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COMPARISON OF SEMI-CAPTIVE AND WILD GRAY-SHANKED DOUC LANGURS' (Pygathrix cinerea) ACTIVITY BUDGETS

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COMPARISON OF SEMI-CAPTIVE AND WILD GRAY-SHANKED DOUC LANGURS'

(*Pygathrix cinerea*) ACTIVITY BUDGETS

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by

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ABSTRACT

COMPARISON OF SEMI-CAPTIVE AND WILD GRAY-SHANKED DOUC LANGURS' (*Pygathrix cinerea*) ACTIVITY BUDGETS

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From 16-10-03 to 16-12-03 I studied four male gray-shanked Douc (GSD) langurs (*Pygathrix cinerea*) in a semi-captive environment and compared results to wild GSD langurs that were studied from 2006-2008. The semi-captive GSD langurs live at the Endangered Primate Rescue Center (EPRC) in Cúc Phương National Park, Vietnam. Four GSD langur males, three born in captivity and one rescued from the pet trade, share 5 hectares of limestone forest in a semi-captive setting at the EPRC. The semi-captive environment is intended to prepare members of this species and other endangered primates for potential release into the wild. In my study, I assessed the group members' activity budgets and feeding behaviors and compared my data to that obtained in a study of wild GSD langurs. I collected data using instantaneous scan sampling at 2 minute intervals (Altmann, 1974). This comparison may assist future conservationists in their efforts to restore wild GSD langur populations in appropriate habitats that may encourage wild behaviors by reintroduced subjects.

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CHAPTER I

INTRODUCTION

Activity budgets are quantified amounts of time an animal spends engaged in various activities (Rave & Baldassarre, 1989). The study of primates' activity budgets can foster an understanding of their habitat use and interactions with their environment (Rave & Baldassarre, 1989). Because natural selection favors those who use energy to promote their fitness and survival, activity budgets can provide an understanding of primates' most advantageous use of energy (Guo et al., 2007; Rave & Baldassarre, 1989). Activity budgets are influenced by seasonal changes, food availability, captive conditions, group structure, age and/or sex (Dasilva, 1992; Guo et al., 2007; Long, 2009).

Gray-shanked douc (GSD) langurs (*Pygathrix cinerea*) are an under-studied species in primatology (Otto, 2005). Since their initial discovery in 1997, wild GSD langurs have been considered endangered by the International Union for Conservation of Nature, with an estimated 500-700 individuals remaining (Ngoc Thanh, Lippold, Nadler & Timmins, 2008). Asian Conservation Network experts place Douc langurs at top priority on the list of species of concern (Salisbury, 2016). Despite this high prioritization of GSD langurs for conservation attention, few researchers have dedicated their studies to better understanding the behavior, social structures and resource acquisition of douc langurs. Furthermore, numerous human-induced threats such as hunting and deforestation of primary forests jeopardize their conservation (Kool & Yeager 2000; Ngoc Thanh et al., 2008; Otto, 2005).

Five national parks have been established in Vietnam to protect the flora and fauna of this country's biodiverse forests. Cúc Phương National Park was declared a forest reserve in 1960 and then became Vietnam's first national park in 1985 (World Conservation Monitoring Center 1989). Dr. Tilo Nadler established the Endangered Primate Rescue Center (EPRC) in Cúc Phương National Park in 1993 as a center for confiscated and rescued primates. Since the center's establishment, the EPRC has become vital in the conservation of many endangered Asian langurs, including GSD. Along with rescues, EPRC staff have successfully bred some of the world's most endangered primates for the first time in captivity such as the Cat Ba langur (*Trachypithecus poliocephaus*). With the financial assistance of the Frankfurt Zoological Society, EPRC staff continue to rescue primates and contribute to their wild populations through breeding (Nadler, 2007; Nadler, Thanh & Streicher, 2007).

In 2005, EPRC staff built two semi-wild enclosures by erecting electric perimeters around primary and secondary forest on a limestone hill (approximately 2 and 5 ha each). These enclosures replicate the rescued or captive-bred individual’s native habitat and consequently, may be used to prepare captive individuals for re-introduction into the wild. In 2007, EPRC staff released eight endangered Hatinh Langurs (*Trachypithecus hatinhensis*) that lived in the semi-captive environment (Nadler, 2007).

Currently, the EPRC houses four endangered, GSD langurs living in the semi-captive environment. Due to their endangered status and low population numbers, it is important that scientists assist with GSD langur reintroduction efforts. In this study, I compared the activity budgets of semi-captive GSD langurs to the activity budgets of wild GSD langurs. Wild GSD langurs were observed from 2006-01 to 2008-08 and consisted of 80+ GSD langurs (Long, 2009). In this study I assessed whether the semi-captive environment was suitable for the expression of GSD langurs’ wild behavioral repertoire. My study indicates that, although some differences were found, semi-captive GSD langurs behave similar to wild GSD langurs, which supports the use of semi-captive enclosures as part of the reintroduction process and furthermore as a conservation strategy.

CHAPTER II

LITERATURE REVIEW

Species Information

GSD langurs were only recently discovered in 1997, making them one of the few new mammals discovered in the 20th century (Long, 2009). Most literature on the *Pygathrix* genus is based on studies of the better-known red-shanked douc langur (*P. nemeaus*). All langurs are members of the sub-family Colobinae, appropriately referred to as the leaf eating monkeys (Kool & Yeager, 2000). Douc langurs are genetically more similar to the odd-nosed Asian colobines (Table 1) than they are to the leaf monkey group, which consists of lutungs (*Trachypithecus*), surilis (*Presbytis*), and gray langurs (*Semnopithecus*) (Roos & Ngoc Vu, 2007).

The odd-nosed group is comprised of all douc langurs (n=3 species) along with the proboscis (*Nasalis larvatus*) and pig tailed (*Simias concolor*) and golden snub-nosed monkeys (*Rhinopithecus roxellana*) (Sterner, Raaum, Zhang, Stewart & Disotell, 2006; Table 1). Several studies have confirmed the GSD langurs' genetic distinctiveness when compared to red-shanked douc (RSD, *Pygathrix nemeaus*) and black-shanked douc (BSD, *P. nigripes*) langurs (Long, 2009; Otto, 2005). BSD langurs are evolutionary the most basal langur, and GSD langurs are more closely related to RSD than to BSD langurs (Roos & Ngoc Vu 2007).

Table 1

Odd Nosed Asian Colobines

Species	Common name	IUCN redlist 2016	Distribution
Pygathrix nemaeus	Red-shanked Douc langur (RSD)	EN	Laos, Vietnam & Cambodia
P. cinerea	Gray-shanked Douc langur (GSD)	CR	Central Vietnam
P. nigripes	Black-shanked Douc langur (BSD)	EN	Cambodia & South Vietnam
Nasalis larvatus	Proboscis monkey	EN	Brunei Darussalam; Indonesia (Kalimantan) & Malayasia (Sabah, Sarawak)
Rhinopithecus roxellana	Golden snub-nose monkey	EN	West & Central China
Simias concolor	Pig-tailed langur	CR	Mentawai Islands, Indonesia

Note. EN: Endangered; CR: Critically endangered
Sources. Meijaard, Nijman & Supriatna, (2008); Ngoc Thanh et al., (2008); Whittaker & Mittermeier (2008); Yongcheng & Richardson (2008); Sterner, Raaum, Zhang, Stewart & Disotell (2006).

GSD Langurs' Physical Description

Male and female GSD langurs have very similar body sizes, masses, and pelage colors. Males are slightly larger, with an average body mass of 11.5 kg and body length of 630 mm, while females weigh 8.45 kg and have a length of 570 mm (Long, 2009; Otto, 2005). Adults have white muzzles and a yellowish face with dark brown, almond shaped eyes, and a large beard of white whiskers. The term "gray-shanked" comes from their predominantly gray-agouti coat which lightens on the upper head, arms, chest and belly. They have a white, long tail that is roughly the length of their body (Long, 2009; Otto, 2005).

GSD Langurs' Distribution throughout Asia

GSD langurs are endemic to central Vietnam, found in primary evergreen and semi-evergreen rainforests in the Annamese Mountain range (Ngoc Thanh et al., 2008). This region supports a rich array of primate taxa. Portions of the GSD langurs' distribution is sympatric with stump-tailed (*Macaca arctoides*), Assamese (*M. assemensis*), crab eating/long-tailed (*M. fascicularis*), rhesus (*M. mulatta*), and pig tailed (*M. nemestrina*) macaques; pygmy slow (*Nycticebus pygmaeus)* and Sunda slow (*N. couucang*) lorises; Loation (*Trachypithecus laotum*), Hatinh (*T. hatinhensis*), silvery (*T. ristatus*) and western purple faced (*T.vetulus*) langurs; and black crested (*Nomascus concolor*) and southern white-cheeked (*N. siki*) gibbons (Long, 2009).

Langurs' Activity Budget

Previous researchers studying RSD, BSD and GSD langurs have noted that resting behavior comprises the largest portion of time in the douc langur activity budget (Duc et al., 2009; Long, 2009; Otto, 2005). After resting, feeding behavior comprised the second largest portion of the of the douc's activity budget, and social behavior (excluding "other behavior") was the least observed (Duc, Baxter & Page, 2009; Otto, 2005).

Colobinae primates typically spend large portions of their day resting (Dasilva, 1992; Long, 2009). This is likely a response to a folivorous diet where resting is a strategy to conserve energy and allow the foregut to digest plant matter through microbial fermentation (Chivers, 1994; Dasilva, 1992; Long, 2009). A folivorous diet requires individuals to consume food for longer periods and conserve more energy than those compared to non-folivorous species that derive increased energy from high nutrient food sources (such as the frugivorous spider monkey (*Ateles sp*.)).

