Winter 2021

Extirpation Risk of the Endangered Golden Langur (*Trachypithecus geei*) Inside and Outside Biological Corridors, Langthel Sub-district, Trongsa, Central District Bhutan

Kuenzang Dorji
Central Washington University, kuenzang.dorji@cwu.edu

EXTIRPATION RISK OF THE ENDANGERED GOLDEN LANGUR (*TRACHYPITHECUS GEEI*) INSIDE AND OUTSIDE BIOLOGICAL CORRIDORS, LANGTHEL SUB-DISTRICT, TRONGSA, CENTRAL DISTRICT BHUTAN

A Thesis

Presented to

The Graduate Faculty

Central Washington University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Primate Behavior

---

by

Kuenzang Dorji

March 2021

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

Kuenzang Dorji

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

______________ ________________________________
Dr. Lori K. Sheeran, Committee Chair

______________ ________________________________
Dr. Kathleen Barlow, Committee Member

______________ ________________________________
Dr. Tim Englund, Committee Member

______________ ________________________________
Dr. Jennifer Lipton, Committee Member

______________ ________________________________
Dr. Kevin Archer, Dean of Graduate Studies

ABTRACT

EXTIRPATION RISK OF THE ENDANGERED GOLDEN LANGUR (*TRACHYPITHECUS GEEI*) INSIDE AND OUTSIDE BIOLOGICAL CORRIDORS, LANGTHEL SUB-DISTRICT, TRONGSA, CENTRAL DISTRICT BHUTAN

by

Kuenzang Dorji

March 2021

I assessed extirpation risks of the golden langur (*Trachypithecus geei*) in two landscapes (inside and outside the biological corridor). Working with a team of trained scientists, I collected data on group size, feeding range, sleeping sites, and predation on golden langurs from Langthel sub-districts, Trongsa district, central Bhutan. I used scan sampling to follow 24 groups of golden langurs (15 groups outside and 9 groups inside the biological corridor) to estimate average group sizes in the two landscapes. I confirmed their sleeping sites and recorded the physiognomies of sleep sites and dimensions of the trees used as sleeping sites. I used a GPS device to record each encounter point and from these aggregated points, I estimated winter feeding range for each group. Using a combination of remote camera trapping, sign survey method, and key informant interviews, I confirmed the presence of potential predators for golden langurs. I used qualitative risk analysis to analyze the probability and impact of six extirpation risks: 1) electrocution, 2) road kill, 3) retaliatory killing, 4) predation, 5) habitat destruction, and 6) population instability. I hypothesized that the golden langur's average group size and feeding range would be bigger in the landscape outside the biological corridor, and that golden langur groups living outside the biological corridor would be more vulnerable to these six extirpation risks. My data and analysis showed that for groups living outside the biological corridor, average group size was larger, feeding range was larger, and groups were more vulnerable to extirpation risks. Focused efforts will be needed to conserve golden langurs living outside of protected areas.

ACKNOWLEDGMENTS

I would like to extend my wholehearted thanks and high reverence to three people whom I referred to as a triple gem or three jewels. One, Dr. Lori Kay Sheeran, for providing me an opportunity to become a graduate student at Central Washington University. She continuously supported my studies and thesis with patience and enthusiasm. I am very much thankful for her generosity and being one of my best advisors ever. Two, I thank Dr. Kathleen Barlow, for consenting to be one of my thesis committee members and for her precious time to go through my thesis draft and provide valuable feedback. Three, I thank Dr. Tim Englund for waiving my tuition fees for entire MSc course, which was the backbone of my studies and special thanks for consenting to be one of the thesis committee members and providing his valuable feedback on this project. I am also very thankful to Dr. Jennifer Lipton for consenting to be one of the thesis committee members and for valuable feedback particularly on GIS components. The great blessings, guidance, support and technical backstopping rendered by all those great people have enabled me to complete my MSc on time with great success.

I am indebted to Mr. Ratan Giri, Langthel Park Range Office, and Jigme Singye National Park for his assistance during data collection. Thanks to my son Mr. Jigme Singye Dorji and brother in-law Mr. Kinzang Sonam for helping me during winter season data collection. The research would not be possible if there was no financial support. For this, I am highly indebted to Central Washington University for granting graduate student research fund and Rufford foundation for kindly funding this study.

Lastly, I would like to thank my wife, Mrs. Kuenzang Choden, my daughters Ms. Namgay Pem Dorji, Ms. Rigzin Lhamo Dorji, and Ms. Nawang Rigzom, and my sons

Jigme Singye Dorji and Lodrak Wangchuk Tshering for their love, support and tolerance throughout my study. Without their help and understanding, this project would not have been completed on time. I also thank my father Mr. Tenzin Chola and father in-law Mr. Dolay for their continued parental support throughout my study. Approval for this project was granted from the Central Washington University (CWU) Institutional Animal Care and Use Committee (IACUC) board (protocol #2019-111) and Human Subjects Review Committee (HSRC) (protocol #2019-116).

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Bhutan is a conservation stronghold for seven species of non-human primates: slow loris (*Nycticebus bengalensis*), Assamese macaque (*Macaca assamensis*), rhesus macaque (*M. mulatta*), Nepal gray langur (*Semnopithecus schistaceus*), golden langur (*Trachypithecus geei*), and capped langur (*T. pileatus*) (Wangchuk et al., 2004; Choudhury, 2008). A descendant species of the Assamese macaque, named *Macaca munzala*, was recorded recently in Sakteng Wildlife Sanctuary (northeastern Bhutan), and its existence in Bhutan confirmed on the basis of direct observation, photographic documentation, and experts' comments (Tobgay et al., 2019).

The endangered golden langur is endemic to Bhutan and a small area of western Assam in northeast India (Srivastava et al., 2001). The species was identified as one of the world's Top 25 Most Endangered Primates 2016-2018 (R. Chetry et al., 2019). In Bhutan, golden langurs were recorded in six districts: Dagana, Sarpang, Trongsa, Tsirang, Wangduephodrang, and Zhemgang (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019) at elevations as low as 199 m asl and as high as 2,600 m asl.

Thinley and colleagues (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019) conducted an extensive census of Bhutan's golden langur population and reported a total population of 2,439 individuals, which is much lower than the most recent International Union for the Conservation of Nature (IUCN) species assessment estimate of 4,000 individuals in Bhutan (Das et al., 2015). However, another related study on golden langur population structure and habitat use based in Royal Manas National Park in southern Bhutan revealed that Bhutan has a healthy golden langur population based in part on the large number of immature individuals observed in each group (Lhendup et al., 2018). The authors reported that Royal Manas National Park has the most golden langurs (443 individuals), and Thinley and colleagues (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019) sighted the largest number of golden langur individuals (135 groups) in Zhemgang district. While both studies indicate a healthy golden langur population in Bhutan with potential to grow, it is important to note that only 33% of the golden langur's suitable habitat is within protected areas in Bhutan. The other 67% of suitable habitat lies outside protected areas (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019). Habitat situated outside protected areas is more exposed to habitat fragmentation and degradation due to developmental works such as construction of roads, dams, and large complexes of government offices. Additionally, golden langurs living outside of protected areas are more likely to be near farms where issues such as conflict over their crop use and exposure to potential predation by dogs are more likely to occur.

The golden langur is classified as a totally protected species in Bhutan (Department of Forests & Park Services, 2017) and is categorized as endangered by conservation experts. Golden langurs in Bhutan are exposed to two broad threat categories, namely, habitat threats due to development including (1) hydropower, (2) roads, (3) housing, (4) resource extraction, and (5) agricultural expansion; and population threats due to living near settled areas, including: (1) electrocution, (2) road kill, (3) road injury, (4) dog kill, (5) retaliatory killing, (6) illegal pet keeping, and (7) hybridization with capped langurs (Thinley, Norbu, Rajaratnam, Vernes, Dhendup, et al., 2019). However, no detailed research has been conducted in Bhutan on how these threats influence golden langur group sizes and compositions and the species' responses to living in human-dominated landscapes. In this study, I explore in more detail the influence of disturbed habitat on golden langur group size and composition by controlling for broadleaved habitat type (warm broadleaf). I also characterize how larger golden langur group size—an observed response to habitat fragmentation and degradation in Assam (Medhi et al., 2004)--might amplify the number and intensity of human-golden langur interactions. In this research, I explore in detail the extirpation risks of golden langur in two different landscapes (outside and inside biological corridor) of Langthel Sub-Districts, Trongsa District, and Central Bhutan. I predict the vulnerability of golden langurs living inside and outside the biological corridor based on identified extirpation risks that fall into three broad categories:

1. Group size and structure and sex ratio;
2. Winter feeding range for 24 golden groups and associated natural and anthropic risks; and
3. Characteristics of sleeping sites and trees and the associated natural and anthropic risks that influence the choice of sleep sites.

Areas outside biological corridors have more intense human impacts on the environment. Consequently, I hypothesized that the group size of the golden langur was bigger, feeding range was larger, and groups were more vulnerable to extirpation outside than inside the biological corridors.

CHAPTER II

LITERATURE REVIEW

Evolution, Taxonomy, and Morphology

The evolution of the golden langur can be discussed in term of the species' phylogeny, ecology, and biogeography (Wangchuk et al., 2008). Here, I briefly describe the history of scientific descriptions of the golden langur. The species was made known to science by naturalist E.P. Gee in the 1950s. The golden langur in Bhutan was recorded in "Tongso" in central Bhutan by Griffith (Pembertons, 1838 cited in Khajuria, 1882), which might have been intended to be pronounced as Trongsa, central Bhutan. Later, E.O. Shebbeare, working with field rangers and hunters, also reported seeing a cream-colored langur in Jamduar, India (Gee, 1961). However, no photographic or museum specimens existed to confirm these reports. In 1919, Inglis and team reported seeing a pale, yellow-colored langur in Gopalpara District, Assam, India and assumed it was a species of the genus *Pithecus* (Khajuria, 1956). After this latter unpublished record, no work or record of this species' discovery exists. From 1953-1955, Gee, with support from the experts of Zoological Society of London and Zoological Society of India, studied six golden langur specimens and in 1956, described a new species, *Presbystis geei* (Khajuria, 1956). Subsequently, Groves (1986) cited in (Karanth et al., 2008) separated genus *Presbytis* into distinct genera, with the golden langur classified in the genus *Trachypithecus.*

Prior to the species being known to science, the species was sacred to Himalayan and Bhutanese people. Most of the Bhutanese people view an encounter with a golden langur as a lucky sign or a harbinger of good fortune (Thinley, Rajaratnam, et al., 2019).

The golden langur is classified with other leaf-eating colobine monkeys (Khajuria, 1956). It is arboreal and is usually found in the upper tree canopy (R. Chetry et al., 2019). Golden langurs are classified in the family Cercopithecidae, and it is one of the world's 25 most endangered primate species (R. Chetry et al., 2019). The golden langur is classified in the *Pileatus* species group, along with the species *T. pileatus* and *T. shortridgei* (B. Wang et al., 2015). *T. pileatus* is also distributed in eastern Bhutan, and it hybridizes with golden langurs where their ranges overlap (Wangchuk et al., 2008). Currently, two subspecies are recognized: *T. geei geei* and *T. g. bhutanensis* (Wangchuk et al., 2003). My research focuses on the latter subspecies.

Morphologically, the golden langur is similar to its close relative, the capped langur *T.pileatus* (Khajuria, 1956) in many features. It has golden orange coat color during the breeding season, but the color varies in different lighting conditions and seasons. Ventral coat color is comparatively lighter, and females are a brighter golden orange color than males are (Chetry et al., 2019). Golden langurs are sexually dimorphic, with adult males being slightly larger and more robust than adult females. The average body mass is 10.8 kg for males and 9.5 kg for females (Nigam et al., 2014). For both sexes, the length of the head and body ranges from 50-75 cm, and the tail length ranges from 70-100 cm (Wangchuk et al., 2004).

Distribution of Golden Langurs

Golden langurs are endemic to India and Bhutan (Horwich et al., 2013). In India, the species is confined to a small region of western Assam between the Sankosh and Manas Rivers and as far south as the Raimona mountain range in Golapara District (Srivastava et al., 2001). In Bhutan, golden langurs have been recorded in six districts:

Dagana, Sarpang, Trongsa, Tsirang, Wangduephodrang, and Zhemgang (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019). Among these districts, Zhemgang has the largest number of golden langurs (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019). At the sub-district level, Nichula sub-district in Dagana district forms the species' western and the southern distributional limit; Nubi sub-district in Trongsa district forms its northern limit, and Phangkhar sub-district in Zhemgang district forms its eastern limit. The species is confined by major river systems in Bhutan, including the Punatsangchhu River in the west and the Mangdechhu, Chamkharchhu, and Manas Rivers in the east (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019). Golden langurs' distribution spans three protected areas: Jigme Singye Wangchuck National Park (JSWNP), Royal Manas National Park (RMNP), and Phibso Wildlife Sanctuary (PWS). These three protected areas are connected by forested biological corridors. Among the protected areas, RMNP has the largest golden langur population (n = 574 individuals); followed by JSWNP (n = 497 individuals) and PWS (n = 298 individuals) (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019, p. 6).

Golden Langur Ecology and Activity Budget

Golden langur ecology includes information on habitat types, diet, locomotion, predators, and activity budget. The golden langur is found in moist evergreen, dipterocarp, riverine, and moist deciduous forests, and occasionally in degraded habitats with secondary growth (Srivastava et al., 2001). This species is adapted to a wide elevation range from near sea-level in southern Bhutan to above 3,000 m in the north (Wangchuk et al., 2003). One isolated population is found in the Abhaya Rubber Plantation, Nayakgaon, in the Kokrajhar district of Assam (Medhi et al., 2004). Study of this population has shown that the animals can to some extent withstand the effects of habitat change and survive in human-altered habitats (Medhi et al., 2004). The golden langur diet consists of young and mature leaves, ripe and unripe fruits, and seeds, with most feeding time spent on young leaves (Gupta, 2001). Subba and Santiapillai (1989) reported that the species prefers fruits and buds to leaves, and in forest fragments, they may depend on cultivated crops such as tapioca, betel, and guava. Golden langurs are diurnal and arboreal (Khajuria, 1978). Similarly, golden langurs in Bhutan prefer mostly leaves, followed by fruits, shoots, flowers, and sap; occasionally, they use rock minerals from the steep rocky areas as mineral supplements (Lhendup et al., 2018).

Non-human primates in general spend most of their time at sleeping sites. The qualities of sleeping sites have commonly been explained in terms of predation avoidance, food access, parasite avoidance, comfort/thermoregulation, and range/resource defense (Roy & Nagarajan, 2018). Golden langurs appear to prefer to sleep in tall trees to avoid natural predators (R. Chetry et al., 2019). Clouded leopards and pythons are the main natural predators of many Asian primates (Cheyne et al., 2013), along with domestic dogs who may attack golden langurs at forest edges (Chetry et al., 2010).

The movement and ranging pattern of non-territorial primates is influenced by details of the species' morphology, diet, habitat, ecology, and social interactions (Ripley, 1967 cited in Larson, 2018). Gray langurs (*Trachypithecus pileatus*) move primarily in a quadrupedal manner both terrestrially and arboreally (Ripley, 1967; Sugiyama, 1976). Similarly, the golden langur moves quadrupedally (Fleagle, 1988) and leaps from tree to tree when moving fast (Mukherjee & Saha, 1974). While leaping, a golden langur pushes off using its powerful hind limbs and lands on the fore- and hind limbs. When they are on the ground or in a tree, running is more common than walking (Gurung, 1996). Day ranges for golden langurs are 200-700 m, and home range sizes are reportedly 10 to 58 ha (R. Chetry et al., 2019).

Chetry, Chetry, and Bhattacharjee (2019) note that golden langurs are diurnal and authors provide information on golden langur's activity budgets, which vary to some extent by site and methodology used by the researcher. For sites in Assam, they report: 12.8 to 33% feed, 40-63.1% rest, 6.3-19% locomote, 5-11.5% monitor environment, 2-3.7% play, and 0.3-6% groom. Golden langurs forage from 8:00 to 11:00 h, rest from 11:00 to 14:30 h, and forage again from 14:30 to 17:00 h (Wangchuk, 1995).

Golden Langur Life History

R. Chetry, D. Chetry, and Bhattacharjee (2019) summarize the reproductive biology of golden langurs. The species has a gestation length of 168-180 days (Subba, 1989; Subba Santiapillai, 1989; Wangchuk, 2005), with a two-year interbirth interval (R. Chetry et al., 2019). Mating occurs between January and June, and births occur between June and December (R. Chetry et al., 2019). Depending on the climate and resource availability, births may be concentrated during certain months, for example January and February in Manas National Park, Bhutan (Subba, 1989; Subba & Santiapillai, 1989). Male golden langurs become sexually mature at 5 to 7 years of age, and females reach maturity at 4 years (R. Chetry et al., 2019). Data on lifespan are lacking for golden langurs and for most species classified in the genus *Trachypithecus*, with the exceptions of *T. cristatus* (31 years) and *T. francoisi* (< 20 years) (Covert, 2012).

In many primate species, females appear motivated to handle infants (Dunayer & Berman, 2018). In *Trachypithecus* species, handling includes such behaviors as carry, hold, groom, nuzzle, and inspect (Kumar et al., 2005). Golden langurs are hypothesized to be cooperative breeders similar to what has been reported for gray langurs, and young are cared for by the mother and other females in the group (Nigam et al., 2014). Usually, one infant is born at a time.

Social Organization, Social Structure, and Mating System

The social system of a given species is an outcome of its social structure and its social organization (Swedell, 2012). Social structure is the size and composition of the group, whereas social organization refers to how individuals are organized within a group. There is considerable variation in social group composition among primates but little variability within each species.

Gray langurs are observed in three types of groups: uni-male/multi-female groups, comprising one adult male, several females and offspring; multi-male/multi-female groups, comprising males and females of all ages; and all-male groups (Sterck, 1999). Nearly 90% of the observed capped langur population lives in uni-male/multi-female groups with an average size of 7 to 9 individuals (Kumar & Solanki, 2008). Shortridge's langur groups are composed of uni-male/multi-female with an average group size of 8 (range 7 to 9) individuals, including one adult male, two or three adult females, and up to five offspring (Y. C. Li et al., 2015). Golden langurs are observed to live in uni-male/multi-female groups of 3 to 9 individuals, bi-male/multi-female groups of 8 to 15 individuals, and multi-male/multi-female groups (R. Chetry et al., 2019). All-male bands (2 to 5 individuals) and solo males have also been reported (R. Chetry et al., 2019).

However, the social structure varies in human-altered habitats, where langurs live in larger groups with higher population density, but with lower birth rates. A troop size of 25 golden langurs was observed in and around hydro-power dam construction sites in Bhutan (pers. communication, Giri, 2019). Sex ratio directly impacts a population's potential for growth, and it varies in different group structures reported for golden langurs (R. Chetry et al., 2019). Though golden langurs live in diverse social systems, the most stable and common social structure are bi-male/multi-female or uni-male/multi-female groups (Biswas, 2004).

