbed and undisturbed troops (Gtest of independence, $G=122.37$, $df=5$, $p<0.05$).

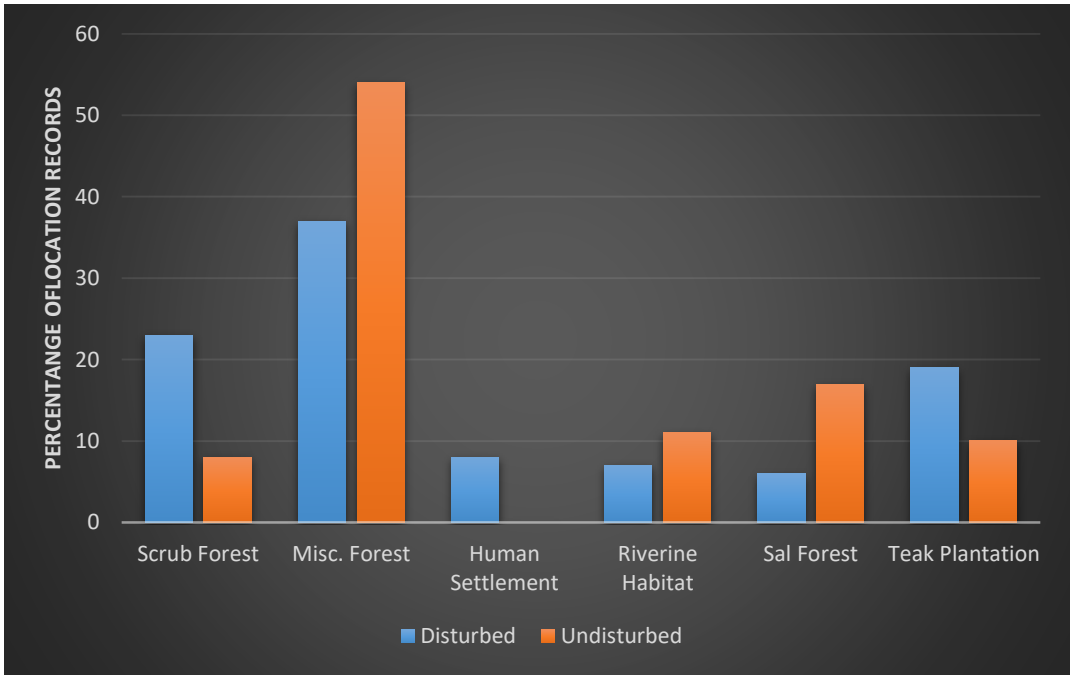


**Figure 13:** Bar graph representing the percentage of location records in different habitat category during the study period in langur troops of disturbed and undisturbed habitat.

### 5.4.3 Daily distance moved

Mean daily distance range of langur troops in disturbed habitat was 1.45±0.07 km in winter and 2.48±0.14 km in spring while the mean daily day range of undisturbed troop was 0.9±0.1 in winter and 1.35±0.12 in spring (Figure 14). The effect of disturbance and seasons on daily distance moved between the troops in disturbed and undisturbed habitat was significant (Two way anova, F-stat(Treatment)= 37.556, df=1, $p<0.05$; F-stat(Seasons)= 39.346, df=1, $p<0.05$).