Douc Langur Feeding Behavior

GSD langurs are arboreal, folivorous primates that can survive on low value food sources such as leaves (Davies & Oates, 1994). Feeding competition has not been observed between and within GSD langurs' social groups, most likely due to the abundance of low value foods (Kool & Yeager 2000). GSD langurs exhibit fission fusion behavior. Long (2009) found that GSD langurs' monthly fruit consumption and group size were negatively correlated. He also found a positive trend among group size and consumption of young leaves among GSD langurs (Long, 2009), indicating that fission/fusion events within GSD langurs are influenced by seasonality and food availability (Long, 2009). Long (2009) noted that the GSD langurs' travel behavior was affected by the season. Their shortest day range occurred during the wet season (50m) and their longest day range occurred in the dry season (4,080m).

Douc langurs have physical adaptations to aid in their consumption of plant matter, including a large, multi-chambered stomach for pregastic fermentation, enlarged salivary glands and molars with pointed cusps and deep notches for mastication (Duc et al., 2009; Sterner et al. 2006; Otto 2005; Kool & Yeager, 2000; Davies & Oates 1994). Pregastic fermentation is an advantageous adaptation of leaf eaters that allows them to ferment and digest fiber in the small intestine's lumen with the assistance of symbiotic bacteria. Through pregastic fermentation, leaf-eating monkeys extract energy and protein from low-quality foods (Long, 2009; Otto 2005). Pregastic fermentation also allows them to digest unripe fruits and secondary plant compounds that are highly toxic to most primates (Davies & Oates 1994).

Wright, Ulibarri, Brien, Sadler, Prodhan, Covert & Nadler (2008) compared mastication, gut volume and retention rates in five langur species: *P. nemaeus*, *P. cinerea*, *Trachypithecus delacouri, T. laotum* and *T. hatinhensis*. Their results showed that the two *Pygathrix* species emphasized chewing more through which they masticated leaf matter more slowly and thoroughly than did the other langurs tested (Wright et al., 2008).

In previous studies, douc langurs have shown flexibility in their folivorous diet (Long, 2009; Thanh et al., 2008). Duc and Long studied wild BSD and GSD langurs across wet and dry seasons in order to observe seasonal changes in diet. Their results confirmed that both of these monkeys relied on leaf matter throughout the year, but fruits and other items were opportunistically foraged during the wet season (Duc et al., 2009; Long, 2009). The forests of central Vietnam are markedly seasonal, and GSD langurs' diets and behaviors fluctuate with the seasons and available resources (Long, 2009; World Conservation Monitoring Center 1989). For example, BSD langurs consumed a high variety of plant species (n = 152) that increased along with fruit intake during the wet season (Duc et al., 2009). GSD langurs studied in southern Vietnam spent the least amount of time feeding and the most amount of time resting during the wet season (Long, 2009).

Otto (2005) investigated the nutrition and feeding ecology of the EPRC's captive and semi-captive RSD, BSD, and GSD langurs. She assessed food and nutrient intake and food selection of captive and semi-captive douc langurs. Collectively, the douc langurs' diet consisted of 95% plant and leaf matter with a preference for fresh leaves that had high crude protein values and low fiber (Otto 2005).

Langurs' Use of Vertical Habitat Space

GSD langurs are arboreal primates that rarely come down to the forest floor (Long, 2009). Primates exploit different tree heights and heights in the canopy in relation to their ecological niche within their native forests. Study of forest canopy use enables better understanding of specie's partitioning of primate niches (Long, 2009; Thanh et al., 2008). Thermoregulatory benefits, anti-predator strategy, avoidance of competition and metabolic dietary related needs encourage primates to exploit different tree heights and heights in the canopy (Long, 2009). For example, to aid in predator detection, male colobus (*Colobus guereza*) and male squirrel monkeys (*Saimiri oerstedi*) use taller trees more than females (Boinski, 1988; Oates, 1977).

Douc Langur Social Behavior and Group Structure

Feeding competition has not been observed in douc langurs, most likely due to the high availability of resources in their home range. Interestingly, both captive and wild douc langurs were observed breaking off a portion of their branch and sharing it with another individual (Bennett & Davies 1994). Most field studies of douc langurs are focused on the BSD and RSD species (Phiapalath, Borries & Suwanwaree, 2011). Therefore, similarities between the GSD, RSD and BSD langurs' behaviors and social structures are accepted as likely until proven otherwise.

A sexual skew in favor of more females is present in RSD and BSD langur groups (Phiapalath et al., 2011). Long (2009) found GSD langurs in one-male groups (OMG) containing ~11 females for 43% of his observations and all-male groups (AMG) containing 2-5 males for 4.5% of his observations. (OMG) that exhibit fission fusion in response to resource availability (Long, 2009; Phiapalath 2011). Duc, Baxter, and Page (2009) found BSD in OMGs that gathered to form larger bisexual groups of up to 45 individuals. Long (2009) studied 88 GSD langurs dispersed into OMGs, AMGs and multi-male/multi-female groups. Phiapalath (2011) conducted a census of RSD langurs in Laos and found each group to have approximately 90 members that disbanded into ten separate groups. AMGs were the most common group structure among RSD and varied significantly in size (range = 5 to 51 animals; Phiapalath et al., 2011). Fission-fusion can be influenced by patch size and food availability, which are both regulated by the season; this may explain the occurrence of a larger group formations in the dry season (Kool & Yeager, 2000).

Long (2009) found male and female GSD langurs engaged in the most intragroup social behavior, which largely consisted of males being groomed by females. Males that dispersed from their natal group often formed small cohesive units referred to as "bachelor groups" (n = 4 to 5; Long, 2009). Males did not engage in social behavior with other males, and male's relationship with other males is considered weak. Female-female relationships were not observed (Long, 2009).

Gray-Shanked Douc Langur Conservation Threats

GSD langurs live in fragmented habitat in central Vietnam. The species has an unstable population status (Long & Nadler, 2009). In 2015, Fauna and Flora International scientists discovered a new population of GSD langurs in Kon Tum Province, Vietnam (Salisbury, 2016). This discovery boosted the estimated count of GSD langurs from ~700 to ~1,500 GSD langurs in the wild (Long & Nadler, 2009; Salisbury, 2016). The GSD langur is found in an area of political unrest, which has resulted in an estimated loss of 11 million hectares of forest and uncontrolled poaching (Kool & Yeager 2000). Deforestation occurs at an annual rate of 10,000 ha, creating ever-more fragmented forests (Ngoc Thanh et al. 2008).

Commercial logging, agriculture, and subsistence farming are legally and illegally carried out in the forests where GSDs are found (Ngoc Thanh et al., 2008; Otto, 2005; Kool & Yeager, 2000). Douc langurs are hunted by humans to make traditional medicines, for meat, or are captured to sell as pets (Ngoc Thanh et al., 2008). When threatened, GSD langurs remain still, which makes them easy, motionless targets (Ngoc Thanh et al., 2008; Salisbury, 2016). However, a gun ban has resulted in a transition from hunting by shooting to snaring the monkeys at popular feeding trees or natural bridges between fragmented forests (Long & Nadler, 2009). The degraded habitat forces the monkeys to move terrestrially, which also makes them easy targets for snare traps. Conservation of GSD langurs requires that the Vietnamese government, local communities, scientists and donors collaborate to ensure that GSD langurs are effectively protected from hunters, and their habitat is protected from further fragmentation (Salisbury, 2016).

Endangered Primate Rescue Center, Cúc Phương National Park

The Endangered Primate Rescue Center (EPRC) established in 1993, is the operational base of the Vietnam Primate Conservation Programme of the Frankfurt Zoological Society. The center is located in Cúc Phương National Park, Nho Quan District, Ninh Binh Province. Cúc Phương National Park is the first national park of Vietnam. EPRC staff care for 15 species and 150 primates total (Nadler, 2007).

The EPRC is the only place in the world to house RSD, GSD and BSD langurs in captivity. EPRC staff collaborate with the faculty and students of Danang University, Central Washington University and primate specialists at the Frankfurt Zoo. EPRC staff have contributed to academic understanding of douc langurs with the collaboration of visiting researchers. For example, Roos & Ngoc (2007) conducted genetic research that documented the distinctiveness of GSD relative to the other doucs. The EPRC's captive breeding program of endangered Delacour's (*T.delacouri*), Hatinh (*T.hatinhensis*), Cat Ba (*T.poliocephalus*) and gray-shanked douc langurs has contributed to each species' overall conservation by maintaining genetically diverse captive groups.

Semi-Captive Environment

In 2005, with the financial assistance of the Frankfurt Zoological society, EPRC staff established two semi-captive environments that consist of an electric fence surrounding 2 limestone hills. Referred to as 'hill 1' and 'hill 2' these two semi-captive environments surround 7ha total (hill 1 = 2 ha; hill 2 = 5 ha) of primary forest with a dense canopy and shrubby understory (Appendix A&B). The semi-captive enclosures were made for the pre-release of primates scheduled for eventual reintroduction. In 2005, eight Hatinh langurs (*T. hatinhensis*) moved into the semi-captive environment before their successful re-introduction to the wild in 2007 (Nadler 2007).

Currently, a social group of four males are living in the semi-captive environment referred to as 'hill 2'. The bachelor group consists of three captive-bred GSD langur males and one wild GSD langur male. Kleiman (1989) supports the technique of pairing wild with captive born individuals to educate the younger, inexperienced individuals before reintroduction. She (1989) emphasizes that before reintroductions are carried out, efforts should be made to ensure that "captive specimens are viable, well managed, self-sustaining…with broad genetic representation" (Kleiman, 1989, P.154). EPRC staff are creating an environment that has the potential to promote GSD langurs' successful release into the wild by pairing the three captive males with one formerly wild male, and through their successful and ongoing breeding program of shanked douc langurs. Semi-captive environments are a unique conservation strategy that may allow critically endangered primates to acquire and practice species specific behaviors in semi-wild environments. The semi-captive environment addresses the lack of protected forests and the need to prepare endangered primates for release into the wild.

Hypothesis and Predictions

In this study, I hypothesized that the wild behavioral repertoire of gray-shanked douc langurs' is expressed in the semi-captive environment. This was assessed by observing the semi-captive langurs' activity budgets, feeding behaviors and habitat use. I compared these results to wild WSD langurs' and determined similarities and deviations between semi-captive and wild GSD langurs.