In most mammals, one or both sex(es) disperse from the natal group which avoids inbreeding (Chapman & Rothman, 2009). Wangchuk (2005) observed female philopatry and male dispersal in golden langurs. Closely-related langur species such as *Trachypithecus cristatus* live in uni-male/multi-female groups and smaller multimale groups with polygynous mating (Harding, 2010). *T. pileatus* females sometimes move between groups, and due to the lack of observed successful male takeovers, their mating system is characterized by mate defense polygyny (Stanford, 1990).

Conservation Status of Golden Langurs

Globally, the golden langur is classified as Endangered on the International Union for the Conservation of Nature (IUCN) Red List and is classified as an Appendix-I species by the Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES). In India, the golden langur is a Schedule–I species in the Wildlife (Protection) Act of India 1972 (R. Chetry et al., 2019). In Bhutan, the Forest and Nature Conservation Act of Bhutan 1995 protects the golden langur as a Schedule–I species

(Royal Government of Bhutan, 1995) and as a totally protected species in Forest and Nature Conservation Rule (Department of Forests & Park Services, 2017). However, Thinley et al. (Thinley, Rajaratnam, et al., 2019) found in their survey of Bhutanese people living near golden langurs that only 47% were aware of the species' protected status. Golden langurs' protected status is well known to primatologists in part due to its listing as one of the Top 25 most endangered primates in the last two IUCN assessment cycles (R. Chetry et al., 2019).

Habitat fragmentation and depletion due to deforestation is a major threat endangering the survival of the golden langur. In Assam, golden langur habitat was destroyed through massive deforestation that occurred during the 1993 Bodo autonomous movement (Horwich et al., 2013). Besides rapid habitat loss, the golden langur in Assam is threatened by occasional poaching and unreported accidental deaths (Choudhury, 2002). A few remarkable conservation actions to revive the species' habitat and foster pro-conservation attitudes among local resident in India includes "self-help groups" to aid in economic development (Horwich et al., 2013, p.79).

Until recently, for many Bhutanese farmers, golden langurs seemed to be harmless. However, in Langthel sub-district of Trongsa district and Patshaling sub-district of Tsirang district, they are perceived as agricultural pests (Thinley, Rajaratnam, et al., 2019). Even though golden langur crop damage was not significant and they are totally protected by strong national policies, golden langurs are likely to receive retaliation from farmers frustrated by repeated crop damage (Thinley, Rajaratnam, et al., 2019). Retaliatory killing of golden langurs is more likely to occur in rural areas due to inadequate enforcement of rules and regulations (Wangchuk, 2005). The first study of conservation threats for golden langur in Bhutan identified five habitat threats: (1) hydropower development, (2) road development, (3) housing development, (4) resource extraction, and (5) agricultural expansion, and seven population threats: (1) electrocution, (2) roadkill, (3) road injury, (4) dog kill, (5) retaliatory killing, (6) illegal pet keeping, and (7) hybridization with capped langurs (Thinley, Norbu, Rajaratnam, Vernes, Dheundup, et al., 2019).

The survival of the golden langur in Bhutan is further undermined by Bhutan's free cattle grazing system, through which people who live inside the protected areas are allowed to manage their cattle following traditional practices. Golden langur habitat fragmentation is due to felling of trees and human encroachment; and opportunistic poaching and trade that occurs mainly along Bhutan's southern border (Choudhury, 2008).

Currently, 71% of Bhutan is under forest cover (Department of Forests & Park Services, 2017), and through a network of biological corridors and national parks, there is contiguous habitat for primates and other species to survive and disperse. Conservation approaches to ensure survival of golden langurs in Bhutan includes enforcement of Forest and Nature Conservation Rule 2017 which provides total protection under section 415 and imposition of higher penalties for violations [currently, the fine is 15,000 Nu or approximately 210 USD] (Royal Government of Bhutan, 2017). To increase people's awareness of existing policies and strengthen inadequate law enforcement, staff of respective park and forest offices have organized meetings and awareness programs to teach rural people about amended policies.

Management regimes differ in the two landscapes in my study. The extent of resource extraction and developmental activities differs in the forests outside protected areas and in biological corridors, which are protected. Most developmental activities are prohibited inside biological corridors except a few activities of national importance. Similarly, the threats to langur populations may also differ in two different landscapes. The langur population living outside the protected area may be imperiled by hydropower development, road development, housing development, resource extraction, agricultural expansion, electrocution, roadkill and injury, and retaliatory killing. The langur population living inside the biological corridor may also face risks from electrocution, roadkill, and injury, but with a lower probability than occurs outside the biological corridor.

Bhutan's constitution mandates that 60% of the country's total land area remain under forest cover for all times to come (Royal Government of Bhutan, 2008). More than 51% of the country is strictly protected in Bhutan's nine national parks. Additional protection of Bhutan's forests both inside and outside protected areas will ensure that Bhutan remains a paradise for primate species, including golden langurs.

CHAPTER III

METHODS

Study Site and Subjects

I conducted this study to evaluate the extirpation risk to the golden langur population based on population demography, sleep site preferences, predation risk, and human attitudes in Langthel sub-district in central Bhutan from 10 November 2019- 30 April 2020. This research occurred in the midst of Covid-19 pandemic with limited movement and less interaction with local farmers. The study site is comprised of two distinct landscapes. The biological corridor (BC) in my study connects Phrumshingla National Park (PNP), Jigme Singye Wangchuk (JSWNP) and Royal Manas National Parks (RMNP). It measures 154.09 km^2 and is administered by the Nature Conservation Division (NCD), Department of Forests and Park Services. My study area outside the BC measures 184.79 km^2 and is administered by Zhemgang Forest Division. The Regulatory Framework for Biological Corridors in Bhutan defines corridors as being a cost-effective, reliable strategy to conserve meta-populations of wide-ranging species, gene flow for all species, and allow species to adapt to climate change (Wildlife Conservation Division, 2010). Similarly, the forest areas outside the BC are managed for protection, management, development and utilization of natural resources on sustainable principles, and to fulfill the needs of both rural and urban populations (Department of Forests & Park Services, 2017).

These two landscape types vary in their degree of wildlife protection and in the intensity and type of human use. Resource extraction for commercial purpose is not permitted inside BC, which prioritize protection for all wild animals. Commercial activities such as extraction of natural resources, hydropower development, development of roads, and establishment of small-scale factories occur outside BC. Both landscape types in my study are similar in size and in forest composition, which is warm, broadleaf forest.

Langthel sub-district covers an area of 508.4 km² It is bordered by Tangsibji and Drakteng sub-district to the west and north, Korphu sub-district to the south, and Zhemgang District to the east. In 2005, Langthel sub-district consisted of 13 major villages with 335 households (trongsa.gov.bt-Langthel) and 2,637 people (National Statistics Bureau, 2015). The population increased to 3,750 by 2017 (Royal Government of Bhutan, 2017a), of which 850 are non-Bhutanese, mostly Indian, people who were assisting in hydro-power construction. The 2017 census indicates that 2,642 persons are the regular household population who always live in the sub-district.

The permanent residents of Langthel sub-district farm three categories of agricultural land: dry land (khamzing, 271 ha), wetland (chuzhing, 291 ha), and orchard (2.27 ha). Residents mainly grow staple crops of rice, wheat, and vegetables and cash crops of oranges, guava, and bananas.

Seventy-six kilometers of different classes of road (primary roads = 44 km, tertiary roads = 16.18 km, secondary roads = 3.36 km, farm roads = 12.41 km, and residential roads = 0.25 km) run through the two landscapes and connect most of Langthel’s villages. Similarly, 28 km of power transmission lines run through these two landscapes. Roads, particularly primary and tertiary ones, and power lines fragment golden langur’s habitat and pose threats to their survival.

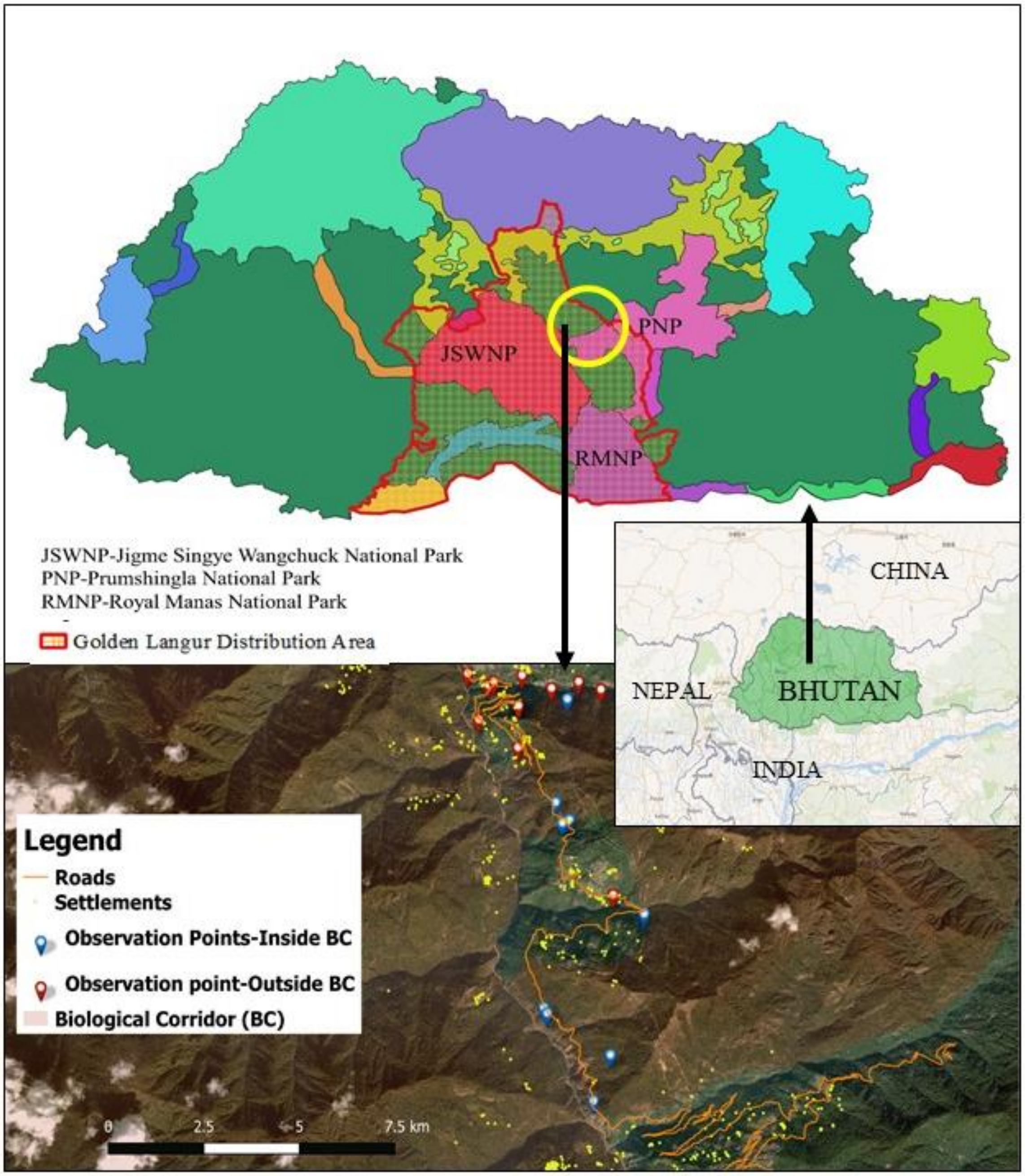
Langthel sub-district's elevation ranges between 1,000 m to 4,200 m asl. This altitudinal gradient yields high habitat diversity, and the sub-district has 17 land use types (alpine shrubs, broadleaved forests, built up areas, wet land, chirpine forests, fir forests, dry land, lake, landslides, meadows, mixed conifer forests, non-built-up areas, orchards, rivers, rocky outcrops, shrubs and snow and glaciers) (Ministry of Agriculture and Forest, 2016). Among all, the broadleaved forest (338.30 KM^2) and chirpine forests (12.68 KM^2) are the two main habitats found in my study area.

The study site harbors some of Asia's rarest species, including the tiger (*Panthera tigris*), golden langur, alphine musk deer (*Moschus chrysogaster*), and red panda (*Ailurus fulgens*) (Letro, 2015), and the two landscape types provide contiguous habitat for rare species such as the clouded leopard (*Neofilis nebulosa*), black leopard (*Panthera pardus*), Asiatic golden cat (*Catopuma temminckii*), and wild dogs (*Cuon alpinus*). Wild pigs (*Sus scrofa*), sambar deer (*Rusa unicolor*), macaques (*Macaca*), barking deer (*Muntiacus muntjac*), and leopard are among the most common species of wild animals found in the sub-district.

I surveyed 24 and intensively studied 14 golden langur groups, seven inside the BC and seven outside of it (Figure 1).

Figure 1

Location of Golden Langur Groups in Langthel Gewog (Block) Trongsa District, Bhutan



Procedures

I stratified golden langur habitat within the study area into different forest types and sampled those that are highly suitable habitats for golden langurs. Past studies reported that golden langurs are usually distributed in tropical semi-evergreen forest (Choudhury, 2002), broadleaf forest (Wangchuk et al., 2008), and warm broadleaf forest (Lhendup et al., 2018). For this study, my team members and I sampled warm broadleaf forests associated with chirpine (*Pinus roxbhurgii*) forests both within and outside BC.

Data Collectors and Inter-Observer Reliability

I am the principal investigator for this study, and I work for the government office Ugyen Wangchuck Institute for Conservation and Environmental Research, which is the national data repository center. Both the social and ecological data are archived at the institute. For published and unpublished scientific work occurring under the leadership of UWICER employer, data sharing protocols permit use of some of the data upon consent from the author. The UWICER office has most of the spatial layers of Bhutan, so employees have access to the GIS and other data (e.g., households in each sub-district) required for this study.

In the field, my data collection was assisted by the park staff of Jigme Singye Wangchuk National Park and territorial division staff of Zhemgang Forest Division. I sought their assistance and local support for my research through official communication with the heads of their respective offices. Prior to data collection, I trained them on how to use equipment essential for our data collection: GPS and spotting scope, how to count the number of langurs in each group, how to identify langur age and sex classes, how to identify golden langur feeding trees, set-up of the remote camera traps, and how to conduct interviews with farmers. The first week in the field, we all followed a few langur groups together, counted the number of langurs, recorded their behaviors, and conducted farmer interview questionnaire pretests to ensure we all collected data in the same way.

Research Permits

The study was conducted based on subsequent approval by the Department of Forests and Park Services of the Royal Government of Bhutan (approval number DoFPS/Nga-5-35/2019/6685804905F96956546240 dated 20-11-09; Appendix C which officially regulates studies of both animals and human subjects. I complied with Central Washington University HSRC (2019-116) and IACUC (2019-111) protocols in all aspects of data collection and analysis.

Equipment

For precise measurement of langur group size and composition, langur location, and habitat features (e.g. sleeping tree location, girth, and height), I used these essential kind of equipment: spotting scope (Vortex Viper HD 20-60x85 Spotting Scope), binoculars (Celestron 8x42 Nature DX Binocular), Global Positioning Unit (GPS), Smartphone GPS and app (SW Maps), Camera (Nikon COOLPIX P1000 Digital Camera), Reconyx camera trap, Samsung Tablets, Compass (SUNTO), clinometers (SUNTO), and diameter tape for measuring tree girth.

Langur Surveys and Group Sizes and Compositions

To date, conservation surveys and research on golden langurs has occurred through three stages: extensive surveys, intensive surveys, and long-term monitoring of langur groups' ecology and behavior (Lhendup et al., 2018; Srivastava, 2008). Through intensive surveys, my team members and I recorded 24 golden langur groups that range along roads and near agricultural farms inside and outside the BC. Using roads (both primary and farm roads) and existing trails as transect lines (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019), we followed each group twice a week from 8:00AM-11:00AM, which spans the time when langurs are usually traveling and foraging (Wangchuk et al., 2008). When we encountered a golden langur group, we counted the individuals first, and then classified them as adult males, adult females, infants, or juveniles (following the age/sex classes described in Srivastava et al., 2001). Following Thinley and team (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019), we closely observed for unique individual characteristics such as scars and injured/deformed body parts to characterize individuals and their groups.

Langur Behavioral Data and Sleeping Sites

From 14:30 to 17:00 h, we used scan sampling to collect behavioral data from the 24 golden langur groups. The number of follows per group range from a minimum of two times to a maximum of 16 times. We recorded behaviors such as feeding and travel and noted where sleeping sites were located. Using GPS, we recorded the latitude and longitude of sleeping sites and the locations of trees in which golden langurs fed. For each sleeping tree, we recorded its species name, girth (DBH), height, crown cover, and connectivity (Table 1). We classified the shape of the trees in the view of seven different shapes that are columnar, pyramidal or conical, base-shaped, round and oval shaped, spreading or open shaped, umbrella shaped and weeping shape. We classified the slope gradient of the ground surrounding each sleeping site based on four categories: 1) very gentle (0-20%); 2) moderate (21-30%); 3) strong slope (31-50%); and 4) steep slope

(51% and above). I measured the aspect of the sleep sites counterclockwise in degrees from 0 to 360.

Table 1

Sleeping Trees Measurements

Variables	Descriptions
Species	Scientific name
Tree types	Evergreen, deciduous, or partially deciduous
DBH	Diameter of the tree at breast height
Crown cover	Sky view from base of sleeping tree (Low 1-49%; Medium 50-84% and Dense 85-100%)
Height	Length from tree base to first branch and to tree top
Trees statra	Emergent, canopy, understory, and undergrowth
Canopy layer	0 to 5 m (understory), 5 to 15 m (midstory), and 15 m to canopy top (overstory)
Tree shapes	Columnar, pyramidal or conical, base-shaped, round and oval shaped, spreading or open shaped, umbrella shaped, weeping shape
Tree trunk	Clean and straight, branchy and crooked (clean bole are preferred by the people to fell)
Crown cover	Sky view from base of sleeping tree (Low 1-49%; Medium 50-84%, and Dense 85-100%)
Connectivity	Sleep trees' branch overlap with neighboring trees (high), trees within 3-5 m of langurs' leap range; trees are at 10 m apart (low)

Assessment of Extirpation Risk

Assessment of species vulnerability is a significant aspect in conservation and environmental management (He et al., 2018). I assessed the extirpation risk of golden langur groups residing inside and outside the BC based on population demography, predation risk, sleeping sites, and human attitudes toward langurs. Vieira and team (2019) used Minimum Convex Polygon (MCP) and grid size method to estimate home range size for a chimpanzee community inhabiting a forest–farm mosaic. Likewise, I used GPS locations to calculate winter feeding range in two landscapes using the Minimum Convex

Polygon (MCP) method. Through integrated spatial analysis of Geographic Information System (GIS) method, I integrated the spatial data at the study area (land use, settlements, roads, built-up areas) with data on langurs' feeding range (polygon) to analyze the length of the roads, length of transmission lines, scale of farm land, land-use change, and distance from hydropower dam for each langur group's range. I assessed each group's vulnerability risk based on risk exposure pathways and a measurement scale derived from population demography, predation risk, preference of sleeping sites, and human attitudes (Table 2).

