Golden Langur Distribution, Habitat Selection and Corridor – Connectivity: Assessing Patterns and Addressing Threats

By

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Under the supervision

of

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Declaration

I, **Rishi Basumatary**, hereby declare that the work conducted under the thesis entitled **"Golden Langur Distribution, Habitat Selection and Corridor-Connectivity: Assessing Pattern and Addressing Threats"**, is a record of original and independent research work done by me and subsequently submitted for the award of the degree of **Master's in Wildlife Science** at the **Academy of Science and Innovative Research, Ghaziabad, Uttar Pradesh 201002**. This research work has been carried out under the guidance and supervision of **Dr. Anukul Nath, Scientist – C** of **Wildlife Institute of India, Dehradun** and Co-Supervisions of **Dr. G.V. Gopi, Scientist – F** of **Wildlife Institute of India (Dehradun)** and **Dr. Dilip Chetry, Primate Research & Conservation Division (Aaranyak).** The work has not formed the basis for the award of any other degree, diploma, or any other qualification. I also declare that the thesis embodies my own work, analysis, observation, understanding and the particulars given it true to the best of my knowledge.

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This is to certify that the thesis by **Mr. Rishi Basumatary** entitled **"Golden Langur Distribution, Habitat Selection and Corridor-Connectivity: Assessing Pattern and Addressing Threats"** is an original and independent research work submitted to the **Academy of Scientific and Innovative Research, Ghaziabad, Uttar Pradesh 201002**.

Mr. Rishi Basumatary has put one semester of research work embodied in this thesis under our guidance and supervision. The work presented in this thesis has not been submitted to any other University or Institute for the award of any degree, diploma or distinction.

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Contents

List of Figures

List of Tables

Executive Summary

The Golden Langur (*Trachypithecus geei*), is an endangered colobine primate, confined to fragmented forest patches in western Assam, India, and south-central Bhutan. The golden langur has experienced severe habitat loss and fragmentation due to ethnolinguistic and religious conflicts between the late 1980s and late 1990s, followed by developmental activities in western Assam. The primary threat faced by the golden langur in India are the rapid reduction of its natural environment and the fragmentation of its habitat. Factors such as a limited population size, the breakdown of meta-population dynamics, and unique traits of a species often make a population in a fragment more likely to experience local extinction. Due to the significant decline in the range of Golden langur in both Bhutan and India, as well as the ongoing destruction of their habitat in India, it is imperative to safeguard even the smallest local populations. The populations residing in these fragmented Reserved Forests and Proposed Reserved Forests are effectively confined, separated from the primary breeding population, and susceptible to demographic and genetic influences. The objective of this study is to understand the current distribution, suitable habitat, and connectivity of corridors for the severely fragmented southern population of golden langur in India. Additionally, the study aims to examine the specific habitat preferences and demographic patterns of langur groups, as well as evaluate the threats that this fragmented population faces. The study was carried out in nine fragmented forest patches that includes Wildlife Sanctuary (WLS), Community managed RF (CMRF) Reserved Forest (RFs), and Private Rubber Plantations and Adjoining Forests (PRP_AF). In the present study, a total of 123 trails, ranging from 0.4 km to 1.6 km, were walked, covering a total distance of 118.72 kilometers. During these surveys, a total 51 troops (including 8 multi-male multi-female troops and 5 all-male groups), consisting of 499 individuals were encountered. The mean group size and age-sex ratio between different

protected regimes that include wildlife sanctuary (WLS), community managed RF (CMRF), reserved forest (RF) and private rubber plantation and adjoining forests (PRP_AF) were compared.

The overall mean group size of the langur was 9.78 (± 0.69 $_{SE}$). Of the total 499 individuals, 13.22 % comprised of adult males, 41.88 % adult females, 16.83 % sub-adults, 10.02 % was juveniles and 18.03 % was infant. The average age-sex ratio of adult males to adult females was 0.287 (± 0.04 $_{SE}$), juveniles to adult females was 0.224 (± 0.02 $_{SE}$) and infants to adult females was 0.407 (± 0.04 $_{SE}$). The infant to female ratio was found higher in wildlife sanctuary as compared to other reserved forests in the study area. The current study revealed that approximately 883 km^2 of the area is highly suitable for the endangered golden langur. Percent forest cover was found to be the most important variable in determining the probability of occurrence of golden langur in India. The corridor connectivity analysis showed high conductance for corridors namely Bamungaon and Khoragaon RF. Similarly, the connectivity is permeable between Kakoijana and Bamungaon. Other corridors identified in the study are Bhumeshwar Hill, Nakati RF and Kakoijana RF. On the other hand, there is high conductance among corridors of Chakrashila WLS and Nadangiri RF. Additionally, fine scale habitat selection study showed that tree species diversity, canopy cover and food plant density are the key in determining the occurrence of golden langur.

In the last six years, a total of 56 mortality and injury incidents were reported from the study area which include 45 deaths and 11 injuries. Electrocution accounted for 29 cases, especially near forest edges, while 21 road accidents occurred mainly on national and state highways, as these roads are broader and have higher traffic volumes compared to village and town roads. Most accidents happened in the corridors between Chakrashila WLS-Nadangiri RF and Kakoijona RF-Bamungaon RF. Specific measures need to be taken to minimize electrocutions and road accidents of golden langur in the region. Mitigation measures like insulating electric lines and road safety protocols such artificial canopy bridges (ACB) and metal animal overpasses (MAOP) are essential for safe and easy movement along these corridors for the golden langur's survival in fragmented habitats.

CHAPTER I

1.1 Introduction

Ecosystems are constantly changing due to unprecedentedly rapid land use and land cover changes, particularly in emerging nations, endangering livelihood systems and sustainability (Ndegwa et al., 2009). Anthropogenic activities are the most essential elements negatively altering the natural state of the resources and landscape. Along with a growing world population, the rapid conversion of land for agricultural and urban development has led to an unmatched reduction and fragmentation of natural ecosystems (Estrada et al., 2017; Haddad et al., 2015) and are a significant contributing factor to the global endangered status and extinction of the species (Harris, 1984; Ehrlich, 1986; Kerr & De Guise, 2004; Rudnick et al., 2012; Talukdar et al., 2020). Habitat fragmentation not only reduces total habitat area and isolates remaining patches from one another but also modifies the fragmented habitat through edge effects (Saunders *et al.*, 1991). Reduced connectivity causes population isolation and reduction in genetic diversity by limiting the fitness of populations to environmental response, leading to inbreeding depression and local extinction because of stochastic events (Rudnick et al., 2012). However, connectivity promotes gene flow between populations, therefore improving species survival and lessening the negative impacts of habitat changes (Doerr et al., 2011; Olds et al., 2012). Recent developments and encroachment in forest areas lead to habitat fragmentation and alteration of most of the suitable habitats of many species; among them, primate species are no exception. As per the IUCN 2021 report, about 85 % of all primate species are experiencing a decline in population worldwide. Human activities such as increased agricultural production, hunting and trapping, timber extraction, civil upheaval, etc., have resulted in changed and degraded habitats for about 419 primate species (Estrada & Coates-Estrada, 1996; Estrada et al., 2017). Within the Indo-Malayan region, by the early 1990s, 31% to

96% of the natural habitat of 42 species of primates had been lost (MacKinnon & MacKinnon, 1991; Schwitzer et al., 2011). Tropical deforestation and fragmentation have severely affected the primate population of the world over, as most of them are forest-dependent and sensitive to modifications in their natural habitats (Marsh, 2003). Factors such as small population size, collapse meta-population dynamics, and particular species-specific characteristics may, however, often predispose a population in fragments to the risk of local extinction (Gibbons & Harcourt, 2009).

All primate species respond to habitat alteration, impacting the species' demographic pattern and survival (Hill & Bernstein, 1969). The endangered golden langur *Trchypithecus geei* is not an exception and has been observed to respond to these changes in recent years. Rapid loss of habitat and habitat fragmentation due to various developmental activities like road, housing and various other infrastructure development, hydropower projects, followed by ethno-political violence within the distribution limit of the species, are the major threats to the golden langur in India (Srivastava, 2001b; Choudhury, 2002; Thinley et al., 2020; Nath et al., 2023).

The golden langur, *Trachypithecus geei* Khajuria, 1956, is one of the rare and endangered Colobine primates in India, discovered in the early 20th century by naturalist E. P. Gee and described by Khajuria. It is endemic to western Assam in India and some parts of south-central Bhutan, inhibiting the forest reserves, now restrictedly distributed to a few pockets of small forest fragments to the north of river Brahmaputra between the Sankosh river on the west and Manas River on the east in Assam in India, and to the foothills of Mt. Jowo Durshing, previously known as Black Mountain in south-central Bhutan between high mountain ridge of Tsirang district in the west and Manas River, Mangde Chu and west of Chamkhar Chu in the east (Gee 1961, 1964; Choudhury, 1992, 2002, 2008; Srivastava et al., 2001; Saha, 1980; Subba & Santiapillai, 1989;

Subba, 1989; Wangchuk, 1995; Lhendup *et al.*, 2018; Thinley et al., 2019). It is listed in Appendix I of CITES, as 'endangered' on the IUCN Red List of Threatened Species and protected as Schedule I species under Indian Wildlife (Protection) Act, 1972, and Bhutan's Forest and Nature Conservation Act, 1995. Golden langur inhabits moist deciduous, sub-tropical evergreen and semi-evergreen forest (Champion & Seth, 1968; Srivastava, 1999). The majority of the locations where it is still present are not included within the protected area network. In 1997, the Indian population of this species saw a significant decrease as a result of a fragmented habitat, leading to a rapid decline and a bleak outlook for its future. The continued existence of golden langur is contingent upon genetic interchange. Currently, golden langurs are confined to diminutive, secluded groups across a significant portion of their habitat (Biswas 2005). According to Srivastava (2006), the estimated langur population in India in 2001 was less than 1,500 individuals. The Golden Langur Conservation Project (GLCP) was established in 1998. The study aimed to combine existing approaches from other sources to engage communities in conservation efforts, specifically focusing on safeguarding India's critically endangered primate species (Mukherjee and Southwick 1997). The methods used were previously established by Horwich and Lyon in 2007, as well as by Horwich et al. in 2011 and 2012. The initiative showcased the effectiveness of utilizing the golden langur as a flagship species for the conservation of landscapes and ecosystems in western Assam, including the forests of the Manas Biosphere Reserve (Horwich et al. 2010).

The primary concentration of its population in Assam is found within the Manas Biosphere Reserve, which is a wooded region situated along the Bhutanese border. Additionally, there exist substantial populations in remote forests located to the south of the Manas Biosphere Reserve, as documented by Deuti in 2005. Following the start of the Bodoland autonomy movement in 1993, which was triggered by a rise in the number of non-Bodos migrating to Assam, extremist groups sought shelter in the forests of Assam. As a result, significant forest depletion occurred. The intricate political situation led to the clearance of over half of the reserved forests in western Assam. The growing human population living near langur populations in diminished, deteriorated, and fragmented forests has led to langurs being killed by humans and dogs or dying from electrocution when they leap onto power lines and road accident while attempting to traverse between forest fragments. The latest censuses conducted between 2008 and 2012, in collaboration with the Forest Department, Assam, utilized trained villagers as researchers to assess the number of Indian golden langurs. The results indicate a significant increase in the langur population, from 1,500 langurs in 1997 (Srivastava 2001b) to over 5,600 langurs in the period of 2008-2012. The details on distribution and population status of the endangered golden langur are provided in box 1.

Box 1. Distribution and Population-Golden Langur

There have been several studies that have examined the distributional limits and the population status of the species in India and Bhutan (Gee, 1961; Khajuria, 1956; Wayre, 1968; Mukherjee & Saha, 1974; Mukherjee 1978, 1997; Mukherjee & Southwick, 1997; Subba, 1989; Choudhury, 2008; Wangchuk, 1995; Mohnot 1995–2001).

Bhutan: In Bhutan, it is distributed throughout south-central Bhutan up to the foothills of Mt. Jowo Durshing, formerly known as Black Mountain and between Manas River, Mangde Chu and west of Chamkhar Chu in the east and high mountain ridge of Tsirang district in the west with an altitudinal elevation ranging between 150 m asl in the south low-lying plains and 4900 m asl at the peak of Mt. Jowo Durshing (Thinley et al., 2019). The current population of golden langur in Bhutan is approximately 2439 with a density of 0.88 individuals/sq. Km, much lower than the current IUCN estimation of 4000 individuals for Bhutan (Thinley et al., 2019).

India: The historical range of the golden langur extends to approximately 2,500 sq. km in India. In India, it is restricted in western Assam to the north of river Brahmaputra between river Sankosh in the west and river Manas in the east. However, recent human activities have led to significant population fragmentation in various areas. It is now restricted to at least 19 fragmented areas in India (about 950 sq. km), originally a single habitat (Choudhury et al., 2002; Roy & Nagarajan, 2018). Ghosh et al. 2009 reported a total of 5141 individuals with an average density ranging between 0.28 to 10.99 individual/sq. Km. Additionally, a recent population study carried out in Chakrashila WLS (Chetry et al., 2020) and Kakoijana RF

(Chakravarty et al., 2020) in the highly fragmented southern population reported a total of 558 and 489 individuals, respectively.

Presently, in India, the population can be classified as:

(A) Northern population – The population in the north is well-connected with the population in Bhutan, as the remaining forests are protected. The population is distributed to the north of National Highway 31 between east of the Sankosh river in Raimona National Park and west of Manas river in Manas Tiger Reserve. In between, the population also occurs in various reserved forests, including Chirang-Ripu RF, which are under the jurisdiction of Raimona NP and Manas TR.

(B) Southern Population – The southern population has become isolated from the northern population only in the last 15 years mainly due to forest fragmentation and a rise in developmental activities such as the expansion of human habitation post-ethno-political conflict, upgradation of National Highway 31 and Railway line that cut through the Ripu-Chirang RFs (Ghosh et al., 2009; Nath et al., 2023). The southern population is spread across nine small fragments, which include Chakrashila Wildlife Sanctuary, Nadangiri Hill RF, Abhya Rubber Plantation, Bhumeshwar PRF, Nakati PRF, Bhairab Hill PRF, Bamungaon RF, Kakoijana RF and Khoragaon PRF (Ghosh et al., 2009).

The conservation of this unique species is complicated and not solely associated with the traditional conservation methods of protection limited to specific protected areas. Given the greatly reduced distribution of Golden langur both in Bhutan and India and the current trend of habitat destruction in India, it is critical to protect even small local populations. The populations that live in these fragmented Reserved Forests and Proposed Reserved Forests are virtually trapped, isolated from the main breeding population and vulnerable to demographic and genetic factors. Therefore, the present study aims to understand the current distribution, suitable habitat, and corridor connectivity for the highly fragmented southern population of golden langur in India, and investigate their fine-scale habitat selection and group demography patterns, and assess the threats faced by this highly fragmented southern population.

1.2 Objectives

The key objectives are as follows:

1. To understand the current distribution, habitat suitability and corridor-connectivity for the highly fragmented southern population.

2. To investigate fine-scale habitat selection and group demography pattern of golden langur in highly fragmented southern population.

3. To assess current threats in the highly fragmented southern population.

I hypothesized that the present distribution of golden langur has changed, with potential expansion, contractions, or shifts in their habitat. I expect forest cover changes, elevation, and the level of human disturbance, significantly influence the distribution and connectivity of golden langur. The remaining suitable habitat for the highly fragmented golden langur population has decreased, indicating increased habitat loss and fragmentation. Besides, I anticipate that the degree of connectivity will vary among distinct hill patches within their distribution zone in the southern population. I also expect that within the distribution limit the fine scale habitat selection of the species would vary in terms of availability of food plants, canopy cover, diversity of plant species and at different level of anthropogenic gradient. I also anticipate variation in the intensity of identified direct and indirect threats among different protection regimes. Within the distribution range, the southern population comprises wildlife sanctuary, reserved forests, plantations, and reserved forest under community control, and I expect differences in the intensity of the threats across these areas.

CHAPTER II

2.1 Review of Literature

The golden langur (*Trachypithecus geei*) is a primate species discovered in the early 20th century in the region of south-central Bhutan and western Assam, India. In 1838, naturalist Pemberton mentioned that Griffith initially observed the golden langur near Tongsa in central Bhutan. Since Pemberton's report was lost, the scientific discovery of this langur remained unfolded till the 1970s. Later in the early twentieth century, around 1907, hunters and forest rangers, accompanied by E. O. Shebbeare, reported the sighting of a "cream-coloured langur" near the Jamduar Forest Rest House on the east bank of the Sankosh River, in proximity to the border of British India with Bhutan. Unfortunately, at that time, neither photographs nor live or dead specimens could be obtained. In 1955, Gee led a focused effort to identify the Golden Langur, observing groups along the east bank of the Sankosh River. The observations included colour movies of a large group, leading him to report his findings to the Zoological Society of London in August 1954 and again to the Zoological Survey of India in January 1955. The suggestion that the golden langur might be a new species received support, leading to the collection of six specimens in 1955 by the Zoological Survey of India (ZSI) during a survey of the Jamduar region. In 1956 Khajuria, provided the first morphological and physiological descriptions of six specimens collected from forests around Jamduar Forest Rest House on the eastern bank river Sankosh in the then Goalpara District (now Kokrajhar), Assam, India. Later, in 1960, Khajuria provided detailed information about the distribution, morphology, affinities, and habits of Gee's langur (*Presbytis geei*) in Assam. He explained that the external genitalia of the female Gee's langur are similar to those of *P. pileatus* and *P. obscurus*, and the skull resembles that of *P. pileatus*, and accordingly, he assigned the species to the subgenus *Trachypithecus*.