Activity Budget Predictions

GSD langurs in a semi-captive environment will have a similar activity budget to wild GSD langurs. I predicted semi-captive GSD langurs would engage in resting and feeding behavior more than other state behaviors. I predicted social behavior would be the least observed behavior. Previous studies of RSD, BSD and GSD langurs noted that resting and feeding behaviors were most observed (Duc, 2007; Long, 2009; Otto, 2005). Furthermore, a study of wild BSD langurs and captive RSD found that social behavior was the least observed behavior, accounting for < 6% of the activity budgets (Duc, 2007; Otto, 2005).

Daily Activty Budget Predictions

GSD langurs in a semi-captive environment will have hourly activity budgets similar to wild GSD langurs. I predicted that there would be feeding peaks in the early morning and late afternoon. I predicted that resting behavior would follow the peaks of feeding, resulting in two prominent resting periods during the day. Long (2009) noted that wild GSD langurs exhibited two feeding peaks, the first at 0600h and the second at 1600h and that resting increased after feeding. Wild GSD langurs had two prominent resting peaks that followed intensive feeding behavior (Long, 2009).

Feeding Behavior Predictions

GSD langurs in a semi-captive environment will have similar feeding behavior to wild GSD langurs. I predicted that more young leaves and unripe fruits would be consumed in October than in November, and that overall I would observe more young leaves being consumed than mature leaves. I predicted ripe fruit to be the least consumed food item across all sampling periods. During the dry seasons, fruit availability is low and young leaf availability high. In the north of Vietnam, where my study site is located, October and November are the driest months of the year according to historical weather records from Hanoi, Vietnam ("Average Weather in Hanoi, Vietnam" 1992-2012). Long (2009) noted that the GSD langurs' diet was affected significantly by seasonal availability of food. During the dry season young leaves were consumed for 82% of observations, mature leaves 5% and total fruits only 12% (Long, 2009). Langurs consume more young leaf than mature leaf due to the lower fiber content in young leaves, which makes digestion easier (Otto, 2005).

Tree Height Use Predictions

GSD langurs in a semi-captive environment will vary in their use of tree heights in three height classes: 0-10m, 11-20m, 21+m equally. I expected trees 21+m tall to be used most and trees 0-10m to be used least. I expected trees 21+m to be used most for resting and feeding behavior. Long (2009) found that the average height of trees used by wild GSD langurs was 20.3m and that trees taller than 19m were used more for resting and feeding. Wild GSD langurs used trees in height class 20-24m most (41% of observations) and the average height of the forest was 12.2m.

Height in the Canopy Predictions

GSD langurs in a semi-captive environment will use lower, mid and upper canopy levels disproportionately overall and at varied rates when engaged in different state behaviors. Overall, I predicted the upper canopy to be the most used level and the lower canopy to be used the least. I predicted the semi-captive GSD langurs would use the upper canopy more than the lower or mid canopy for all state behaviors. I predicted the semi-captive group would select the upper-canopy for rest and social behavior. Long (2009), found wild GSD langurs used the upper canopy most for all state behaviors.

Substrate Use Predictions

GSD langurs in a semi-captive environment will use boughs, branches and twigs disproportionately and at varied rates when engaged in different state behaviors. Overall, I predicted semi-captive GSD langurs would use branches most and boughs least. I expected twigs to be used most for feeding, and boughs to be used mostly for social interactions and resting.

Long (2009) noted that wild GSD langurs used branches most and boughs least but proportional to twigs (branches = 67%, twigs = 17%, boughs = 16.3%). Wild langurs used branches and boughs most during rest and social behavior, and twigs most for feeding and traveling (Long, 2009).

CHAPTER III

METHODS

Study Site and Subjects

My research was carried out in a semi-captive enclosure consisting of 5ha of secondary forest on a limestone hill located in Cúc Phương National Park (Figure 1). The study site is in the foothills of the northern Annamite Mountains approximately 100km south-west of Hanoi. I studied four male gray-shanked douc (*P. cinerea*) langurs housed in a 5ha semi-wild enclosure at the Endangered Primate Rescue Center (EPRC) located in Cúc Phương National Park , Central Vietnam. Four research assistants were present throughout the course of the study (Đỗ Đăng Khoa, Đinh Văn Nhất, Đinh Văn Tín, Nguyễn Ngọc Thành). Assistants did not collect data during this study, instead, they tracked the langurs, navigated the hiking path and labeled feeding trees. The studyR group members vary in age and life history (Table 2; Appendix C). They have been a social group since the three juveniles were displaced from their natal group by their fathers in 2012, an occurrence which is common in douc societies (Kool & Yeager, 2000).

Observation Design

I conducted non-invasive behavioral observations four to five times weekly over the course of 10 weeks (16/10/03-16/12/03). Each day began with the langurs' being fed sweet potato to facilitate EPRC staff's visual checks of each individual's health. Once all langurs moved from the site where the sweet potato is given, I began the day's observations (~0700h). I recorded each langur's behavior using instantaneous scan sampling (Altmann, 1974) at 2-minute intervals. I ended at ~1700h, when the EPRC staff's work day concluded. Observations continued past 1700h if langurs were active (engaged in any behaviors excluding resting behavior).

Figure 1. Location of study site in Cúc Phương National Park, Vietnam. (Google Maps, 2017)

Table 2

Study Subjects: Male Pygathrix cinerea *at the Endangered Primate Rescue Center*

Name	**Birthplace**	**Age in 2016**	**Birth date**
Barak	EPRC	4 yr	12/06/03
Cactus	EPRC	6 yr	10/05/06
Gordon	Wild born, Central Vietnam	~20 yr	1996, arrived 01/12/15
Manh	EPRC	5 yr	11/04/16

Note. Birth date: year/month/day. S.Possner, personal communication, April 2016

I used neon pink or green tree flag tape to mark trees that GSDs used for feeding (Appendix D). I numbered and recorded tree flags daily to categorize tree use by GSD langurs. At the end of the field season, a botanist and employee of Cúc Phương National Park identified all flagged trees in the study site. I recorded state behaviors using Thang Long Ha's ethogram (Long, 2009; Table 3). I recorded food type consumed by study subjects when I had good visibility (Table 4).

I recorded each langur's substrate use, tree height, and height in the canopy every 15 minutes and regular scans discontinued while I took ~2-4 minutes to record the information. I categorized tree heights by three divisions: 0-10m, 11-20m and 21+m. I visually estimated tree height, 85% intra-observer reliability was confirmed after extensive practice with clinometer. Height in the canopy was also categorized by three divisions: lower-canopy, mid-canopy and upper-canopy. Lower-canopy is defined as a location in tree that is lower than half of the tree's total height. Mid-canopy is defined as a location in tree that is at or between 50-80% of the trees total height. Upper-canopy is placement in the canopy that is at the top 20% of the canopy.

I recorded each langurs' use of substrate, which were categorized by Thang Long Ha as boughs, branches or twigs (2009). Long defined a bough as substrate that has a diameter ≥ 10cm, and it does not bend or sway under the weight of the monkeys. He defined a branch as substrate that has a diameter of < 10cm, and it bends slightly and sways under the weight of the monkeys. Finally, he defined a twig as substrate that sways considerably under the weight of the monkeys.

Table 3

Activity Ethogram

Category	Definition
*Feeding	Subject puts food item into mouth and swallows or masticates.
*Resting	Subject does not move or engage in any activity.
*Traveling	Subject engages in any movement between two locations. Sub-divided into travel within- and between trees.
°Social	Subject appears engaged with other group members in agonistic or affiliative manner.
*Other	Includes any behaviors not listed above.

Note. * = Definition simplified by Hemmes-Kavanaugh with no additional terms; ° = Definition created by Hemmes-Kavanaugh; Long, T.H. 2009

Table 4

Feeding Ethogram

Category	Description
Mature leaf	Full-developed leaves
Young leaf	Distinguished from mature leaves by at least 2 of the following: smaller size, paler/redder, and less turgid
Flowers	Reproductive tissue; calyx, corolla and germ cells
Unripe fruits	The carpal and the tissues which surround it, excluding fibrous pericarps.
Ripe fruits	Have the same characters as unripe fruit, but show red, brown, or yellow color
Seeds	Seed alone, seed and pod
Bark	Surface of tree or stem
Shoots	Tender stem

Source. Long, T.H. 2009

CHAPTER IV

RESULTS

Activity Budgets

I observed the langurs from 2016/10/03 to 2016/12/02. I recorded thirty-five observation days (*N* = 300h 50m) with four semi-captive GSD langurs (Table 2). My activity budget analysis includes 4,964 scans of behavior for Barak, 5,065 for Cactus, 4,157 for Gordon, and 4,942 for Mahn and 19,128 scans of behavior total (Table 5 & 6). Barak was in view for 59.53% of the studies observations (*N* = 4,964 scans), Cactus 60.75% (*N* = 5,065), Gordon 49.86% (*N* = 4,157) and Mahn 59.27% (*N* = 4,942).

I performed the Kruskal Wallis *H* test to compare individual langur activity budgets. A significant difference among the langurs “other, social”, and “travel” behavior was found (other = $p < .001$; social = $p < 0.001$, df = 3; travel = $p = .0158$). Travel behavior was not significantly different when I removed study subject Gordon from the Kruskall Wallis *H* analysis (p = 0.5299). This indicates that Gordon’s travel behavior is the outlier. The langurs did not differ in their feeding or resting behavior (Feeding: $p = 0.0655$, df=3; Resting: $p = .0697$). I aggregated the individual langur’s and present one activity budget for the group. The group time budgets for different activities varied significantly ($\chi^2 = 56.24$, df = 3, $p < .0001$; Figure 2).

There is a significant difference between the activity budgets of semi-captive and wild GSD langurs ($\chi^2 = 52.15$, df = 4, $p < .0001$). All previous douc langur studies found them to spend the majority of their time resting (Table 7). Semi-captive langurs spent more time feeding and less time engaged in social and travel behavior than did wild GSD langurs (Figure 3).