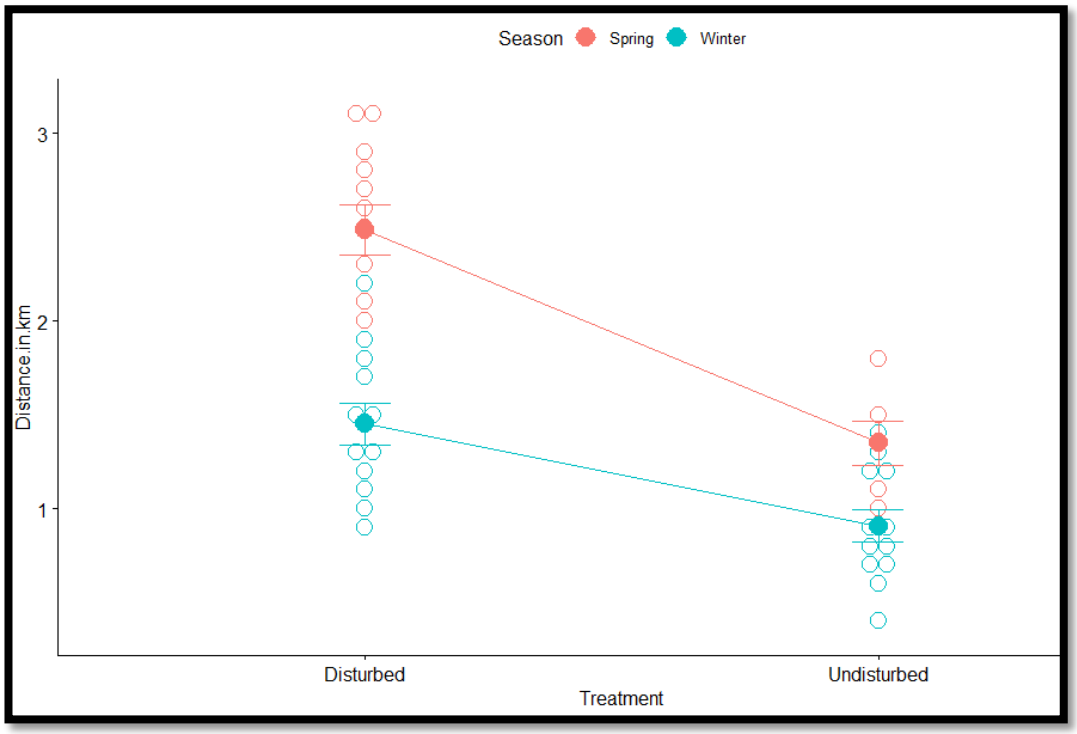


**Figure 14**: Dot plot representing the daily distance travelled in km by disturbed and undisturbed troops in winter and spring. Solid dots represent the mean along with standard error.

### 5.4.4 Home range

The overall home ranges of all four troops are represented in figure 15, 16, 17 and 18. Troop D2 has the largest home range followed by D1, UD2, and UD1. Home ranges of all the troops along with fixes and area is represented in Table 5. Figures 16, 17, 18 and 19 show the home ranges of D1, D2, UD1 and UD2 troops respectively.

**Table 7:** The number of fixes used for 100% MCP and size of home ranges in square km.

| Troop Id | Fixes | | | Home range in square km |
|---|---|---|---|---|
| | **Winter** | **Spring** | **Total** | |
| **D1** | 122 | 92 | 214 | 2.98 |
| **D2** | 141 | 109 | 250 | 3.42 |
| **UD1** | 94 | NA | 94 | 1.37 |
| **UD2** | 136 | 122 | 258 | 2.25 |