Following the description and new taxonomic name, Gee, in 1961, provided the distribution and feeding habits of golden langur. He conducted field studies in northwest Assam and the Khasi and Garo Hills to gather further information about the golden langur. He found the existence of *P. geei* in the vicinity of the Sankosh and Ranga rivers, as well as on the west bank of the Manas River, but he was uncertain about the existence of this langur in Khasi and Garo hills. In 1968, Philip Wayre wrote about golden langur and the Manas Sanctuary in Bhutan, where he mentioned about the sightings of langur near about 20 to 35 individuals in a tropical, moist deciduous forest with high trees and a dense shrub layer. Since then, there has been an increase in studies focusing on the golden langur.

In 1974 Mukherjee and Saha, discussed the ecology and behavior of golden langurs in the western forests of Assam, explicitly focusing on group composition, sex ratio, daily activity pattern, intra-inter group and inter-specific relations, reaction to disturbances, and vocalization. The study is based on a field trip conducted in May-June 1973, and the information collected during this short field session forms the basis of the paper. In 1978, he highlighted the continuation of fieldwork and surveys conducted to gather further information about the golden langur, *Presbytis geei*, including characteristics of the study area, langur group observations, their size and composition, food utilization during winter months, inter-group and inter-specific relationships, and comparisons with other langurs. He also mentioned observations of the capped langur in the Manas sanctuary and remarks on the allopatry of distribution between golden and capped langurs in this sanctuary, additionally comparing the social organization of the golden langur in different seasons and locations, explicitly focusing on concentrations in Jamduar and Raimona forests during winter months.

In 1978, Khajuria again provided an appraisal of the present information available on the discovery, authorship, and taxonomic status of the golden langur, *Presbytis geei* Khajuria of Assam, India. He compiled an exhaustive list of 26 references published or in the press, which deals with this recently discovered species and clarifies that the species was named after GEE in recognition of his long and dedicated services to Indian wildlife and because he took an exceptional initiative by showing a colour film of the langur to professional taxonomists, facilitating its taxonomic discovery. The author emphasizes that Gee cannot be considered the discoverer of the species, but his role has been appreciated by naming the species after him.

Srivastava et al., 2001 emphasized the need for a conservation plan for endangered golden langur and the importance of protecting the Manas National Park to prevent adverse demographic consequences. He highlighted the negative relationship between group density and habitat quality, indicating that as habitat quality deteriorates, the number of groups increases. He did a comparative analysis of satellite images taken in 1988 and 1998, which showed a 50% loss of the original golden langur habitat. The study collected data on population dynamics using line transect and total count methods, recording an average group size of 8.2 individuals and a total of 1,064 individuals living in 130 groups. The sex ratio was 1.9-2.5 adult females for each adult male, and a low percentage of juveniles and infants suggests an unstable population. The study estimated that less than 1,500 golden langurs are left in India, with a larger population in Bhutan, but much of their known range is not a suitable habitat. In 2006, he conducted an extensive survey to assess the population with the data from the Indo-U.S. Primate Project in 1997 as a baseline and to understand the long-term consequences of habitat disturbance on their behavioral ecology. He found a negative relationship between habitat quality, specifically canopy cover, and the number of golden langur groups and individuals. His study highlighted the importance of community participation in conservation efforts, emphasized the need for holistic management plans and the translation of research into practical solutions and emphasized the need for long-term research to understand the dynamics of the ecosystem and prevent the uncontrolled destruction and exploitation of natural ecosystems.

In 2002, Choudhury, in his paper, provided insights into the status and distribution of golden langurs in Assam, highlighting the decline in population, habitat degradation and the need for conservation efforts. As per his study, golden langur is now found in at least 19 fragmented areas, with many populations having little possibility of long-term survival.

Chetry et al., 2004 conducted a study on the status of golden langurs within a rubber plantation in Western Assam, India. He compared data from 2002 to a previous census in 1997, revealing an overall increase, with an average troop size of 17.3 and the ratio of adult males to adult females as 1:3.16 in the golden langur population in the rubber plantation. He mentioned that the high percentage of immatures and low percentage of adults suggest that the population is increasing. However, there has been a decrease in the number of adult males and adult females. During a comprehensive study in 2010 and 2020 in Chakrashila Wildlife Sanctuary, Chetry and his team exhibited promising trends in the golden langur population. In 2010, the study revealed 474 individuals in 64 groups, with an average group size of 7.40 individuals, showcasing a healthy and growing age structure. In 2020, the survey recorded a noteworthy increase, with 558 golden langur individuals in 72 groups and an average group size of 7.75 individuals. They found the adult male-to-female sex ratio as 1:2.06 and the ratio of adult females to infants as 1:0.50, reflecting the stability of the prevalent single male-multi female group structure.

Wangchuk et al., 2003 reported the existence of sub-species, namely the *Trachypithecus geei bhutanensis* in the north and *Trachypithecus geei geei* in the south, separated by the Main Frontal Thrust (MFT) of the Indian Plate hitting into the Himalayas. However, the assertion regarding the recognition of sub-species needs to be more substantiated within the scientific community. Wankchuk et al. 2008 looked at the evolution and phylogeography of golden langur in Bhutan. They hypothesized that it was the Sankosh river and Pelela mountain systems that restricted a population of capped langurs during a period in central Bhutan, which later speciated into the morphologically distinct golden langur. The molecular phylogenetic analysis using the cytochrome b region of mitochondrial DNA showed that capped langur and golden langurs are closely related to each other and to other species in *Trachypithecus* from Southeast Asia, while gray langurs in Bhutan grouped into a distinct clade with conspecifics in *Semnopithecus* from India and Nepal.

Howrich et al. 2008 mentioned the involvement of local communities and NGOs in protecting the endangered golden langur and its habitat in the Manas Biosphere Reserve in Assam, India. Their study aimed to achieve community-based regional conservation and forest protection goals by working at the community level. The project started with two NGOs, evolving into the formation of a forum of five NGOs and ten community-based groups focusing on the protection of the entire Manas Biosphere. In 2008, Howrich and his team highlighted the success of the Golden Langur Conservation Project (GLCP) in motivating communities to protect their environment and promote wise use and sustainability. They mentioned the increase in population density of golden langurs in Assam due to community conservation intervention, from 1500 individuals in 1997 to 5600 individuals between 2007 and 2012.

Shil et al. 2016 studied the genetic diversity in the Indian population of golden langur using mitochondrial DNA (mtDNA) hypervariable region-I sequencing and analysis. The genetic diversity was found to be high and comparable to other colobines, with smaller fragments showing lower nucleotide diversity compared to larger forest fragments. Their study also revealed possible hybridization between golden langurs and capped langurs in the wild, emphasizing the need to ascertain the genetic affiliation of captive golden langurs before using them in breeding programs and reintroductions. They emphasized the need for scientific management of fragmented populations, including protecting fragments from further degradation and establishing canopy corridors to facilitate gene flow and maintain genetic diversity. In 2020, Shil et al. conducted a study aimed at understanding the consequences of habitat conditions on group size, social structure and birth seasonality. The study was conducted in Chakrashila WLS and adjoining rubber plantations. They selected 12 groups inhabiting the forest core, forest edge and rubber plantation. They found the overall group size of 11.3 ± 3.5SD with significant differences in mean group size among forest core as 7.4 ± 1.7, forest edge as 12.7 ± 2.2, and rubber plantation as 13.9 ± 2.3. However, they did not find significant differences in birth rates per adult female or group among habitats. Shil et al., 2019 studied to understand the population dynamics, demographic structure and persistence of golden langur in rubber plantations by comparing with the previous data available. They found the overall population growth from 1997 to 2016 to be 5.54% per year.

In 2018, Roy and Nagarajan provided information on the biology, ecology, and conservation of the golden langur. They highlighted the fragmented distribution of the species in Western Assam, India, and Bhutan. They identified habitat loss, degradation, and fragmentation as significant threats and the need for long-term monitoring and large-scale planning for its conservation. In 2019, they conducted a study focused on the eco-ethological aspects of golden langurs in western

Assam, India, specifically their social organization. Their study involved observing and recording the group size and composition, age-sex ratios, and relationships of the golden langur troops. They recorded a total of 33 troops, with troop sizes ranging from 3 to 25 individuals. They found the occurrence of bi-male-multi-female groups in golden langurs to be more during the wet season when females were receptive.

Thinley et al. (2019) conducted a study in Bhutan to investigate local awareness and attitudes toward the endangered golden langur. The research involved interviewing 1,143 households in different districts and utilized conditional inference tree analysis for data analysis. The findings revealed a need for more awareness regarding the golden langur's protected and endangered status among respondents. Thinley et al. (2019) involved a nationwide survey of golden langurs in Bhutan in which they utilized a double-observer survey method along trail-based transects in 17 blocks within the langur habitat, aimed to provide reliable population estimates and distribution information. Their study resulted in estimating a total population of 2439 individuals with a density of 0.88 individuals/sq. Km which is much lower than the current IUCN estimation of 4000 individuals for Bhutan. Another study conducted by Thinley et al. 2019 was a comprehensive threat assessment for the endangered golden langur in Bhutan based on interviews with local people, discussions with field forestry staff, and social media interaction. Their study classified and ranked direct threats to the endangered golden langur in Bhutan and identified five habitat threats and seven population threats. They found hydropower, road, and housing development to be the topmost threats, whereas agricultural expansion, resource extraction, electrocution, and road kill were also identified as threats with a 'medium' impact. Their study suggested immediate mitigation measures such as installing speed limit signage, insulated electric cables, and reducing domestic dog populations.

Chakravarty et al. 2020 conducted an extensive survey in the Kakoijana reserved forest of Assam to determine the population size, troop size, distribution, and demographic structure of the golden langur species. Their survey used the total count method and direct encounter method to estimate the population size and identify troops based on their locations and number of individuals. They collected vegetation data of trees, shrubs, and climbers at the point of contact with golden langur troops to understand their habitat. Their study revealed a total of 45 distinct troops with a mean troop size of 10.87 ± 3.42 SD and a total population size of 489 individuals in various habitat zones, including dense forest, open forest, edge matrix zones, and human habitation areas. They found the age-sex composition as 25% immature, 29% sub-adult, and 46% adult individuals.

In 2023, Chatterjee et al. conducted a study in which they mapped the habitat suitability for the species across its entire distribution and simulated landscape for the future (2031). They found the total range extended to 66,320 sq. km, of which only 12,265 sq. Km (which is 18.49% of total extended range) is suitable for the species at present, predicted to be reduced to 8884 sq. km by the year 2031, indicating significant range contraction.

CHAPTER III

3.1 Study Area

Assam, a state in northeastern India, lies at the intersection of two biodiversity hotspots—the Eastern Himalayas and the Indo-Burma region, contributes to an exceptional variety of flora and fauna. Endemic to India and Bhutan, the endangered golden langur (*Trachypithecus geei*) is restricted to few fragmented forests in western Assam, India, and hilly forests in south-central Bhutan. The study includes both extensive and intensive study areas (**Figure 1**). The extensive study area includes the entire distributional ranges of golden langur in India, which is about 2500 sq. km extending between the Sankosh river in the west and Manas river in the east and to the north of river Brahmaputra. The northern part of the study area falls within the Manas Biosphere Reserve, is the first addition to Manas NP (350 km^2) and adjoining contiguous forest habitat including Raimona National Park, Koila-moila, Chirang, Ultapani and Ripu Reserved forest. The landscape is located at the confluence of three bio-geographic realms – lower Gangetic Plain, the Central Himalayas and the Brahmaputra Valley. The forest types in the study area include Sub-Himalayan High Alluvial Semi-evergreen forest, Eastern Bhabhar type forest, Moist Mixed Deciduous Forest, Assam Valley Semi-evergreen forest and the Eastern Wet Alluvial Grassland (Champion & Seth, 1968; Kanjilal, 1997; Srivastava, 1999). The yearly temperatures range between 15 and 35 degrees Celsius, with an annual rainfall between 1200 and 4000 mm per year and an average relative humidity of 83% (Srivastava, 2006). Administratively, the majority of the study area (except a few forest fragments under Aie Valley Forest Division) falls under the jurisdiction of BTR (Bodoland Territorial Region), formerly known as Bodoland Territorial Council that was carved out from the northern part of western Assam in 2003, as per the provisions under the Sixth Schedule of the Indian Constitution.

However, the study will focus intensively in nine recognized fragmented forests (**Figure 1**) to the south of Manas Tiger Reserve, which include (1) Chakrashila WLS, (2) Nadangiri Hill RF, (3) Private Rubber Plantation & Adjoining Forests, (4) Bhumeshwar RF, (5) Nakati RF, (6) Bhairab Hill RF, (7) Kakoijana RF, (8) Bamungaon RF and (9) Khoragaon PRF. The forest reserves are highly fragmented with railway lines, national highways (NH-17, NH-117) and state highways (SH-2, SH-14). Most of the forests in the south are scrubland and degraded forest, including some private plantation patches such as Abhya Rubber Garden, which is about 277 ha. comprises 80 % rubber plantation and 20 % natural forests with human settlements and roads (Medhi et al., 2004). Among, Chakrashila WLS which is about 45.58 sq. km is the largest and only protected forest fragments in the south.

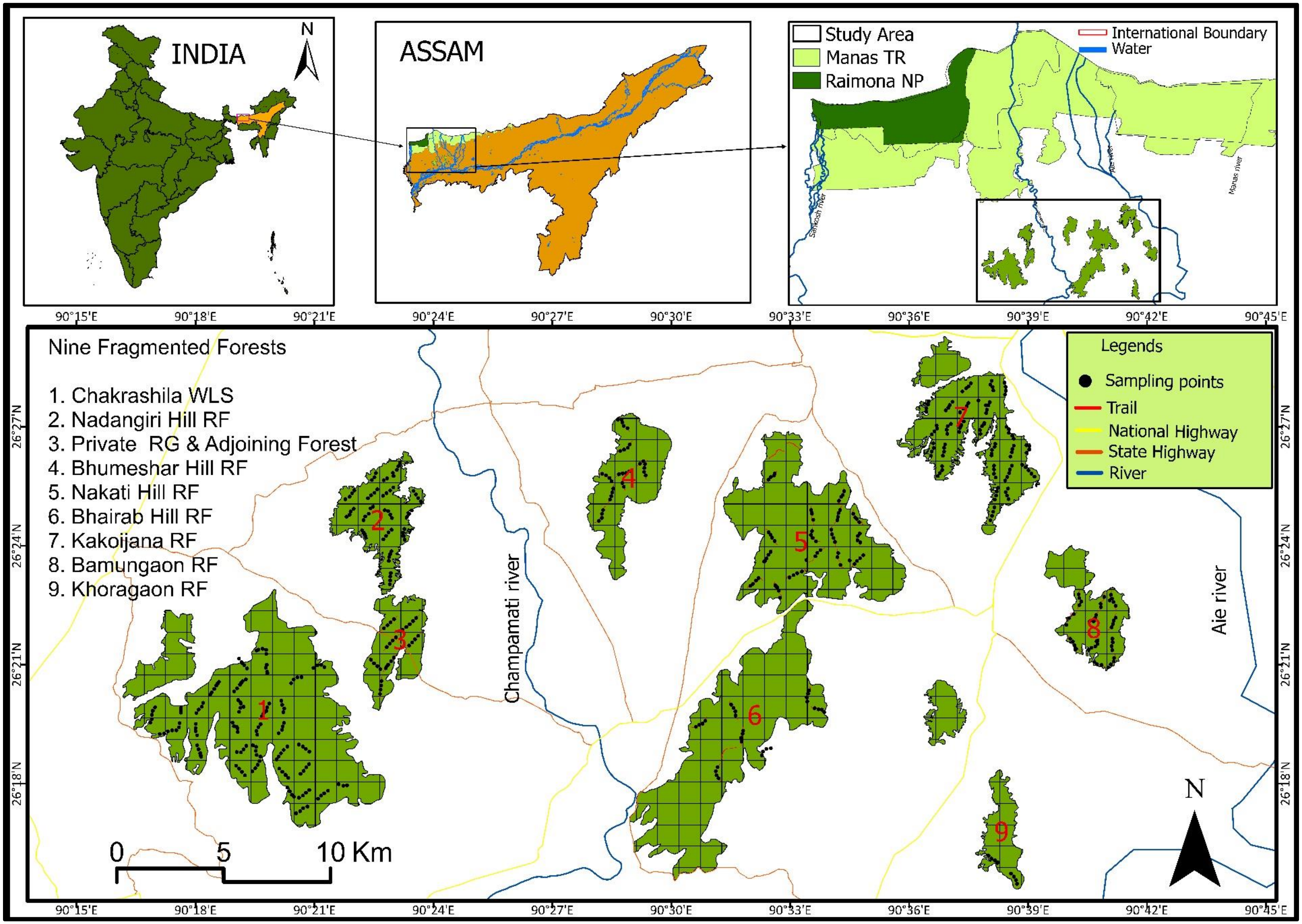


Figure 1. Map showing the intensive study area sampling trails and vegetation plots in fragmented forest patches of Golden Langur habitat in Assam.