Table 5

Individual Pygathrix cinerea *Activity Budget in a Semi-Captive Environment, Cúc Phương National Park*

Subjects	Feed N (scans)	Feed %	Rest N (scans)	Rest %	Social N (scans)	Social %	Travel N (scans)	Travel %	Other N (scans)	Other %	Total *N*
Barak	1,439	29	2,443	49	313	6	694	14	75	2	4,964
Cactus	1,122	22	3,143	62	157	3	625	12	18	>1	5,065
Gordon	987	24	2,624	63	70	2	475	11	1	>1	4,157
Mahn	1,296	26	2,591	52	359	7	642	13	54	1	4,942
Total	4,844		10,801		899		2,436		148		

Table 6

Summary of Data Collected from Pygathrix cinerea *in a Semi-Captive Environment, Cúc Phương National Park* from 16-10-03 to 16-12-02

Statistic	Feed	Rest	Social	Travel	Other	Total
Total Scans	4,844	10,801	899	2,436	148	1,9128
Daily Mean	166	379	31	82	5	
Daily Range	59-329	171-548	6-65	40-135	0-14	

Note. Incomplete observation days (n = 9) were not included in the range. Social and "other" behavior were also significantly different between group members yet were left compiled due to low overall occurrence of these behaviors (social = 5%, n = 540; other = 1%, n = 148).

Table 7

*Comparison of Activity Budgets among Douc Langurs (*Pygathrix sp.*)*

Species	**Feed**	**Rest**	**Social**	**Travel**	**Other**	**References**
Pygathrix cinerea	25.8	54.6	5.5	13.1	< 1.0	This study
P.cinerea	11.9	37.0	25.1	25.8	< 1.0	Long, 2009
P.nemaeus	34.0	49.0	5.0	7.0	3.0	Otto, 2005
P.nigripes	35.0	42.9	5.9	14.6	< 1.0	Duc, 2007

Note. This study was based on semi-captive langurs. *Pygathrix nemaeus* were captive langurs at a rescue center in central Vietnam.

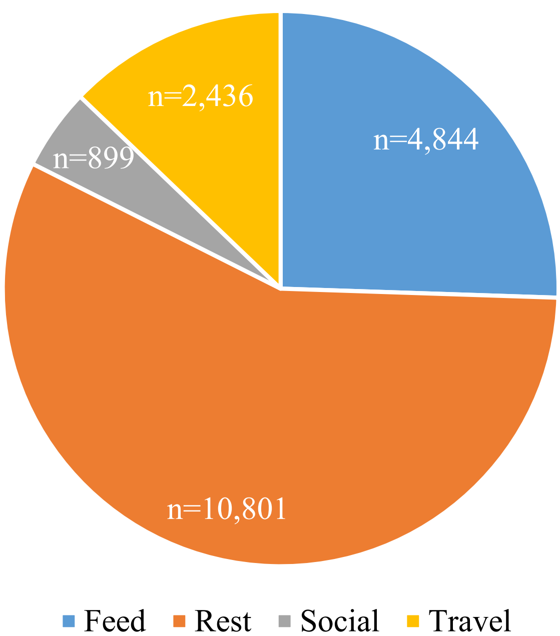

Figure 2. *Pygathrix cinerea* activity budget in semi-captive environment, Cúc Phương National Park.

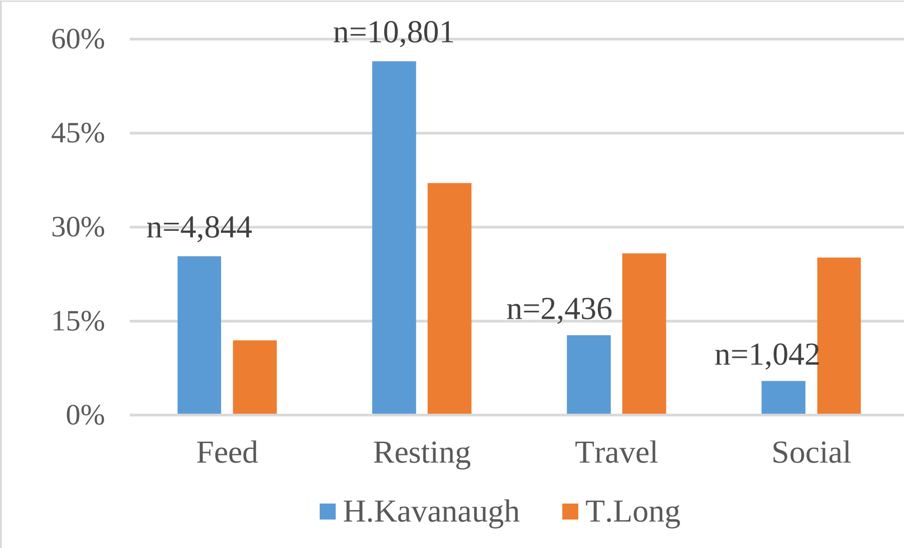

Figure 3. Comparison of wild and semi-captive *Pygathrix cinerea* activity budgets. Self-grooming behavior that I originally recorded as “other” was added to social behavior following H.Long. *N* from H.Long’s wild study are not available. Long studied wild langurs in Kon Ka Kinh National park located in southern Vietnam and the semi-captive GSD langurs (*P.cinerea*) were in Cúc Phương National Park located in the central highlands of Vietnam.

Daily Activity Budget

I calculated the frequency of state behaviors observed per hour from 0700h-1700h to determine an hourly activity budget for semi-captive GSD langurs (Figure 4). Observations of feeding and travel behavior increased during the afternoon among semi-captive and wild GSD langurs (Figure 5 & 6). Observations of resting behavior decreased in the afternoon (Figure 7).

I determined the minimum and maximum percent of state behaviors per hour of observation and compared results to wild GSD langurs (Table 8).

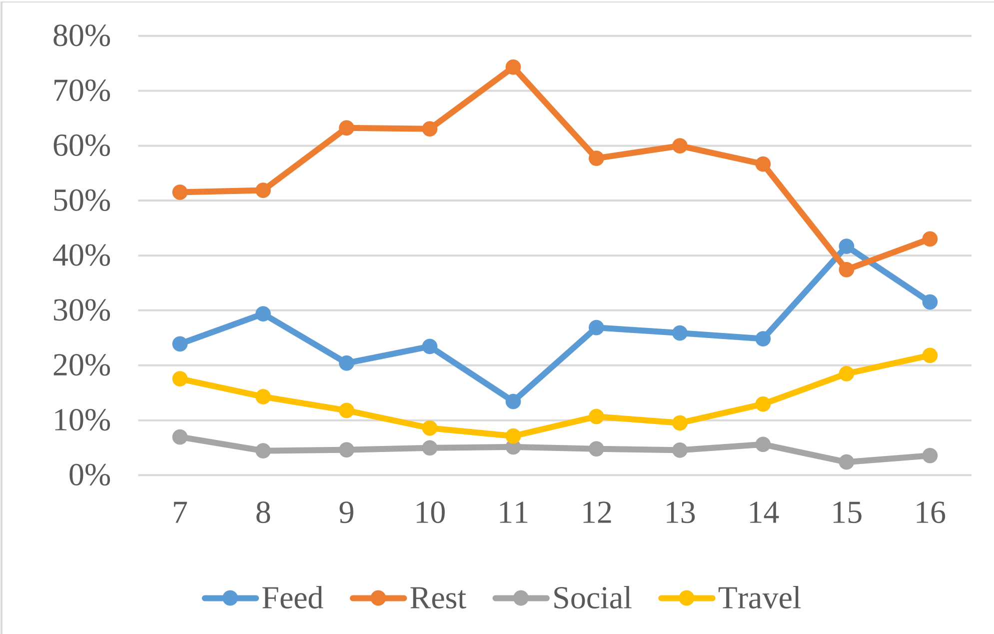

Figure 4. Hourly activity budget of *Pygathrix cinerea* in semi-captive environment, Cúc Phương National Park. Percent calculated by total observed behaviors per hour. I omitted observed behaviors between 0630h-0659h and after 1700h from the daily budget due to low and inconsistent observations.

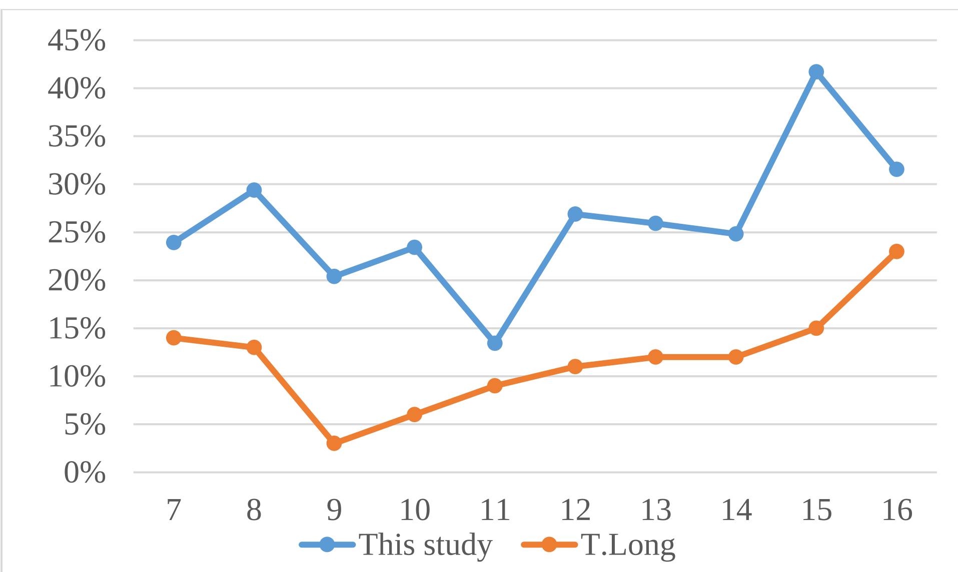

Figure 5. Comparative hourly budget of feeding behavior between wild and semi-captive *Pygathrix cinerea*. I omitted observed behaviors between 0630h-0659h and after 1700h from the daily budget due to low and inconsistent observations.