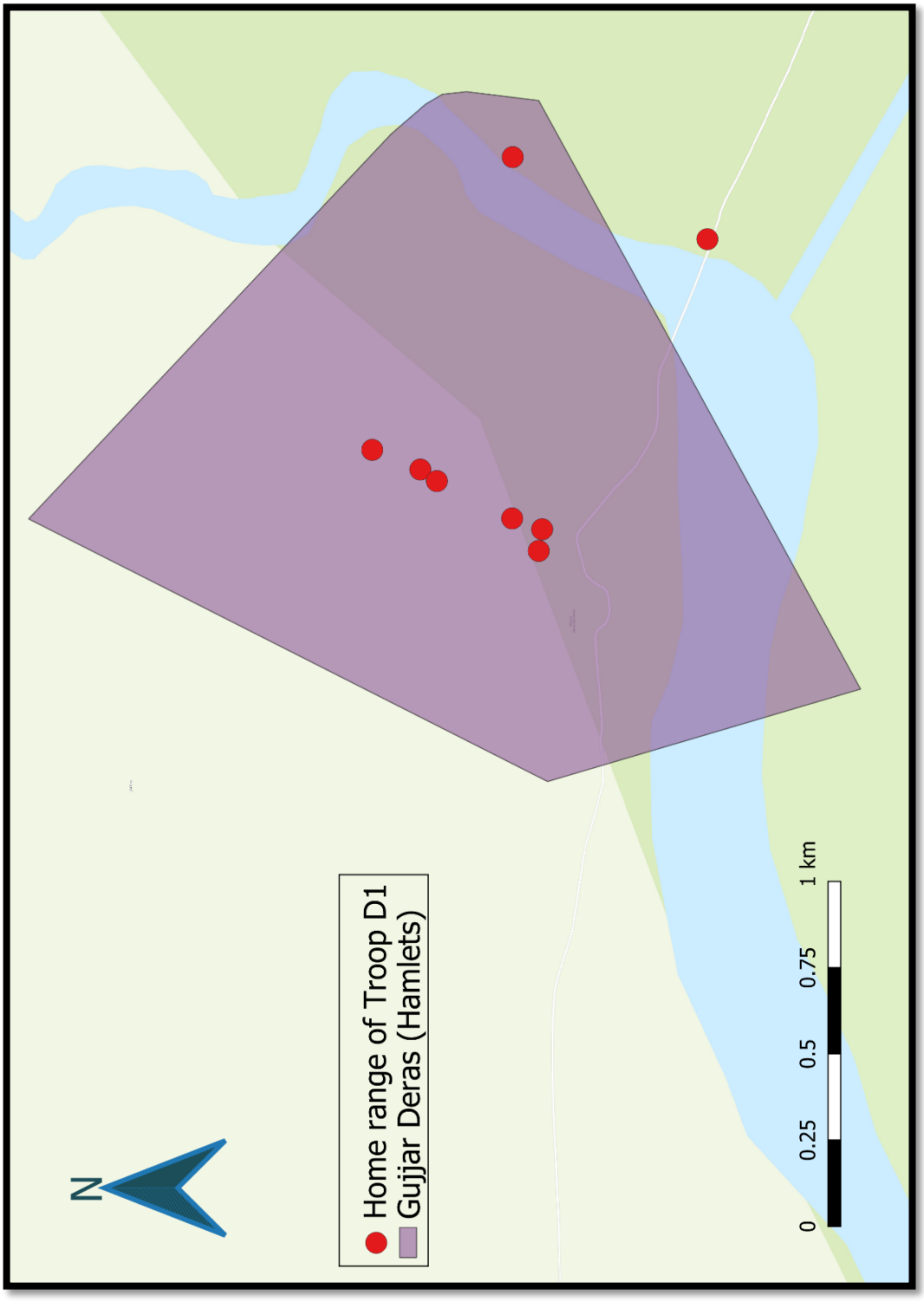


**Figure 15**: Map representing the overall home range for troop D1 in winter and spring combined.

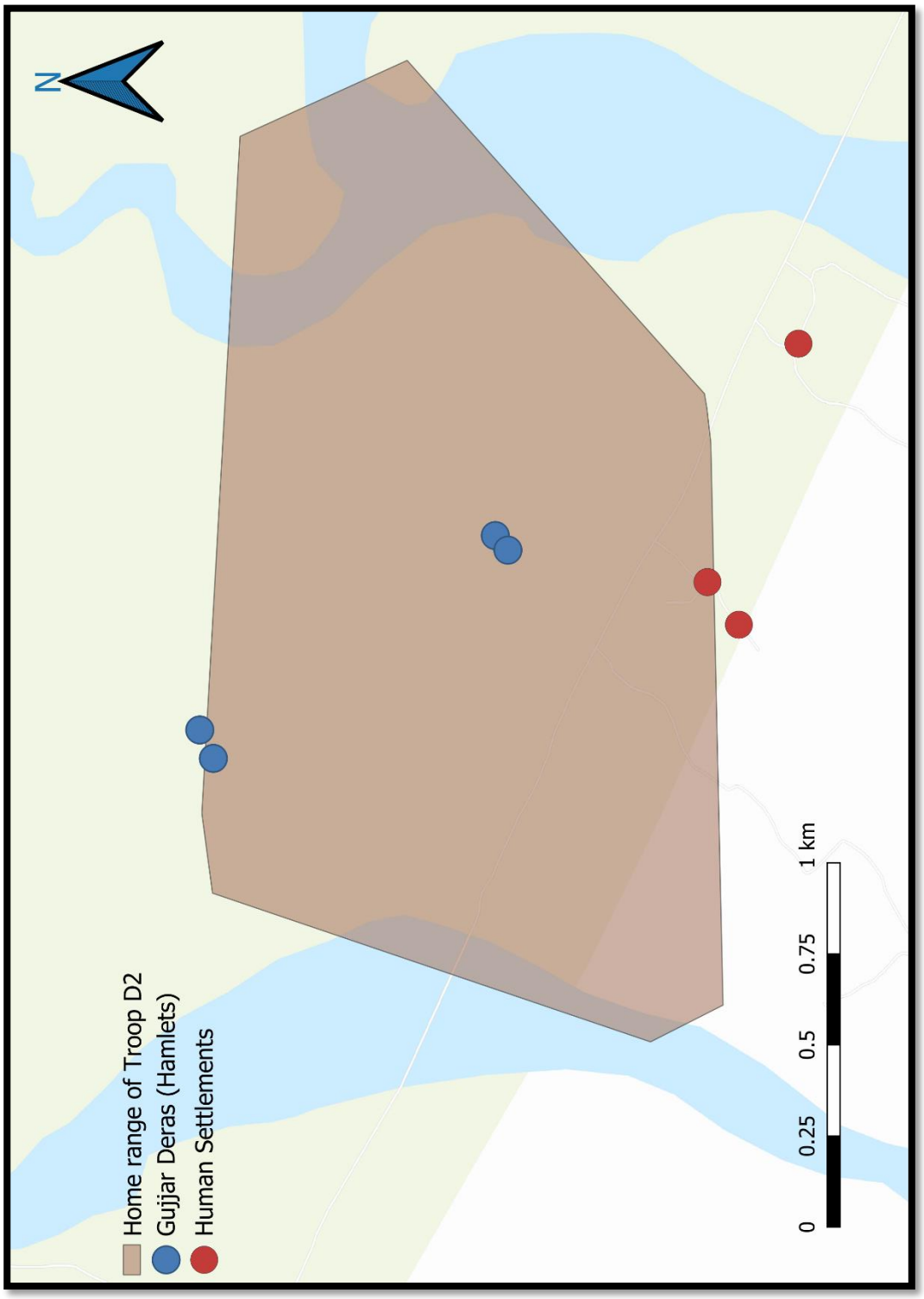


**Figure 16**: Map representing the overall home range for troop D2 in winter and spring combined.

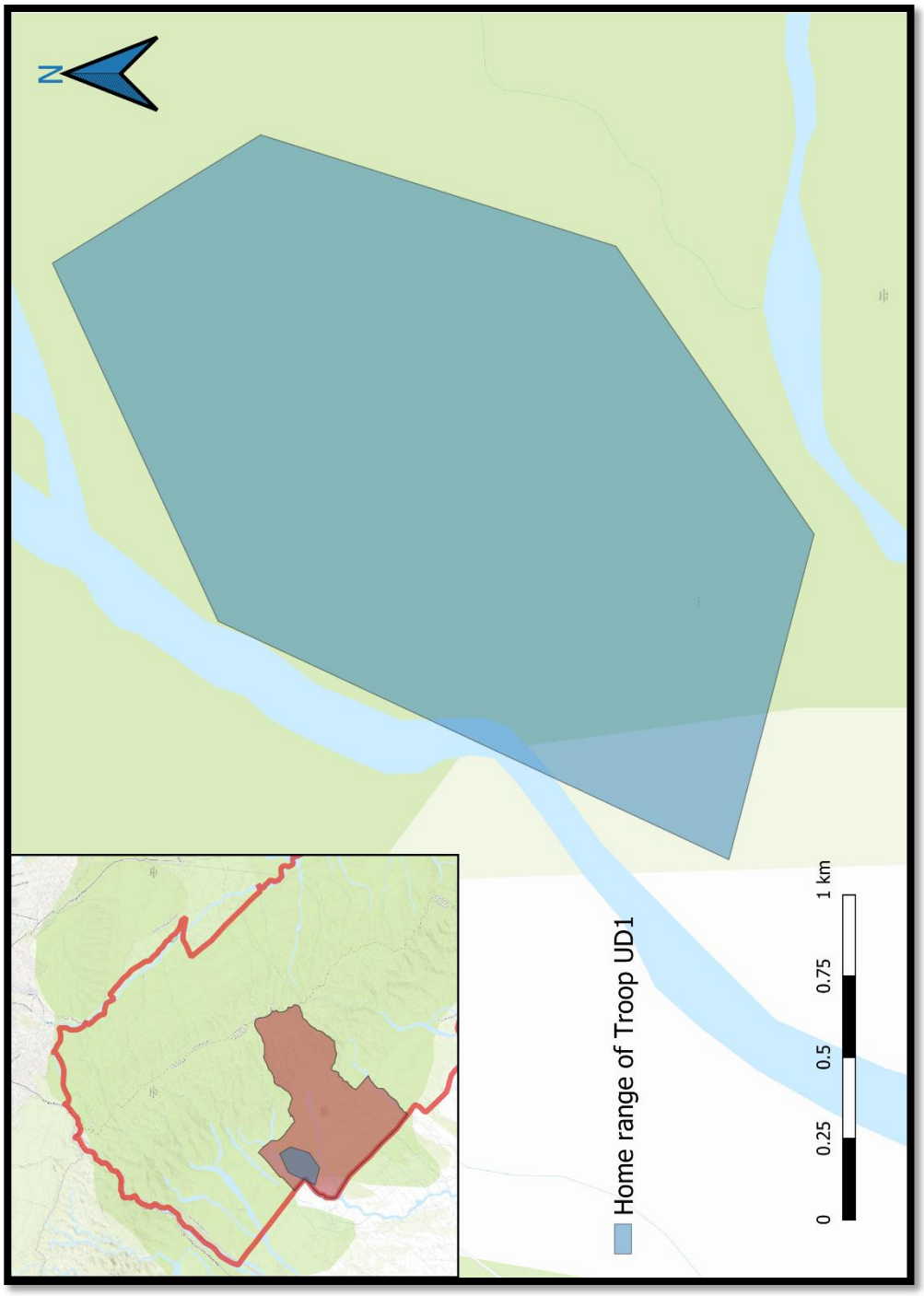


**Figure 17**: Map representing the overall home range for troop UD1 in winter and spring combined.

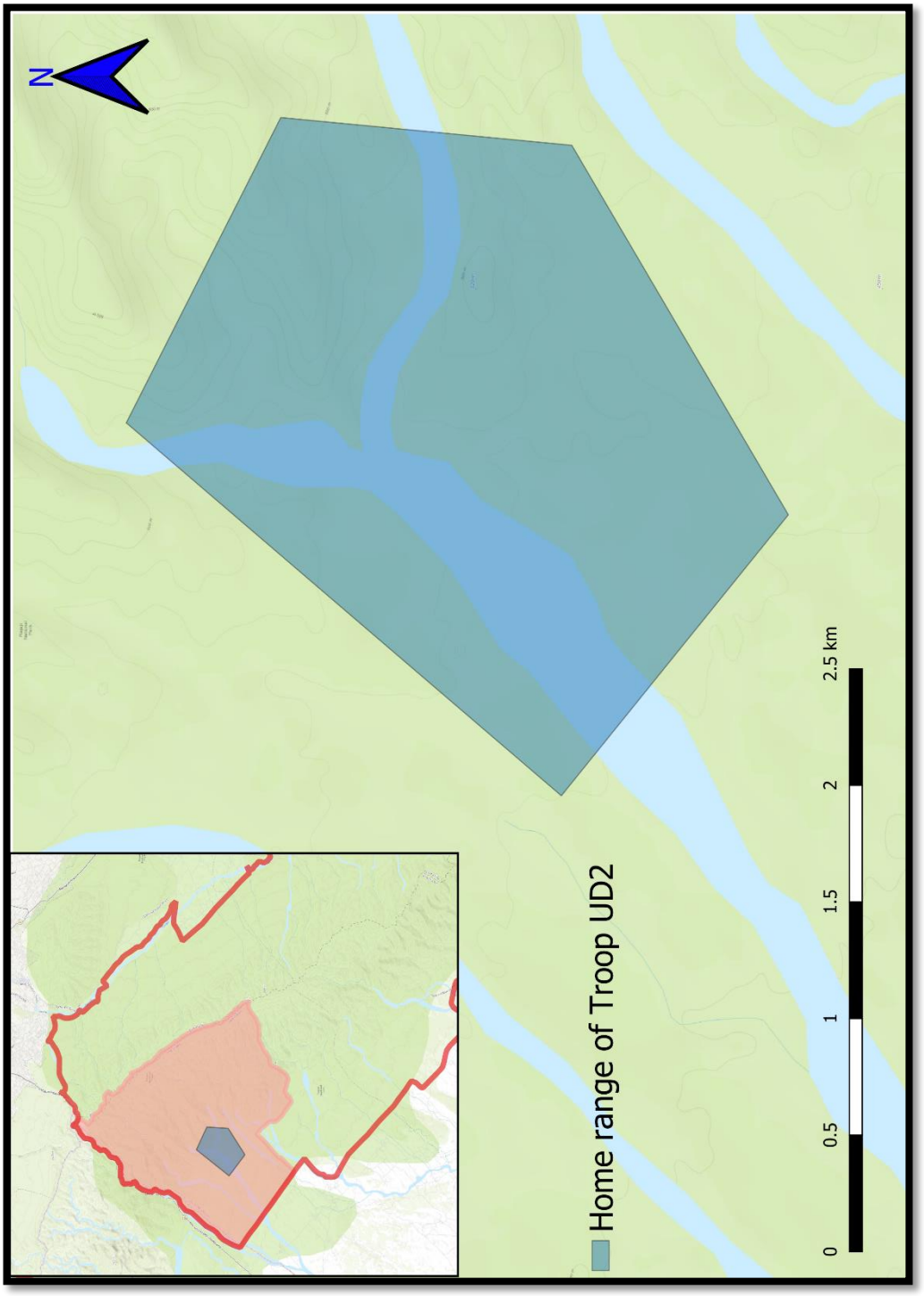


**Figure 18:** Map representing the overall home range for troop UD2 in winter and spring combined.

# Chapter 6: Discussion

## 6.1 Activity Budgets

In this study, the activity patterns of Terai Gray langur in undisturbed habitat were dominated by resting, followed by feeding. This result is consistent with most studies on folivores where they are seen to spend more amount of time on resting and less on feeding (Hendershott, Behie, and Rawson 2016; Nautiyal 2015; Sayers and Norconk 2008). There was a significant change in this generalised pattern of activity in disturbed habitat, where the time spent on resting was reduced drastically and the time spent in feeding and moving was increased. This trend supports the flaw discussed by Sayers (Sayers 2013) in the early socioecological models on leaf eating species, where leaves as a resource was considered abundant and thus less likely for folivores to have resource as a limiting factor. The activity pattern in disturbed habitat, where almost similar amount of time was spent on resting, feeding and moving could be a result of the differential spread of resource in space and time. In the disturbed habitat, this patchiness of resource was attributed to the different degree of human influence on the natural habitat of Terai gray langur. Reduction in the time of resting in disturbed habitat has been observed in other leaf eating primate species like Francois' langurs, Hanuman langur, etc. With the reduced percentage of time for resting and more in moving, the energy requirements for the troops in disturbed habitat are higher and thus this could be a potential reason for such an increase in the percentage of time spent on feeding. Terai Gray langur troops in undisturbed habitat for this study engaged more in socialising which could be a result of localised food abundance, leading to less time

spent on locating food resource, less energy requirements and thus availability of time for other activities like socialising.