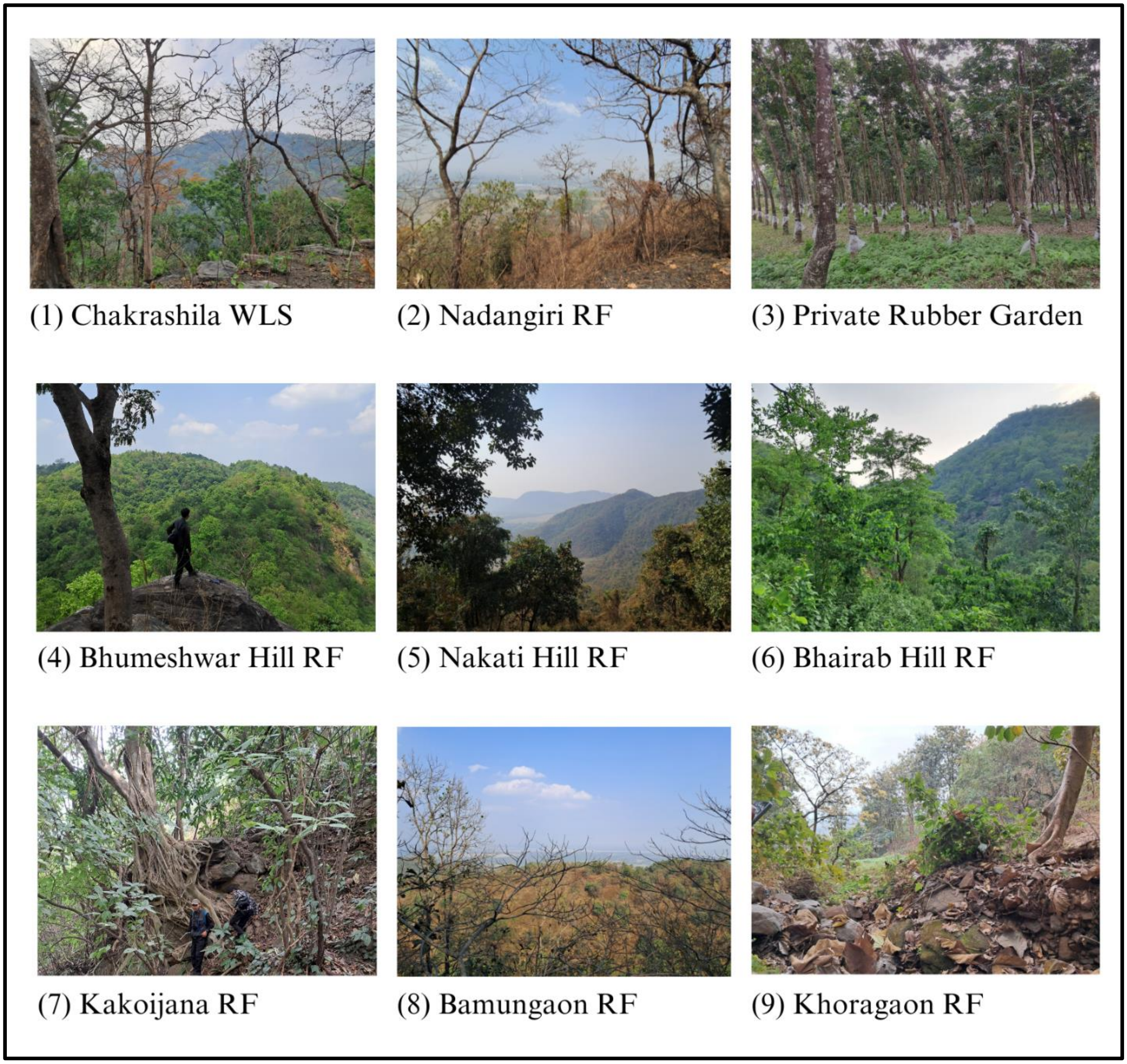


Figure 2. Nine fragmented forests in the highly fragmented southern population.

CHAPTER IV

4.1. Methodology

4.1.1. Data Collection

4.1.1.1. Golden langur occurrence and group demography data

The fragmented forest patches within the distribution limit of the golden langur were gridded (1 × 1 km) and walked along random trails, attempting to follow a straight line as much as possible. The length of the trails varied from 0.4 to 1.6 km, covering a total distance of 118.72 kilometers to record the presence of the golden langur. On encounter with the langur troops GPS location was noted using GARMIN *ETREX* 10 hand-held GPS. Subsequently, I counted number of individuals in a troop and classified as adult males (AM), adult females (AF), sub-adults (SA), juveniles (JUV), infants (INF) following Srivastava et al. (2001) and Biswas et al. (2002). The sex of adults, sub-adults, juveniles and infants was recorded using 8 × 40 binocular and a camera (*Nikon Coolpix P950*). Additionally, for Manas Tiger Reserve (includes both Raimona and Manas National Park and other Reserved Forest under MTR) I have collected presence location of golden langur from researchers working in the landscape.

4.1.1.2. Collection of eco-geographical and anthropogenic variables at spatial scale

I considered 10 predictor variables (includes eco-geographical and anthropogenic) to model the distribution of golden langur in India. Description, method of quantification, and a-priori hypothesis for selecting these variables are presented in **Table 1** and **Figure 3**. I extracted these variables at 6.25 ha (i.e., 250×250 m) spatial resolution since the daily movement of langur troops varied from 200-700 m (Mukharjee, 1996; Chetry 2002; Medhi and Chetry 2003; Biswas 2004; Chetry and Chetry, 2009).

Table 1. *A priori* hypotheses and predictions on factors influencing distribution and habitat suitability of Golden langur in Assam. Variable collection method and data sources.

Features	Variable	Description and Source	*A-priori* hypotheses
Topographic	Elevation	Computed using the SRTM digital elevation (Jarvis et al., 2008) model-90 m	Elevation plays a significant role in shaping the climate and vegetation types in a particular area. We predicted that elevation driven climatic conditions and vegetation could play crucial role in distribution of Golden langur.
Land Cover	Percent Forest Cover (fc)	I extracted forest cover from Roy et al. (2016) dataset and reclassify and modify (digitization) using Google Earth Pro and Google Earth Engine.	Forest cover is critical for the survival of primate species, an arboreal primate like golden langur exclusively dependent on dense canopies for food, shelter and protection.
	Percent home gardens (hg)		Home gardens in Assam play a critical role in maintaining biodiversity outside PA network. These traditional agroforestry systems are rich in biodiversity, incorporating variety of plant species, vegetables and fruit trees. Previous studies showed that few langur troops are residing in these village home gardens adjacent to forest patches. Further, home gardens could play potential role in connecting the fragmented forest patches.
	Percent Cropland (cl)		The proportion of cropland could negatively impact the golden langur by further fragmenting forest patches and hindering their movement.
	Distance from water sources (dishwater)	Generated a surface by calculating the Euclidean distance from rivers, streams (both permanent and seasonal) and stagnant water bodies using fine scale data from OpenStreetMap.org and Roy et al. (2016)	Water sources can also influence the availability of food and shelter for golden langur. Areas with abundant vegetation and cover may be more common near water sources, which can provide ideal foraging opportunities to langurs.
	NDVI (Normalized Difference Vegetation Index)	Download from NASA AppEEARS (resolution of 250 m). The output for the year of 2023 was averaged.	High NDVI values indicate dense and healthy vegetation that are important for the survival of golden langur. Subsequently, low NDVI values can signal degraded or sparse vegetation, which may correspond to unsuitable or fragmented habitats.
Anthropogenic	Human Foot Print (hpf)	Data extracted from hub.worldpop.org (resolution 100 × 100 m). The spatial information incorporates drive-time areas, block-by-block event management in urban areas, and natural- or human-produced hazard footprints.	Human could directly (hunting) or indirectly (encroachment, habitat degradation) influence the golden langur. Moreover, intensive cattle grazing in the forest patches brings invasive species and degrade forest patches. Here, I predicted that with increasing human population density adjacent to forest patches could have negative impact on golden langur distribution and connectivity.
	Distance from Human Settlement (dishs)	Generated a surface by calculating the Euclidean distance (using ArcGIS 10.8) from built-up and settlement areas	
	Distance from Forest Edges (disfe)	Generated a surface by calculating the Euclidean distance from the edges of forest boundary	I predicted that the probability of langur distribution will decrease at the edges of the forest since these areas are vulnerable to all sorts of anthropogenic activities
	Distance from Roads (disroad)	Different type of Road and Railway Network shape files are downloaded from OpenStreetMap.org and Digitized on Google Earth Pro. The final raster file was generated by calculating the Euclidean distance from the roads.	Distance from road can significantly impact the distribution and habitat suitability of the golden langur. Roads fragment forest patches creating barriers and restrict the movement of the golden langur. Proximity to roads often correlates with habitat degradation due to increased human activity. Moreover, all most all roads have electricity lines, posing direct threats, as langurs are at risk of electrocution. There were several reports of electrocution and road accident of golden langur in recent years in the fragmented forest patches.

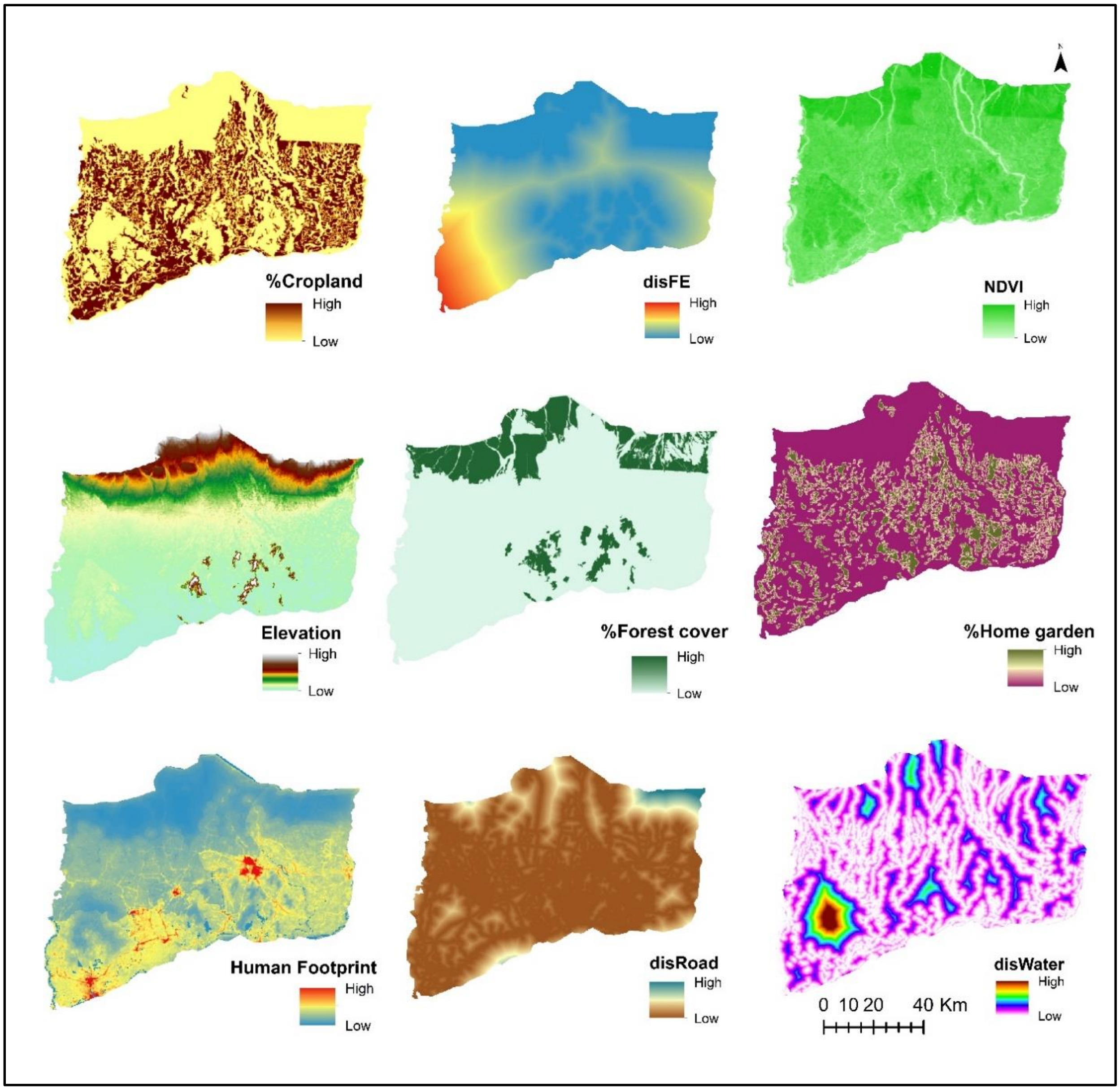


Figure 3. Landscape and eco-geographical variables used for modeling the distribution of golden langur.

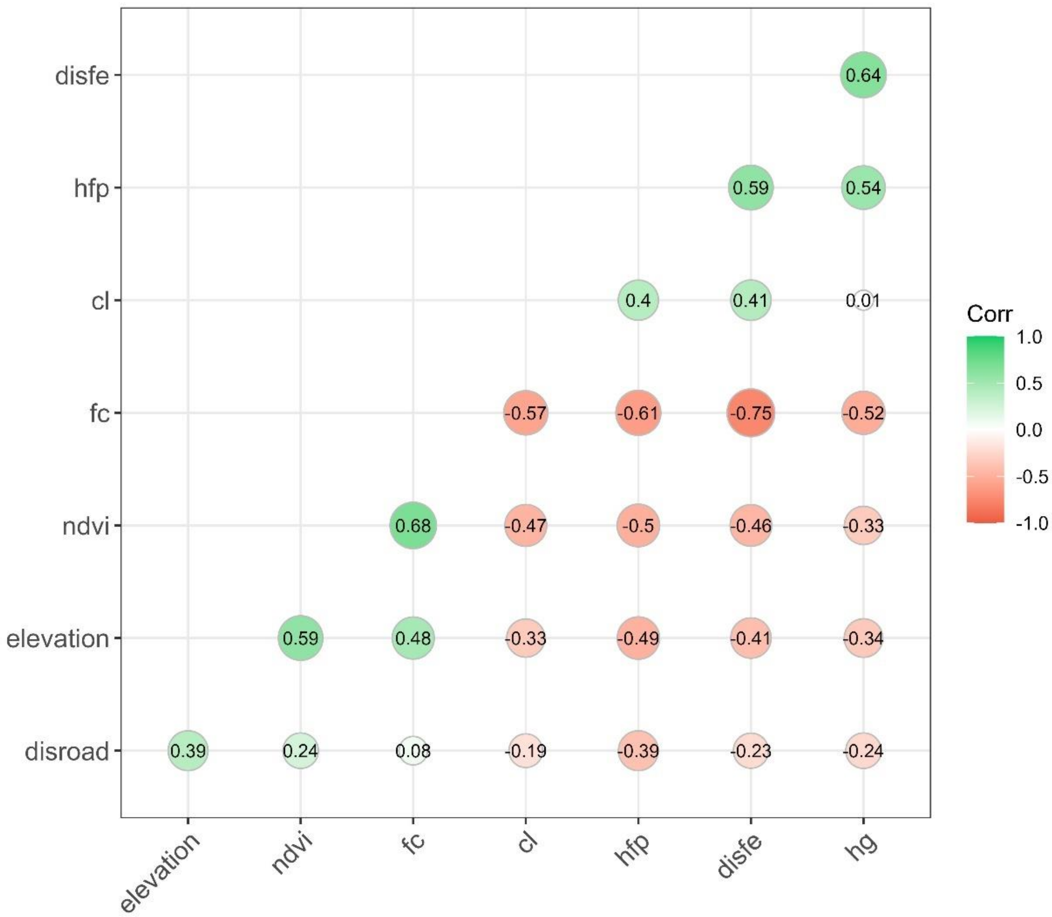


Figure 4. Correlation matrix among landscape variables selected for habitat suitability model.

4.1.1.3. Vegetation sampling

In addition to species occurrence data, to investigate the fine-scale habitat selection of the golden langur in the highly fragmented southern population, broad vegetation structure data (tree species composition, richness, abundance, canopy cover, canopy height, forest type, etc.) were collected in 15-meter radius circular plots on langur sighting, as well as at regular intervals of 200 meters.

4.1.1.4. Threats

The identification, evaluation, and ranking of risks to particular conservation targets are crucial steps in the planning and management of species conservation (Rao et al., 2007). To identify threats within the nine distinct fragmented forests, data on anthropogenic pressures such as the presence of invasive species, signs of lopping and cutting, logging, and the presence of cattle were collected in 15-meter radius circular plots at regular intervals of 200 meters and upon sightings of langurs. Additionally, I have collected data from the Assam Forest Department on the various reasons for mortality and injury of golden langurs in the fragmented southern population.

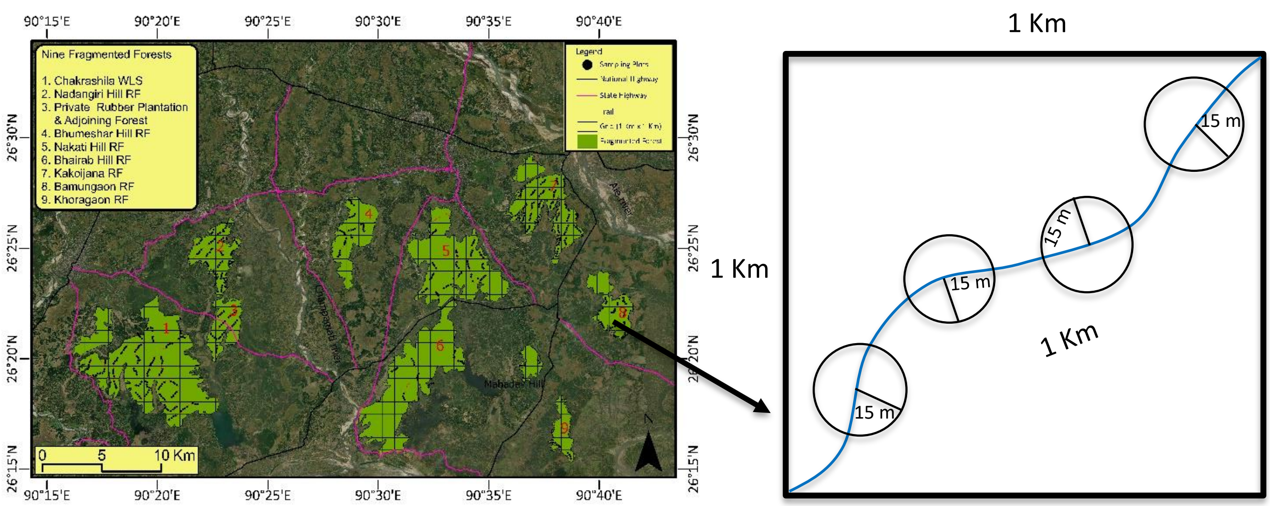


Figure 5. Sampling plots for vegetation and threats in 1 x 1 km^2 grid.