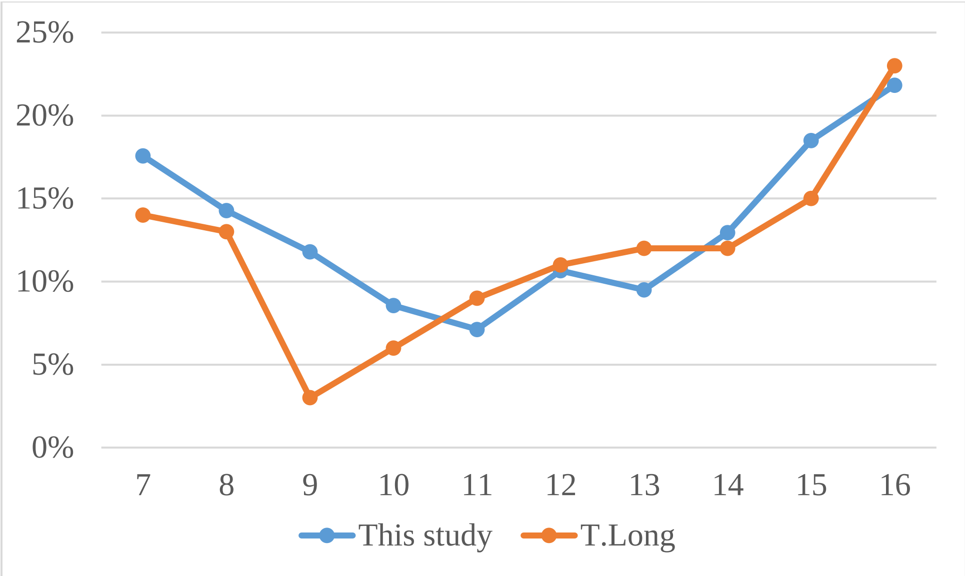

Figure 6. Comparative hourly budget of travel behavior between wild and semi-captive *Pygathrix cinerea*. I omitted observed behaviors between 0630h-0659h and after 1700h from the daily budget due to low and inconsistent observations.

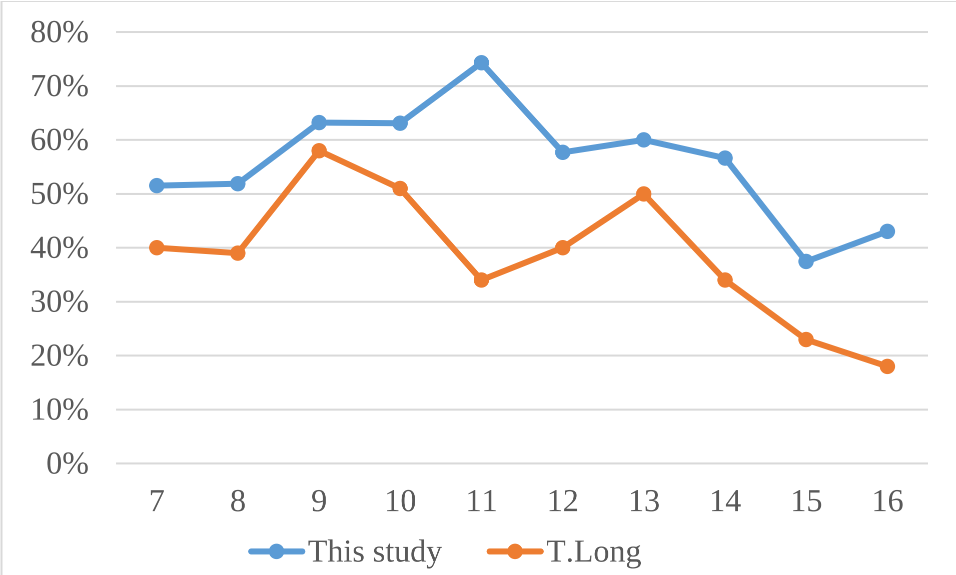

Figure 7. Comparative hourly budget of resting behavior between wild and semi-captive *Pygathrix cinerea*. I omitted observed behaviors between 0630h-0659h and after 1700h from the daily budget due to low and inconsistent observations.

Table 8

Comparison of Hourly Minimum and Maximum Observed Behaviors between Semi-Captive and Wild Pygathrix cinerea

Behavior	Time of semi-captive minimum	Time of wild minimum	Time of semi-captive maximum	Time of wild maximum
Feeding	1100h	0900h	1500h	1600h
Resting	1600h	1100h	1100h	0900h
Social	1500h	1300h	1400h	1100h
Travel	1100h	0900h & 1300h	1600h	1600h

Note. I omitted observed behaviors between 0630h-0659h and after 1700h from the daily budget due to low and inconsistent observations. My observations spanned 10 hours per day.

Feeding Behavior

Similar feeding behavior was recorded among study subjects. Therefore, individual data was aggregated into group data and the group's feeding behavior is analyzed. The semi-captive groups' observed feeding behavior varied significantly between food options (Figure 5) ($\chi^2 = 75.61$, df = 3, $p < .05$). The "other" food item was removed from this analysis due to low frequencies (< 5%) during observations.

The semi-captive groups' feeding behavior varied significantly from wild GSD langurs ($\chi^2 = 114.21$, df = 4, $p < .0001$; Figure 8). Semi-captive langurs consumed more young leaves and mature leaves and less ripe fruit compared to wild langurs (Figure 8). Semi-captive langurs fed from 47 different tree species throughout this study (Table 9). Trees in the family Moraceae were used in over 50% of the semi-captive groups' feeding behavior (Table 10). Throughout the study, I observed ripe fruit and mature leaf feeding behavior the least among all food items.

However, my observations of mature leaf feeding increased as observations of young leaf feeding decreased (Figure 9). During week three, observations of feeding from mature leaves were the lowest across a 5 week period, which is simultaneous to when I observed the highest rates of young leaf consumption (Figure 9).

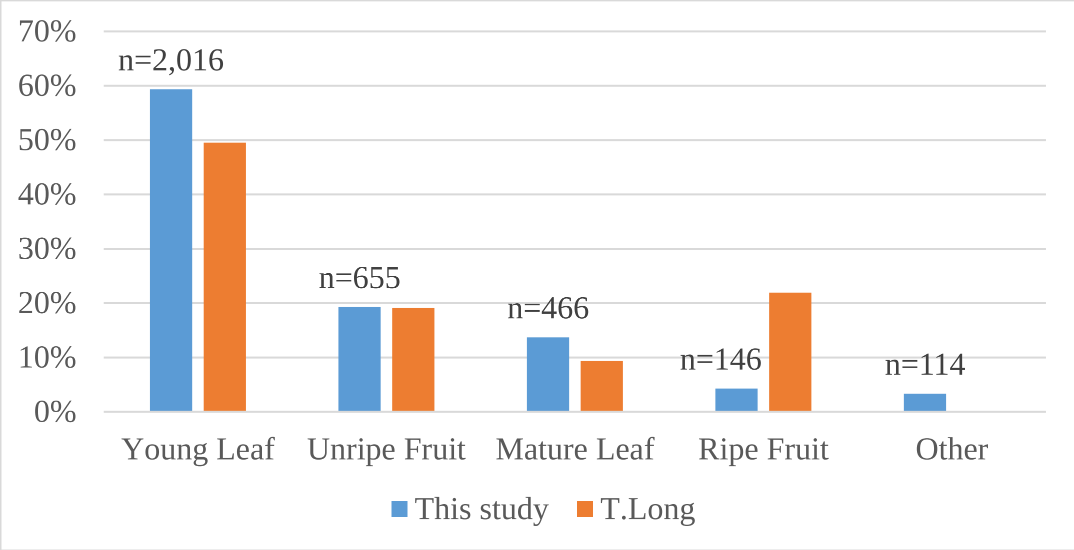

Figure 8. Comparison of observed feeding behavior between semi-captive and wild *Pygathrix cinerea*. Unidentified leaves (n = 1,295) and unidentified fruit (n = 3) were not included in this graph.

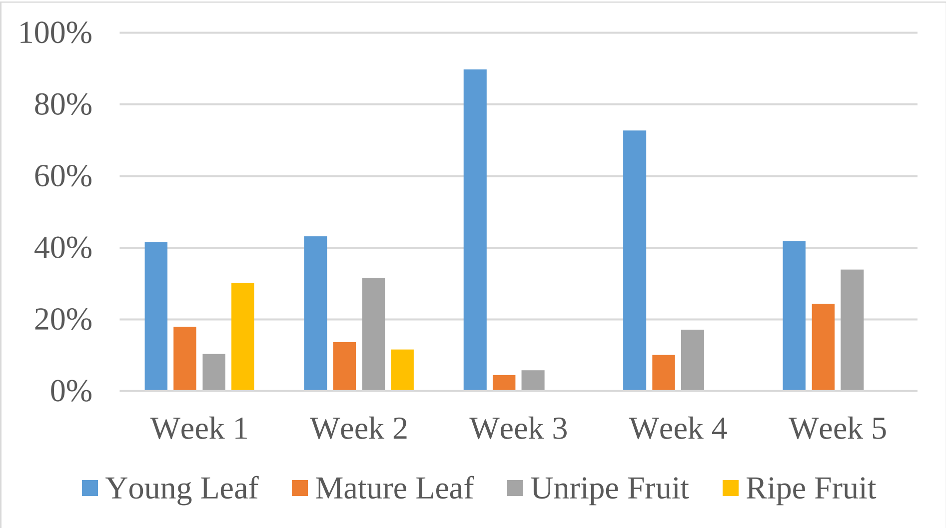

Figure 9. Weekly feeding behavior of semi-captive *Pygathrix cinerea* in Cúc Phương National Park. I excluded unidentified leaves (n = 1,295) and fruits (n = 3) from this table. Each week had seven full day observations (n = 35 observations). Week 1: 16/10/03-16/10/13, week 2: 16/10/14-16/10/28, week 3: 16/10/29-16/11/09, week 4: 16/11/10-16/11/19, week 5: 16/11/20-16/12/02