Table 2

Risk Exposure Pathways for Golden Langurs

Risk Exposure Pathways	**Probability**	**Impact**	**Risk**
Risk 1: Electrocution			
• Presence of 440KV open wire; optic fabric wire connected to 440KV, electric transformer inside feeding range, golden langur walks over the optic wires frequently and record of past incident present	0.9	0.9	High
• Presence of optic fabric wire connects to 440KV open wire inside feeding range, and langur walk over the wire occasionally, no record of past incident present	0.6	0.9	Medium
• Optic fabric wire is present, langur walk over optic wire rarely and no past record	0.3	0.3	Low
Risk 2: Roadkill			
• Paved, straight, wide road passes through steep slopes, visibility for langur low, crosses the road regularly, has past incidence	0.9	0.9	High
• Paved, zig-zag, narrow road passes through moderate slopes, visibility for langur moderate, crosses the road occasionally, has no past incidence	0.6	0.9	Medium

Table 2 (Continued)

Risk Exposure Pathways	Probability	Impact	Risk
• Paved- narrow road passes through gentle slopes, visibility for langur high, crosses the road rarely, has no record of past incident	0.3	0.6	Low
3. Retaliatory Killing			
• Golden langur visits agricultural farm regularly; people are not tolerant; unaware of its conservation status; consider langur as pest, past record of killing	0.9	0.9	High
• Golden langur visits agricultural farm occasionally; consider it as a pest; people are tolerant and aware of its conservation status	0.6	0.9	Medium
• Golden langur visits agricultural farm rarely; people are tolerant; aware of its conservation status	0.3	0.3	Low
4: Predation			
• Sign of leopard, python, raptors birds are abundant, >5 domestic dogs present; langurs sleep near agricultural farm; used low and open trees as sleeping sites; record of past incident	0.6	0.9	High
• Sign of leopard, python, raptors birds are occasional; >2 domestic dogs present; sleep in low trees and open trees-exposed to predators	0.3	0.6	Medium
• Sign of leopard, python, raptors birds are rare; 1 domestic dog present.	0.3	0.3	Low
Risk 5: Habitat destruction			
• High frequency of power lines, roads, built ups areas, timber extraction, stone quarry, waste disposal and cattle grazing inside feeding range; record on that most golden langur preferred tree sleep site were marked for extraction.	0.9	0.9	High

Table 2 (Continued)

Risk Exposure Pathways	Probability	Impact	Risk
• Moderate frequency of power lines, roads, built up areas, timber extraction, stone quarry, waste disposal and cattle grazing inside feeding range; record on some golden langur preferred tree sleep site were marked for extraction	0.6	0.9	Medium
• Low frequency of power lines, roads, built up areas, timber extraction, stone quarry, waste disposal and cattle grazing inside feeding range; no record of golden langur preferred tree marked for extraction	0.3	0.6	Low
Risk 6: Population instability			
• The group comprised of only adult males or adult females	0.9	0.9	High
• The group comprised of adult males and females	0.6	0.9	Medium
• The group comprised of equal proportion of adult males, adult females, juvenile and infants	0.3	0.3	Low

Note. For each risk, I assigned a value of probability and impact scaled between 0-0.3 (low), 0.4-0.6 (medium), and 0.7-1 (high), where risk score is an output of probability multiplied by impact.

Predator Presence Survey

Camera traps are useful to conduct surveys or record general observations (Meek et al., 2012) and can support research on elusive species such as nocturnal predators. I used remote cameras to validate animal species present in and around feeding ranges and sleeping sites of the golden langur groups. I chose camera sites near langurs' sleeping sites and feeding ranges to maximize the probability of recording target predators. I deployed 20 remote camera traps placed at approximately 1 m height from the ground, facing away from any large objects or dense vegetation to minimize camera obstruction and false-trigger events (O'Connor et al., 2017). I recorded droppings and other visual cues along with direct prey sightings to generate rudimentary knowledge of the presence of prey species near langur sleeping sites. I probed for evidence of predators such as scats, scrapes (scratching on trees), and carcasses from large-cat kills. I counted raptors to assess presence/absence or number of encounters I had with predators in and around sleeping sites.

Wildlife sign surveys can be used to detect animal presence and monitor their distributions (Stokes et al., 2010). Sign surveys are commonly used to study and monitor wildlife species (Jeffress et al., 2011). My field assistants and I followed (K. U. Karanth et al., 2011) and walked from morning to dusk trails that traversed feeding ranges and sleeping sites. I photographed, georeferenced, and recorded signs of leopards, their ungulate prey species, and signs of livestock presence. I used a point count method with a fix radius of 30 m and stopped for 15 minutes (Mulyani et al., 2020; Rashid et al., 2020) to monitor the presence of raptors.

Analysis

I analyzed data on golden langurs' group size and structure, sleep site preferences, and predation risk along with people's attitudes toward langurs, and I used this information in part to assess golden langur extirpation risks. I used inferential and descriptive statistics to test my predictions.

I calculated langur population demography, male to female ratio, adult female to juvenile ratio, and average group size in two different landscapes using Microsoft Excel™ version 2015. I calculated the group size mean inside and outside the BC. Using R, I set an alpha value (p) at ≤ 0.05 and performed t tests to determine whether there was a significant difference between the mean group sizes inside and outside the BC.

Extirpation risk for the golden langur was assessed based on six determined threats such as electrocution, road kill, retaliatory killing, predation, human destruction, and population instability. I performed a qualitative Risk Analysis (QRA) by assessing and combining the probability of occurrence and impact based on subjective categories (e.g. low, medium, high). I identified risk exposure pathways based on the criteria assigned for the values for probability and impact. I calculated the risk weightage or score by multiplying the probability and the impact. I used this methodology based on the principles and procedures of the *Australian/New Zealand Standard for Risk Management ISO 31000:2009* and *HB 203: 2000 Environmental Risk Management – Principles and Process* (Standards Australia, 2009). I assigned the value for probability and impact of each risk to each golden langur group irrespective of the landscapes. I used a heat map (GIS analysis tool) to present the risk assessment process.

I analyzed golden langurs' preferences for sleep sites using both descriptive and inferential statistics. Descriptive analysis includes tallying diameter at breast height (DBH), height of the tree, height of the tree from the ground to first branch, shape of the tree, crown cover, tree layer, and tree connectivity with other neighboring tree(s). I used the Pearson correlation to test the relationship between tree DBH, tree height, and langur group sizes. I also calculated the proportion of the slopes and aspect of the sleeping sites.

CHAPTER IV

RESULTS

Frequency of Golden Langur Encounters

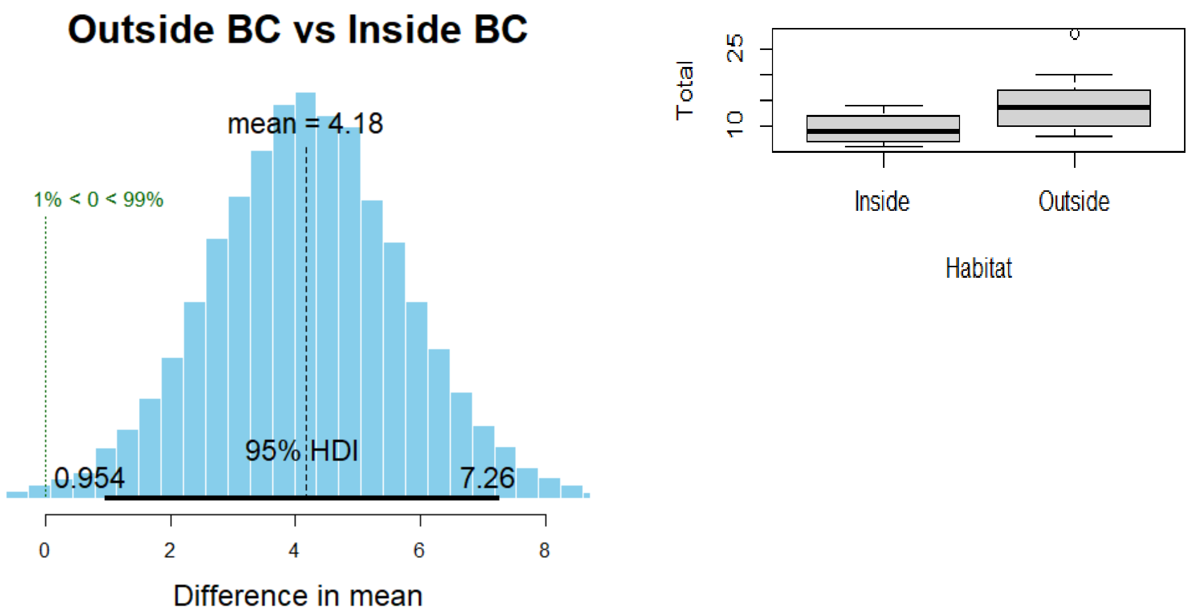
From 11 November 2019 to 30 April 2020, my field assistants and I observed 24 langur groups ranging inside (n = 9) and outside (n = 15) the BC. In total, we recorded 297 langur individuals in the 24 groups through intensive surveys. The groups of golden langurs ranging along the roads outside the BC were easy to observe and monitor. Outside the BC, the mean sighting of golden langur was 10.33 times; we sighted some groups a minimum of two times and a maximum of 17 times across the entire observation period. Inside the BC, the mean sighting of golden langur was 6.33 times; we encountered the golden langurs inside the BC a minimum of two times and a maximum of 11 times.

Golden Langur Group Size and Composition and Sex Ratio

Through our intensive surveys, we monitored 24 groups and counted 297 individuals along 15 km of transects. We estimated the mean size for groups inside the biological corridor at 9.55±3.04 individuals (s^2 = 15.49 individuals) and 13.73 ± 3.94 individuals (s^2 = 9.27 individuals) for groups outside the biological corridor. Overall mean group size is 12.08 ± 4.62 individuals (SE = 0.96). The mean group size inside the biological corridor ($\overline{X}$=9.55 individuals) is lower than the mean group size outside the biological corridor ($\overline{X}$=13.73 individuals; Figure 2). The mean difference in group sizes between the two landscapes is 4.18 individuals, with a 99% certainty that groups living outside the BC are larger than groups living inside the BC.

Figure 2

Golden Langur Group Size Mean Difference Inside and Outside the Biological Corridor



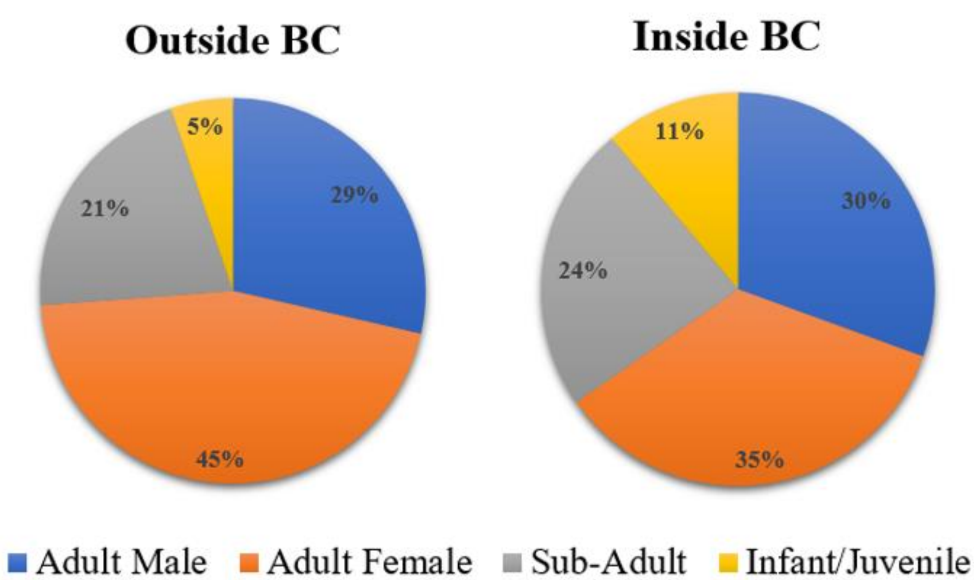
I used a two sample t test to test the hypothesis that mean golden langur group size is the same inside and outside the BC. The test showed that average group sizes outside the BC were statistically significantly larger (t (22) = 0.01, n_1 = 9, n_2 = 15, p < .05), which is consistent with our prediction that langur groups near human settlements would be larger than groups living in less impacted environments.

Of the 24 golden langur groups we observed, 60% of groups (n = 9) outside the BC and 22% of the groups (n = 2) inside the BC were multi-male/multi-female groups with 12-24 individuals. Fifty-five percent of the groups (n = 5) we observed inside the BC and 26% of the groups outside the BC were uni-male/multi-female groups with 6-10 individuals. Twenty-two percent of the groups we observed inside the BC and 13% outside the BC were bi-male/multi-female group with 10-15 individuals. Two groups of golden langurs living in and around human settlements had an unusually large number of males (8 and 9) in a group, and in both cases more adult males than adult females and immature individuals.

The overall group composition of the two landscapes was 28% (*n* = 82) adult males, 45% (*n* = 134) adult females, 21% (*n* = 61) subadults, and 6% (*n* = 19) infants/juveniles (Figure 3). The area outside the BC has a larger number of adult males (28.57%, *n* = 21), adult females (45.24%, n = 95), and subadults (20.95%, *n* = 44) compared to the groups living inside the BC. The groups in the BC have a larger number of infant/juveniles (9.30%, n = 8) than the groups living outside the BC (5.24%, *n* = 11).

Figure 3

Overall Sex Composition (%) of Golden Langurs Inside and Outside Biological Corridors



The average adult male and female sex ratio was 1:1.59 (84:134); sub-adult to adult female ratio was 1:2.19 (61:134); and infants to adult female ratio was 1:7.05. My estimation revealed high adult male-adult female sex ratio (1:1.77) and adult female-infant sex ratio (1:0.22) for those groups observed in the biological corridor. For the groups outside the BC I estimated an adult male-adult female sex ratio of 1:1.55, and an adult female-infant ratio of 1:0.11 (Table 3).

Table 3

Group Composition Ratios of Golden Langur Groups in Two Different Landscapes

Landscape type	**Adult Male: Adult Female**	**Adult Female: Sub adult**	**Adult Female: Infant**
Outside Biological Corridor	1:1.55	1:0.46	1:0.11
Inside Biological Corridor	1:1.77	1:0.43	1:0.20

Locations and Characteristics of Sleeping Sites

Of 24 golden langur groups, I randomly selected and then intensively monitored seven groups from each landscape (*n* =14 groups total). I followed the groups from 05:30 h until they settled at night to sleep. Langurs used trees to sleep at night, and I never observed them sleeping on the cliffs. Twenty-eight tree species of 21 families and 14 orders were used as sleep sites by the 14 langur groups. My test for proportions showed that the most frequently used species were *Sapium insigne* (*n* = 9), *Sapium eugeniigolium* (*n* = 4), *Bischopia javanica* (*n* = 3) of Euphorbiaceae and Phyllanthaceae families (Table 4) and Malpighiales order (Figure 5). I classified the shape of each tree as columnar, pyramidal or conical, base-shaped, round and oval shaped, spreading or open shaped, umbrella shaped and weeping shape (Figure 4).