(a) Cattle grazing inside Bhairab Hill RF

(b) Felling inside Kakoijana RF

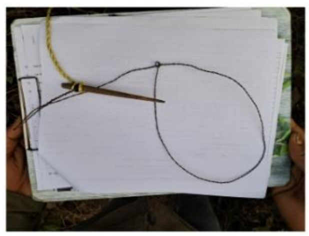
(c) Human leftover waste materials inside Chakrashila WLS

(d) Illegal timber extraction inside Nadangiri Hill RF

(e) *Areca catechu* plantation inside Chakrashila WLS

(f) Presence of human inside Chakrashila WLS

(g) Invasive *Chrromolena odorata* and illegal felling in Chakrashila WLS



(h) A snare, particularly for Indian hare and small mammals inside Nadangiri RF

(i) Illegal timber ectraction inside Bamungaon RF

(j) An adult male golden langur died on electrocution in Kakoijana

(k) Golden langur died on road accident in NH 117

(l) Golden langur died on road accident in State Highway 14 in Nayekgaon

(m) Golden langur crossing State Highway 14 in Nayekgaon Rubber Plantation (Photo by: Amulya Boro)

Plate 1. Threats of Golden Langur in fragmented forest patches.

4.1.2 Data Analysis

4.1.2.1. Current Distribution and Habitat Suitability

To assess the spatial distribution of golden langurs and identify key landscape and eco-geographical variables constraining their distribution, I used *MaxENT 3.4,* a program designed for modelling species distributions based on presence-only records (Phillips et al., 2006). To compile the presence records of golden langurs, as mentioned above I gathered data from field sampling and researcher working in the field and consult subject experts. The presence locations were further filtered using *spThin* package in *R* retaining one location in 500 m radius (following Khan et al. 2020). A total of 148 locations were used to build the species distribution model. Spatial autocorrelation of variables may violate the assumptions of SDM, leading to over-estimation in predictive performance (Bellamy et al., 2013, Khan et al., 2019), and difficulty in interpreting individual effects of variables on habitat suitability (Graham, 2003). Each variable was extracted corresponding to the occurrence location of each species to observe multi-collinearity between those variables and dropped highly correlated variables retaining the variable which is ecologically more explainable (Pearson's correlation coefficient, $r \geq 0.75$; (**Figure 4**).

I used the default parameter settings for prevalence and the regularization multiplier (Phillips and Dudík 2008, Radosavljevic et al. 2014). I ran models with 100 bootstraps, randomly assigning the presence records as training (70%) and test (30%) data sets. I adopted Jackknife analysis to estimate which variables were most important for model building.

4.1.2.2. Corridor – Connectivity

I employed circuit theory to detect probable pathways connecting central regions within the landscape by utilizing the *Circuitscape 4.0.5* program (McRae & Shah, 2009). The output I obtained from the *MaxENT* model was transformed by inverting the values of habitat suitability. This conversion resulted in each pixel representing a resistant value ranging from 0 to 1, with higher values signifying greater resistance. In *ArcGIS 10.8*, I used the export to *Circuitscape tool* to convert focal nodes (which are fragmented forest patches of the southern population of golden langur) and the habitat permeability layer into ASCII layers. These layers have the same extents, cell size, and spatial references. I employed nine focal nodes and habitat permeability layers in *Circuitscape v.4.0.5* to quantify the corridor conductance across fragmented forest patches.

4.1.2.3. Group Demography

For the group demography of golden langurs, data was analyzed using Microsoft Excel and R. The mean group size, age-sex ratios [AM:AF, JUV:AF, INF:AF] and their standard errors (± SE) were calculated. I performed Kruskal-Wallis test to determine if there is any significant difference in mean troop size and average age-sex ratios of the golden langur populations between wildlife sanctuaries (WLS), community-managed reserved forests (CMRF), reserved forests (RF), and private rubber plantations and adjoining forests (PRP_AF). Prior to that I checked for normality of dataset using Shapiro-Wilk test.

4.1.2.4. Fine-Scale Habitat Selection

I formulate hypotheses regarding fine-scale habitat selection and tested these predictions using Multiple Regression technique (Generalized Linear Mixed Models). The response variables were the presence and absence of langur troops. For the habitat selection, 13 predictor variables (including ecological and anthropogenic) collected in 15 m radius circular plot at each langur sighting as well as at regular interval of 200 m in each km^2 grid as follows: (i) tree density (ii) tree species diversity (iii) food plant density (iv) food plant diversity (v) % bamboo cover (vi) canopy cover (vii) number of woodcutting-lopping and invasive plant species (viii) % *Chromolaena odorata* cover (ix) % *Mikania micrantha* cover (x) % *Lantana camara* cover. Subsequently, Shannon Diversity Index (H´) was calculated using R studio software. In addition, three other landscape variables (xi) distance to road (xii) distance to waterbody (xiii) distance to human settlement that may influence golden langur's habitat selection were also calculated. The Pearson Correlation test was performed to determine the degree of association among the ecological variables (**Figure 6**). In the final model building, the variables which were highly correlated, I have retained variables which is ecologically more explainable (**Figure 6**). Apart from *Chromolaena odorata* the occurrence of other two invasive species is highly sporadic and hence not included in the model building. Generalized linear mixed-effects models (GLMMs) were fitted using binomial function with the total number of langur troop detections as the response variable (glmer function in the lme4 package; Bates et al., 2015) in R 3.3.2 (R Core Team, 2016). In the model building, I kept site as random effect and other predictor variables mentioned above as fixed effect. All variables were Z-transformed prior to model building.

Furthermore, I performed Kruskal-Wallis test to know if there is any significant difference tree species diversity, food tree density, tree density, canopy cover and strength height in wildlife sanctuary, community managed RF, reserved forests and private rubber plantations and adjoining forests.

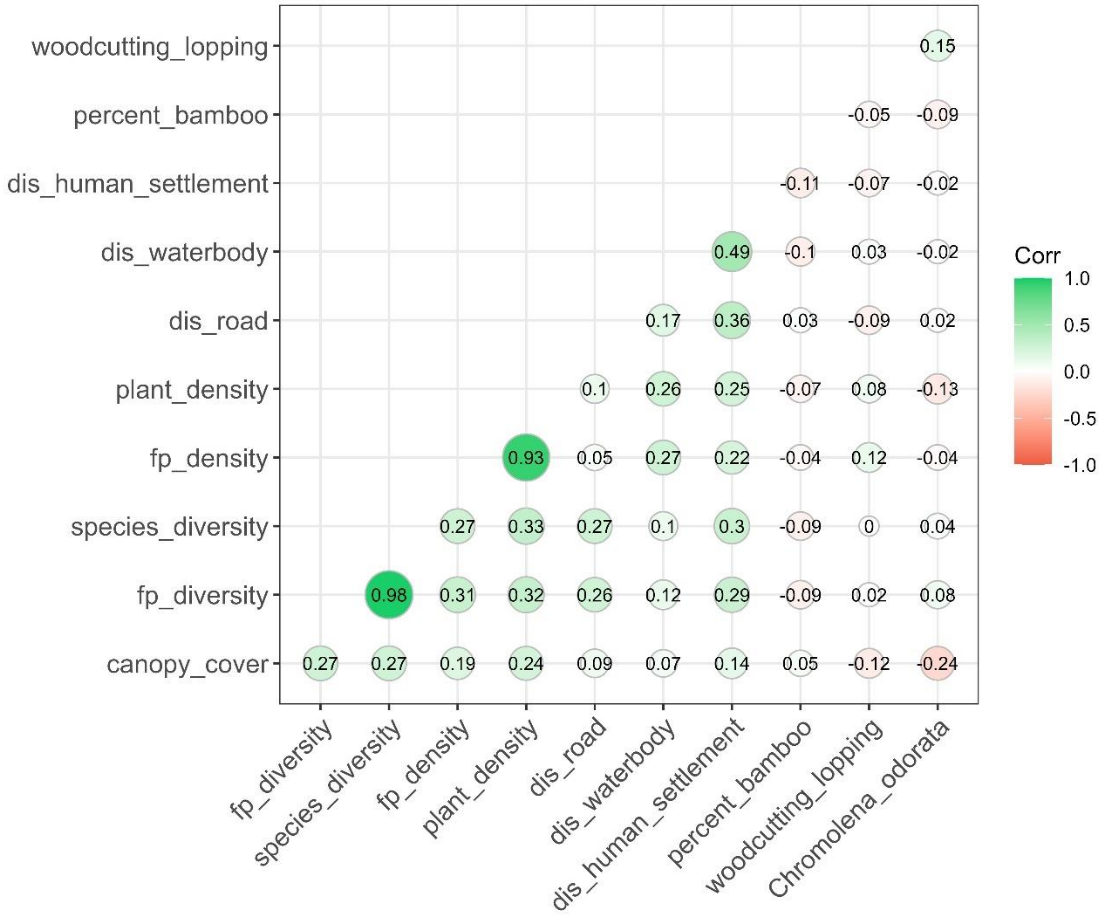


Figure 6. Correlation matrix among predictor variables selected for fine scale habitat selection of Golden langur.

4.1.2.5. *Threats*

To investigate the threats associated to endangered golden langur, *Trachypithecus geei* in the highly fragmented southern population, data on percentage of invasive plants species and anthropogenic pressures such as woodcutting, presence of cattle and free-ranging dogs and humans were collected in 15 m radius circular plot at a regular interval of 200 m as well as at each langur sightings whereas data on threats contributing to golden langur mortalities/injuries were collected secondarily by obtaining official records from the forest department.

The analysis was done in micro-soft word excel and R Studio software. The mortalities/injuries of the golden langur in highly fragmented southern population were analyzed in micro-soft excel whereas R Studio software was employed to analysis the test for normality and significant difference of the various threats such as percentage of invasive plant species and anthropogenic pressure including woodcutting-lopping and encounter rate of livestock between wildlife sanctuary (WLS), community managed RF (CMRF), reserved forest (RF), and private rubber plantations and adjoining forest (PRP_AF). I performed Shapiro-Wilk test for normality and based on the normality test's results, I performed Kruskal-Wallis test to know if there is any significant difference in percentage of invasive plant species and anthropogenic pressure including woodcutting-lopping and encounter rate of livestock in wildlife sanctuary, community managed RF, reserved forests and private rubber plantation and adjoining forests.

4.1.2.5.1. Electrocution Risk Mapping

The data on mortality and injury of golden langur acquired from the Assam Forest Department between 2017 to May 2024, was summarized using Microsoft Excel. I have predicted electrocution risk map for the southern population using *MaxENT* following same approach as mentioned in the **section 4.1.2.1**. As mentioned in **Table 1**, roads were used as a proxy for electricity lines, which pose direct threats to langurs due to the risk of electrocution. Since no shape files are available for the electricity distribution lines to households (comprising 11 KV and 220 V lines). Field verification was conducted and I have digitized all the road network and pathways that have distribution lines within the range of the southern population of golden langurs. Prior to the analysis, we assessed the correlation of all variables using Pearson's correlation coefficients as (**Figure 7**) mentioned in the above section. Of the total 29 mortality/injury reported in the last seven years, 26 incidents were used to build the risk map. The predictor variables used to build the risk map were elevation, distance to road, distance to forest edges, human footprint, % home garden and cropland, NDVI, % forest cover, elevation. Here also I used the default parameter settings for prevalence and the regularization multiplier (Phillips and Dudík 2008, Radosavljevic et al. 2014). I ran models with 100 bootstraps, randomly assigning the presence records as training (90%) and test (10%) data sets.

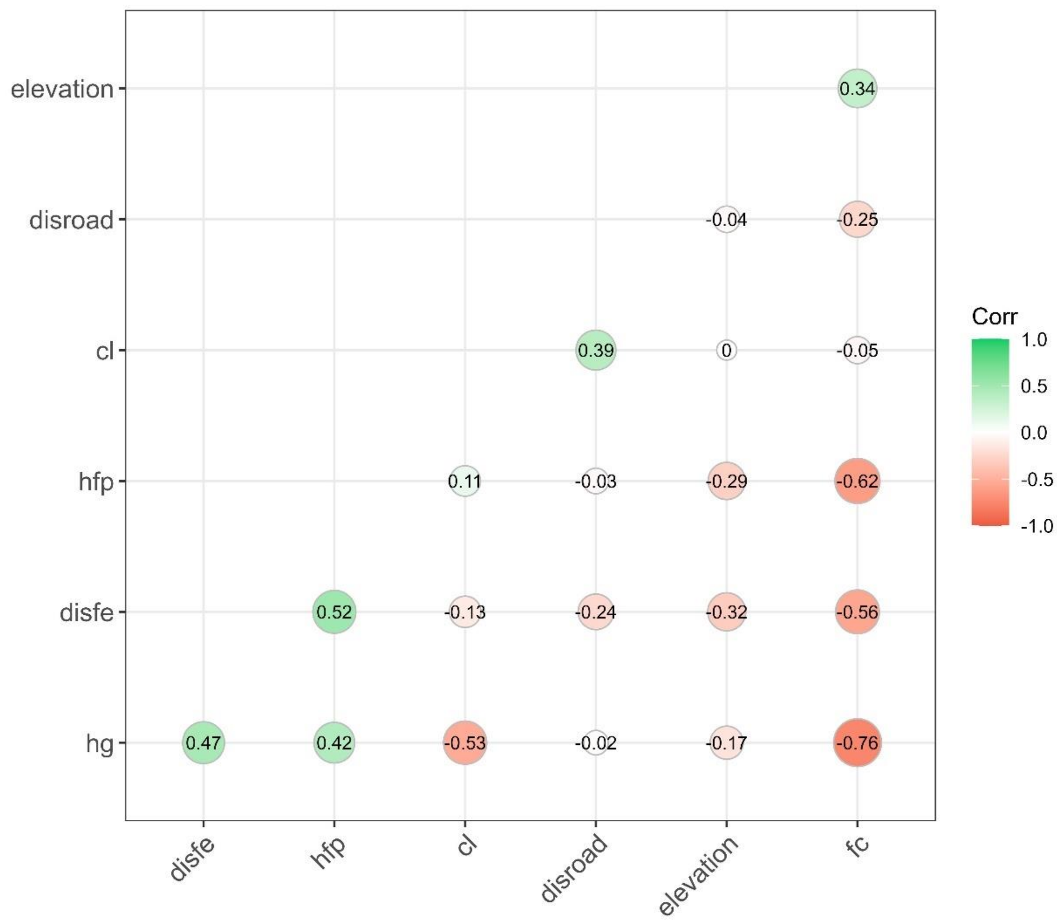


Figure 7. Correlation matrix among predictor variables selected for electrocution risk map.

CHAPTER V

5.1 Result

5.1.1. Group Demography

A total of 123 trails, ranging from 0.4 km to 1.6 km, were walked, covering a total distance of 118.72 kilometers. During these surveys, a total 51 troops (including 8 multi-male multi-female troops and 5 all-male groups), consisting of 499 individuals of various age-sex classes were encountered. The overall mean group size of the langur was found 9.78 (± 0.69 $_{SE}$). Of the total 499 individuals, 13.22 % was adult male (n = 66), 41.88 % was adult female (n = 209), 16.83 % was sub-adults (n = 84), 10.02 % was juveniles (n = 50) and 18.03 % was infant (n = 90). The average age-sex ratio of adult males to adult females was 0.287 (± 0.04 $_{SE}$), juveniles to adult females was 0.224 (± 0.02 $_{SE}$) and infants to adult females was 0.407 (± 0.04 $_{SE}$).

Moreover, the mean group size and age-sex ratio of the langur population in wildlife sanctuary (WLS), community managed reserved forests (CMRF), reserved forest (RF) and private rubber plantation and adjoining forest (PRP_AF) were compared. The study found that mean group size was highest in private rubber garden which was 14.33 (± 6.56 $_{SE}$). The mean group size in wildlife sanctuary was 10.57 (± 1.04 $_{SE}$), community managed reserved forest was 8.81 (± 1.11 $_{SE}$) and reserved forests was 8.56 (± 1.06 $_{SE}$). The average ratio of adult males to adult females was found 0.211 (± 0.02 $_{SE}$), juveniles to adult females was 0.165 (± 0.04 $_{SE}$) and infants to adult females was 0.531 (± 0.06 $_{SE}$) in wildlife sanctuary whereas the average ratio of adult males to adult females, juveniles to adult females and infants to adult females was 0.296 (± 0.05 $_{SE}$), 0.314 (± 0.08 $_{SE}$) and 0.370 (± 0.07 $_{SE}$) in community managed reserved forest respectively. In reserved forest, the ratio of adult males to adult females was 0.833 (± 0.58 $_{SE}$), juveniles to adult females was 0.375 (± 0.21

SE) and infants to adult females was 0.325 (± 0.07 SE). Apart, the average ratio of adult males to adult females was 0.271 (± 0.04 SE), juveniles to adult females was 0.208 (± 0.05 SE) and infants to adult females was 0.333 (± 0.22 SE) in private rubber garden. The infant-to-female ratio of golden langur was significantly higher in the wildlife sanctuary compared to other fragmented forests, with a statistically significant difference at $p < 0.05$ (**Figure 8 & 9**). This finding underscores the critical importance of the wildlife sanctuary in providing favorable conditions that enhance reproductive success and overall population stability of the species in fragmented forest patches.