Table 9

*Food Families Consumed by Semi-Captive GSD langurs (*P.cinerea*) in a Semi-Captive Environment, Cúc Phương* National Park

#	Scientific Name	Family	Tree ID	# of visits	YL	ML	UL	UF	RF
1	*Dracontomelon duperreanum*	ANACARDIACEAE	12	6	X		X		
2	*Allospondias laconensis(pierre)*	ANACARDIACEAE	22	8	X		X		
3	*Goniothalamus macrocalyx*	ANNONACEAE	18	2		X	X		
4	*Goniothalamus macrocalyx*	ANNONACEAE	5	1			X		
5	*Schefflera pes-avis*	ARALIACEAE	59	40	X	X	X		
6	*Bursera tonkinensis*	BURSERACEAE	34	8			X		
7	*Siphonodon celastrinues*	CELASTRACEAE	23	5			X		
8	*Merremia boisiana*	CONVOLVULACEAE	24	361	X	X	X		
9	*Cleistanthus myrianthus*	EUPHORBIACEAE	37	35	X	X	X	X	

Table 9 (Continued)

#	Scientific Name	Family	Tree ID	# of visits	YL	ML	UL	UF	RF
9	*Cleistanthus myrianthus*	EUPHORBIACEAE	37	35	X	X	X	X	
10	*Cleistanthus myrianthus*	EUPHORBIACEAE	44	21	X		X		
11	*Cleistanthus myrianthus*	EUPHORBIACEAE	50	13	X				
12	*Cleistanthus myrianthus*	EUPHORBIACEAE	57	13	X	X	X		
13	*Croton yunnanensis*	EUPHORBIACEAE	29	6	X		X		
14	*Cleistanthus myrianthus*	EUPHORBIACEAE	36	8	X		X		
15	*Cleistanthus myrianthus*	EUPHORBIACEAE	30	2	X		X		
16	*Ormosia sumatrana*	LEGUMINOSAE	33	10	X	X	X		
17	*Saraca dives*	LEGUMINOSAE	21	2			X		
18	*Saraca dives*	LEGUMINOSAE	28	7	X	X	X		

Table 9 (Continued)

#	Scientific Name	Family	Tree ID	# of visits	YL	ML	UL	UF	RF
19	*Saraca dives*	LEGUMINOSAE	32	6	X		X		
20	*Ormosia sumatrana*	LEGUMINOSAE	38	5	X		X		
21	*Saraca dives*	LEGUMINOSAE	27	3		X	X		
22	*Saraca dives*	LEGUMINOSAE	45	3	X		X		
23	*Ormosia sumatrana*	LEGUMINOSAE	42	2	X		X		
24	*Bauhinia wallichii*	LEGUMINOSAE	9	1	X				
25	*Melira azedaracherb*	MELIACEAE	10	30		X	X		
26	*Walsura bonii*	MELIACEAE	17	3			X	X	
27	*Walsura bonii*	MELIACEAE	39	18			X	X	X
28	*Walsura bonii*	MELIACEAE	56	5	X				

Table 9 (Continued)

#	Scientific Name	Family	Tree ID	# of visits	YL	ML	UL	UF	RF
29	*Ficus altissima*	MORACEAE	26	508				X	
30	*Ficus altissima*	MORACEAE	707	159	X	X	X	X	
31	*Ficus altissima*	MORACEAE	15	68					X
32	*Ficus langkokensis*	MORACEAE	48	55	X		X		
33	*Ficus hispida*	MORACEAE	46	25		X	X	X	
34	*Ficus fistulosa Reinx.*	MORACEAE	43	21	X		X		
35	*Ficus langkokensis*	MORACEAE	41	7		X	X	X	
36	*Ficus altissima*	MORACEAE	11	1	X				
37	*Streblus macrophyllus*	MORACEAE	16	1		X			
38	*Hedyotis hedyotidea*	RUBIACEAE	40	9	X		X		

Table 9 (Continued)

#	Scientific Name	Family	Tree ID	# of visits	YL	ML	UL	UF	RF
39	*Dimocarpus longan*	SAPINDACEAE	58	31	X		X		
40	*Dimocarpus longan*	SAPINDACEAE	4	17	X		X		
41	*Dimocarpus longan*	SAPINDACEAE	7	10		X	X		
42	*Dimocarpus longan*	SAPINDACEAE	47	8	X				
43	*Dimocarpus longan*	SAPINDACEAE	3	5		X	X		
44	*Dimocarpus longan*	SAPINDACEAE	49	2	X				
45	*Dimocarpus longan*	SAPINDACEAE	53	2	X				
46	*Sapindaceae sp*	SAPINDACEAE	25	1				X	

Note. YL: young leaf, ML: mature leaf, UL: uknown leaf, UF: unripe fruit, RF: ripe fruit.

Table 10
Comparison of Food Families Consumed by Wild and Semi-Captive Pygathrix cinerea

Semi-captive GSD Langurs			Wild GSD Langurs	
Family	Feeding (%)(*N*)		Family	Feeding (%)
Moracea	**55**	**845**	Myrataceae	22
Convolvulaceae	24	361	**Sapindaceae**	**18**
Euphorbiaceae	6	98	**Moraceae**	**15**
Sapindaceae	**5**	**76**	Theaceae	9
Meliaceae	4	56	Fagaceae	9
Leguminosae	3	41	Guttiferae	3
Araliaceae	3	40	Flacourtiaceae	3
Annonaceae	1	23	Tiliaceae	3
Anacardiaceae	1	14	Alangiaceae	3
Rubiaceae	1	9	Loranthaceae	3

Note. I excluded unidentified leaves (n=1,295) and fruits (n=3) from this table. Same tree families between wild and semi-captive groups are bold.

Use of Varied Tree Heights

I compared the use of trees in three height categories (0-10m, 11-20m, 21+m between group members using Kruskal Wallis *H* test. There was no significant difference among individuals (H = 1.15, df = 3, $p = 0.765$), so I aggregated the data. The group's use of trees in the 0-10m, 11-20m, or 21+m varied significantly ($\chi^2 = 9.33$, df = 2, $p = .0094$). Semi-captive GSD langurs used trees that were 0-10m least, (25%; $n = 1{,}622$), 11-20m most (48% $n = 3{,}130$) and 20+m were used moderately (28% $n = 1{,}820$). The group's use of trees in height classes 0-10m, 11-20m, 20+m varied significantly for feeding ($\chi^2 = 13.4$, df = 2, $p < .05$), resting ($\chi^2 = 12.1$, df=2, $p < 0.05$), social ($\chi^2 = 8.0$, df = 2, $p = .02$), and travel behavior ($\chi^2 = 16.5$, df = 2, $p < .05$; Figure 10).

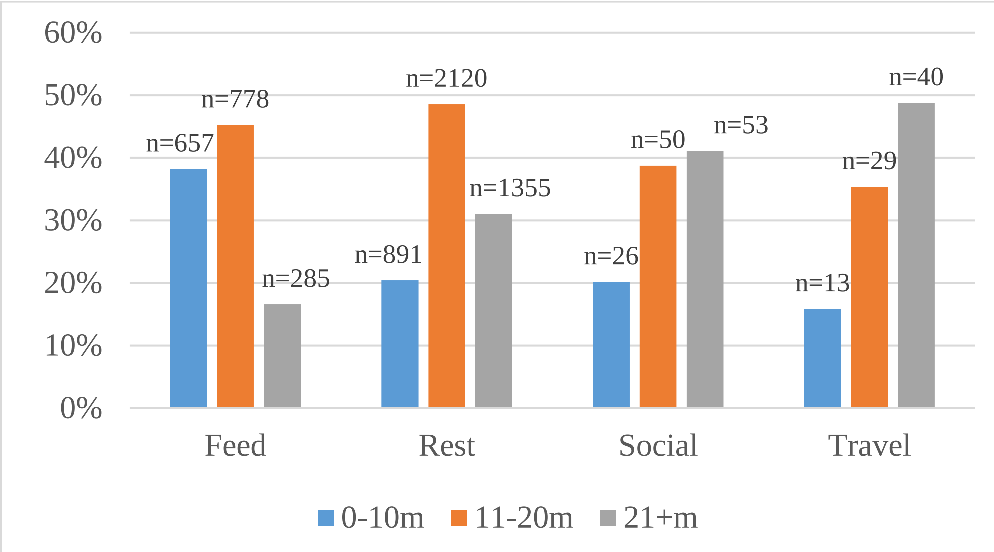

Figure 10. Tree use in relation to state behaviors by *Pygathrix cinerea* in a semi-captive environment, in Cúc Phương National Park.

GSD Langurs' Height in the Canopy

I compared the group's height in the canopy (lower, mid, upper) using Kruskal Wallis H test before combining data. No significant difference is present between individuals use of the canopy, so I aggregated the data (H = 0.44, df = 3, p = .9319). The group's use of lower, mid or upper canopy varied significantly (χ^2 = 12.06, df = 2, p < .05). The semi-captive GSD langurs used the upper canopy most (49.70% n = 1,591) and the lower and mid canopy at a similar frequency (lower = 24.90% n = 707; mid = 25.40% n = 813). The group's use of lower, mid and upper-canopies varied significantly for feeding (χ^2 = 95.3, df = 2, p = < .05), social (χ^2 = 13.09, df = 2, p < .05) and travel behaviors (χ^2 = 37.57, df = 2, p < .05; Figure 11). The group's use of canopy height did not vary significantly for resting behavior (χ^2 = 4.89, df = 2, p = .0867).