Figure 4

Illustration of Different Tree Shapes Sleeping Tree used by Golden Langurs

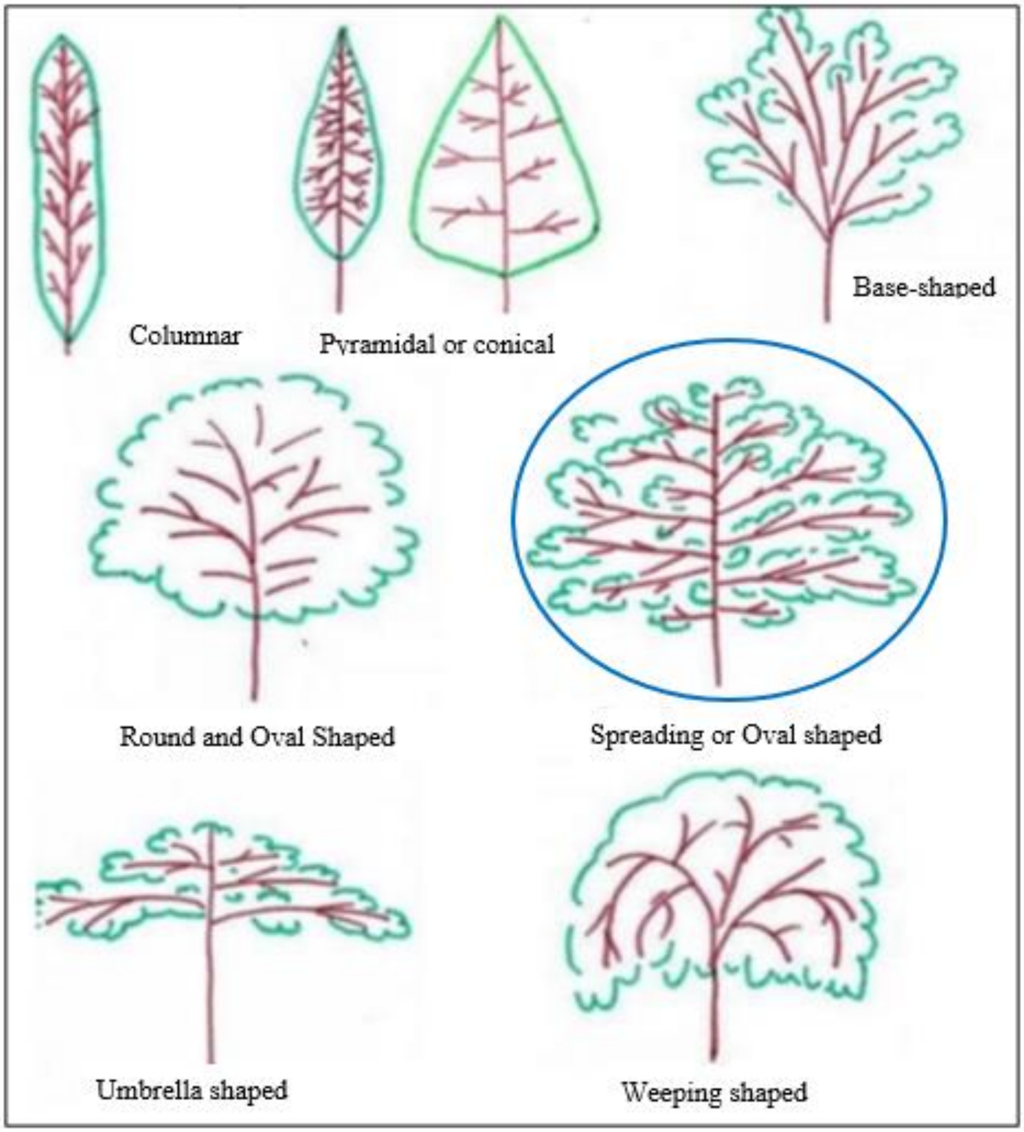


Table 4

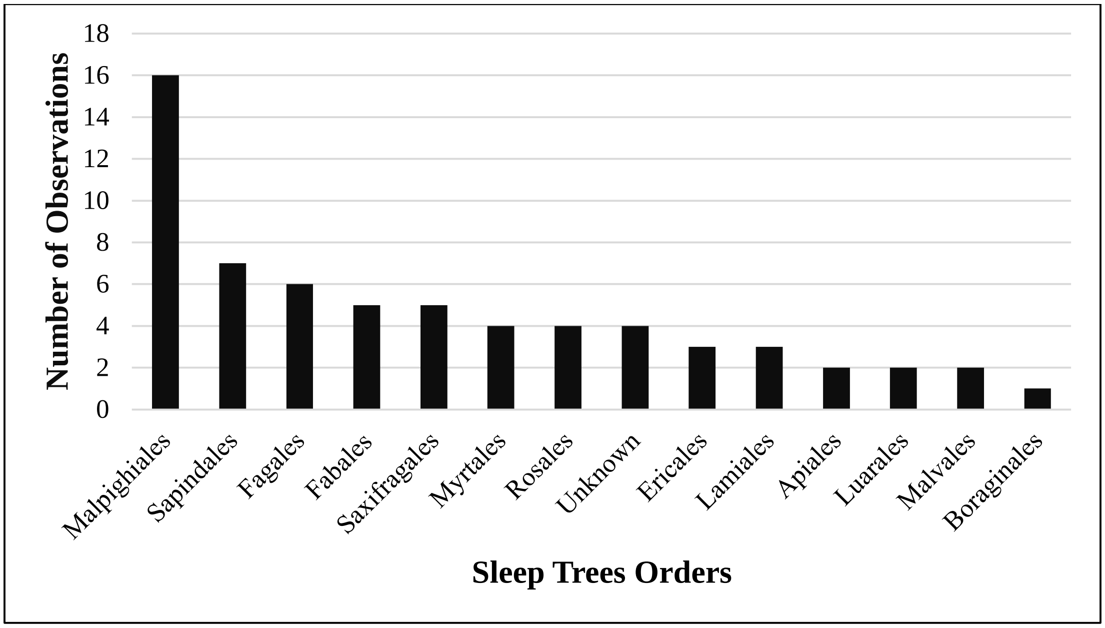
Tree Species used by Golden Langurs for Sleeping Inside and Outside the BC

Sl.No	Order[a]	Family[a]	Species[a]	Count
1	Fabales	Fabaceae	*Albizia spp.*	3
2	Saxifragales	Altingiaceae	*Altingia excelsa*	5
3	Malpighiales	Phyllanthaceae	*Bischopia javanica*	3
4	Malvales	Bombacaceae	*Bombax ceiba*	2
5	Lamiales	Lamiaceae	*Callicarpa arborea*	2
6	Fagales	Fagaceae	*Castanopsis hystrix*	3
7	Fagales	Fagaceae	*Castanopsis tribuloides*	1
8	Luarales	Lauraceae	*Cinnamomum glanduliferum*	2
9	Boraginales	Boraginaceae	*Cordia obliqua*	1
10	Myrtales	Lythraceae	*Duabanga grandiflora*	1
11	Sapindales	Meliaceae	*Dysoxylum chisocheton*	2
12	Apiales	Araliaceae	*Eluetherococcus spp.*	1
13	Fagales	Juglandaceae	*Engelhardia spicata*	1
14	Fabales	Papilionaceae	*Erythrina spp*	2
15	Rosales	Moraceae	*Ficus tinctoria*	3
16	Apiales	Araliaceae	*Heteropanax chinensis*	1
17	Sapindales	Anacardiaceae	*Mangifera indica*	1
18	Rosales	Rosaceae	*Prunus cerasoides*	1
19	Fagales	Fagaceae	*Quercus griffithii*	1
20	Sapindales	Anacardiaceae	*Rhus succedanea*	4
21	Malpighiales	Euphorbiaceae	*Sapium eugeniigolium*	4
22	Malpighiales	Euphorbiaceae	*Sapium insigne*	9
23	Ericales	Theaceae	*Schima wallichii*	3
24	Myrtales	Myrtaceae	*Syzygium cumini*	1
25	Myrtales	Combretaceae	*Terminalia spp*	2
26	Unknown	Unknown	*Unknown*	4
27	Lamiales	Lamiaceae	*Vitex pinnata*	1

Note. The list was prepared based on alphabetical order of plant orders.
[a] Classification is based on Bentham and Hooker (1962-1983), Gamble (1956**),** Saldanha (1995) and Saldanha and Nicolson (1976).

Figure 5

Number of Species Based on Plant Orders



I found that 62.5% (*n* = 45) of trees used by the golden langurs have spreading and open shape. The species (*Sapium insigne*, *S. eugeniigolium*, and *Bischopia javanica*) that were most often used by the golden langurs have spreading and open shapes. The mean DBH of the sleeping trees was calculated at ($\overline{X}$ = 51.57 cm, *SD* = 30.82 cm), and the mean height was $\overline{X}$ = 19.37 m, *SD* = 7.50 m). The girth of largest tree was measured at 160 cm and the smallest was measured at 12 cm. Similarly, the tallest tree used by the golden langur measured at 36 m and the shortest measured at 7.60 m (Table 5). Golden langurs mostly used trees of DBH range of 26-30 cm and height range of 11-20 m as their sleeping sites (Figure 6). I investigated crown cover percent, stand, and tree layer where each golden langur group sleeps and the site's connectivity with neighboring trees. My field assistants and I observed these trees in the post fall, winter, and early spring months

(November-April). Most of the sleeping trees were deciduous (34.21%, n = 26) and 21.05% (n = 16) were semi-deciduous. Thirty-five (46.05%) of their sleep trees had low crown cover because the trees had shed their leaves at the time of our observations. We observed golden langurs sleeping on emergent trees (50%, n = 38), in the mid-level (61.84%, n = 47) of the canopy. Thirty-three (43.42%) of the sleep sites had low connectivity to the surrounding canopy.

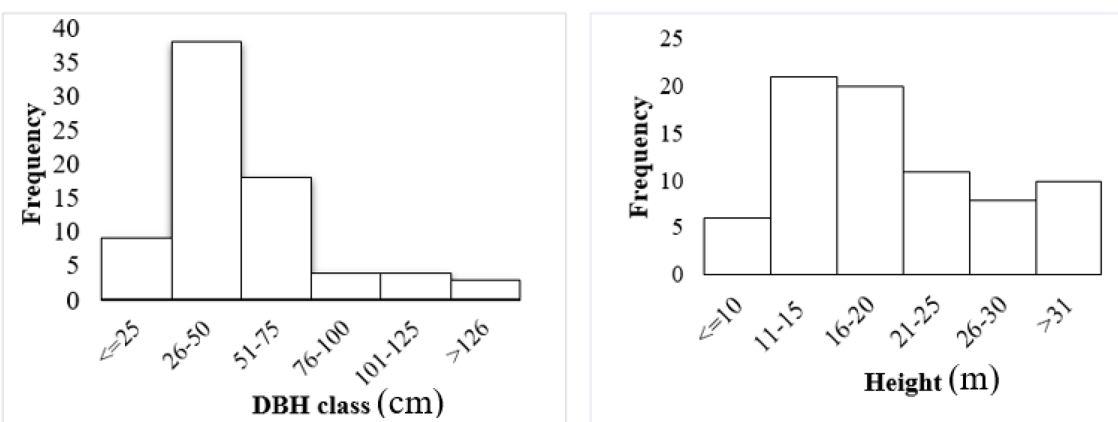
Table 5

Descriptive Statistics of Diameter at Breast Height (DBH) and Height of the Tree Species Used as Sleeping Sites by the Golden Langurs

	DBH (cm)	*Height (m)*
Mean	51.58	19.37
Median	45.95	18.30
Standard Deviation	30.82	7.50
Minimum	12.00	7.60
Maximum	160.00	36.00

Figure 6

Frequencies of Diameter at Breast Height (DBH) and Height of Sleep Site Trees

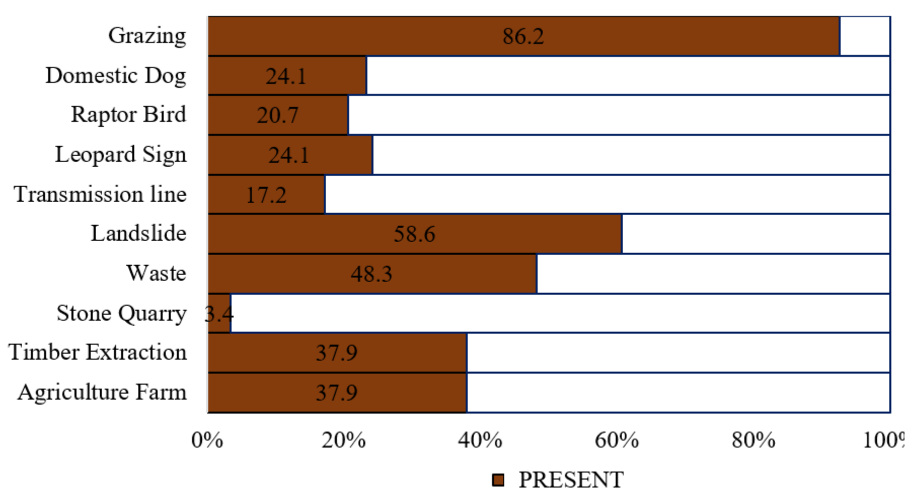


Anthropic and Environmental Factors

I assessed the presence of both anthropic factors (grazing, domestic dogs, transmission line, landslide, waste, stone quarry, timber extraction, and proximity to an agricultural farm) and predators at sleep sites. Cattle grazing (86.2%, *n* = 25) was common in all the sleep sites. Seventeen (58.6%) sleep sites had both major and minor landslides caused by recent road widening. At 14 (48.3%) sleeping sites, we observed garbage. Eleven sleep sites (37.9%) were along the periphery of the agricultural land, and eleven (37.9%) sites showed signs of timber extraction (Figure 7). I calculated proportions or presence/absence of predator signs through direct and indirect encounters. Combining my data from inside and outside the BC and for all 29 sleeping sites, I detected 17.24% (*n* = 5) of leopard signs (e.g., scats and scrapes) and five times, I observed raptors hovering over the landscapes at the time of my surveys.

Figure 7

Anthropic and Environmental Factors at Each Sleeping Site (n = 29)



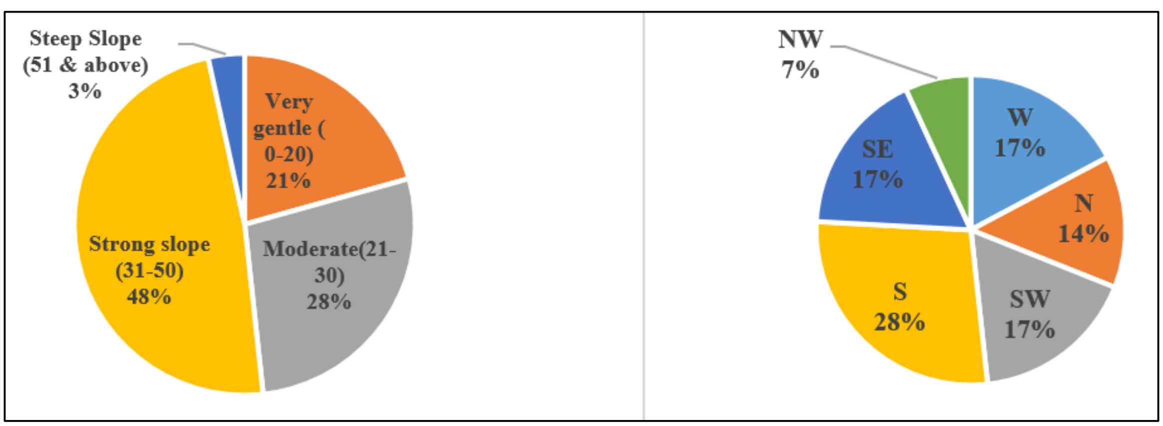
Note: Bars indicate the percent of sleep sites where I observed the presence of each factor.

Slope Gradient and Aspect of the Sleeping Sites

I measured the slope gradients in percentage and aspect (orientation of slope of the sleeping sites) in degrees, and I classified the areas surrounding each sleeping tree into one of four categories. The study sites mostly measured strong (48%) and moderate slopes (28%). Six sites (21%) had gentle slopes, and 3% (n = 1) had steep slope. I measured the aspect of the sleep sites counterclockwise in degrees from 0 to 360. Eight sites (28%) were oriented south (180 degrees); 17% (n = 5) faced towards southeast, southwest and west; 14% (n = 4) faced north, and 7% (n = 2) faced northwest (Figure 8). I predicted that most of the sleep sites would be inclined on strong slopes (31-50%) facing south (180 degrees).

Figure 8

Slope Gradient and Aspect Proportion of Sleep Sites (n = 29)



Golden Langur Extirpation Risks

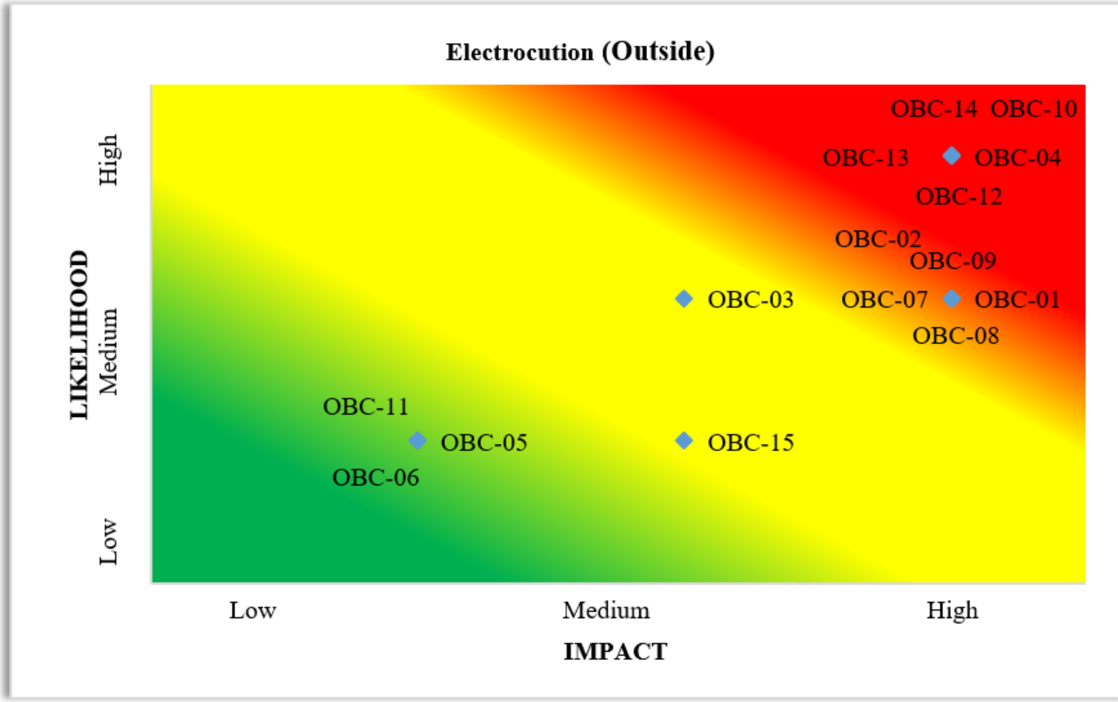
I identified six major risks, viz. electrocution, road kill, retaliatory killing, predation, human disturbance, and abnormal group structure, to examine to assess each golden langur group's extirpation risk. For all risks, I assessed probability and consequences based on preset criteria that I developed based on the literature. I assessed the vulnerability of the group to electrocution based on presence of transmission and distribution lines 1-3 m inside their feeding range. Of the nine groups I observed inside the BC, one group (IBC-07) was exposed to electrocution. Of 15 groups I observed outside the BC, any members of ten groups (OBC1, OBC2, OBC4, OBC7, OBC8, OBC9, OBC10, OBC12, OBC13, and OBC14) were at risk to experience electrocution. I assessed the road kill risk based on the number of cars per hour and frequency with which the group crossed the road. Two groups inside the BC (IBC1 and IBC3) were likely to get killed on the road. Outside the BC, five groups (OBC1, OBC7, OBC8, OBC9, and OBC10) were likely to get killed on roads. People living in and near golden langurs' ranges were asked how tolerant they are to golden langur crop raiding and how frequently langurs visit their farms. I considered these two indicators to examine how likely local people might be to kill golden langurs out of frustration. Inside the BC, two groups (IBC2 and IBC8) reportedly visited the farm often, and farmers were displeased about their losses of mandarin oranges, guava, and vegetables. It is probable that these groups might be killed by the angry farmers. Most of the golden langurs living outside the BC ranged in and around agricultural farms. Eight groups (OBC1, OBC4, OBC8, OBC9, OBC10, OBC13, and OBC14) were highly exposed to the possibility of retaliatory killing as they lived nearby settlements. Golden langurs were exposed to both domestic and wild predators. I assessed the risk for golden langur based on presence of wild predators (leopard, raptors, phython) through sign surveys and counting the number of domestic dogs. Inside the BC, I rated one group (IBC03) as highly vulnerable to both wild and domestic predators. Outside the BC, two groups (OBC3 and OBC9), living along the forest edge, were exposed to all types of wild and domestic predators.