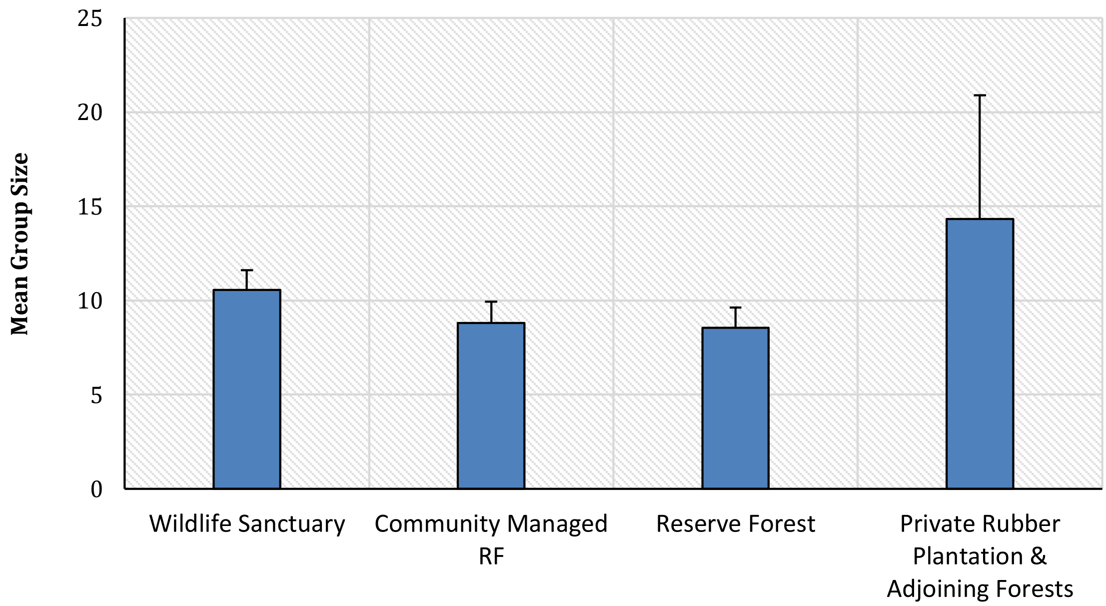


Figure 8. Mean group size of golden langur in wildlife sanctuary, community managed RF, reserved forest and private rubber plantations and adjoining forests.

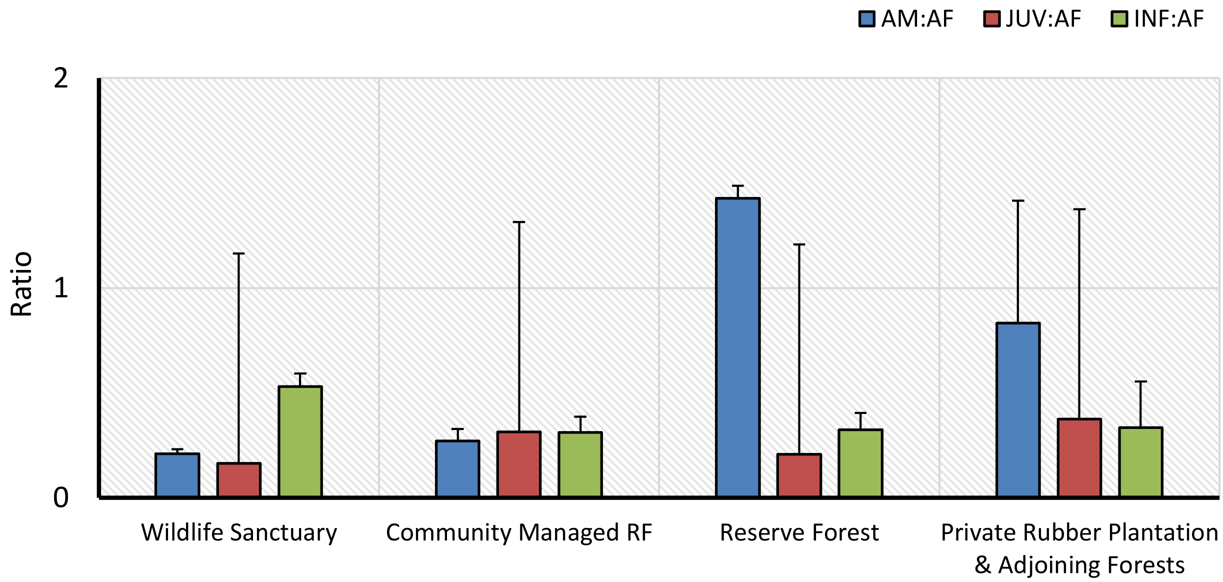


Figure 9. Average age-sex ratio of golden langur between wildlife sanctuary, community managed RF, reserved forest and private rubber plantations and adjoining forests.

(a) Adult Male

(b) Adult Female with infant

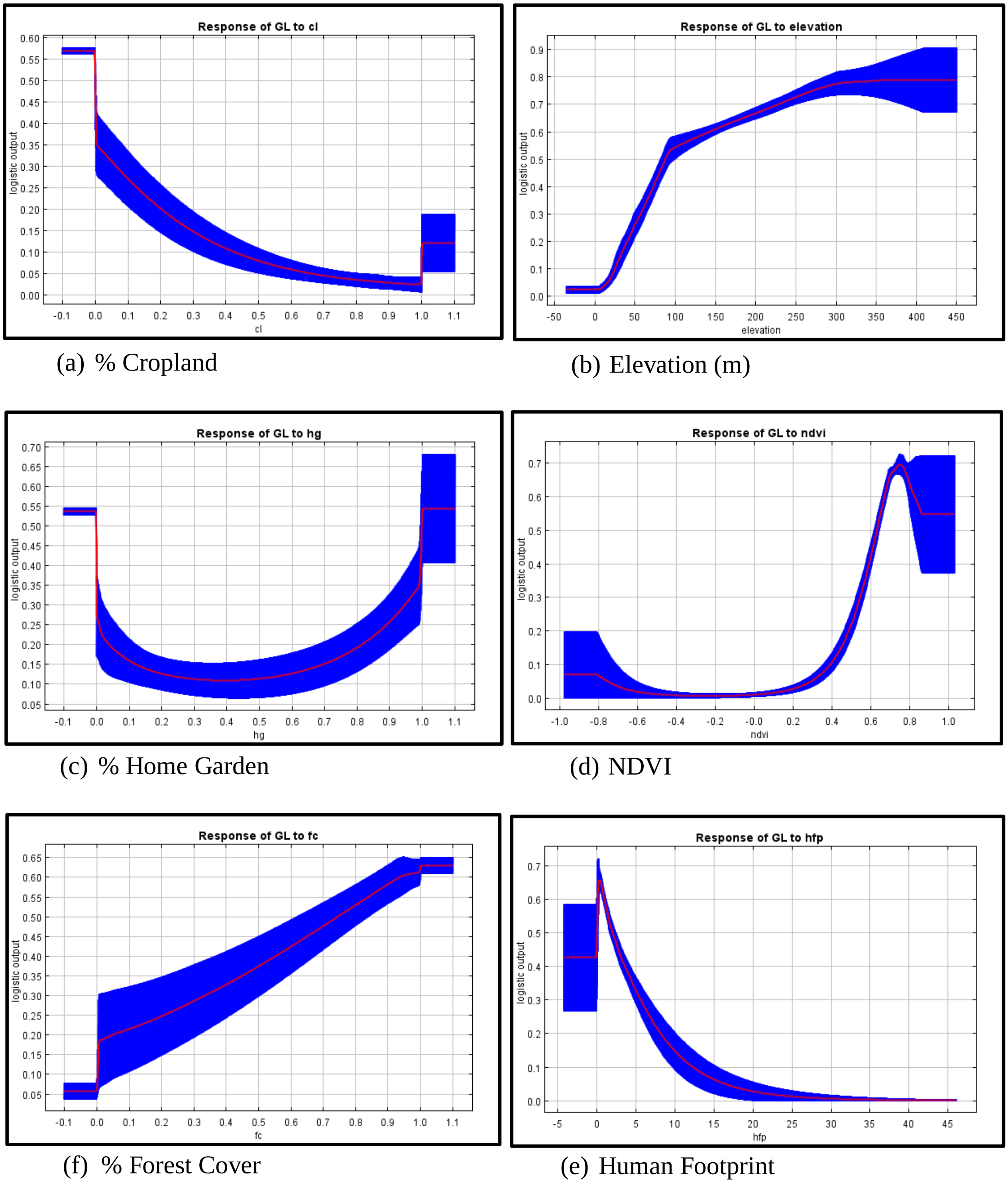
(c) Sub-Adult

(d) Juvenile

Plate 2. Different age-sex categories of golden langur.

5.1.2. Current Distribution and Habitat Suitability

A total of 187 golden langur's identified locations were collected from fieldwork and records from forest departments. Out of 187 occurrence locations, 148 points were selected for the final model after spatial thinning. As expected, the predicted distribution of golden langur formed three distinct clusters namely, (a) Raimona National Park-Chirang RF, (b) western part of Manas National Park and the (c) highly fragmented southern population which includes Chakrashila WLS and other Eight Reserved Forests (**Figure 12**). The northern population is connected with Bhutan although in Indian part the Manas Reserved Forest is highly encroached. The average area under the curve (AUC) values for the boot-strap model is 0.916 ± 0.009. Percent forest cover (80.3%) found to be the most important variable in determining the probability of occurrence of golden langur in the study area followed by human foot print index (6%), % cropland (4.6%), NDVI (4.2%), % home garden (3.1%), and elevation (1.8%). The response curves of each variable in determine the occurrence probability of Golden langur shown in **Figure 11**. From the predicted model, I inferred that the potential distribution area (>0.025 threshold; 10 percentiles logistic threshold) in the study area is 1,778 sq.km. However, 883 sq.km were identified as highly suitable areas for the endangered golden langur, where the occurrence probability is higher than 0.5.



(a) % Cropland

(b) Elevation (m)

(c) % Home Garden

(d) NDVI

(f) % Forest Cover

(e) Human Footprint

Figure 11. Response curve showing the occurrence probability of Golden langur for different predictor variable.

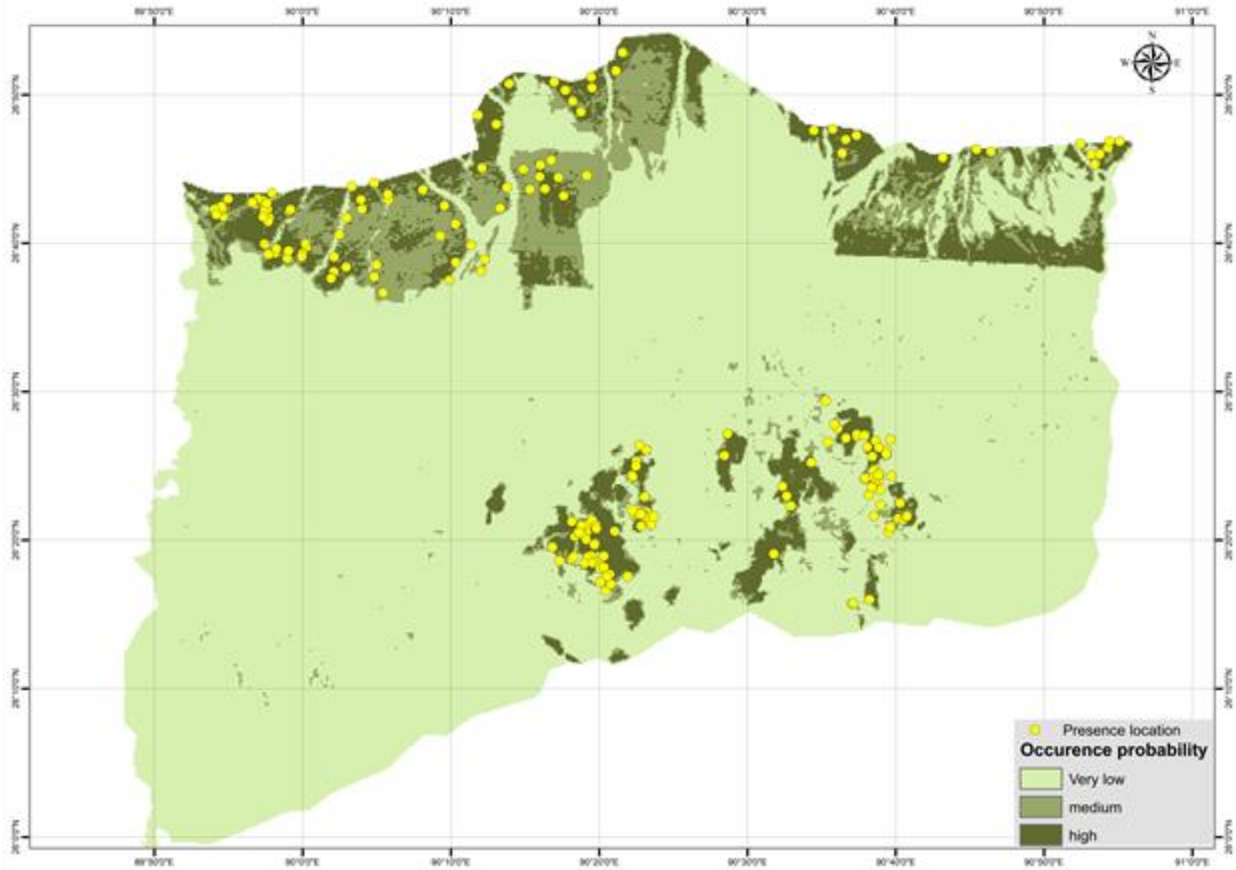


Figure 12. Map showing habitat suitability and occurrence probability of golden langur in India.

5.1.3. Corridor-connectivity

The Circuitscape analysis showed high conductance for corridors namely Kakoijana, Bamungaon and Khoragaon RF (**Figure 13**). Similarly, the connectivity is permeable between Kakoijana and Bamungaon. Other corridors identified in the study are Bhumeshwar hill, Nakati and Kakoijana. On the other hand, there is high conductance among corridors of Chakrashila WLS and Nadangiri RF.

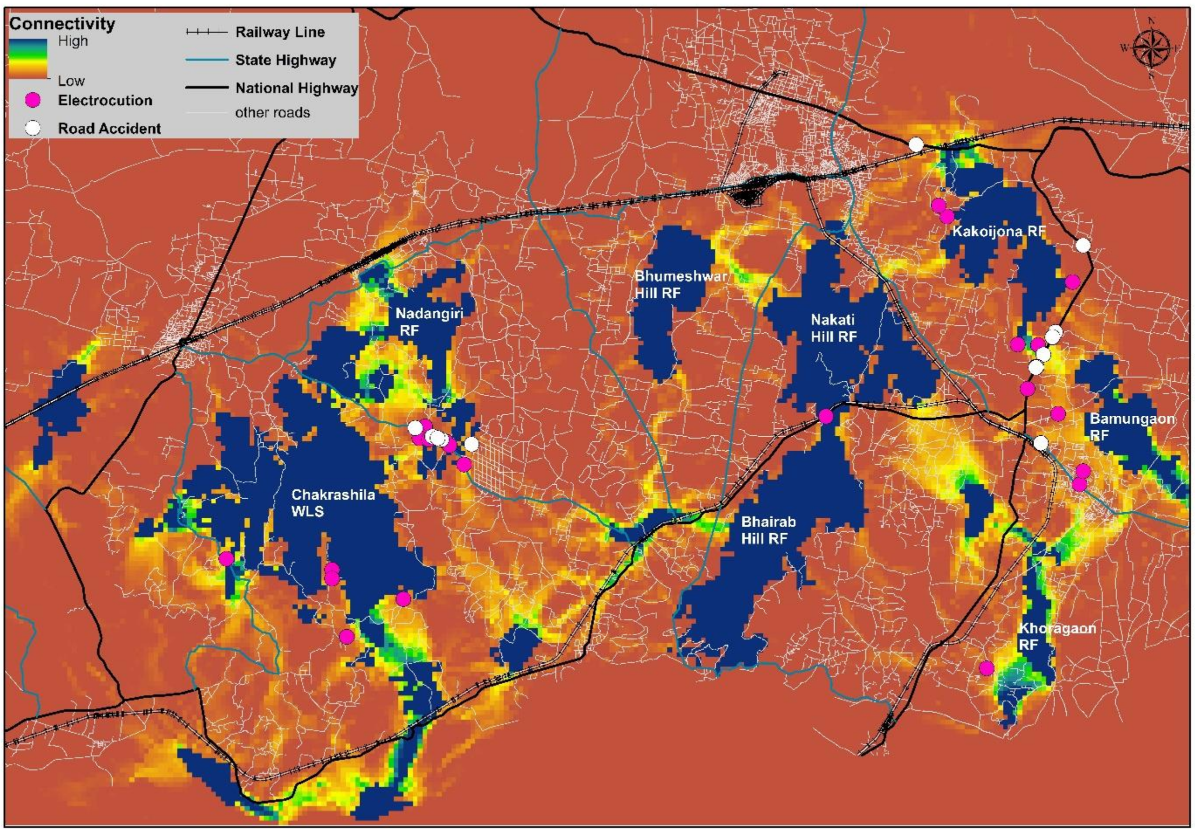


Figure 13. Map showing potential corridor-connectivity for endangered golden langur in the highly fragmented southern population.

5.1.4. Vegetation Structure

The study highlighted considerable differences in vegetation parameters among the nine sampling sites (**Table 2**). Among the sampling sites, tree species diversity and density, along with the density of food plants for the golden langur, were highest in Chakrashila WLS. Conversely, in the community-managed RF, the density of food plants was lowest.