The differences in the activity budgets in different seasons were not observed to be significant, even though the resource availability increased in spring with new leaves, flowers and seeds in the study area. For disturbed troops as the resource increased in spring, the competition of the same resource with local forest dependent community also increased leading to decline in food resources even in spring season, causing similar activity patterns. Another possible reason for such pattern could be the increase in temperature during spring, causing feeding and moving activities to shift in early morning and late evening and were missed out of the observations.

The activity patterns of adult male and adult females followed the similar overall trend in both the treatments. Even though the activity pattern of adult males and adult females show no significant difference, yet adult females in both the treatments were observed to spend more percentage of time on socialising than adult males. It has been observed in many multi-male multi-female primate species that female form the central stable core of the group engaging more in socialisation than any other age sex class (Seyfarth 1980; Lu, Koenig, and Borries 2008).

## 6.2 Agonistic and affiliative interactions

The social networks were used as a way to determine the intensity of affiliative and agonistic interactions among different age sex classes. The high intensity of agonistic interaction in disturbed troop and low intensity of grooming interactions can be attributed to increased competition for resource. In disturbed area where the resources are patchy and limited, within group competition for resource leads to

skewed access of food, increasing direct contest. This could lead to increase in aggression or avoidance strategy by individuals of the group (Snaith and Chapman 2007). Avoidance strategy causes individuals to be spread in larger areas to avoid competition, which reduces the proximity of troop members to engage in other affiliative interactions (Van Schaik and Janson 1988). Apart from within group contest, between-group competition can also lead to increase in aggressive behaviours to defend limited resources from neighbouring troops. When resource is not a limiting factor primate troops become more tolerant and show less aggressive interactions. Studies in the past on adult males of Terai Gray langur, in Rajaji National Park, have depicted the tolerance of adult males towards other males of the troop, and towards non-troop males (Laws and Laws 1984). Adult males participated in the dyadic grooming bouts more than the males in undisturbed habitat, this could eventually lead to a more stable social structure in undisturbed habitat.

Studies on primate social interactions are highly influenced by individuals dominance rank, kinship to other troop members, personality, and preferences (Blaszczyk 2020). Grouping all individuals in any age-sex class together may result in the loss of some heterogeneity of different interactions.

## 6.3 Diet

Langur being predominantly folivores have ruminant like foregut adaptations for effective digestion of leaves (Davies 1994). Studies have suggested that folivores not only rely on leaves but they feed selectively on parts that have high nutritional value and differ in spatial distribution (Chapman and Chapman 2002; Kar-Gupta and Kumar 1994). Availability of food resource along with its nutritional value determine

the time spent on feeding that particular plant species. For overall study period, a total of 41 species with 78 food items accounted for the diet of Terai Gray langur. Even though 65% of the species consumed were similar for troops in disturbed and undisturbed habitat, the troops in disturbed habitat fed on more food items when compared to troops in disturbed habitat. The reason for such a pattern could be the low availability of food resources, with high competition from local forest dependent communities, there is limited access to high nutritional food parts. In such a limited food scenario, the troop in disturbed habitat could potentially incorporate more food items to meet the nutritional required for their survival. Few species of primates like Sulawesi Tonkean macaques and howler monkey are known to show a similar trend of increasing food items in fragmented habitat (Riley 2007).

Another importance inference from this study was the young flush leaves of *Lantana camara* as one of the major consumed species (8% of the feeding records) during the study period. *Lantana camara*, an invasive toxic weed, unpalatable for foraging by most animal species, has changed the forest understory by covering the forest floor and outcompeting the native species (Kohli et al. 2006). The study site in disturbed habitat had vast areas of scrub forest and miscellaneous forest floors dominated by *Lantana camara*, during winters when the resource was extremely scare, the more abundant young leaves of *Lantana camara* could be utilised as a food resource due to the low level of toxins in young leaves compared to mature leaves.

Lopping of trees for fuelwood and fodder by the forest dependent community was more of a direct sign of disturbance in the study area of Shivalik Forest division. By quantifying the extent of lopping on the food species, it was observed that the

species consumed by langurs formed more than 70% of the total trees lopped in disturbed habitat. Thus, it could be inferred that the langurs in disturbed habitat face high levels of resource competition from local communities.