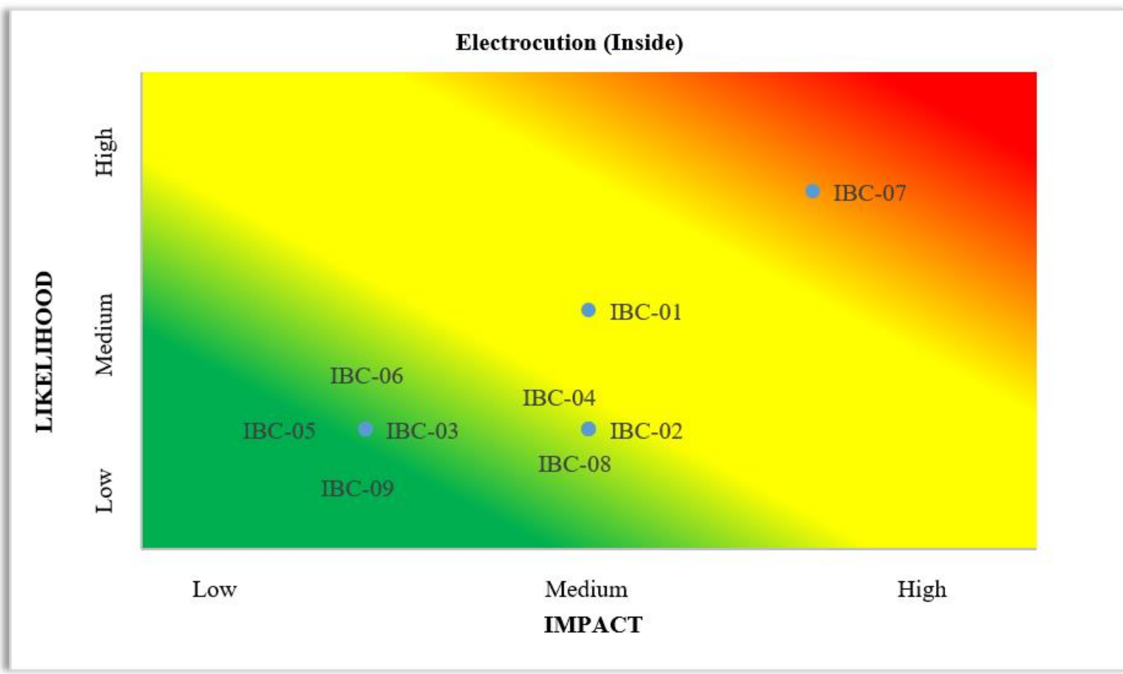
I assessed the presence of cattle grazing, waste disposal, timber extraction, quarrying, and proximity to agricultural land to examine the risk exerted by human actions. A group (IBC03) observed inside the BC was exposed to all these types of human disturbance. Outside the BC, eight groups (OBC3, OBC7, OBC8, OBC9, OBC10, OBC12, OBC13, and OBC14) were exposed to all human disturbances. I assessed extirpation risk based on normality of group structure, with respect to representation of adult males, adult females, subadults, juveniles, and infants. For two of the groups () that I observed outside the BC, I did not record infants, so I categorized their group structures as abnormal. My assessment revealed that OBC9 is the group most vulnerable to extirpation. Groups OBC8 and OBC10 are moderately vulnerable to extirpation, and group OBC7 is the least vulnerable (Figure 9).

Figure 9

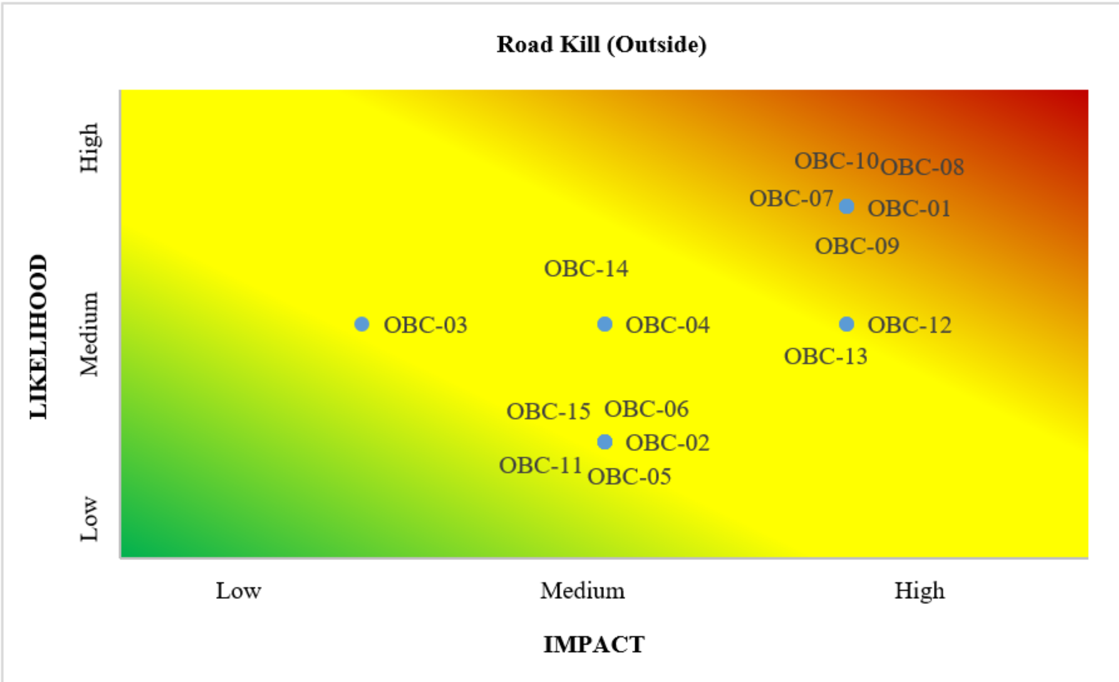
Extirpation Risk Based on Assessment of Six Threats to Golden Langur Survival