Table 2. Vegetation structure in different protected regimes in highly fragmented forest southern population of Golden langur.

Vegetation Structure	**Wildlife Sanctuary**	**Community Managed RF**	**Reserved Forest**	**Private Rubber Garden**
Food Plant Density	336.12 (±14.42)*	272.44 (±14.8)	280.41 (±12.09)	276.01 (±33.62)
Food Plant Diversity	1.62 (±0.05)*	1.34 (±0.05)	1.22 (±0.04)	0.95 (±0.13)
Tree Density	384.78 (±15.01)*	296.07 (±15.01)	292.35 (±12.11)	276.01 (±33.62)
Tree Species Diversity	1.72 (±0.05)*	1.42 (±0.05)	1.27 (±0.04)	0.95 (±0.13)
Canopy Cover	8.18 (±0.35)	10.13 (±1.23)*	6.15 (±0.26)	7.07 (±1)

Note: * - Highest in all

5.1.5. Fine Scale habitat selection

I fitted global model with covariates (i.e., food plant density, tree species diversity, % canopy cover, percent bamboo, distance to road, distance to human settlement, wood cutting & lopping, % *Chromolaena odorata*) and different subset models indicating various plausible ecological hypotheses about golden langurs habitat selection based on a priori expectations. Key factors influencing habitat usage by the langurs are provided in **Table 3**. The most important predictor over all the models for golden langur was the tree species diversity (β=0.46±0.18$_{SE}$), canopy cover (β=0.14±0.11$_{SE}$) and food plant density (β=0.17±0.15$_{SE}$), this had the lowest AICc value (**Figure 14**).

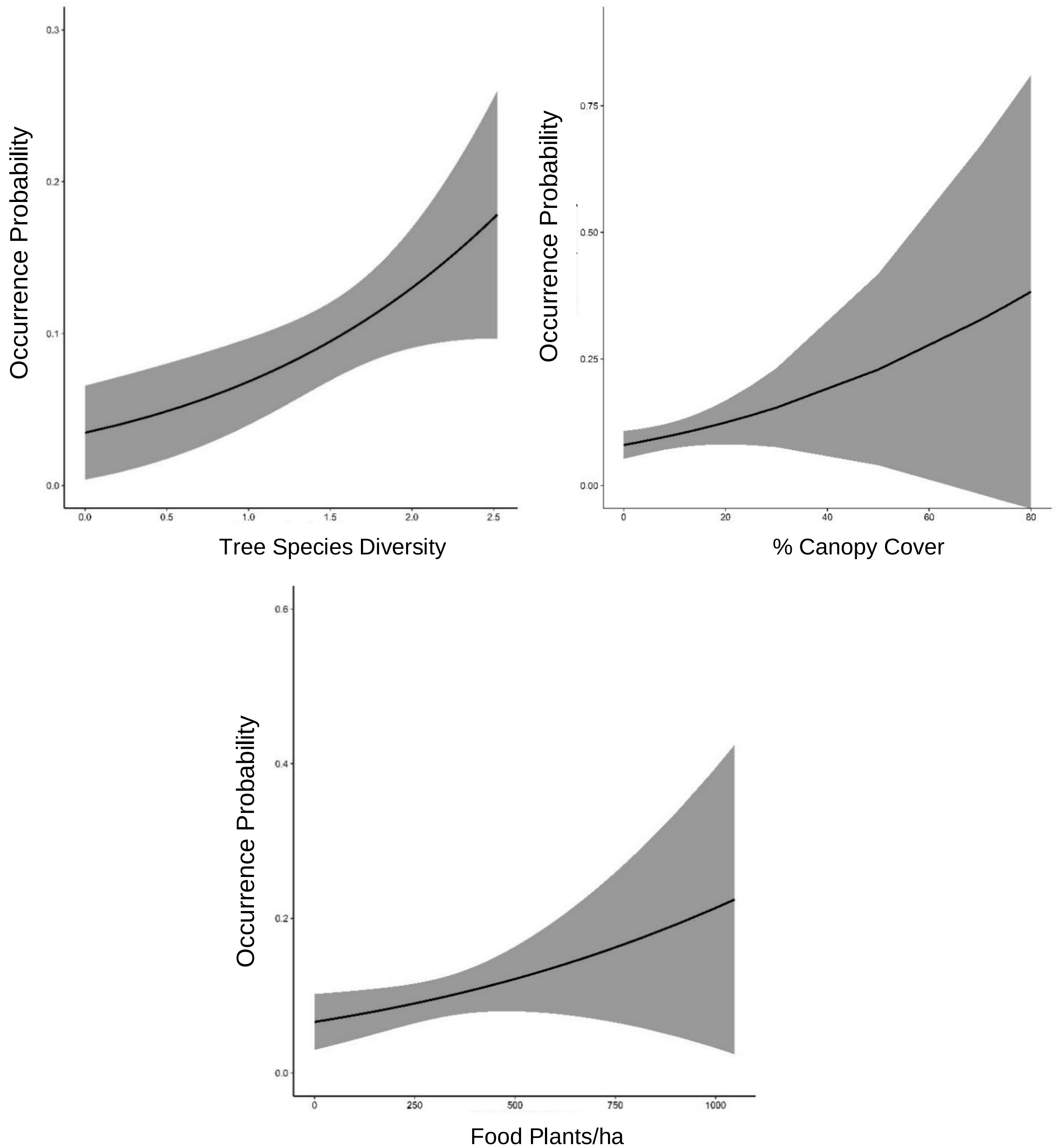


Figure 14. The response of golden langur occurrence probability on increasing tree species diversity, percent canopy cover and food pants/ha.

Table 3. Summary statistics loglikelihood (LogL), Akaike Information Criteria (AICc), relative support for hypothesis (Δ AICc), Akaike weights (Wi) of candidate regression model explaining golden langur habitat usage. Global model in italics. PA: presence/absence of golden langur

Model	logLik	AICc	Δ AICc	weight
PA ~ tree species_diversity +(1 | Site)	-163.46	332.97	0.00	0.27
PA ~ tree species_diversity + canopy_cover+(1 | Site)	-162.78	333.64	0.67	0.20
PA ~ tree species_diversity+fp_density +(1 | Site)	-162.85	333.78	0.81	0.18
PA ~ tree species_diversity + canopy_cover+fp_density+percent_bamboo+woodcutting_lopping+*Chromolaena_odorata*+(1 | Site)	-159.86	336.00	3.04	0.06
PA ~ tree species_diversity + canopy_cover+fp_density+dis_road+(1 | Site)	-162.04	336.23	3.27	0.05
PA ~ canopy_cover+fp_density+percent_bamboo+woodcutting_lopping+(1 | Site)	-162.48	337.13	4.16	0.03
PA ~ canopy_cover+fp_density +woodcutting_lopping+(1 | Site)	-163.51	337.13	4.17	0.03
PA ~canopy_cover+fp_density+percent_bamboo+(1 | Site)	-163.67	337.45	4.48	0.03
PA ~ canopy_cover + (1 | Site)	-165.79	337.62	4.66	0.03
PA ~ canopy_cover+fp_density +(1 | Site)	-164.80	337.68	4.71	0.03
PA ~ fp_density + (1 | Site)	-165.97	337.99	5.02	0.02
PA ~ woodcutting_lopping + (1 | Site)	-166.07	338.18	5.21	0.02
PA ~ percent_bamboo + (1 | Site)	-166.23	338.51	5.54	0.02
PA ~ 1 + (1 | Site)	-167.29	338.61	5.64	0.02
PA ~ tree species_diversity + canopy_cover+fp_density+percent_bamboo+woodcutting_lopping+Chromolaena_odorata+dis_human_settlement+dis_road+(1 | Site)	-159.51	339.44	6.47	0.01
PA ~ dis_road+dis_human_settlement+*Chromolaena_odorata*+woodcutting_lopping + (1 | Site)	-165.25	342.66	9.69	0.00

Table 4. Parameters estimates coefficients (β), standard errors (S.E), significance statistics of influential habitat correlates of golden langur. Model-averaged (conditional average) coefficients.

Coefficients	**β estimate**	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	-2.3199	0.1607	14.398	<2e-16 ***
Tree Species Diversity	0.4533	0.1852	2.442	0.0146 *
Canopy Cover	0.1415	0.1125	1.255	0.2094
Food Plant Density	0.172	0.153	1.122	0.262

5.1.6 Threats

5. 1.6.1 Anthropogenic pressure and invasive plant species

The study aimed at identifying threats such as percentage of invasive plants species and anthropogenic pressures including woodcutting, presence of cattle and free-ranging dogs and humans, associated to endangered golden langur, *Trachypithecus geei* in the highly fragmented southern population. The result revealed wildlife sanctuary with highest woodcutting signs encountered followed by private rubber garden, Reserved Forest and lowest in Community managed Reserved Forest (Figure 15).

Among the surveyed trails in nine different sites, encounter rate of humans was most frequent in the private rubber garden, followed by Community managed RF, Reserved forest and Wildlife Sanctuary. Feral dogs were mostly encountered in Rubber plantations followed by Reserved Forests and community managed reserved forest (Figure 16). The wildlife sanctuary exhibited a significant presence of invasive plant species. *Chromolaena odorata* dominated the invasive flora, followed by *Mikania micrantha* and *Lantana camara*.

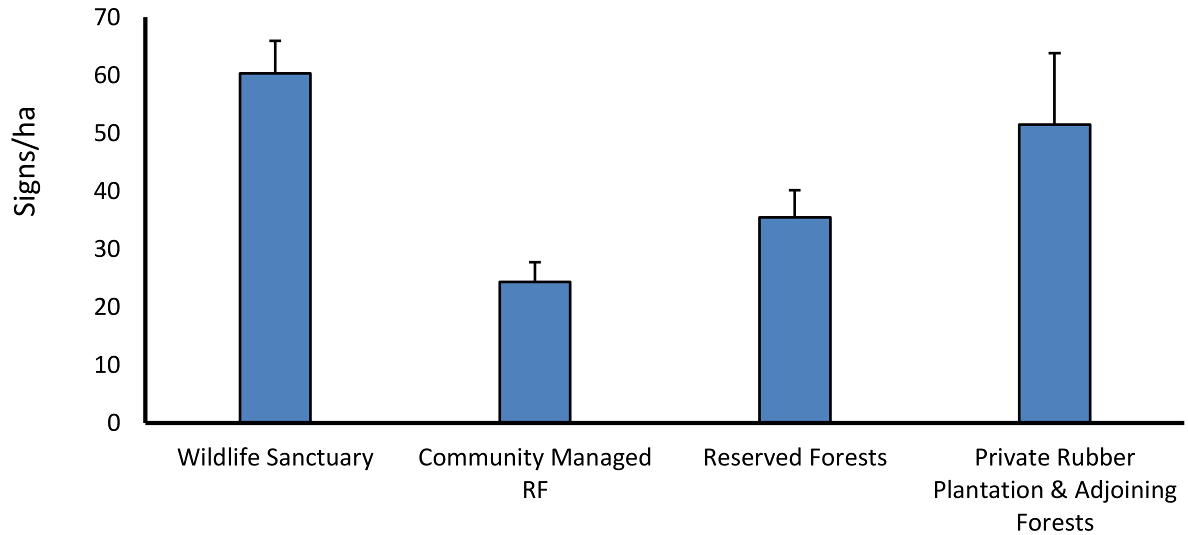


Figure 15. Signs of wood cutting and lopping in different protected regimes of surveyed forests.

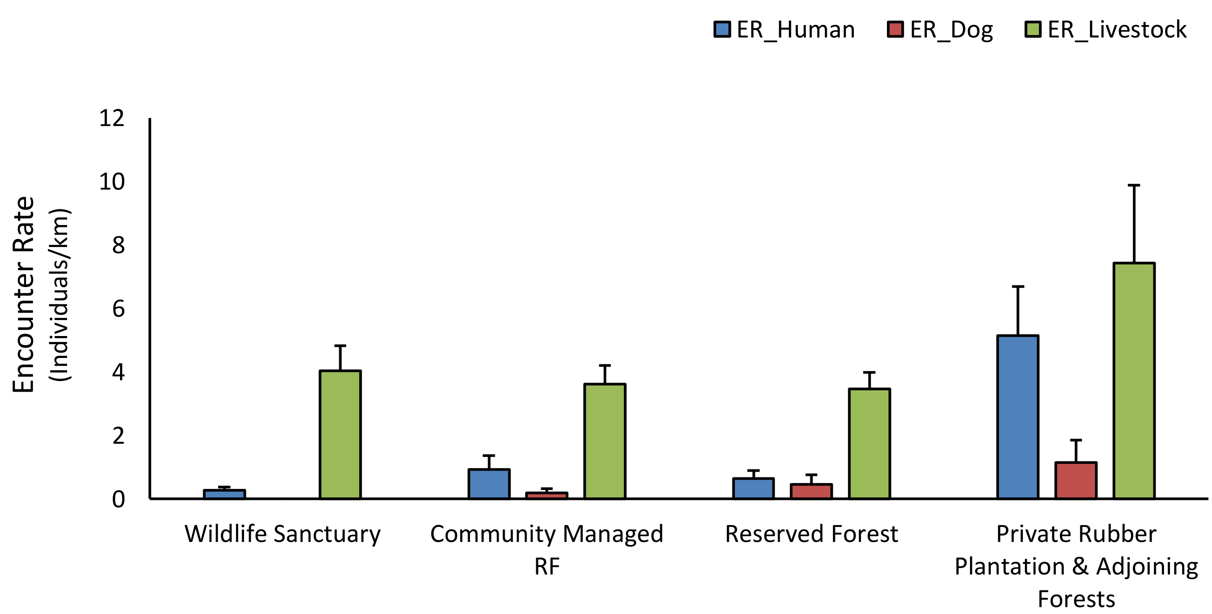


Figure 16. Encounter rate of human, dogs and livestock in different protected regimes of surveyed forest patches.

5.1.6.2. Injury and Mortality

A total of 56 incidents were reported between 2017 and May, 2024 which include 45 deaths and 11 injuries (**Figure 17 & 18**). Of the total 45 mortalities, 48.88 % were recorded for adult males (n = 22), 26.66 % for females (n = 12), 13.33 % for sub-adults (n = 6), 4.44 % for juveniles (n = 2) and 6.66 % for infants (n = 3). It is found that most of the mortalities were due electrocutions (44.44 %; n = 20), followed by road accidents (37.77 %; n = 17) and others (17.77 %; n = 8). Additionally, of the total injury recorded, electrocution (n = 9) was found to contribute 81.81 % in where the adult females (n = 5) was reported the most.

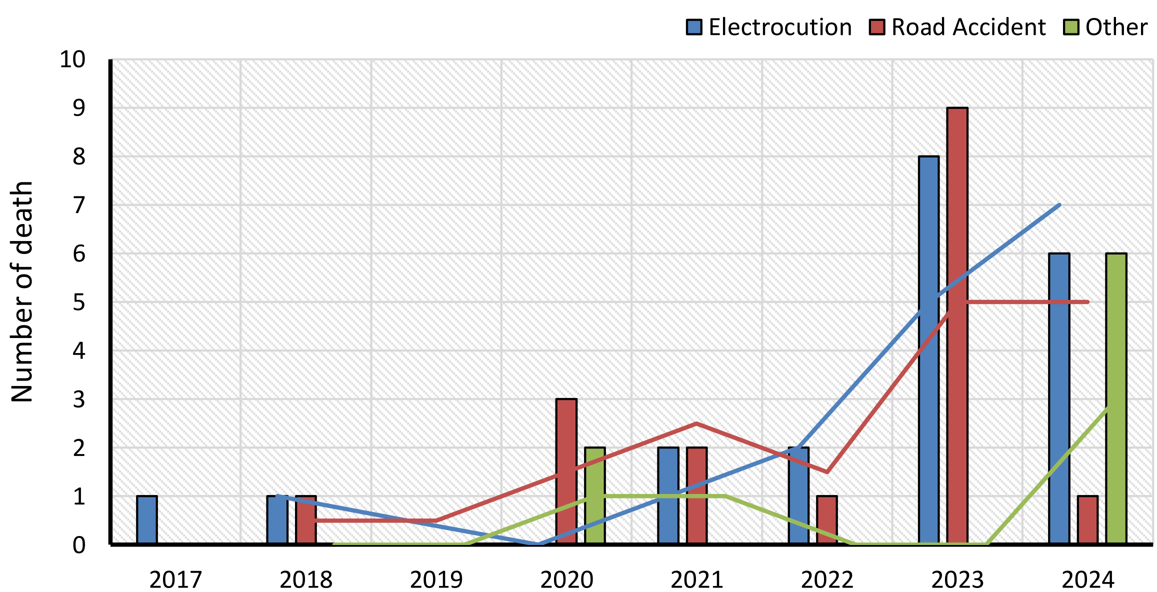


Figure 17. Endangered golden langur, *Trachypithecus geei*, mortality reported between 2017 and May, 2024 in highly fragmented southern population.