## 6.4 Strata and habitat usage

In addition to the impact of lopping on food resource, a more indirect impact could be seen in the form of strata used for locomotion and other activities. The significant difference in the canopy and ground usage in disturbed troop could be a result of unavailability of continuous canopy for movement. Similarly the unavailability of top canopies, due to lopping, could be a reason for preferring lower canopy for all other activities by disturbed troop.

Results from the differences in habitat usage concluded more location records of undisturbed troop in miscellaneous and sal forest while location records of disturbed troop was higher in miscellaneous forest, scrub forest and teak plantation. Most food species of langur were found in miscellaneous forest so maximum habitat records were in this habitat category. Further, the study area inside Rajaji National park for undisturbed system was dominated by sal forest and miscellaneous forest type while the study area of disturbed system in Shivalik forest division was a mosaic of miscellaneous forest, teak plantation , scrub forest and a very few patches of sal forest. This could also be the reason for high number of location records in teak plantation and scrub forest for disturbed troops. Another inference drawn from the results of habitat usage was the presence of langur near human settlements in disturbed habitat. Most of the location records near human settlements were observed during moving

between feeding patches. Langurs were using areas with low density of human settlements.

## 6.5 Spatial use

Daily distance moved and home ranges of any species explains the distribution of food resources and its relation to the foraging habitats. In most primate species where food is a limiting patchy resource, longer daily distances and large home ranges are maintained (Mbora, Wieczkowski, and Munene 2009). Results of daily distance moved and home ranges in this study are consistent with other studies where resource was patchy, troops in disturbed habitat moved significantly more and had bigger home ranges than troops in undisturbed habitat.

The results for seasonal differences in daily distance moved were inconsistent with the general pattern seen in other studies on primates. In winter when the resource is limiting the daily distance moved was longer than spring where resource was quite abundant (Hendershott, Rawson, and Behie 2018). In this study the daily distance moved was more in spring than winter. This could be because of the increase in temperature during spring in the study area. Generally, folivores are known to fulfil majority of their water requirement from the leaves, but in extreme temperatures water can also act as a limiting resource. In disturbed habitat, water as a resource was rare and thus troops had to travel long distances in spring as well. In undisturbed habitat, there were a few water holes present in home ranges of each troop. There was an increase in visitation rate of water holes during spring which might be the reason for long daily distance travel for undisturbed troop as well.

Overall, each analysis was carried out without the spring data for UD1. For more robust ecological inferences from this study, larger area along with more number of troops should be extensively and intensively sampled. Long term study based on the quantification of changes in biomass of food resource as a result of disturbance would give a better understanding of the processes behind the patterns observed in this study.

## 6.6 Conservation Implications

Disturbed area which is a part of Shivalik Forest division has several Gujjar deras (Hamlets) inside it and villages on its eastern boundary. Although, disturbance in the form of selective lopping is considered less severe than other forms of habitat destruction like tree felling, conversion of forest land for agriculture use and other infrastructural developments (Almeida-Rocha, Peres, and Oliveira 2017), but these small patchy forest pockets are very crucial for the survival of most primate species in India. Their extreme modification can impact these species to a greater extend. This study can help the forest staff in management of these habitats, for long term conservation of Terai Gray langur, by controlling the selective lopping and plantation of highly preferred food species in this landscapes. Providing more artificial sources of water during spring and summer. Management interventions in the current circumstance would reduce the possibility of human-langur conflict in future when scarcity of resources could lead these primate species to move in human-dominated landscapes. Lastly, the dependency of local communities should be reduced on the forest produce by providing them alternative livelihood source.

# Chapter 7: Conclusion

From this study, it can be concluded that Terai Gray langur occupying the modified forest with anthropogenic pressures, show differences in their socio-ecology from the ones occupying intact inviolate areas. Changes in activity pattern with differential amount of time allocated for major activities was observed in the study period. Intensity of affiliative and aggressive interactions were altered among different age-sex classes. There were differences in the preference of food resources, and the impact of disturbance in form of lopping on these food resources was also observed. Further, habitat usage and spatial usage varied between the two sites for this study. However, a long term study would be more conclusive in quantifying the impacts of disturbance during different seasons, on different group size and composition of Terai Gray langur.

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# Appendix I

The ethogram used for this study has been adapted and modified from the behaviour repertoire of Gray langur described by Dolhinow (Dolhinow 1978). 30 behaviour categories were used in this study and each one of them was categorised into 5 major activities.