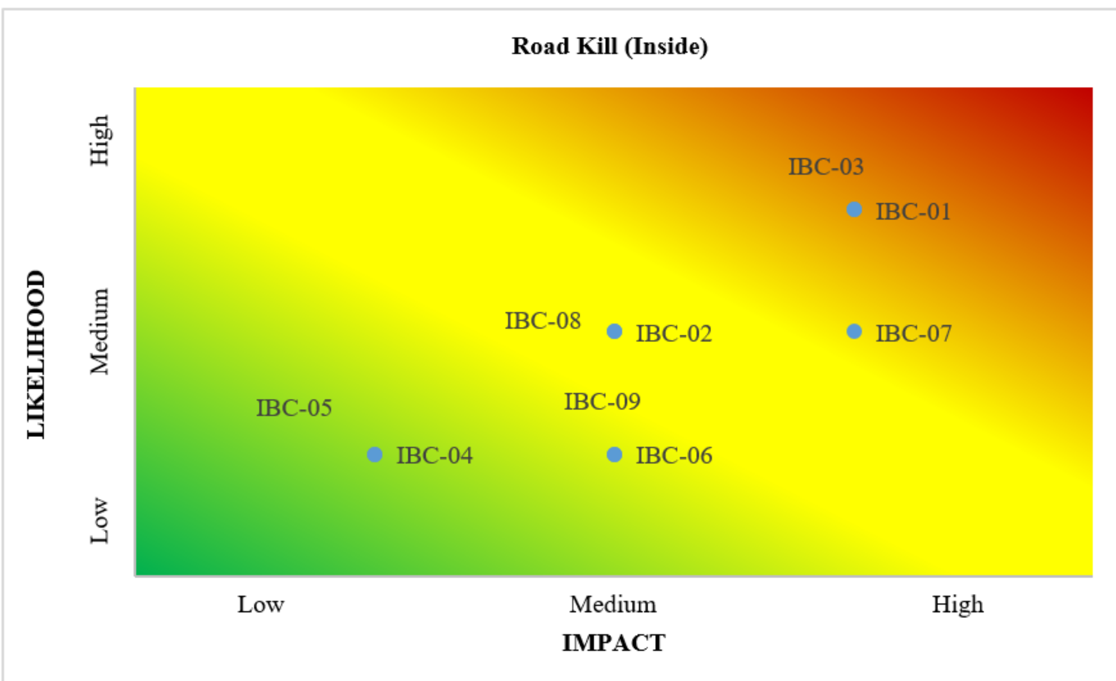
Risk 1: Electrocution



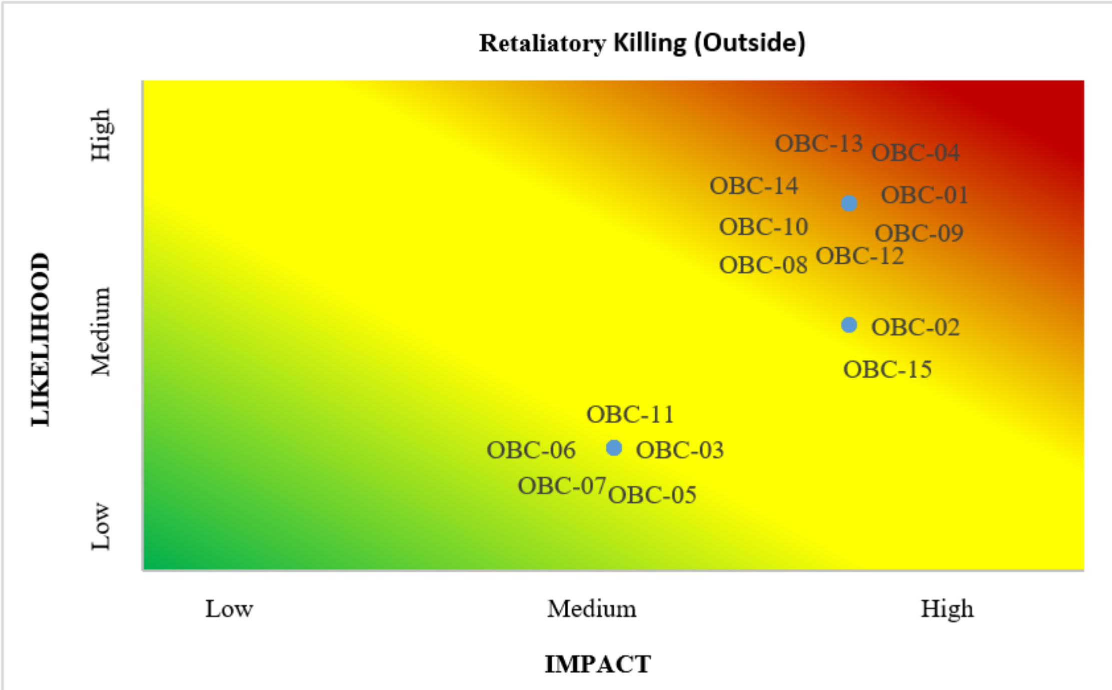


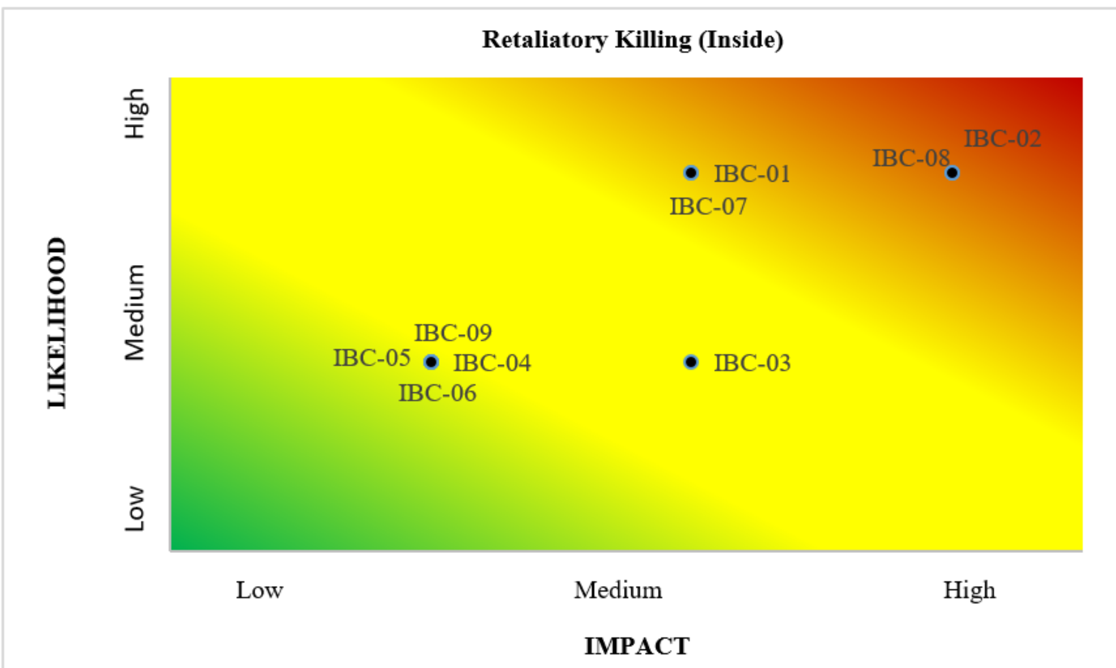
Risk 2: Road Kill



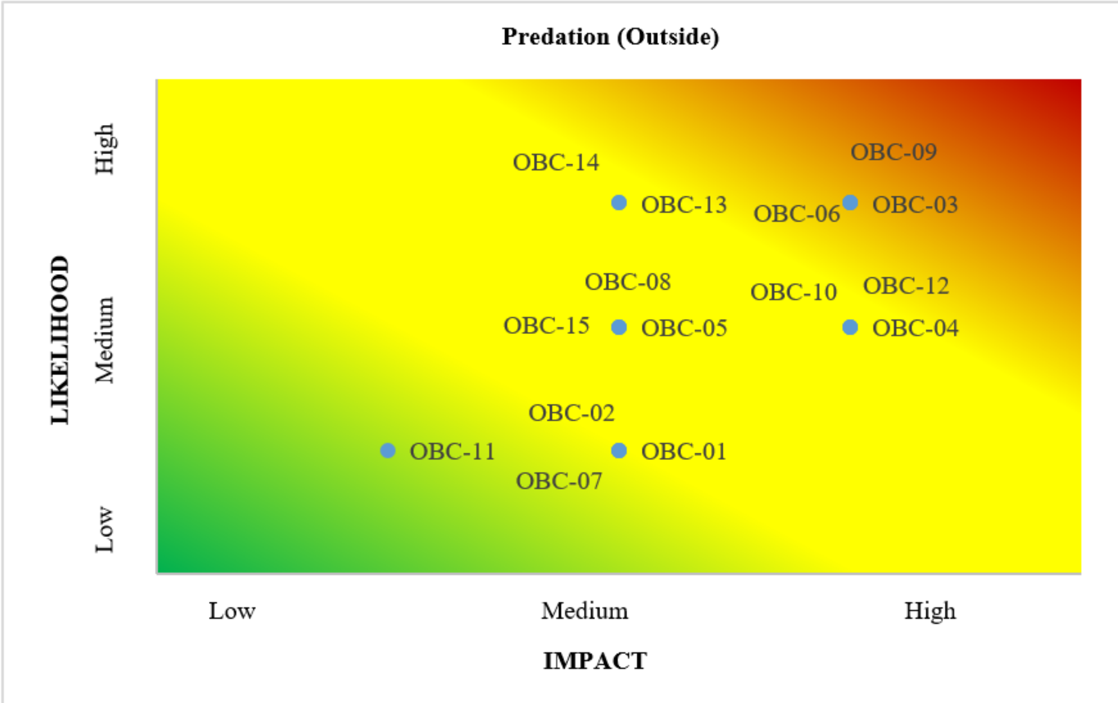


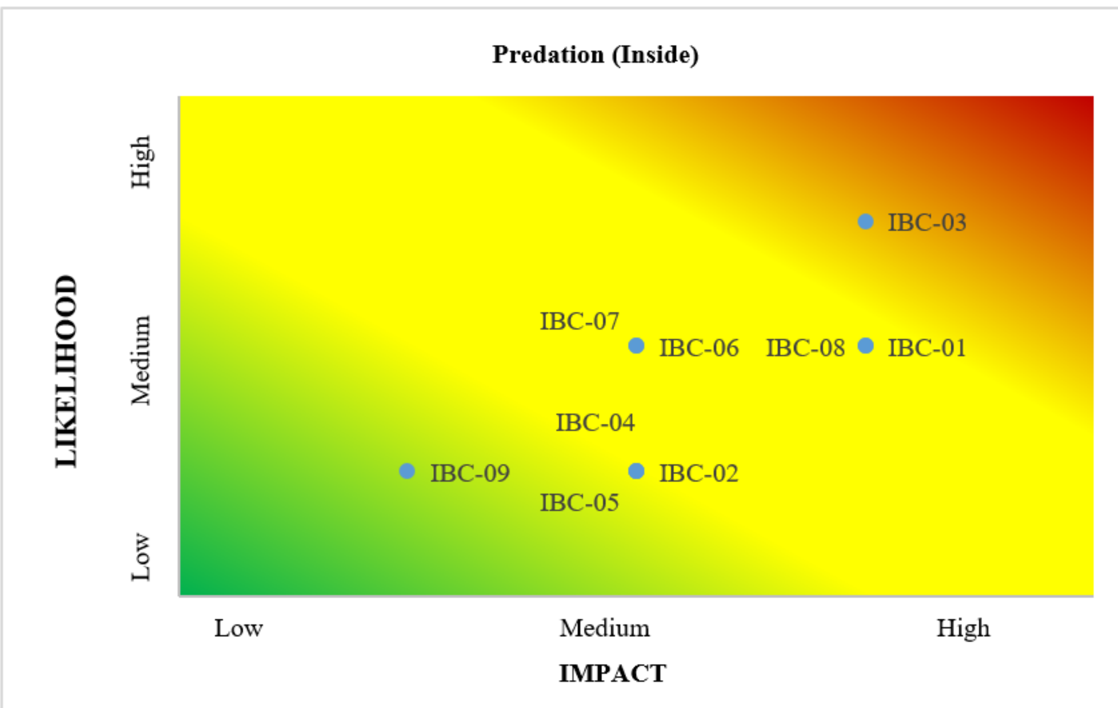
Risk 3: Retaliatory Killing



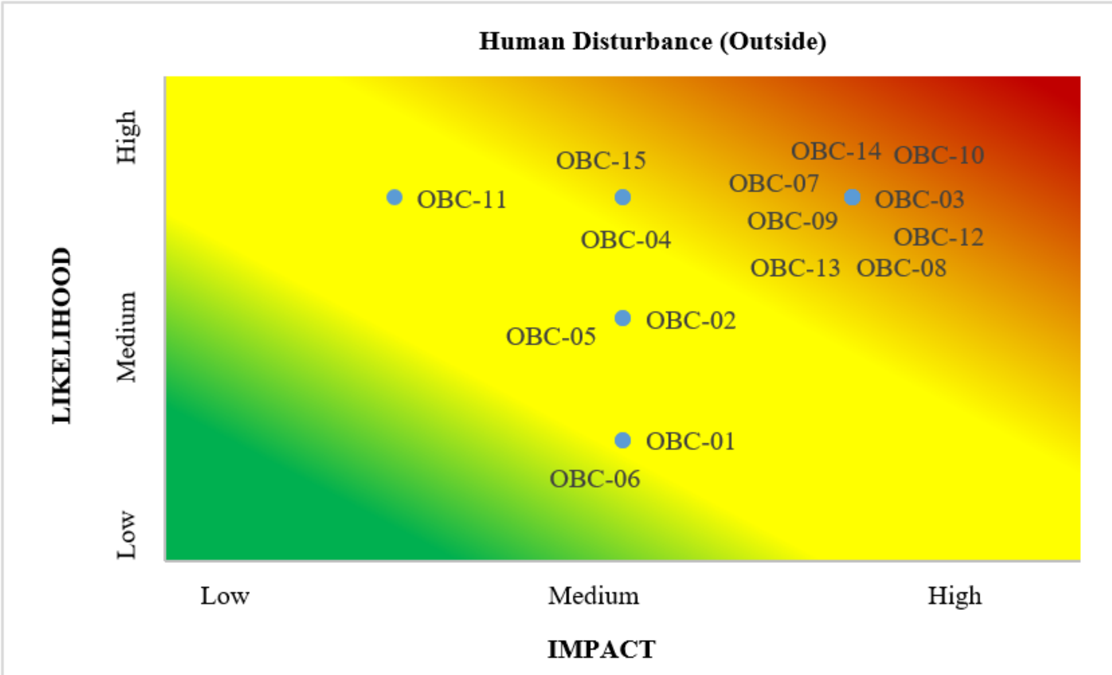


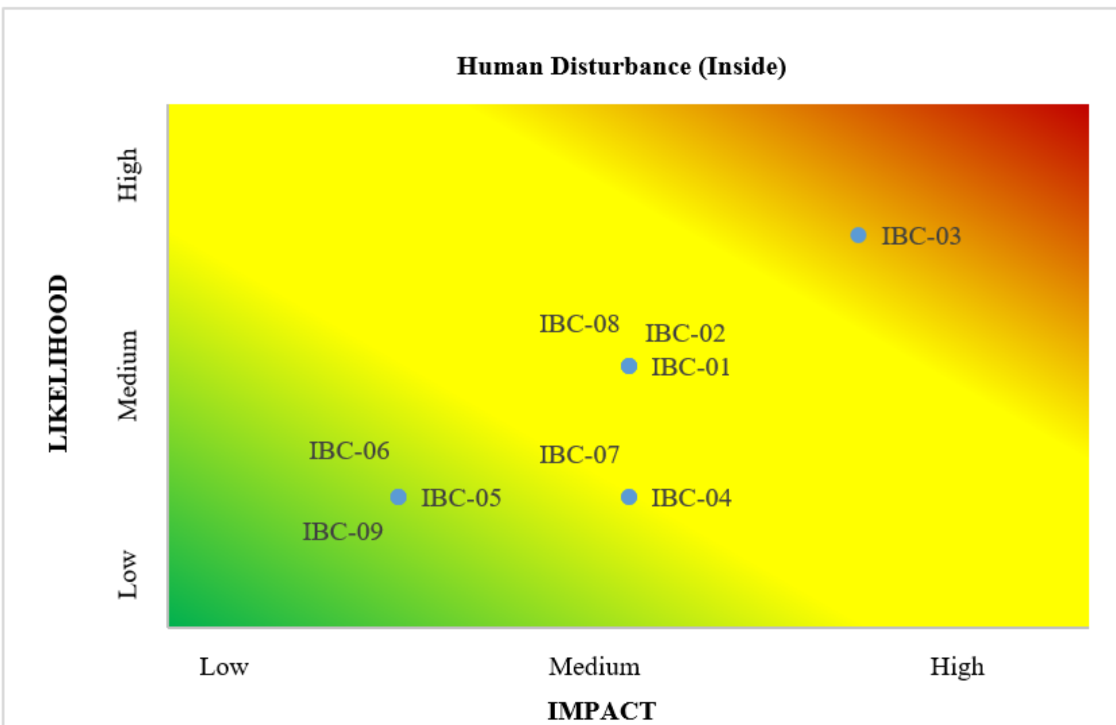
Risk 4: Predation



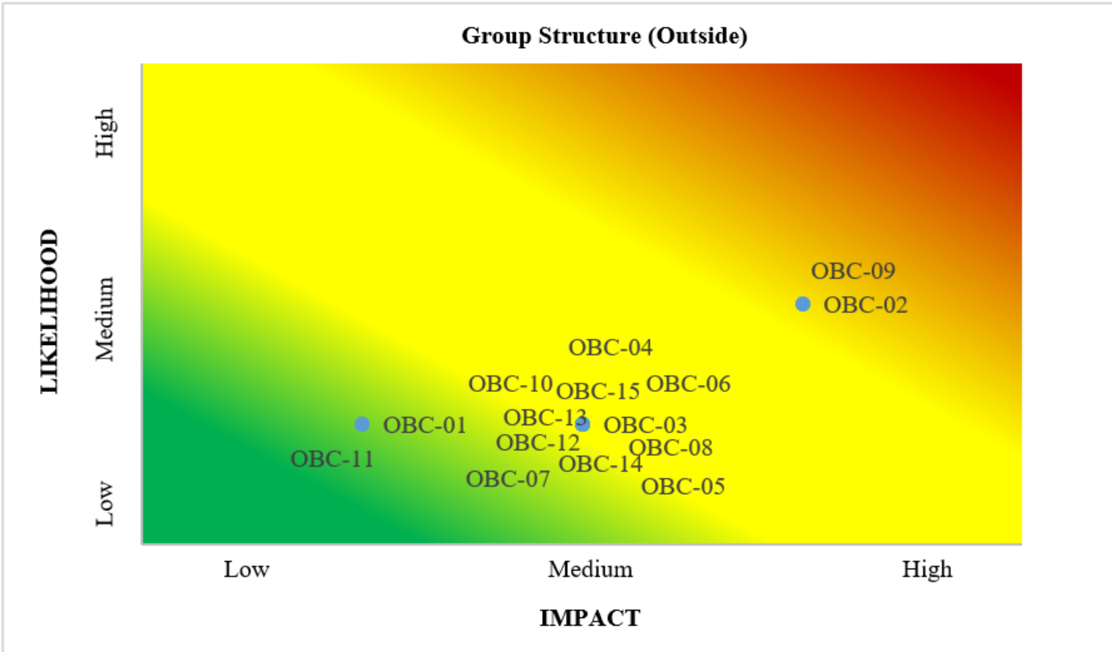


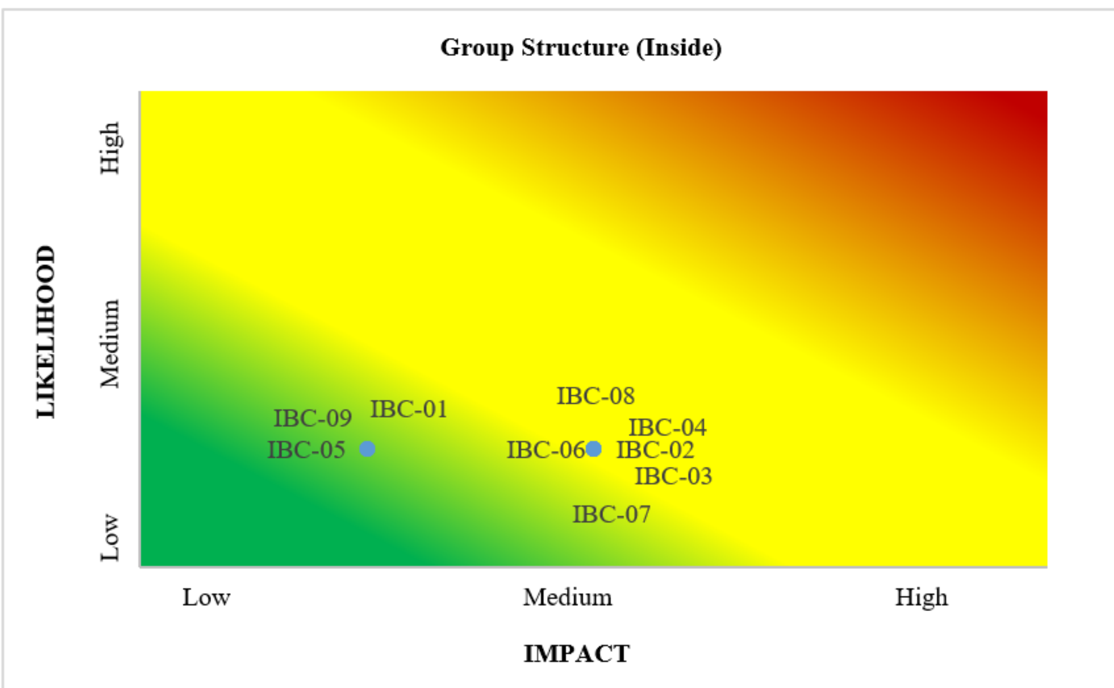
Risk 5: Human Disturbance





Risk 6: Group Structure





Note: OBC stands Outside Biological Corridor and IBC stands for Inside Biological Corridor

CHAPTER V

DISCUSSION

I explored how living inside or outside of a biological corridor (BC) influenced golden langur group dynamics, including group size, composition, and sex ratios. I documented the basic ecology of golden langurs by recording data from 24 groups. I found that langurs most often sleep in tall, spreading and open trees and choose the sites that have steep and south facing slopes during winter season.

I used ecological and other data to assess extirpation risks of 24 golden langur groups (15 groups outside and 9 groups inside the BC). I predicted that the groups living outside the BC would be more vulnerable to electrocution, retaliatory killing and human disturbances. I found that the groups living inside the BC were less vulnerable to extirpation compared to groups outside of the BC.

Encounters with Golden Langurs

My field assistants and I located and attempted to regularly track 24 golden langur groups that were distributed within and outside of the BC in my study area. I detected more groups and with greater regularity outside the BC than inside it. However, this finding may not be true that inside BC had fewer groups. The forest inside the BC are intact, and this makes sighting of langurs and other wildlife difficult (see also Dasmann & Mossman, 1962). Outside the BC, trees had been cut down for developmental activities such as road construction, and those canopy openings gave me more visibility to spot golden langurs even from large distances. I have collected data at my site during the winter through early spring, which has been considered a time of scarce forest resources (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al., 2019). This seasonal variation in food availability might have prompted some langur groups to rely more on farmers' crops. I observed seven groups of golden langurs living outside the BC and two groups living inside the BC frequenting orchards and feeding on mandarin oranges (*Citrus reticulate*) and guava (*Psidium guajava)*, and I often sighted those groups near farms or by the roadside.

I noted that habitat outside the BC was fragmented due to road networks and different classes of power lines that had been installed two years ago. Habitat loss and fragmentation is considered to be the most serious threat to global biodiversity, and it exerts adverse effects on the demography, movement, and abundance of primates populations (Fletcher et al., 2018). Habitat fragmentation hinders dispersal of arboreal primates (Morales et al., 2018). My observations indicate that food availability and home range sizes decreases outside the BC due to habitat fragmentation, and limitations on langurs' dispersal and movement increased population densities outside BC, similar to what has been observed for howler monkeys (Rodríguez & Dias, 2010). Human created canopy openings, reduction in forest resources, and habitat fragmentation due to roads influenced my probability of detecting golden langurs outside the BC, both by affecting langurs' behavior and influencing their visibility.

Golden Langur Group Sizes, Compositions, and Sex Ratios

I found that the mean size of groups outside the BC was significantly larger than group sizes inside the BC. The sex ratio for groups outside the BC was 1:1.55 compared to 1.1.77 for groups inside the BC. The ratio of adults to immature individuals was 1:0.11 in outside the BC and 1:0.22 inside the BC. These values reflect differences in dispersal options and mortality risks in the two landscapes at my study area.

The overall mean group size I calculated was 12.34 individuals, which was larger than the mean group sizes reported by Thinley et al. (Thinley, Norbu, Rajaratnam, Vernes, Wangchuk, et al.,2019) (11 individuals); Lhendup et al., 2018 (6.80 individuals); Srivastava, 2008 (9.8 individuals), and Shil et al., 2020 (11.3 individuals).The variability between the mean group size I reported and what others observed could occur when a single troop was followed over a given period of time and cases where the observer did not distinguish one group from the other (Beauchamp & Cabana, 1990). I followed 24 golden langur groups that I could distinguish based on my documentation of unique characteristics of individuals.

I reported that the mean group sizes of the golden langurs were larger outside than inside the BC. This calculation was supported by my data. Similarly, Lhendup and team (2018) reported larger group sizes from the disturbed habitats of tropical forests that were degraded due to illegal wood cutting. Larger golden langur group size was also recorded from a rubber plantation, followed by smaller groups living near forest edges, and smallest groups in core forested areas (Shil et al., 2020).The quality of habitat and group sizes are inversely proportional: when forest habitat quality deteriorates, the number of individuals in each group increases (Srivastava, 2008). This might occur due to a lack of dispersal options and/or to increased reliance on crops in the golden langur diet.

Population dynamics are influenced by births, deaths, emigrations, and immigrations, and these factors cause variation in group composition in different habitat types (Chhangani, 2002). For golden langurs, a uni-male/multi-female social structure is considered to be the most stable and common, followed by bi-male/multi-female groups (R. Chetry et al., 2019). In my study, the golden langurs inside the BC mostly lived in uni-male/multi-female groups while 11 groups living outside the BC has the multi-male/multi female groups. In human-dominated habitats such as my study area outside the BC, males might benefit from associating with other males (Kappeler, 1999) for collective protection from intruders, ease in finding a mate, and better access to resources such as food (Port et al., 2010). Further, primates exhibit a wide range of ecological and behavioral responses to human presence and activities (Humle & Hill, 2016). This literature supports my finding that golden langurs' behavior and social structure changed in human-dominated landscapes such that they often formed multi-male/multi-female groups. Outside the BC, my data also showed a high numbers of adult males and adult females and a low numbers of sub-adults and juveniles/infants, which suggests an unstable population (Srivastava et al., 2001). However, the group sizes I documented are large and are not isolated from each other. I recorded more adult males and adult females outside the BC, and more infants/juveniles inside the BC.

Golden langur population trends have been characterized in terms of age and sex ratios (Lhendup et al., 2018). At my site, the adult male: adult female; adult female: sub adult and adult female: juvenile/infant sex ratio varied between two landscapes. The adult male-female ratio and adult female- infant ratio in the BC was higher compared to what I recorded for groups outside the BC. The overall adult sex ratio of my study site is low compared to the past estimates provided by Lhendup et al. (2018), Srivastava et al. (2001), and Srivastava (2008). My lower estimates might be due to the change in group structure I observed outside the BC, where I found more multi-male/multi-female groups. Lhendup and team (2018) estimated high adult sex ratio in the undisturbed habitats, which supports my high estimation of the adult sex ratio inside the BC. Furthermore, the adult female to infant/juvenile ratio was higher inside the BC, which supports my view that the golden langur population in the BC is more stable.

Golden langur births are affected by social and environmental factors, such that adult langurs living in human-dominated landscapes appear to prioritize investment in their own survival over nurturing their offspring (Shil et al., 2020). The fitness costs and benefits of group living, derived from high pressures of both within- and between-group competition for space and food, are higher in human-dominated landscapes (Kerhoas et al., 2014). In group-living mammals, survival of infants is reportedly higher where there are more females living in the group (Kalbitzer et al., 2017), but my findings contradict this observation. Though the group has more female members, I recorded a lower number of infants in the human-dominated landscapes. My field work coincided with the peak mating season (January to June, Roy & Nagarajan, 2018). Golden langur birth peaks occur from May to September, so I counted fewer infants during the time of my observations (November 2019 and April 2020).

Sleeping Trees

For primates, the choice of specific sleeping trees is very crucial for survival, as they spend about half of their lives at sleeping sites (Bernard et al., 2011; Heymann, 1995; González-Zamora et al., 2012). The selection of sleep site for non-human primates is often defined by predation avoidance (Liu & Zhao, 2004). Sleeping animals are more vulnerable because their ability to detect predators is reduced, and primates may sleep in trees to reduce the likelihood of predation (Fruth et al., 2018). Proximity to food resources also influences selection of sleeping site (white-headed langurs, Li et al., 2011). I observed golden langurs sleeping in 21 different tree families. Their sleeping sites were in proximity to the last feeding site of the day and the first feeding site of the subsequent morning, which is consistent with prior observations of langurs (Qihai et al., 2009; Wang et al., 2011; Li et al., 2011).

The physical structure of the tree (Di Bitetti et al., 2000; Bernard et al., 2011) and its age, density, and crown shape influence primates' choice of sleeping site (Aquino & Encarnación, 1986). Proboscis monkeys sleep in tall, branchy trees of wide girth (Di Bitetti et al., 2000; Bernard et al., 2011) and Hanuman langurs sleep in large trees (Chhangani & Mohnot, 2006) The shape and size of the trees determined the choice of sleeping sites for the golden langurs at my site. Golden langurs seldom sleep on small, short trees, but two groups outside the BC slept on small trees in a patchy forest that was generally situated on steep slopes. Tree shape also influenced the choice of the sleep sites. I observed most golden langur groups to sleep in spreading and open-shaped trees. These large, tall, spreading and open-shaped trees could accommodate all group members in the same tree, which may facilitate social interaction, group cohesion, and communication (Anderson, 1998).

Primates reportedly prefer to sleep in trees with thick canopy (Chopra et al., 2012), to maintain high concealment from predators (Anderson, 1998). Silver leaf monkeys (*Trachypithecus cristatus selangorensis*) sleep in treetops for protection from predator attack (Hambali et al., 2016). Golden langurs at my site sometimes slept in emergent trees, but I more often recorded them sleeping on mid-storied trees which are less exposed compared to emergent trees. Past researchers noted that primates choose sleep trees with low connectivity to neighboring trees so the predator cannot easily move from tree to tree. At the same time, primates appear to choose trees with easy access and exit routes permitting rapid movement when necessary (Aquino & Encarnación, 1986; Fan & Jiang, 2008). I found that the sleep sites of golden langurs were generally situated on steep slopes (31-50%) facing south (180 degrees). Comparatively, the vegetation on steep slopes were sparse and may have provided langurs' better visibility for early detection of predators. Slope orientation may also be important to avoid strong wind and for a high sun exposure potential when located at the mid-canopy level of a valley (Liu & Zhao, 2004).

Biotic and abiotic factors affect primates' sleep site preferences sleep sites, and shifting of sleep sites are likely due to factors specific to each site (Chopra et al., 2012). Though the degree of influences might vary, both anthropic factors (grazing, domestic dogs, transmission line, landslide, waste, stone quarry, timber extraction, and proximity to an agricultural farm) and ecological factors (presence of predators like leopard and raptors) that I recorded at golden langurs' sleep sites influenced their selection of sleep sites. Golden langurs shifted the sleep sites within their feeding range. Shifts might be due to abiotic and/or biotic factors, but the proximity to food resources strongly influence for sleep site location for primate species (Li et al., 2011). This was the case for the sleep sites I recorded, as golden langurs usually slept near the first or last forage site. I observed only one troop of golden langur using the same sleep site for two consecutive nights. In that case, their familiarity with the site might help them escape from nocturnal predators (Di Bitetti et al., 2000).

My results show that sleeping sites in close proximity of roads and agricultural farms are less exposed to predators like leopards. I found that golden langurs avoided sites that have more predators (leopards, domestic dogs, raptors) and anthropic factors (stone quarry, transmission lines). Anthropic activities such as cattle grazing, landslides, timber extraction, and proximity to agricultural farms appears to have no or little influence on golden langurs' choice of sleep sites, at least during the time of year when I collected my data.