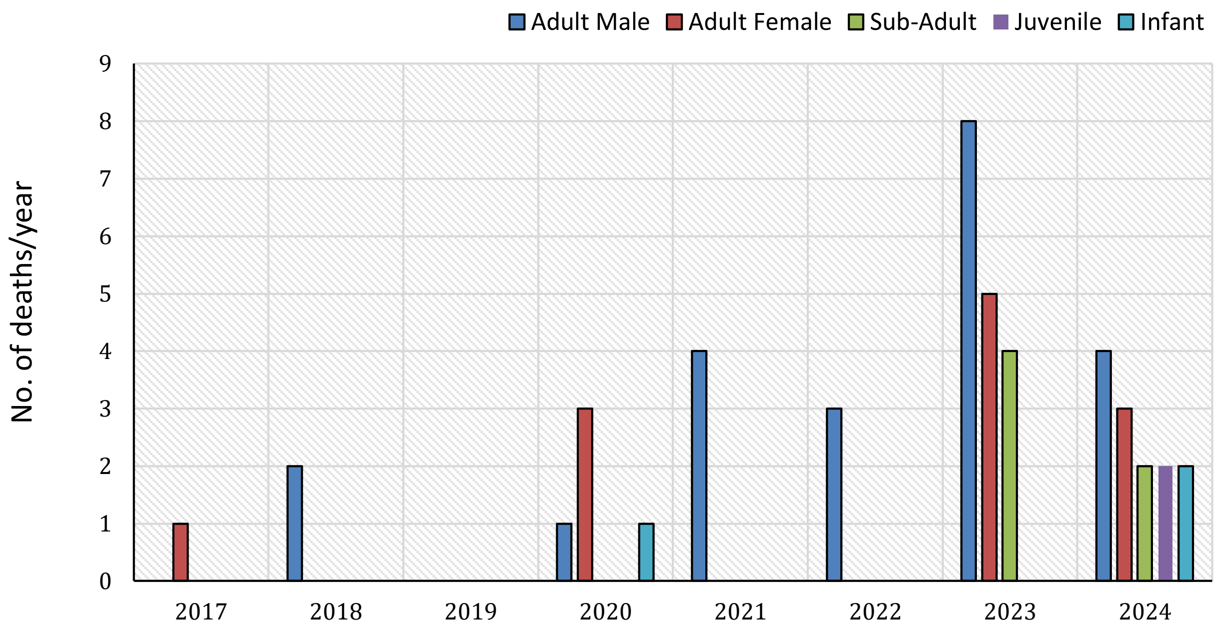
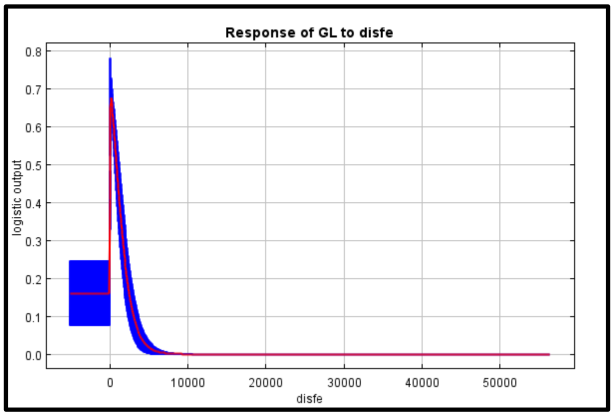


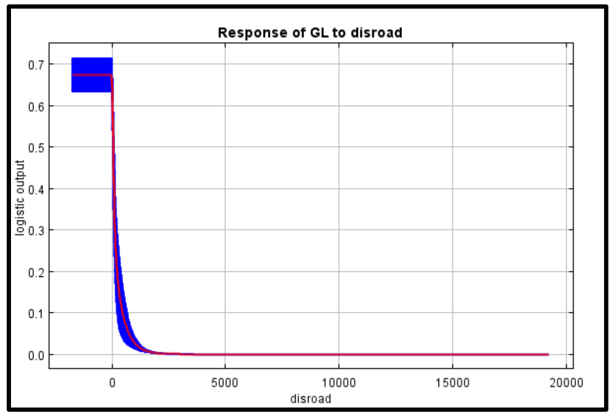
Fig 18. Age-sex composition of Golden langur killed during 2017-2024.

5.1.6.3. *Electrocution Risk-Mapping*

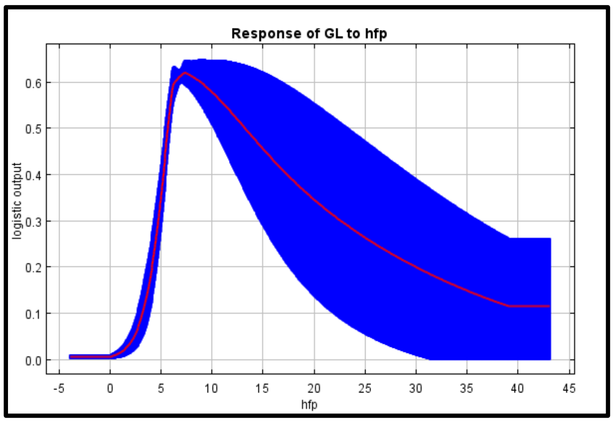
The analysis resulted an average training Area Under the Curve (AUC) of 0.989, with a standard deviation (SD) of 0.002 across replicate runs, indicating a high predictive accuracy for assessing the electrocution risk to golden langurs in the region. Among the selected variables, distance to forest edge was identified as the most significant contributor to the probability of electrocution of the golden langur, accounting for 36.4% to the model (**Figure 19**). Distance to road accounting for 28.6% followed by human footprint index (24.7%), and % home garden (5.1%). The electrocution risk map was shown in **Figure 20**.



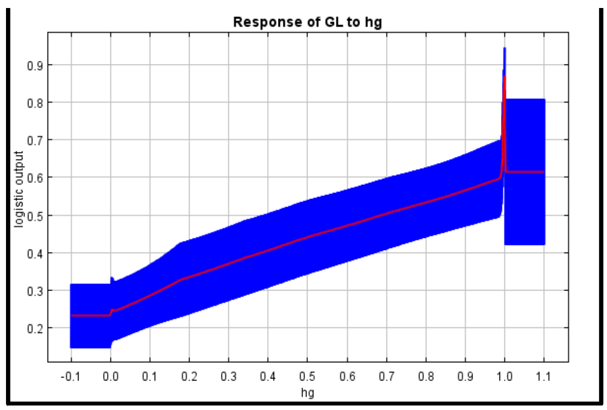
(d) Distance to Forest Edge (disfe)



(c) Distance to Road (disroad)



(b) Human Footprint (hpf)



(a) % Home Garden (hg)

Figure 19. Response curve showing probability of electrocution of Golden langur for different predictor variable.

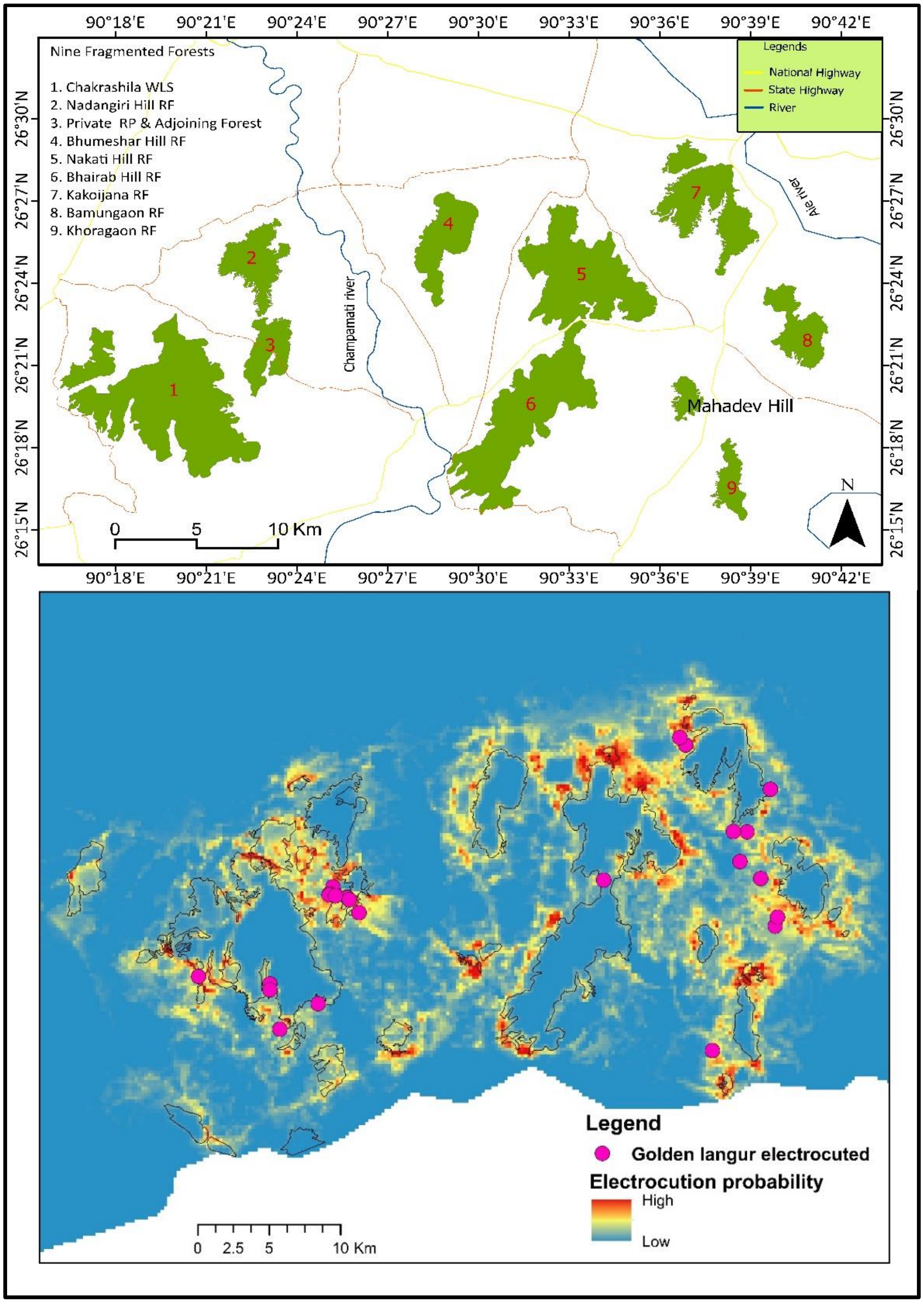


Figure 20. Map showing the electrocution risk of golden langur in the fragmented forest patches.

CHAPTER VI

6.1. Discussion

6.1.1. Distribution, Habitat Suitability and Corridor Connectivity

The current study predicted the distribution of golden langur in three distinct clusters namely, Raimona National Park-Chirang RF (b) western part of Manas National Park (c) highly fragmented southern population which includes Chakrashila WLS and eight other Reserved Forests. Earlier, studies found 93 % of the golden langur population in India distributed in contiguous forest, the remaining 7 % in small isolated fragmented forest patches (Srivastava, 2001). My studies found an approximately 883 km² (49.63%) of the area as highly suitable for the endangered golden langur, indicating a continuous decline in their suitable habitat in India. Earlier studies also reported a decline in suitable habitat for the golden langur in Assam and India, from 2,500 km² in the early 1970s to nearly 950 km² (Choudhury et al., 2002; Roy & Nagarajan, 2018). Assam experienced armed conflict along ethnolinguistic and religious lines between the late 1980s and late 1990s, contributing to present-day deforestation and illegal encroachment. This caused significant environmental damage, with 50% of the forest in western Assam destroyed and population fragmentation in various areas (Baruah, 1999; Dutta, 2020; Vandekerckhove & Suykens, 2010; Srivastava et al., 2001b; Nath et al., 2023).

Since most of the golden langur habitat (except a few forest fragments in the Aie Valley Forest Division) in India falls under the administration of the Bodoland Territorial Region (BTR), formerly known as the Bodoland Territorial Council, which was carved out from the northern part of western Assam in 2003, the decline in suitable habitat may be due to rapid development following ethno-political instability in the region. The model finds forest cover to be the major contributing factor to the occurrence probability of the golden langur. The model predicts some edges of the forest patch in the northern part of the Panbari Range of the Manas Tiger Reserve as highly suitable. This may be due to the NDVI data showing sal (*Shorea robusta*) intermixed with some associated species as high reflectance among the forest cover.

Most of the forest patches inhabited by golden langurs in India are non-protected, with variations in vegetation type and degradation level. The forest reserves inhabited by the northern population of golden langurs are well protected with fewer anthropogenic threats compared to the forest patches in the southern population. Although anthropogenic threats are limited, the forest type is restricted to monoculture sal (*Shorea robusta*) plantations intermixed with some associated species and grasslands. The golden langur populations in India are highly fragmented, with the population in the south being completely cut off from those in the north. The National Highway – 27, which passes through the Bodoland Territorial Region from east to west, bifurcates the golden langur habitat into two halves. Additionally, National Highway – 127C, which connects India with Bhutan, bisects the habitats of the Raimona NP, Chirang-Ripu Reserve and Manas TR populations, creating a significant barrier to their movement and connectivity. Despite this, the population in the north, distributed across Raimona NP, Manas TR, and Chirang-Ripu RF, is well connected with the population in Bhutan.

Additionally, the only protected area designated for the conservation of this primate to the south, apart from Manas National Park and Raimona National Park in India, is the Chakrashila Wildlife Sanctuary, with an overall size of 45.58 km^2. It is bordered by multiple RFs, PRFs, USFs, and private holdings that are known to host the species (Ghosh, 2009). Their isolated populations are highly vulnerable to threats from habitat loss, road accidents, and electrocution. Golden langur populations in the south are reported to adapt and persist in small, fragmented, degraded woods with secondary growth, such as the Abhaya Rubber Garden (Srivastava, 2001; Medhi et al., 2004; Shil et al., 2021). Nine fragmented forests were identified that hold the species in the southern part (to the north of the Brahmaputra River). A recent study on genetic diversity revealed that the population in highly fragmented southern forests is threatened with severe inbreeding depression (Shil et al., 2016). This is likely attributable to the existence of state highways (SH-2 and SH-14), national highways (NH-117 and NH-17), and human settlements, which act as barriers, impeding the dispersal of individuals between fragmented habitats. Despite these barriers, golden langurs have been documented traveling approximately 10 km from Kakoijana to Bhumeshwar Reserved forest, even though these reserved forests appear distant (Howrich et al., 2013), which highlights the need for re-establishment of connectivity.

Therefore, it is pertinent to examine the current distribution and habitat suitability across India and to study habitat use and model connectivity for the endangered golden langur in the highly fragmented southern population. In this study, the outputs from the connectivity model predict home gardens as potential connecting pathways for the highly fragmented southern population. The home gardens between the highly fragmented southern forest patches comprise semi-heterogeneous forests, including bamboo patches, food plants, and other timber-yielding trees.

6.1.2. Fine-scale habitat uses and group demography

Group demography aids in understanding the ecological reasons behind the area's population dynamics. The golden langur group demography varies significantly between different protected regimes. My study found highest average group size in private rubber garden and adjoining forest (PRG_AF). The larger troop size observed may result from the increased protection afforded by larger groups against predators such as stray dogs in and around rubber plantations. This suggests that the langurs are adapting by developing collective protection and foraging strategies in altered habitats, similar to the behaviors exhibited by rhesus monkeys. However, high standard error (SE) suggests a higher likelihood of gathering and dispersal behavior. This might be due to the small size of the rubber plantations, monoculture plantation lacking diverse resources and the high risk involved. The mean group size in wildlife sanctuary, community managed RF and reserved forests were almost similar, showing statistically no significant difference. In the wildlife sanctuary, higher food plant density and diversity were observed, indicating a more abundant and varied food supply for the species. This density in food resources is likely a key factor contributing to the larger group formations and higher infant-to-adult female ratios, as sufficient and diverse food availability supports better nutrition and reproductive health.

Similarly, plant density and species diversity were significantly greater in the sanctuary compared to other forests. These findings suggest a more heterogeneous ecosystem within the sanctuary. Greater plant density and higher species diversity ensures more cover and resources required for the breeding. In contrast, the reserved forest, characterized by lower values in all the parameters assessed, likely suffers from habitat fragmentation, reduced resource availability, and higher human disturbances. These factors collectively contribute to less favorable living conditions for langurs, impacting reproductive success and infant survival rates. The smaller area and increased anthropogenic pressures in the reserved forest might also lead to habitat degradation and decreased ecological resilience, further exacerbating the challenges faced by the langurs.

Overall, this study underscores the critical role of protected areas like wildlife sanctuaries in sustaining healthy langur populations. The findings highlight the importance of habitat quality and protection in influencing group dynamics, reproductive success, and age-sex structure. These insights are crucial for formulating effective conservation strategies aimed at preserving langur populations in diverse ecological settings. Continued monitoring and comparative studies across different habitat types are essential to further our understanding of the factors influencing langur demographics and to enhance conservation efforts.

6.1.3. Threats

The study focused on identifying the primary threats to the endangered golden langur within a highly fragmented southern population, specifically examining the impact of woodcutting, human presence, encounters with free-ranging dogs and cattle, and the prevalence of invasive plant species in four protected status of forest patches (wildlife sanctuary, community managed RF, reserved forest and private rubber garden). The continuous encroachment, unauthorized logging, collection of fuelwoods, and grazing activities from fringe villages inside wildlife sanctuary has always been recognized as threats to golden langurs (Chetry et al., 2020). However, their intensity was not measured and compared. Our findings revealed significant variations in these threats across different habitats. Despite protected under Wildlife (Protection) Act, 1972, Chakrashila Wildlife Sanctuary exhibits highest density (woodcuttings/ha) of woodcutting. This may have resulted because of presence of highest diversity of tree species, which often makes such areas more attractive for illegal logging and woodcutting activities. This may because of the replacement of the mature rubber plants with new saplings. Apart, forest patch adjoins the rubber plantations, although, owned by forest department, are encroached and are frequently for grazing and collection of firewood purposes. In the community-managed reserved forest, woodcutting signs was observed to be the lowest, while in reserved forests, woodcutting occurred moderately. This disparity reflects varying levels of human impact and their commitment in involvement in management practices and conservation. Despite highest average group size ($14.33 \pm 6.56_{SE}$) of golden langur in private rubber garden, human and dog encounters were frequent. The human encounter rate was found least with 0.2 individuals/km, with no dogs encounter inside the sanctuary. The livestock encounter rate was found the highest with 7.43 individuals/km (± 2.4 $_{SE}$) in private rubber garden. My study in private rubber garden not only included homogenous rubber plantations but also a semi-heterogeneous sal (*Shorea robusta*) dominant forests, adjoining rubber gardens. Livestock were not encounter inside rubber garden but in forest patches adjoining private rubber garden. The encounter rate of livestock was found 4.04 signs/km (± 0.78 $_{SE}$) in wildlife sanctuary whereas in community managed RF and reserved forests, it was 3.62 signs/km (± 0.58 $_{SE}$) and 3.47 signs/km (± 0.51 $_{SE}$) respectively. The high encounter rate of livestock within the wildlife sanctuary is particularly concerning. The slightly lower encounter rate in community-managed RF and reserved forest is primarily attributed to the inaccessible terrain of hill reserves.