1. Canine grinding: When an individual produces the sound as the result of the slow closing of the jaws in such a manner that the upper canine is made to grind audibly against the lower first premolar. A grinding noise may also be produced by slow lateral movements of the almost occluded teeth. It is usually done by adult males, although sub-adult males and adult females also produce a grinding noise.
2. Chase: When an individual runs for the pursuit of a target individual and follow it closely for some distance. Chase often terminates into contact and non-contact aggression.
3. Defecate: An individual defecates while sitting or standing on the substrate.
4. Displace: When an individual forces another to move from a specific location, from an object such as a food item, or from an interaction. This behaviour is mostly seen during feeding bouts.
5. Display: An individual runs and leaps or banks off solid objects and bounds from place to place, creating a great deal of noise by these actions. This is a dramatic, highly visible, and complex set of movements. Males typically give the loud whoop during display. Mostly adult males show this behaviour but in a few occasions adult females and sub-adults of both sexes are seen displaying.

6. Drink: Individuals usually drink by either lying flat, or by simply bending over and placing their mouths directly on the source of water.
7. Embrace: Two individuals, usually seated facing each other, place their arms around each other's body and grasp the fur on each other's dorsum. The embrace may be repeated with the two individuals engaging and disengaging in ventral-ventral contact, often with each placing its chin on the other's shoulder and releasing the dorsal fur, looking into the partner's face briefly.
8. Face Threat: When an individual thrusts its face forward with its mouth open and teeth exposed, visually focusing on the recipient of the threat.
9. Feeding: When an individual handles the food item and actively ingests it.
10. Grimace: When an individual draws back the corners of its mouth, exposing the teeth and gums. The teeth are usually clenched but sometimes are parted slightly. The grimace may be repeated and accompanied by vocalizations.
11. Allogrooming: An individual picks through and/or brushes aside the fur of another, using one or both hands. The groomer may remove foreign objects on the skin or fur and may pick at the skin or fur with teeth or fingers. The groomer may also lick the fur or skin alternately, or simultaneously with its hand movements.
12. Hand Threat: An individual swings, grabs at, slaps at, or otherwise moves its hand toward another animal in an aggressive manner. It can be in the form of physical and non-physical contact.
13. Huddle: Two or more individuals rest together and deliberately maintain maximum body contact. This behaviour in mostly seen in adult females with their infants and juveniles.

14. Locomotion: Individuals may move continuously along tree branches or on the ground, usually in a specific direction, often not displaying any particular interest to objects along the way. This behaviour was typically observed during troop movements, when the entire group moved from one particular area to another.
15. Looking around: An individual, while sitting, standing or moving, inspects its surroundings, without focussing on any object or individual.
16. Looking towards: An individual, while sitting, standing or moving, look towards, at an unidentified target, perhaps food or to observe the activities of other troop members.
17. Play: When an individual involves in the activity of play either alone or with other members of the group. The typical play behaviour includes touching, crouching, tail pulling, hugging, rolling, jumping, swinging, running, etc. This behaviour is predominantly shown by infants, juveniles and sub-adults.
18. Receive allogrooming: When an individual is being groomed by another members of the troop.
19. Resting: An individual remains stationary and inactive, sitting, with eyes closed and often with the head down.
20. Resting in contact: Two or more individuals remain stationary and inactive, with eyes closed, and with some body contact, such as sides, arms, or legs touching.
21. Scanning: When an individual is awake and alert, visually inspecting its surroundings but not focusing on another animate or inanimate object. This behaviour is generally exhibited by adult males but in some instances sub-

adults and adult females also act as sentinels for visually looking out towards any probable threat and alarming the troop.

22. Self-grooming: An individual grooms any part on its own body, actively searching for insects, seeds, dirt, ectoparasites or any other object that might be entangled in its hair and focusing its attention on that particular part of the body.
23. Sitting: An individual remains stationary, hindquarters on the supporting surface, awake, alert, with eyes open.
24. Sitting in contact: Two or more individuals remain stationary, hindquarters on the supporting surface, alert, awake, with eyes open and with some portion of their bodies in contact.
25. Sleeping: When an individual remains stationary and inactive, lying flat on back over the branches or other substrate, with eyes closed.
26. Squeal: This sound varies in intensity and volume from very soft and quiet to a high-pitched, loud, intense vocalization. This sound is mostly produced by infants and juveniles.
27. Suckling: An infant or juvenile holds the nipple in its mouth.
28. Take Infant: When an individual grasps and pulls an infant from other individual. The infant may struggle or resist, may make no effort to thwart the transfer, or may assist in the transfer. The individual from which the infant is taken may resist, ignore, or facilitate the transfer. This behaviour was mostly depicted by adult and sub-adult females.
29. Urination: An individual urinates while sitting or standing on the substrate.

30. Vocalisation: This behaviour category was used to record any vocalization an individual gives apart from canine grinding and squealing.