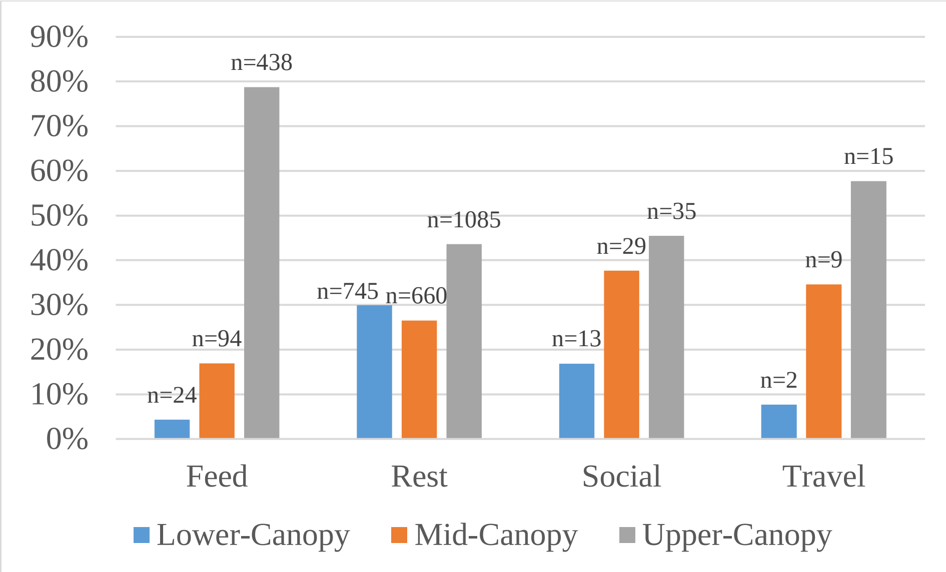

Figure 11. Frequency of semi-captive *Pygathrix cinerea* state behaviors observed at lower, mid and upper height in the canopy. Lower-canopy is defined as a location in tree that is lower than half of the tree's total height. Mid-canopy is defined as a location in tree that is at or between 50-80% of the trees total height. Upper-canopy is placement in the canopy that is at the top 20% of the canopy.

Use of Varied Substrates

I compared semi-captive langurs' overall use of varied substrates using a Kruskal Wallis *H* before I combined the data. No significant difference was found between individuals and their use of boughs, branches or twigs (H = 0.33, df = 3, $p = .9453$) and, so I aggregated the data. The group substrate use varied significantly ($\chi^2 = 68.36$, df = 2, $p < .0001$). The semi-captive groups' use of substrates varied significantly from wild GSD langurs ($\chi^2 = 11.27$, df = 2, $p = .0036$). The semi-captive groups' use of substrate varied significantly from wild GSD langurs for resting ($\chi^2 = 7.78$, df = 2, $p = .0204$), social ($\chi^2 = 26.48$, df = 2, $p < .001$) and travel behaviors ($\chi^2 = 12.75$, df = 2, $p = .0017$). There was no significant difference between semi-captive and wild GSD langurs' substrate use when feeding ($\chi^2 = 1.04$, df = 2, $p = .5945$). Semi-captive GSD langurs used branches most (71.71% n = 2,284), twigs least (8.26% n = 263), and boughs were used moderately (20.03% n = 638; Table 11). The group's use of substrate varied significantly for feeding (χ^2 = 43.7, df = 2, p < .05), resting (χ^2 = 86.27, df = 2, p < .05), social (χ^2 = 47.92, df = 2, p < .05), and travel behaviors (χ^2 = 91.76, df = 2, p <.05; Figure 12).

Table 11

Summary of Substrate Use Between Semi-Captive and Wild Pygathrix cinerea

Substrate	**SC *N***	**SC%**	**W *N***	**W%**
Bough	629	20	1,204	16
Branch	2,262	72	4,911	67
Twig	263	8	1,253	17
Total	3,154		7,368	

Note. SC=Semi-captive, W=Wild. SC data was collected by Hemmes-Kavanaugh in Cúc Phương National Park from 16-10-03 to 16-12-02 and wild data was collected by Long in Kon Ka Kin National Park from 06-01 to 08-08.

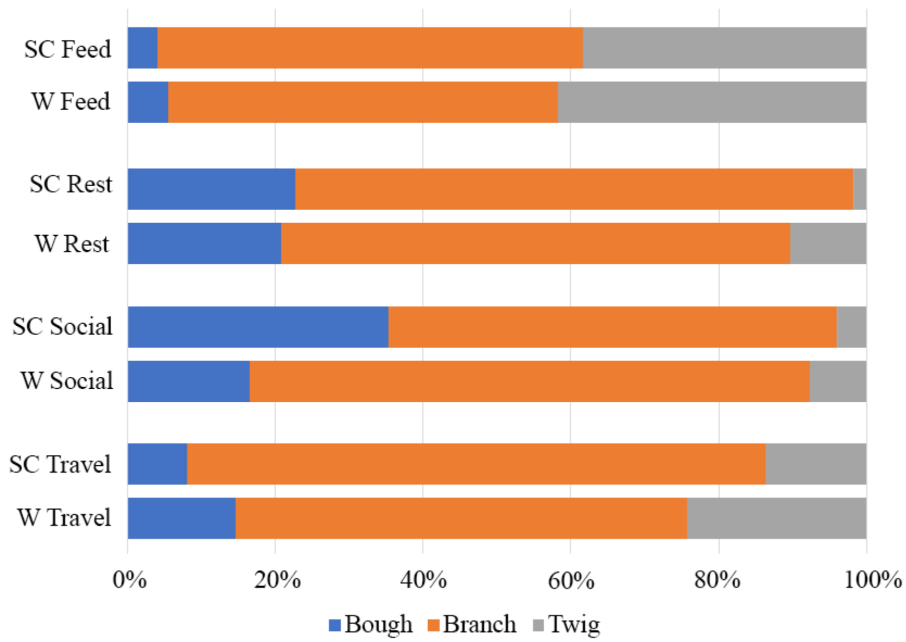

Figure 12. Percent of substrate use while engaged in state behaviors by semi-captive and wild *Pygathrix cinerea*. SC=Semi-captive, W=Wild. A bough has a diameter greater than or equal to 10cm and they do not bend or sway under the weight of the monkeys. A branch has a diameter of less than 10cm and they bend slightly and sway under the weight of the monkeys. A twig sways considerably under the weight of the monkeys.

CHAPTER V

DISCUSSION

Activity Budget

I did not observe a similar activity budget between semi-captive and wild GSD langurs. Because the langurs were out of view for ~40% of my total scans, the activity budget that I analyzed and discuss is comprised only of behaviors that I recorded when the langurs were in view. This might have caused me to over-estimate some behaviors and to under-estimate others. The observed activity budget of the semi-captive GSD langurs show species appropriate proportions of resting, feeding, social and travel behavior. Semi-captive GSD langurs rested for over half of their activity budget (56.47%; Figure 2). Intensive resting behavior was reported in previous douc langur studies, all of which found resting behavior to be the largest proportion of observed behaviors in *P.cinerea*, *P.nigripes* and *P.nemaeus* (Duc, 2009; Long, 2009; Otto, 2005).

Semi-captive GSD langurs had very low observed social behavior (5% ; n = 899) which is also supported by previous douc langur studies that in which social behavior was found to be less than 6% of the activity budget (Duc, 2009; Otto, 2005; Table 7). In general, colobines are less social than most primates. This may be due to the energy required for extensive feeding and resting to aid in digestion (Long, 2009). The wild group of GSD langurs showed unexpectedly high rates of social behavior (25.8%; Table 7) which may be due large group sizes with many females and infants present, or a result of recording self-grooming and vigilance as social behavior (Long, 2009).

In my study, semi-captive GSD langurs spent more of the activity budget feeding and less of the activity budget traveling than did wild GSD langurs (Figure 3). Deviations in state behaviors between wild and semi-captive GSD langurs' may be attributed to a shorter sampling season in my semi-captive group, during the dry months of the year when food resources are lowest ("Average Weather in Hanoi, Vietnam" 1992-2012).

I expected to observe increased feeding behavior during the dry season by semi-captive GSD. This was also found in wild GSD and BSD langurs (Long, 2009; Otto, 2005). According to the "passive foraging strategy", reduced travel and increased feeding is appropriate and advantageous behavior when food density is low (Guo, 2007). Food density is lower during dry seasons when compared to wet seasons is expected. During periods of low food density, animals expend less energy in the search of food in order to maximize their net energy (Dasilva, 1992; Guo et al., 2007).

The decreased traveling I observed in the semi-captive GSD langurs when compared to wild GSD langurs may be a response to the reduced home-range of the semi-captive environment. Although the semi-captive environment totals 5 ha of forest, this may not be an adequate amount of land to allow the semi-captive group to replicate wild traveling behavior. However, traveling rates between semi-captive GSD langurs and wild BSD langurs are more comparable (GSD langurs = 12.5%; BSD langurs = 14.6%; Duc et al., 2009).

Because GSD langurs are an under-studied species, my study is useful in the understanding of their behavioral repertoire. Furthermore, my study promotes understanding of the ways that captive and wild conditions may influence GSD langurs' activity budgets. This is the first study of activity budgets of an AMG of GSD langurs. AMGs are a naturally-occurring group structure of GSDs in the wild; however, they were rarely observed by Long, which may support his observation that they are not as common as OMGs. Because the observed social behavior was very low among my AMG (5%, $N = 899$) and OMGs were observed more often in the wild, I recommend that the EPRC and other primate sanctuaries put GSD langurs in OMGs as often as possible. Social behavior and overall welfare of captive and semi-captive GSD langurs may increase through OMG structures that were observed often in wild GSD langurs.

Daily Activity Budget

A similar daily activity budget was observed between semi-captive and wild GSD langurs. Dr. Long and I both observed more travel behavior at the beginning and end of each observation day for both groups (Figure 6). Increased traveling towards the end of the day is likely in response to langurs' foraging behavior, which occurs before arriving at their sleeping tree. For both study groups, when maximum feeding and traveling behavior occurred towards the end of the day (Table 8).

Dr. Long and I both observed an inverted relationship between feeding and resting in the daily budgets of both groups. This pattern is congruent with published descriptions of the fermentation process required to digest leaf matter (Long, 2009). Thermoregulatory behavior may also explain the daily activity patterns of semi-captive GSD langurs. In my study group feeding and traveling behaviors were highest at the beginning and end of the observation day when the sun is not fully out and temperatures are cool. Towards the middle of the day, it is increasingly warmer and humidity spikes, this is when the langurs exhibited a peak in resting behavior (Figure 7; Table 8).