In the early 1997, habitat degradation was identified as a threat to the golden langur. Earlier studies found illegal felling as major contributor to present day forest fragmentation especially, the southern population. Habitat degradation not only lowers the diversity of flora and fauna, but also provides a favorable environment for invasive plant species to proliferate. As a result, *Chromolaena odorata* and other invasive species dominating in the degraded forest patches.

Electrocution around forest edges has been found to be one of the key threats faced by golden langurs in fragmented forest patches, with 29 reports of electrocution already documented in last six years. The electricity lines around the forest patches need to be insulated to ensure the future survival and movement of golden langurs in the fragmented forest patches. Similarly, road accidents have been found to be another major threat faced by the species in the study area. In the last six years, 21 road accidents have been reported. These accidents have occurred primarily on national and state highways, as these roads are broader and have higher traffic volumes compared to village and town roads. Most accidents happened in the corridors between Chakrashila-Nadangiri and Kakoijona-Bamungaon. Specific measures need to be taken to minimize road accidents and facilitate easy movement along these corridors.

Conclusion

My study provides critical insights into the distribution, habitat preferences, and threats faced by the Golden Langur in fragmented habitats. The study's findings reveal that approximately 883 km² of the area is highly suitable for the Golden Langur, with forest cover being the most critical factor influencing their occurrence. Higher infant to female ratio in Chakrashila Wildlife Sanctuary compared to other reserved forests, highlights the critical roles of protected areas in isolated population. Additionally, the study identified several critical corridors with high connectivity between Bamungaon and Khoragaon RF, Kakoijana and Bamungaon, Bhumeshwar Hill, Nakati RF and Kakoijana RF and Chakrashila WLS and Nadangiri through rubber plantation in Nayekgaon. The research also documented 56 mortalities and injuries over the past six years, with electrocution and road accidents mostly in state highways and national highways being the primary causes. Effective conservation strategies, including habitat protection, corridor connectivity enhancement, and mitigation measures such as insulating electric lines and constructing Artificial Canopy Bridges (ACBs) for electrocution and road accidents respectively, are imperative to ensure the survival of this endangered primate.

References

Al-Razi, H., Maria, M., & Muzaffar, S. B. (2019). Mortality of primates due to roads and power lines in two forest patches in Bangladesh. Zoologia (curitiba), 36, e33540.

Baruah, S. (1999). *India against itself: Assam and the politics of nationality*. University of Pennsylvania Press.

Cagnacci, F., Focardi, S., Heurich, M., Stache, A., Hewison, A. M., Morellet, N., ... & Urbano, F. (2011). Partial migration in roe deer: migratory and resident tactics are end points of a behavioural gradient determined by ecological factors. *Oikos*, *120*(12), 1790-1802.

Chakravarty, A., Saikia, M. K., & Saikia, P. K. Population Status, demography and conservation of Golden Langur *Trachypithecus geei* in an isolated habitat of Kakoijana Reserved forest, Assam, India. *Asian Journal of Conservation Biology*, July 2020. Vol. 9 No. 1, pp. 25-38

Chatterjee, P., Mukherjee, T., Dutta, R., Sharief, A., Kumar, V., Joshi, B. D., ... & Sharma, L. K. (2022). Future simulated landscape predicts habitat loss for the Golden Langur (*Trachypithecus geei*): A range level analysis for an endangered primate. *Science of The Total Environment*, *826*, 154081.

Chetry, D., Chetry, R., Ghosh, K., & Bhattacharjee, P. C. (2010). Status and conservation of golden langur in Chakrashila Wildlife Sanctuary, Assam, India. *Primate Conservation*, *2010*(25), 81-86.

Chetry, D., Phukan, M., Chetry, R., Boro, R. N., Das, A. K., & Bhattacharjee, P. C. (2020). Conservation Status of the Golden Langur *Trachypithecus geei* in Chakrashila Wildlife Sanctuary, Assam, India. *Primate Conservafion*, *34*, 167-173.

Choudhury, A. (1992). Golden langur–distribution confusion. *Oryx*, *26*(3), 172-173.

Choudhury, A. U. (2002). Golden langur *Trachypithecus geei* threatened by habitat fragmentation. *Zoo's Print Journal*, *17*(2), 699-703.

Choudhury, A. (2008). Primates of Bhutan and observations of hybrid langurs. *Primate Conservation*, *23*(1), 65-73.

Crespo-Luengo, G., Hernández-Lambraño, R. E., Barbero-Bermejo, I., & Sánchez-Agudo, J. Á. (2020). Analysis of spatio-temporal patterns of Red Kite Milvus milvus electrocution. Ardeola, 67(2), 247-268.

Dingle, H., & Drake, V. A. (2007). What is migration? *Bioscience*, *57*(2), 113-121.

Dutta, A. (2020). Forest becomes frontline: Conservation and counter-insurgency in a space of violent conflict in Assam, Northeast India. *Political Geography*, *77*, 102117.

Ehrlich, P. R. (1988). *The loss of diversity* (pp. 21-27). Washington, DC: National Academy Press.

Estrada, A., & Coates-Estrada, R. (1996). Tropical rain forest fragmentation and wild populations of primates at Los Tuxtlas, Mexico. *International journal of primatology*, *17*, 759-783.

Estrada, A., Garber, P. A., Rylands, A. B., Roos, C., Fernandez-Duque, E., Di Fiore, A., ... & Li, B. (2017). Impending extinction crisis of the world's primates: Why primates matter. *Science advances*, *3*(1), e1600946.

Gee, E. P. (1956). A new species of langur in Assam. *J. Bombay Nat. Hist. Soc.*, *53*, 252-254.

Gee, E. P. (1961). The distribution and feeding habit of golden langur, *Presbytis geei* (Khajuria, 1956). *J. Bombay Nat. Hist. Soc.* 53:252–254.

Gee, E. P. (1964). The wildlife of India.

Ghosh, S. (2009). Report on Population Estimation of Golden Langur (Southern Population) in Chakrashila Wildlife Sanctuary and Reserved forests Under Kokrajhar, Dhubri and Bongaigaon Districts of Assam. *Report to the Assam Forest Department, Guwahati, Assam*.

Gibbons, M. A., & Harcourt, A. H. (2009). Biological correlates of extinction and persistence of primates in small forest fragments: a global analysis. *Tropical Conservation Science*, *2*(4), 388-403.

Haddad, N. M., Brudvig, L. A., Clobert, J., Davies, K. F., Gonzalez, A., Holt, R. D., ... & Urban, D. (2015). Habitat fragmentation and its lasting impact on Earth's ecosystems. Science, 349(6248), 520-524.

Harris, L. D. (1984). *The fragmented forest: island biogeography theory and the preservation of biotic diversity*. University of Chicago press.

Harris, G., Thirgood, S., Hopcraft, J. G. C., Cromsigt, J. P., & Berger, J. (2009). Global decline in aggregated migrations of large terrestrial mammals. *Endangered Species Research*, *7*(1), 55-76.

Horwich, R. H., Islari, R., Bose, A., Dey, B., Moshahary, M., Dey, N. K., ... & Lyon, J. (2010). Community protection of the Manas Biosphere Reserve in Assam, India, and the Endangered golden langur Trachypithecus geei. *Oryx*, *44*(2), 252-260.

Horwich, R. H., Das, R., & Bose, A. (2013). Conservation and the current status of the golden langur in Assam, India, with reference to Bhutan. *Primate Conservation*, *2013*(27), 77-83.

Inouye, D., & Hare, M. P. (2003). A new subspecies of golden langur (*Trachypithecus geei*) from Bhutan. *Folia Primatol*, *74*, 104œ108.

Khajuria, H. (1956). XII.—A new Langur (Primates: Colobidae) from Goalpara District, Assam. *Annals and Magazine of Natural History*, *9*(98), 86-88.

Khajuria, H. (1960). Further observations on the Gee's langur, Presbytis geei Khajuria, with remarks on the classification of Indian Colobidae (Mammalia: Primates). *Records of the Zoological Survey of India*, *58*(2), 123-129.

Khajuria, H. (1978). The golden langur, Presbytis geei Khajuria: Its discovery, authorship, taxonomic status, and bibliography. *Primates*, *19*, 237-240.

Khan, S., Nath, A., & Das, A. (2020). The distribution of the Elongated tortoise (*Indotestudo elongata*) on the Indian subcontinent: Implications for conservation and management. Herpetological Conservation and Biology, 15(1), 212-227.

Kerr, J.T. & Deguise, I. ,2004. Habitat loss and the limits to endangered species recovery. Ecology Letters 7, 1163–1169.

Lhendup, S., Tshering, U. and Tenzin, J. 2018. Population structure and habitat use of golden langur (Trachypithecus geei) in royal manas national park, Bhutan. International Journal of Fauna and Biological Studies 2018; 5(2), 97-101.

MacKinnon, K., & MacKinnon, J. (1991). Habitat protection and reintroduction programmes. In *Beyond Captive Breeding: Re-introducing Endangered Mammals to the Wild. Symposium of the Zoological Society of London* (Vol. 62, pp. 173-198).

Marsh, L. K. (2003). The nature of fragmentation. In *Primates in fragments: Ecology and conservation* (pp. 1-10). Boston, MA: Springer US.

Medhi, R., Chetry, D., Bhattacharjee, P. C., & Patiri, B. N. (2004). Status of *Trachypithecus geei* in a rubber plantation in Western Assam, India. *International Journal of Primatology*, *25*, 1331-1337.

Mohnot, S. M. 1995–2001. Indo-US Primate Project Reports. Year 1 (1995), 23pp;Year 2 (1996), 16pp.; Year 3 (1997), 24pp.; Year 4 (1998), 40pp.; Year 5(1999), 69pp.; Year 6 (2000), 86pp.; Year 7 (2001), 102pp. Primate Research Centre, Jodhpur.

Mukherjee, R. P., & Saha, S. S. (1974). The golden langurs (*Presbytis geei* Khajuria, 1956) of Assam. *Primates*, *15*, 327-340.

Mukherjee, R. P. (1978). Further observations on the golden langur (*Presbytis geei* Khajuria, 1956), with a note to capped langur (*Presbytis pileatus* Blyth, 1843) of Assam. *Primates*, *19*, 737-747.

Mukherjee, R. P., & Southwick, C. H. (1997). Present status of the golden langur in Assam, India. *Asian Primates*, *6*(3&4), 1-4.

Mukherjee, R. P., Srivastava, A., Mohnot, S. M., Bernstein, I. S., & Southwick, C. H. (1997). Population status of the golden langur (*P. geei*) in Assam. *Am. J. Primatol*, *42*(2), 135.

Nath, A., Lahkar, B. P., Brahma, N., Sarmah, P., Das, A. K., Das, S., ... & Swargowari, A. (2023). Breaking Dawn: Factors influencing mammalian habitat usage in western Assam following socio-political instability. *Journal for Nature Conservation*, *72*, 126357.

Ndegwa Mundia, C., & Murayama, Y. (2009). Analysis of land use/cover changes and animal population dynamics in a wildlife sanctuary in East Africa. *Remote Sensing*, *1*(4), 952-970.

Osman Hill, W. C., & Bernstein, I. S. (1969). On the morphology, behaviour and systematic status of the assam macaque (*Macaca assamensis* McClelland, 1839). *Primates*, *10*, 1-17.

Phillips, S. J. (2005). A brief tutorial on Maxent. *AT&T Research*, *190*(4), 231-259.

Phillips, S. J., Anderson, R. P., & Schapire, R. E. (2006). Maximum entropy modeling of species geographic distributions. *Ecological modelling*, *190*(3-4), 231-259.

Phillips, S. J., & Dudík, M. (2008). Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. *Ecography*, *31*(2), 161-175.

Ram, M. S., Kittur, S. M., Biswas, J., Nag, S., Shil, J., & Umapathy, G. (2016). Genetic diversity and structure among isolated populations of the endangered gees golden langur in Assam, India. *PLoS One*, *11*(8), e0161866.

Rao, M., Johnson, A., & Bynum, N. (2007). Assessing threats in conservation planning and management. *Lessons Conserv*, *1*, 44-71.

Roy, D., & Nagarajan, R. (2018). Biology, ecology, and conservation of golden langur, *Trachypithecus geei*. *Indian Hotspots: Vertebrate Faunal Diversity, Conservation and Management Volume 1*, 251-283.

Roy, D., & Nagarajan, R. An eco-ethological study on Golden Langurs (*Trachypithecus geei*) in Western Assam, India-With reference to their Social organization. *Asian Journal of Conservation Biology*, July 2019. Vol. 8 No. 1, pp. 32-46

Rudnick, D., Ryan, S. J., Beier, P., Cushman, S. A., Dieffenbach, F., Epps, C., ... & Trombulack, S. C. (2012). The role of landscape connectivity in planning and implementing conservation and restoration priorities. Issues in Ecology.

Saha, S. S. 1980. The Golden Langur, *Presbytis geei* Khajuria in Bhutan. Journal Bombay Natural History Society. 76, 493-495.

Saunders, D. A., Hobbs, R. J., & Margules, C. R. (1991). Biological consequences of ecosystem fragmentation: a review. *Conservation biology*, *5*(1), 18-32.

Seki, H. A., Shirima, D. D., Courtney Mustaphi, C. J., Marchant, R., & Munishi, P. K. (2018). The impact of land use and land cover change on biodiversity within and adjacent to Kibasira Swamp in Kilombero Valley, Tanzania. *African Journal of Ecology*, *56*(3), 518-527.

Shil, J., Biswas, J., & Kumara, H. N. (2020). Influence of habitat conditions on group size, social organization, and birth pattern of golden langur (*Trachypithecus geei*). *Primates*, *61*(6), 797-806.

Shil, J., Biswas, J., Nag, S., & Kumara, H. N. (2021). Persistence of *Trachypithecus geei* (Mammalia: Primates: Cercopithecidae) in a rubber plantation in Assam, India. *Journal of Threatened Taxa*, *13*(7), 18679-18686.

Srivastava, A., Biswas, J., Das, J., & Bujarbarua, P. (2001). Status and distribution of golden langurs (*Trachypithecus geei*) in Assam, India. *American Journal of Primatology: Official Journal of the American Society of Primatologists*, *55*(1), 15-23.

Srivastava, A. (2006). Ecology and conservation of the golden langur, *Trachypithecus geei*, in Assam, India. *Primate Conservation*, *2006*(21), 163-170.

Subba, P. B. (1989). The status and conservation of the golden langur (*Presbytis geei* Khajuria, 1956) in the Manas National Park, Bhutan. *Tiger paper (FAO)*.

Subba, P. B. and Santiapillai, C. 1989. Golden Langur in the Royal Manas National Park of Bhutan. Primate Conservation, 10, 31- 32.

Talukdar, N. R., Choudhury, P., Ahmad, F., Al-Razi, H., & Ahmed, R. (2020). Mapping and assessing the transboundary elephant corridor in the Patharia Hills Reserved forest of Assam, India. *Rangeland Ecology & Management*, *73*(5), 694-702.

Taylor, P. D., Fahrig, L., Henein, K., & Merriam, G. (1993). Connectivity is a vital element of landscape structure. *Oikos*, 571-573.

Thinley, P., Norbu, T., Rajaratnam, R., Vernes, K., Wangchuk, K., Choki, K., ... & Gempa. (2019). Population abundance and distribution of the endangered golden langur (*Trachypithecus geei*, Khajuria 1956) in Bhutan. *Primates*, *60*(5), 437-448.

Thinley, P., Rajaratnam, R., Tighe, M., Vernes, K., Norbu, T., Dorji, R., & Tenzin, S. (2019). Understanding primate-human interaction: Socioeconomic correlates of local awareness and attitude toward the endangered golden langur *Trachypithecus geei* (Khajuria, 1956) in Bhutan. *American Journal of Primatology*, *81*(6), e22995.

Thinley, P., Norbu, T., Rajaratnam, R., Vernes, K., Dhendup, P., Tenzin, J., ... & Dorji, N. (2020). Conservation threats to the endangered golden langur (*Trachypithecus geei*, Khajuria 1956) in Bhutan. *Primates*, *61*(2), 257-266.

Vandekerckhove, N., & Suykens, B. (2008). 'The liberation of Bodoland': tea, forestry and tribal entrapment in Western Assam. *South Asia: Journal of South Asian Studies*, *31*(3), 450-471.

Wangchuk, T. (1995). A census and the biogeography of golden langurs (*Presbytis geei*) in Bhutan. *Tiger paper (FAO)*.

Wangchuk, T., Inouye, D. W., & Hare, M. P. (2008). The emergence of an endangered species: evolution and phylogeny of the *Trachypithecus geei* of Bhutan. *International Journal of Primatology*, *29,* 565-582.

Wayre, P. (1968). The Golden Langur and the Manas Sanctuaries. *Oryx*, *9*(5), 337-339.