Extirpation Risk

Sixty percent of all primate species are threatened with extinction, and the populations of 75% of primate species are declining (Garber, 2019) . Across their geographic range, primates are vulnerable to cyclones and droughts (Zhang et al., 2019), and at local-levels are vulnerable to specific threats. Primates range regions extensively overlap with a large and rapidly growing human population (Estrada et al., 2017), which makes primates vulnerable to anthropogenic threats and increases their risk of extinction. These risks are not distributed evenly across the globe, so animals in some spots will suffer more from them than those elsewhere (Lootvoet et al., 2015).

A recent study of conservation threats to golden langurs in Bhutan called for immediate attention focused on mortality risks due to road kills and electrocution, followed by dogs and retaliatory killing (Thinley, Rajaratnam, et al., 2019). Species responses to one threat type does not necessarily predict its response to others (Isaac & Cowlishaw, 2004), so I made an assessment to investigate which golden langur group was vulnerable to each of six identified threats. I predicted that the vulnerability of golden langurs to those threats would vary between two landscapes (inside and outside the BC). Although the BC is officially more protected, it is surrounded and influenced by areas that are currently being altered to install roads, power lines, and other anthropic impacts. Consequently, there are similar anthropic threats in the two landscapes, because the urban/industrial and agricultural areas near BC are threatened by a variety of threat factors (Kiringe & Okello, 2007). The golden langur groups in my study were threatened by anthropic factors inside and outside the BC, yet the scale and degree of those threats differed. Golden langurs inhabiting the area outside the BC are more vulnerable to extirpation than the groups found inside the BC. Previously, electrocution of golden langurs has been reported on 440 kV (kilovolt) uninsulated exposed electric cables and no incidents of electrocution from high tension wires (Thinley, Norbu, Rajaratnam, Venes, Dhendup, et al., 2019). In some places at my site, I observed golden langurs electrocuted on the electric transformer installed near settlements. Outside the BC, both 440 kV (kilovolt) uninsulated, exposed an electric cables and electric transformers were installed within the leap range of golden langurs, and this made most of the golden langur groups more vulnerable to mortality risks. I rated a single group of golden langurs inside the BC as vulnerable to electrocution as both 440 kV (kilovolt) uninsulated exposed electric cables and electric transformer were present inside its feeding range.

Figure 10.

Photographic Evidence of Golden Langur Road Kill: Sub-adult Male Killed on the Road (left), and Adult Male Crossing the Road (right)

In southern areas of Bhutan, flat terrain allows vehicles to speed faster than 100 km/h, over twice the maximum speed limit of 50 km/h in central areas of Bhutan (Thinley et al., 2019), and they recorded road deaths of golden langurs. Though it is a contributing factor, areas with steep slopes and poor visibility contribute to road kill in some areas, including in central Bhutan where my study occurred. Golden langur may get killed when they cross the road, as I found a sub-adult male killed on the road bend where the slope is > 50% (Figure 4). I have assessed the vulnerability of golden langur to road kill based on traffic flow and frequency of golden langur road crossing. I rated two groups from inside and five groups from outside the BC as highly vulnerable as they all crossed the road more frequently than did the other langur groups at my study site.

Human provisioning of primates alters their activity budgets, diets, and ranging patterns (Sengupta et al., 2015), and human presence can induce change in predator–prey interactions (LaBarge et al., 2020). Golden langur in fragmented habitat are likely to cause considerable damage to food crops (Roy & Nagarajan, 2018); similarly, in a few localities of Bhutan, golden langurs feed on cultivated crops (Thinley, Rajaratnam,et al., 2019). I observed golden langur feeding on fruits, particularly oranges and guava, and people complained of golden langurs raiding vegetable crops like chilies, cabbage, broccoli, and radish. Together with two groups of golden langurs inside the BC, I rated eight groups of golden langurs outside the BC as highly vulnerable to retaliatory killing as they very frequently visit farms and eat and damage fruits and vegetables. The crop damage by golden langurs caused affected farmers to feel intolerant and frustrated, even though people regard golden langurs as a sign of good omen.

Although it was known to conservationist that the domestic dogs increasingly impede the conservation of native species (Home et al., 2018), people living in landscapes with natural predators may keep dogs to guard their house and to chase away the wild animals that come to eat their crops. I observed domestic dogs in Baling Village, Langthel dragging and feeding on a golden langur carcass where the langur died due to electrocution on an electric transformer (A. Pema, personal communication, February 09, 2020). I have observed two incidences of domestic dogs chasing golden langurs. Seven incidents of golden langurs being killed by domestic dogs were reported from Chakrashila Wildlife Sanctuary, Assam, India (D. Chetry et al., 2010), and two incidents of golden langurs killed by domestic dogs in Jhornagara, west Bengal, India (Medhi et al., 2004).

In addition to predation from domestic dogs, large carnivores like leopard (*Panthera pardus*) and wild dog (*Cuon alpinus*) along with snakes like python are predators of golden langurs (Chetry and Chetry 2009 cited in Roy & Nagarajan, 2018). A wide variety of primate species are known to fall victim to birds of prey (McGraw & Berger, 2013). To assess langur groups' vulnerability to predation by domesticated and wild animals, I counted the numbers of domestic dogs raised by the people living nearby golden langurs at my study site; I tallied the frequencies of leopard signs; I counted numbers of raptors birds hovering; and I recorded incidents of python encounter by local people. Although I saw raptors hovering above feeding ranges of some vulnerable groups, I did not observe golden langurs attacked by raptors. I considered three groups (one from inside and two from outside the BC) as highly vulnerable to predation, as these groups were exposed to all known predators.

In human dominated landscapes, anthropic factors have strong influence on primates (Brotcorne et al., 2014). Though the degree of threats differed, I observed various human disturbances inside and outside the BC as people are permitted to hold their traditional right of residing inside protected areas. Human disturbance included resource extraction for house construction timber and firewood, stone quarrying, waste disposal, proximity to agricultural land, and grazing. Human disturbances have negative impact on primate density as well as population growth (Zhao et al., 2019; Cavada et al., 2019), so I predicated that golden groups residing outside the BC have a larger group size as a response to human disturbance of the environment. With inclusion of a single group of golden langurs inside the BC, I rated eight groups of golden langurs residing outside the BC as highly vulnerable to anthropic disturbance, as these groups are exposed to all the environmental disturbances listed here.

For golden langurs, the most stable and common social structure are uni-male/multi-female, followed by bi-male/multi-female societies (R. Chetry et al., 2019). Golden langurs living inside the BC are mostly uni-male/multi-female groups, which are considered as stable (R. Chetry et al., 2019). Conversely, multi-male/multi-female groups were common outside the BC. In human dominated habitats, males might benefit from associating with other males (Kappeler, 1999) for collective protection from intruders, to increase chances of finding a mate, and to have better access to resources such as food (Port et al., 2010). Further, primates exhibit a wide range of ecological and behavioral responses to human presence and activities (Humle & Hill, 2016). The primate literature supports my observations that golden langurs formed multi-male/multi-female groups in human dominated landscapes. There was no infant in two groups outside the BC at the time of my survey, so I rated it as highly vulnerable due to its unusual group composition. However, both these groups have a high potentiality of reproducing during birthing season, because each group had numerous adult females and adult males.

Conclusions and Recommendations

Golden langurs in my study area appeared to be responding to the changing environment through behavioral flexibility. I observed flexibility in their group size and social structure, with golden langurs living outside the BC having larger group sizes with multi-male/multi-female structure. Outside the BC, my study area was disturbed due to road construction and power line and infrastructure development. Past research has also shown that when the quality of habitat deteriorates, golden langur group sizes increase.

I observed golden langurs living outside the BC shifting their sleeping sites every night and sleeping in tall, large trees with spreading branches. Tall trees may be preferred to avoid predators, and trees with large, spreading branches can accommodate all group members in one tree. Anthropic disturbances appear to decrease langurs' security while sleeping, so they opt to change sleep sites—another behavioral change golden langur make in response to human disturbance of habitat.

Cattle grazing, quarrying, construction of roads and power line corridors, timber extraction, and firewood collection are common at my study site in the area outside the BC. Waste disposal along the roads is common, and this pollutes the environment and could potentially expose golden langurs to insects (mosquitoes) and other zoonotic diseases.

I confirmed the presence of natural predators (leopard, python. and raptors) at my study site through signs and others evidence such as key informants, but natural predation of golden langur appears to be a rare event. However, local people keep dogs to guard their crops from a wide variety of wild animals. The probability of a golden langur getting killed by domestic dog is increased due to presence of many domestic dogs in my study area. I observed dogs feeding on an electrocuted golden langur's carcass and a pack of dogs hunting for golden langurs outside the BC.

The golden langurs at my study site also adapted to anthropic change through a shift in their dietary habits. I observed golden langurs feeding on fruits (mostly mandarin oranges and guava), and local people complained of golden langurs eating vegetables like capsicum, broccoli, radish, beans, and cabbage. Although most Bhutanese people consider sighting a golden langur as a good omen and this animal has cultural significance, people living near langurs see them as pests. Such perceptions and attitudes of make golden langurs vulnerable to retaliatory killing, if an appropriate community-based program is not initiated.

The vulnerability of golden langurs living outside and inside the BC at my study area varied significantly. Golden langurs living outside the BC were exposed to all six identified extirpation risks, while the golden langurs living inside the BC were only exposed to some risks, and at reduced levels. My simple qualitative risk analysis predicted that golden langurs at my study area were most vulnerable to mortality caused by electrocution, road kill, and dog kill.

To help reduce these mortality risks and promote the survival of the golden langur population at my study area, I recommend installing of speed limit signage and speed breakers to limit the speed; installing of insulated electric cables and fencing around power transformers; refraining domestic dogs freely ranging in langur feeding areas; and the establishing of a community-based awareness program.

My study was limited to only one and half seasons (winter and partial spring). The data I collected during those seasons may not be enough to generalize about group structure, sleeping sites, and extirpation risks. I recommend the collection of data from all seasons to produce a comprehensive assessment of group structure of golden langurs, their sleeping sites, and their vulnerability to identified extirpation risk in two different landscapes.

REFERENCES

Anderson, J. R. (1998). Sleep, sleeping sites, and sleep-related activities: awakening to their significance. *American Journal of Primatology*, *46*(1), 63-75.

Aquino, R., & Encarnación, F. (1986). Characteristics and use of sleeping sites in *Aotus* (Cebidae: Primates) in the Amazon lowlands of Peru. *American Journal of Primatology*, *11*(4), 319–331. https://doi.org/10.1002/ajp.1350110403

Arroyo-Rodríguez, V., & Dias, P. A. D. (2010). Effects of habitat fragmentation and disturbance on howler monkeys: a review. *American Journal of Primatology: Official Journal of the American Society of Primatologists*, *72*(1), 1-16.

Beauchamp, G., & Cabana, G. (1990). Group size variability in primates. *Primates, 31*(2), 171–182. https://doi.org/10.1007/BF02380939

Bentham G, & Hooker JD (1962–1983) *Genera plantarum and exemplaria imprimis in herbariis kewensibus servata defnita*, 3 vols. Reeve & Co., London

Bentham G, & Hooker JD (1983) *Genera plantarum*. Lovell, Reeve and Co, London, p 475

Bernard, H., Matsuda, I., Hanya, G., & Ahmad, A. H. (2011). Characteristics of night sleeping trees of proboscis monkeys (*Nasalis larvatus*) in Sabah, Malaysia. *International Journal of Primatology*, *32*(1), 259–267. https://doi.org/10.1007/s10764-010-9465-8

Biswas, J. (2004). Ecology and social behaviour of golden langur (*Trachypithecus geei*) Khajuria, 1956. PhD thesis. Gauhati University. 456 Pp.

Brotcorne, F., Maslarov, C., Wandia, I. N., Fuentes, A., Beudels-Jamar, R. C., & Huynen, M. C. (2014). The role of anthropic, ecological, and social factors in sleeping site choice by long-tailed macaques (*Macaca fascicularis*). *American Journal of Primatology*, *76*(12), 1140–1150. https://doi.org/10.1002/ajp.22299

Cavada, N., Tenan, S., Barelli, C., & Rovero, F. (2019). Effects of anthropogenic disturbance on primate density at the landscape scale. *Conservation Biology*, *33*(4), 873–882. https://doi.org/10.1111/cobi.13269

Chapman, C. A., & Rothman, J. M. (2009). Within-species differences in primate social structure: evolution of plasticity and phylogenetic constraints. *Primates*, *50*(1), 12–22. https://doi.org/10.1007/s10329-008-0123-0

Chetry, D., Chetry, R., Ghosh, K., & Bhattacharjee, P. C. (2010). Status and conservation of golden langur in Chakrashila Wildlife Sanctuary, Assam, India. *Primate Conservation*, *25*(1), 81–86. https://doi.org/10.1896/052.025.0112

Chetry, R., Chetry, D., & Bhattacharjee, P. (2019). *Golden langur Trachypithecus geei* Khajuria, 1956. In C. Schwitzer, R. A. Mittermeier, R. A. Rylands, F. Chiozza, E. A. Williamson, D. Byler, S. Wich, T. Humle, C. Johnson, H. Mynott, G. McCabe. *Primates in peril: The world's 25 most endangered primates 2018-2020.* (pp. 62-65). Washington, D. C., IUCN SSC Primate Specialist Group, International Primatological Society, Global Wildlife Conservation, and Bristol Zoological Society.

Cheyne, S. M., Höing, A., Rinear, J., & Sheeran, L. K. (2013). Sleeping site selection by agile gibbons: The influence of tree stability, fruit availability and predation risk. *Folia Primatologica*, *83*(3–6), 299–311. https://doi.org/10.1159/000342145

Chhangani, A. K. (2002). Group composition and sex ratio in Hanuman langurs (*Semnopithecus entellus*) in the Aravali Hills of Rajasthan, India. *Zoos' Print*

Journal, *17*(8), 848–852. https://doi.org/10.11609/jott.zpj.17.8.848-52

Chhangani, A. K., & Mohnot, S. M. (2006). Ranging behaviour of Hanuman langurs (*Semnopithecus entellus*) in three different habitats. *Primate Conservation*, *2006*(21), 171-177.

Chopra, G., Bhoombak, M. B., & Kumar, P. (2012). Selection and shifting of sleeping sites by Hanuman langurs in Morni Hills of Haryana, India. *Zoo's Print*, *XXVII*(5), 19–24. http://www.zoosprint.org/zooprintmagazine/2012/may/19-23.pdf

Choudhury, A. (2002). Golden langur *Trachypithecus geei* threatened by habitat fragmentation. *Zoos' Print Journal*, *17*(2), 699–703. https://doi.org/10.11609/jott.zpj.17.2.699-703

Choudhury, A. (2008). Primates of Bhutan and observations of hybrid langurs. *Primate Conservation*, *23*(1), 65–73. https://doi.org/10.1896/052.023.0107

Covert, H. H. (2012). A pictorial guide to living primates and much more. *Evolutionary Anthropology: Issues, News, and Reviews*, *21*(2), 84–85. https://doi.org/10.1002/evan.21301

Das, J., Chetry, D., Medhi, R., & Choudhury, A. (2015). *Trachypithecus geei*. *The IUCN Red List of Threatened Species* 2008: e.T22037A9348940. https://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T22037A9348940.en.

Dasmann, R. F., & Mossman, A. S. (1962). Road strip counts for estimating numbers of African ungulates. *The Journal of Wildlife Management*, *26*(1), 101-104.

Department of Forests & Park Services. (2017a). *Forest and Nature Conservation Rules & Regulations of Bhutan, 2017*. 1–374.

Department of Forests & Park Services (2017b). *National Forest Inventory Report:*

Stocktaking National's Forest Resources. *I*, 1–49.

Di Bitetti, M. S., Vidal, E. M. L., Baldovino, M. C., & Benesovsky, V. (2000). Sleeping site preferences in tufted capuchin monkeys (*Cebus apella nigritus*). *American Journal of Primatology*, *50*(4), 257-274.

Dunayer, E. S., & Berman, C. M. (2018). Infant handling among primates. *International Journal of Comparative Psychology*, *31*.

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

Fan, P. F., & Jiang, X. L. (2008). Sleeping sites, sleeping trees, and sleep-related behaviors of black crested gibbons (*Nomascus concolor jingdongensis*) at Mt. Wuliang, Central Yunnan, China. *American Journal of Primatology*, *70*(2), 153-160.

Fleagle, J. G., & Meldrum, D. J. (1988). Locomotor behavior and skeletal morphology of two sympatric pitheciine monkeys, *Pithecia pithecia* and *Chiropotes satanas*. *American Journal of Primatology*, *16*(3), 227-249.

Fletcher, R. J., Reichert, B. E., & Holmes, K. (2018). The negative effects of habitat fragmentation operate at the scale of dispersal. *Ecology*, *99*(10), 2176–2186. https://doi.org/10.1002/ecy.2467

Fruth, B., Tagg, N., & Stewart, F. (2018). Sleep and nesting behavior in primates: A review. *American Journal of Physical Anthropology*, *166*(3), 499–509. https://doi.org/10.1002/ajpa.23373

Gamble JS (1935) *The flora of the Presidency of Madras*. Adlard and Son's Ltd, London, p 2017

Garber, P. A. (2019). Distinguished primatologist address—moving from advocacy to activism: Changing views of primate field research and conservation over the past 40 years. *American Journal of Primatology*, *81*(9), e23052.

Gee, E. P. (1961). The distribution and feeding habits of the golden langur, *Presbytis geei* Gee (Khajuria, 1956). *Journal of the Bombay Natural History Society*, *58*(1), 1-12.

González-Zamora, A., Arroyo-Rodríguez, V., Oyama, K., Sork, V., Chapman, C. A., & Stoner, K. E. (2012). Sleeping sites and latrines of spider monkeys in continuous and fragmented rainforests: Implications for seed dispersal and forest regeneration. *PLoS ONE*, *7*(10), 1–11. https://doi.org/10.1371/journal.pone.0046852

Groves, C. P. (2001). Primate Taxonomy (Smithsonian Institution, Washington, DC).

Gupta, A. (2001). Non-human primates of India–an introduction. *ENVIS Bulletin*, 1-29.

Gurung, K. K., Singh, R., & Bates, P. (1999). Field Guide to the Mammals of the Indian Subcontinent. *Zoological Journal of the Linnean Society*, *126*(1), 127.

Hambali, K., Md-Zain, B. M., & Amir, A. (2016). Daily movement, sleeping sites and canopy level use of habituated silvered-leaf monkeys (*Trachypithecus cristatus*) in Bukit Malawati, Kuala Selangor, Malaysia. *Journal of Sustainability Science and Management*, *11*(2), 21–30.