Feeding Behavior

Semi-captive GSD langurs did not have similar feeding behavior to wild GSD langurs. I did not test abundance between food availability and preference, so the results observed and discussed here are based on my observational data. Douc langurs are folivorous primates that opportunistically consume fruit when it is seasonally available (Long, 2009; Ngoc Thanh et al., 2008). Excluding ripe fruit, mature leaves were the least consumed food throughout the study (Figure 8). However, mature leaf consumption rates were highest when young leaf feeding was lowest. Conversely, mature leaves were consumed least when I observed the highest rates of young leaf consumption. (Figure 9).

The observed diet of the douc langurs is highly dependent on the season that the langurs are being observed. During the dry seasons, fruit availability is low and young leaf availability high. In the north of Vietnam, October and November are the driest months of the year according to historical weather records from Hanoi, Vietnam ("Average Weather in Hanoi, Vietnam" 1992-2012). I carried out my study during the dry season in northern Vietnam ("Average Weather in Hanoi, Vietnam" 1992-2012). Semi-captive langurs consumed more young leaves and mature leaves than Long (2009) observed in wild langurs feeding behavior.

Semi-captive langurs consumed less ripe fruit than has been observed in wild langurs annual feeding behavior which may be due to geographic or seasonal differences between the semi-captive versus wild GSD langurs. Semi-captive GSD langurs reside in Cúc Phương National Park located in northern Vietnam versus the wild langurs that were studied in Kon Ka Kinh National Park, located in southern Vietnam. Northern Vietnam is referred to as a humid subtropical climate which has much cooler temperatures and experiences four seasons unlike the tropical savanna climate of southern Vietnam. Southern Vietnam has much warmer temperatures than the north and experiences only a wet and dry season. These climatic differences may increase the amount of fruiting trees available and fruit eating behavior observed in wild GSD langurs.

However, Long (2009) notes that the GSD langurs' diet was affected significantly by seasonal availability of food and that during the dry season young leaves were consumed 82% of observations, mature leaves 5% and total fruits only 12% (Long, 2009). Langurs consume more young leaf than mature leaf due to the lower fiber content in young leaves, which makes digestion easier (Otto, 2005). Previous research shows that Douc langurs are leaf specialists who exhibit are selective nature in their feeding behavior (Dasilva, 1992; Davies & Oates, 1994). In my study I rarely observed ripe fruit feeding behavior (4%), which is not surprising since sugar-rich foods are unhealthy for the langurs and large consumptions cause bloating and can harm the micro-flora in the forestomach that aid with fermentation (Long, 2007).

At my site, the Moraceae tree family was very important to semi-captive langurs as it comprised more than 50% of feeding events (Table 10). Moraceae and Sapindaceae are within the top ten feeding trees for both wild and semi-captive GSD langurs (*P.cinerea*; Table 10). At my site, I observed more repeated use of trees that produced fruit than non-fruiting trees. Six of the 47 identified trees produced fruit during my sampling period, they were used for 20% of feeding events from identified trees.

The feeding behavior that I recorded were separated into five week periods in order to determine if feeding behavior was affected by the progression towards the dry season (Figure 9). Ripe fruit (RF) was only consumed during the first two weeks of observation (16/10/03-16/10/13). I observed the langurs feed from young leaves (YL) consistently throughout my entire study. Mature leaf (ML) was the second least consumed food during my study, ripe fruit was the least consumed. I observed ML feeding most during week five (16/11/20-16/12/02) which is simultaneous to when I observed the least YL feedings. The semi-captive GSD langurs are exhibiting species-appropriate feeding behavior by consuming fruit at higher rates when it is possible and by consistently feeding on young leaves over mature leaves.

The information I found in this study supports the view that although folivorous, GSD langurs supplement their leaf diet with fruit. Both semi-captive and wild GSD langurs were observed consuming fruit often from trees in the Moraceae families. Semi-captive langurs were also observed consuming fruit from trees in the Euphorbiaceae family. It is important that staff at primate sanctuaries conduct surveys of tree species abundance before securing semi-captive, or reintroduction environments for GSD langurs. This measure would clarify if appropriate fruiting trees are available for the GSD langurs to encourage species typical feeding behaviors during seasonal shifts of food availability.

Use of Varied Tree and Canopy Heights

Semi-captive GSD langurs varied in their use of tree heights and used lower, mid and upper canopy levels disproportionately overall and at varied rates when engaged in state behaviors. I found a number of similarities between semi-captive and wild GSD langurs' use of tree heights. Both semi-captive and wild langurs' used the tallest trees (21+m) most during social behavior. Wild langurs used trees 21+m for 43% of all social behavior and semi-captive langurs for 41%. Semi-captive langurs also used trees 21+m tall most during travel behavior (49%; Figure 10). Lippold and Thanh (2008) observed RSD langurs most often in the upper canopy of the tallest trees (unspecified) during their census in Son Tra National Forest.

Both semi-captive and wild langurs were observed feeding more often from trees taller than 10m (semi-captive = 62%; wild = 60%). These collective results highlight the significance of trees

taller than 10m for GSD langurs and support that conservationists should establish GSD langurs in forests with an adequate presence of trees taller than 10m.

In my study, trees in the 21+m category were likely used more than represented in the frequencies I observed; however, poor visibility did not allow for an accurate recording of behavior when the langurs were at those heights. My results suggest that GSD langurs prefer taller trees for traveling and social behavior. In my study the upper canopy was used significantly more than the mid or the lower canopy. In total, the upper canopy was used in 50% of all observations when I recorded height in the canopy.

When comparing state behaviors, the upper canopy was used most for feeding (79%) and travel behaviors (58%; Figure 11). The lower canopy was used least of all, indicating that GSD langurs prefer mid to upper canopy significantly more in their daily use than the lower canopy.

Use of Varied Substrates

GSD langurs in a semi-captive environment used boughs, branches and twigs disproportionately and at varied rates when engaged in different state behaviors. Overall, both semi-captive and wild langurs used branches more than twigs or boughs for all behaviors (semi-captive branch use = 72%, n = 2,262; wild branch use = 67%, n = 4,911; Figure 12). I observed semi-captive langurs using twigs least (8%, n = 263), and boughs were used moderately (20%, n = 638; Table 11). These results are dissimilar from wild GSD langurs, which Long observed to use twigs and boughs at nearly equal proportions (twigs = 17%, boughs = 16%; Table 11).

Branches were used more than twigs or boughs across all behaviors for semi-captive langurs. This was also observed in wild GSD langurs (Figure 12). However, twigs were used more often for feeding than other behaviors in both my semi-captive study and in Long's study of wild langurs (Figure 12).These results are consistent with folivorous primates' acquisition of young (preferred) leaves at the most exterior layer of the canopy. Both semi-captive and wild langurs used branches and boughs most for resting (Figure 12).

Recommendations for Captive Care

Based on the information found in this study, I recommend the staff of EPRC and other primate sanctuaries with captive GSD langurs put GSD langurs in OMGs as often as possible. Social behavior and overall welfare of captive and semi-captive GSD langurs may increase through OMG structures that were observed often in wild GSD langurs. Primate staff can promote natural feeding and travel routines that were observed in semi-captive and wild GSD langurs by providing fresh food and enrichment activities that encourage travel and foraging behavior between 0800 - 0900h and 1600 - 1700h.

Furthermore, sanctuary staff can encourage natural resting behavior by avoiding husbandry practices that create loud noises between 0900h – 1500h. The EPRC staff should supplement captive GSD langurs' diet of young leaves with fruit from Moraceae and Euphorbiaceae trees when it is available during the wet season. A diet supplemented with seasonally available fruit may result in captive GSD langurs resting and feeding at more species typical rates.

I recommend that primate staff elevate food and enrichment items to the highest points of GSD langurs' enclosures in order encourage captive individuals to mimic height use that was observed among semi-captive and wild GSD langurs.The welfare of captive GSD langurs may be improved through encouraging captive langurs to mimic the behaviors and routines that were observed in semi-captive and wild GSD langurs.

CHAPTER VI

CONCLUSION

In conclusion, my study shows that the semi-captive space used by EPRC staff as part of langur reintroduction encourages some species typical behaviors among the bachelor group of GSD langurs I observed. My study may assist the staff of EPRC and other primate sanctuaries to make more informed decisions when rearing or rehabilitating GSD langurs. Specifically, the information gathered in my study can be used when designing enclosures, assigning group members, creating and implementing enrichment activities and preparing appropriate diets for captive GSD langurs.

My study subjects showed species appropriate proportions of resting and feeding behavior. The deviations between the activity budgets of semi-captive and wild GSD langur can potentially be explained by variations in sampling periods, reduced home range and/or differences in group composition.

My observations of semi-captive GSD langur feeding behavior shows that my study subjects are foraging and consuming various nutrients to sustain their energy demands. This is evident in their intensive use of fruiting trees and prevalence of observed feeding on young leaves over mature leaves.

My study subjects’ substrate use, and use of varied tree and canopy heights, are similar to wild GSD langurs. My results support the effectiveness of the EPRC’s semi-captive environment to encourage species-typical behaviors in GSD langurs. Furthermore, my results support the use of semi-captive enclosures as part of the reintroduction process and as a conservation strategy. It is my hope that other primatologists will continue to study the GSD langurs, specifically in relation to their social behavior and rehabilitation process, so conservationists can more effectively plan for this critically-endangered species' future.

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APPENDIXES

Appendix A. Semi-captive environment in Cúc Phương National Park.

Appendix B. Electronic perimeter and research assistant, Đinh Văn Tín, in semi-captive environment in Cúc Phương National Park

Appendix C. Four male GSD langurs in a semi-captive environment, Cúc Phương National Park

Appendix D. Tree labeled with tree flagging tape in semi-captive environment in Cúc Phương National Park