Harding, L. E. (2010). *Trachypithecus cristatus* (Primates: Cercopithecidae). *Mammalian Species*, *42*(862), 149–165. https://doi.org/10.1644/862.1

He, L., Shen, J., & Zhang, Y. (2018). Ecological vulnerability assessment for ecological conservation and environmental management. *Journal of Environmental Management*, *206*, 1115–1125. https://doi.org/10.1016/j.jenvman.2017.11.059

Heymann, E. W. (1995). Sleeping habits of tamarins, *Saguinus mystax* and *Saguinus* *fuscicollis* (Mammalia; Primates; Callitrichidae), in north-eastern Peru. *Journal of Zoology*, *237*(2), 211–226. https://doi.org/10.1111/j.1469-7998.1995.tb02759.x

Home, C., Bhatnagar, Y. V., & Vanak, A. T. (2018). Canine conundrum: Domestic dogs as an invasive species and their impacts on wildlife in India. *Animal Conservation*, *21*(4), 275–282. https://doi.org/10.1111/acv.12389

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*, *27*(1), 77–83. https://doi.org/10.1896/052.027.0104

Humle, T., & Hill, C. (2016). People–primate interactions: Implications for primate conservation. In S. A. Wich, & A. J. Marshall (2016), *An Introduction to Primate Conservation* (pp. 219-240), Oxford University Press.

Isaac, N. J. B., & Cowlishaw, G. (2004). How species respond to multiple extinction threats. *Proceedings of the Royal Society B: Biological Sciences*, *271*(1544), 1135–1141. https://doi.org/10.1098/rspb.2004.2724

Jeffress, M. R., Paukert, C. P., Sandercock, B. K., & Gipson, P. S. (2011). Factors affecting detectability of river otters during sign surveys. *Journal of Wildlife Management*, *75*(1), 144–150. https://doi.org/10.1002/jwmg.12

Kalbitzer, U., Bergstrom, M. L., Carnegie, S. D., Wikberg, E. C., Kawamura, S., Campos, F. A., ... & Fedigan, L. M. (2017). Female sociality and sexual conflict shape offspring survival in a Neotropical primate. *Proceedings of the National Academy of Sciences*, *114*(8), 1892-1897.

Kappeler, P. M. (1999). Primate socioecology: New insights from males. *Naturwissenschaften*, *86*(1), 18–29. https://doi.org/10.1007/s001140050563

Karanth, K. P., Singh, L., Collura, R. V., & Stewart, C. B. (2008). Molecular phylogeny and biogeography of langurs and leaf monkeys of South Asia (Primates: Colobinae). *Molecular Phylogenetics and Evolution*, *46*(2), 683–694. https://doi.org/10.1016/j.ympev.2007.11.026

Karanth, K. U., Gopalaswamy, A. M., Kumar, N. S., Vaidyanathan, S., Nichols, J. D., & Mackenzie, D. I. (2011). Monitoring carnivore populations at the landscape scale: Occupancy modelling of tigers from sign surveys. *Journal of Applied Ecology*, *48*(4), 1048–1056. https://doi.org/10.1111/j.1365-2664.2011.02002.x

Kerhoas, D., Perwitasari-Farajallah, D., Agil, M., Widdig, A., & Engelhardt, A. (2014). Social and ecological factors influencing offspring survival in wild macaques. *Behavioral Ecology*, *25*(5), 1164–1172. https://doi.org/10.1093/beheco/aru099

Khajuria, H. (1882). The golden langur (*Presbytis geei* Khajuria). *Nature*, *128*(3238), 849–851. https://doi.org/10.1038/128849a0

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. (1978). The golden langur, *Presbytis geei* Khajuria: Its discovery, authorship, taxonomic status, and bibliography. *Primates* 19**,** 237–240 (1978). https://doi.org/10.1007/BF02373243.

Kiringe, J. W., & Okello, M. M. (2007). Threats and their relative severity to wildlife protected areas of Kenya. *Applied Ecology and Environmental Research*, *5*(2), 49–62. https://doi.org/10.15666/aeer/0502_049062

Kumar, A., & Solanki, G. S. (2008). Population status and conservation of capped langurs (*Trachypithecus pileatus*) in and around Pakke Wildlife Sanctuary, Arunachal Pradesh, India. *Primate Conservation*, *23*(1), 97–105. https://doi.org/10.1896/052.023.0111

Kumar, A., Solanki, G. S., & Sharma, B. K. (2005). Observations on parturition and allomothering in wild capped langur (*Trachypithecus pileatus*). *Primates*, *46*(3), 215–217. https://doi.org/10.1007/s10329-004-0121-9

LaBarge, L. R., Hill, R. A., Berman, C. M., Margulis, S. W., & Allan, A. T. L. (2020). Anthropogenic influences on primate antipredator behavior and implications for research and conservation. *American Journal of Primatology*, *82*(2), 1–13. https://doi.org/10.1002/ajp.23087

Larson, S. G. (2018). Nonhuman primate locomotion. *American Journal of Physical Anthropology*, *165*(4), 705–725. https://doi.org/10.1002/ajpa.23368

Letro, L. (2015). Jigme Singye Wangchuck National Park. *Protected Areas of Bhutan*, *August 2016*, 45–59.

Lhendup, S., Tshering, U., & 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*, *5*(2), 97-101.

Li, D., Zhou, Q., Tang, X., Huang, H., & Huang, C. (2011). Sleeping site use of the white-headed langur *Trachypithecus leucocephalus*: The role of predation risk, territorial defense, and proximity to feeding sites. *Current Zoology*, *57*(3), 260–268. https://doi.org/10.1093/czoolo/57.3.260

Li, Y. C., Liu, F., He, X. Y., Ma, C., Sun, J., Li, D. H., Xiao, W., & Cui, L. W. (2015). Social organization of Shortridge's capped langur (*Trachypithecus shortridgei*) at the Dulongjiang Valley in Yunnan, China. *Zoological Research*, *36*(3), 152–160.

Liu, Z. H., & Zhao, Q. K. (2004). Sleeping sites of *Rhinopithecus bieti* at Mt. Fuhe, Yunnan. *Primates*, *45*(4), 241–248. https://doi.org/10.1007/s10329-004-0091-y

Lootvoet, A. C., Philippon, J., & Bessa-Gomes, C. (2015). Behavioral correlates of primates conservation status: Intrinsic vulnerability to anthropogenic threats. *PLoS ONE*, *10*(10), 1–11. https://doi.org/10.1371/journal.pone.0135585

McGraw, W. S., & Berger, L. R. (2013). Raptors and primate evolution. *Evolutionary Anthropology*, *22*(6), 280–293. https://doi.org/10.1002/evan.21378

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*(6), 1331–1337. https://doi.org/10.1023/B:IJOP.0000043965.38722.63

Meek, P. D., Fleming, P., & Ballard, G. (2012). *An Introduction to Camera Trapping for Wildlife Surveys in Australia*. Canberra, Australia: Invasive Animals Cooperative Research Centre.

Morales, A. M., Ruiz-Miranda, C. R., Galetti, P. M., Niebuhr, B. B., Alexandre, B. R., Muylaert, R. L., Grativol, A. D., Ribeiro, J. W., Ferreira, A. N., & Ribeiro, M. C. (2018). Landscape resistance influences effective dispersal of endangered golden lion tamarins within the Atlantic Forest. *Biological Conservation*, *224*(May), 178–187. https://doi.org/10.1016/j.biocon.2018.05.023

Mukherjee, R. P., & Saha, S. S. (1974). The golden langurs (*Presbytis geei* Khajuria, 1956) of Assam. *Primates*, *15*(4), 327–340. https://doi.org/10.1007/BF01791670

Mulyani, Y. A., Haneda, N. F., Purnomo, H., & Kaban, A. (2020). Insectivorous birds in edge and interior habitats of forest plantation in Gunung Walat, Sukabumi. *IOP*

Conference Series: Earth and Environmental Science, *528*(1). https://doi.org/10.1088/1755-1315/528/1/012026

National Statistics Bureau. (2015). *Dzongkhag Population Projections 2006-2015*. http://www.nsb.gov.bt/publication/files/pub3uu3600pb.pdf

Nigam P., Nilofer B., Srivastav A., & Tyagi P.C. (2014) National Studbook of Golden Langur (*Trachypithecus geei*), Wildlife Institute of India, Dehradun and Central Zoo Authority, New Delhi.

O'Connor, K. M., Nathan, L. R., Liberati, M. R., Tingley, M. W., Vokoun, J. C., & Rittenhouse, T. A. G. (2017). Camera trap arrays improve detection probability of wildlife: Investigating study design considerations using an empirical dataset. *PLoS ONE*, *12*(4), 1–12. https://doi.org/10.1371/journal.pone.0175684

Port, M., Johnstone, R. A., & Kappeler, P. M. (2010). Costs and benefits of multi-male associations in redfronted lemurs (*Eulemur fulvus rufus*). *Biology Letters*, *6*(5), 620–622. https://doi.org/10.1098/rsbl.2010.0091

Qihai, Z., Chengming, H., Ming, L., & Fuwen, W. (2009). Sleeping site use by *Trachypithecus francoisi* at Nonggang Nature Reserve, China. *International Journal of Primatology*, *30*(2), 353–365. https://doi.org/10.1007/s10764-009-9348-z

Rashid, G. M., Butt, A., Qadir, A., & Ali, M. H. (2020). Avian assemblage along an urban gradient: Diversity, abundance and richness. *Ornis Hungarica*, *28*(1), 49–64. https://doi.org/10.2478/orhu-2020-0004

Ripley, S. (1967). The leaping of langurs: A problem in the study of locomotor adaptation. *American Journal of Physical Anthropology*, *26*(2), 149–170. https://doi.org/10.1002/ajpa.1330260206

Roy, D., & Nagarajan, R. (2018). Biology, ecology, and conservation of golden langur, *Trachypithecus geei*. *Indian Hotspots* (pp. 251-283). Springer, Singapore.

Royal Government of Bhutan. (1995). *Forest and Nature Conservation Act of Bhutan*.

Royal Government of Bhutan. (2008). *The Constitution of The Kingdom of Bhutan*.

Royal Government of Bhutan. (2017a). *Population & Housing Census of Bhutan*. https://www.google.com/search?client=firefox-b-d&q=PHCB+bhutan

Royal Government of Bhutan, Department of Forests and Park Services (2017b). *Forest and Nature Conservation Rules and Regulations of Bhutan*.

Royal Government of Bhutan, Ministry of Agriculture and Forest. (2016). *Land Use and Land Cover of Bhutan.*http://www.dofps.gov.bt/wp-content/uploads/2018/07/LULC2016_Maps-and-Statistics.

Royal Government of Bhutan, Wildlife Conservation Division. (2010). *Regulatory Framework for Biological Corridors in Bhutan, Part III: Policy Recommendations and Framework for Developing Corridor Management Plans*.

Saldanha CJ (1995) *Flora of Karnataka*. Oxford and IBH Pub Co, New Delhi, p 1984

Saldanha, C. J., & Nicolson, D. H. (1976). Flora of Hassan District, Karnataka. *India, Amerind Publishing Co Pvt Ltd*, *New Delhi*, *4*, 15-31.

Sengupta, A., McConkey, K. R., & Radhakrishna, S. (2015). Primates, provisioning and plants: Impacts of human cultural behaviours on primate ecological functions. *PLoS ONE*, *10*(11), 1–13. https://doi.org/10.1371/journal.pone.0140961

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*, *0123456789*. https://doi.org/10.1007/s10329-020-00829-y

Srivastava, A. (2008). Ecology and conservation of the golden langur, *Trachypithecus geei*, in Assam, India. *Primate Conservation*, *2006*(21), 163. https://doi.org/10.1896/0898-6207.21.1.163

Srivastava, A., Biswas, J., Das, J., & Bujarbarua, P. (2001). Status and distribution of golden langurs (*Trachypithecus geei*) in Assam, India. *American Journal of Primatology*, *55*(1), 15–23. https://doi.org/10.1002/ajp.1035

Standards Australia/Standards New Zealand Standard Committee. (2009). AS/NZS ISO 31000: 2009 Risk Management–Principles and Guidelines. *Standards Australia/Standards New Zealand Standard Committee, Sidney*.

Stanford, C. B. (1990). Colobine socioecology and female-bonded models of primate social structure. *Kroeber Anthropological Society Papers*, *71*, 21-28.

Sterck, E. H. M. (1999). Variation in langur social organization in relation to the socioecological model, human habitat alteration, and phylogenetic constraints. *Primates*, *40*(1), 199–213. https://doi.org/10.1007/BF02557711

Stokes, E. J., Johnson, A., & Rao, M. (2010). Monitoring wildlife populations for management. *Wildlife Conservation Society and the National University of Laos, Vientiane*.

Subba, P. B. (1989). The status and conservation of the golden langur (*Presbytis geei* Khajuria, 1956) in the Manas National Park, Bhutan. *Tigerpaper.* Food and Agriculture Organization (FAO) Accession No: XF90:297747

Subba, P. B., & Santiapillai, C. (1989). Golden langur in the Royal Manas National Park of Bhutan. *Primate Conservation*, *10*, 31-32.

Sugiyama, Y. (1976). Characteristics of the ecology of the Himalayan langurs. *Journal of*

Human Evolution, *5*(3), 249–277. https://doi.org/10.1016/0047-2484(76)90029-4

Swedell, L. (2012). Primate sociality and social systems. *Nature Education Knowledge*, *3*(10), 84.

Thinley, P., Norbu, T., Rajaratnam, R., Vernes, K., Dhendup, P., Tenzin, J., ... & Chhetri, D. B. (2019). Conservation threats to the endangered golden langur (*Trachypithecus geei*, Khajuria 1956) in Bhutan. *Primates*, 1-10.

Thinley, P., Norbu, T., Rajaratnam, R., Vernes, K., Wangchuk, K., Choki, K., Tenzin, J., Tenzin, S., Kinley, Dorji, S., Wangchuk, T., Cheda, K., & Gempa. (2019). Population abundance and distribution of the endangered golden langur (*Trachypithecus geei*, Khajuria 1956) in Bhutan. *Primates*, *60*(5), 437–448. https://doi.org/10.1007/s10329-019-00737-w

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.

Tobgay, S., Dorji, K., & Yangdon, N. (2019). Sighting of Arunachal macaque *Macaca munzala* Sinha et al., 2005 (Mammalia: Primates: Cercopithecidae) in Sakteng Wildlife Sanctuary, Bhutan. *Journal of Threatened Taxa*, *11*(6), 13805–13807. https://doi.org/10.11609/jott.3332.11.6.13805-13807

Vieira, W. F., Kerry, C., & Hockings, K. J. (2019). A comparison of methods to determine chimpanzee home-range size in a forest–farm mosaic at Madina in Cantanhez National Park, Guinea-Bissau. *Primates*, *60*(4), 355-365.

Wang, B., Zhou, X., Shi, F., Liu, Z., Roos, C., Garber, P. A., Li, M., & Pan, H. (2015).

Full-length Numt analysis provides evidence for hybridization between the Asian colobine genera *Trachypithecus* and *Semnopithecus*. *American Journal of Primatology*, *77*(8), 901–910. https://doi.org/10.1002/ajp.22419

Wang, S., Luo, Y., & Cui, G. (2011). Sleeping site selection of Francois's langur (*Trachypithecus francoisi*) in two habitats in Mayanghe National Nature Reserve, Guizhou, China. *Primates*, *52*(1), 51–60. https://doi.org/10.1007/s10329-010-0218-2

Wangchuk, T. (1995). A census and the biogeography of golden langurs (*Presbytis geei*) in Bhutan. *Tigerpaper,Food and Agriculture Organization (FAO)*

Wangchuk, T. (2005). *The Evolution, Phylogeography, and Conservation of the Golden Langur (*Trachypithecus geei*) in Bhutan* [Unpublished doctoral dissertation]. Univerisity of Maryland.

Wangchuk, T., Inouye, D. W., & Hare, M. P. (2003). A new subspecies of golden langur (*Trachypithecus geei*) from Bhutan. *Folia Primatologica*, *74*(2), 104–108. https://doi.org/10.1159/000070007

Wangchuk, T., Thinley, P., Tshering, K., Tshering, C., Yonten, D., Pema, B., & Wangchuk, S. (2004). *A Field Guide to the Mammals of Bhutan*. Royal Government of Bhutan, Thimphu, Bhutan.

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*(3), 565–582. https://doi.org/10.1007/s10764-008-9258-5

Wildlife Conservation Division. (2010). *Regulatory Framework for Biological Corridors in Bhutan, Part III: Policy Recommendations and Framework for Developing*

Corridor Management Plans. Wildlife Conservation Division, Department of Forests, Royal Government of Bhutan, Thimphu

Zhang, L., Ameca, E. I., Cowlishaw, G., Pettorelli, N., Foden, W., & Mace, G. M. (2019). Global assessment of primate vulnerability to extreme climatic events. *Nature Climate Change*, *9*(7), 554-561.

Zhao, X., Ren, B., Li, D., Xiang, Z., Garber, P. A., & Li, M. (2019). Effects of habitat fragmentation and human disturbance on the population dynamics of the Yunnan snub-nosed monkey from 1994 to 2016. *PeerJ*, *2019*(3), 1–13. https://doi.org/10.7717/peerj.6633

APPENDIXES

APPENDIX A

EQUIPMENT USED FOR GOLDEN LANGUR SURVEY

APPENDIX B

TAK ING TREE GIRTH MEASUREMENT

APPENDIX C

RESEARCH PERMIT

ཨོ་རྒྱན་དབང་ཕྱུག་མཐའ་འཁོར་དང་ཉམས་སྲུང་ཞིབ་འཚོལ་སློབ་ཁང་།

Ugyen Wangchuck Institute for Conservation and Environmental Research
Department of Forests and Park Services
Ministry of Agriculture and Forests
ROYAL GOVERNMENT OF BHUTAN

RESEARCH PERMIT

Date: 2020-11-09

Applicant ID : 6685804905F96956546240
Name of Researcher : Kuenzang Dorji
Address : UWICER, DoFPS, Ministry of Agriculture and Forests

With reference to the approval of the Research Steering Committee and in accordance with Forest and Nature Conservation Rules and Regulations, 2017, this permit is issued to the above applicant to conduct research in State Reserved Forests/Community Forest/ Protected Areas/any other management regimes w.e.f. 2020-03-01 till 2021-12-31

Research Site : Langthel, Central Bhutan

Research Topic : Extirpation risk of the endangered golden langur Trachypithecus geei (Khajuria, 1956) in two landscapes in Langthel Gewog, Trongsa district, Central District Bhutan

Note : The researcher is instructed to meet the CFO of the above Park/Division office before start of his/her research work in the field. The researcher is also instructed to submit the set of his/her research data and a copy of his/her research thesis to UWICER.

The research work shall adhere to the provisions of the Forest and Nature Conservation Rules and Regulations 2017.

OFFICIAL SEAL

Signature of Chairman

Research Steering Committee