A Comparative Study of Activity Budgets in Two Endangered Leaf Monkey Species

(Trachypithecus hatinhensis and T. delacouri) in Semi-wild and Caged Living Conditions

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the faculty of
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of the requirements for the degree
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This thesis titled

A Comparative Study of Activity Budgets in Two Endangered Leaf Monkey Species

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ABSTRACT

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A Comparative Study of Activity Budgets in Two Endangered Leaf Monkey Species

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Director of Thesis: Nancy J. Stevens

Primate reintroductions have become a successful tool to increase viable populations of endangered primates in the wild. To better understand time budgets of Delacour’s langurs and Hatinh langurs (Trachypithecus delacouri and T. hatinhensis) prior to captive reintroduction efforts, a study was conducted at the Endangered Primate Center in Cuc Phuong National Park, Vietnam. During the observation period from July 3rd-August 31st, 2011 both species were observed on rotating days in caged and semi-wild enclosures using scan samples conducted at three-minute intervals. Although dominant behaviors included resting and feeding in all species-enclosure combinations, significant differences in time budgets were observed between species and enclosure types, with particularly marked changes found among age/sex classes. A principal interaction was found in time budgets of infant/juvenile males, with significant differences in the amount of time spent feeding, foraging, moving, resting, social and anti-predator behaviors. Juveniles and infants of both sexes engaged in play behavior more than did adults.
Approved: _____________________________________________________________

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CHAPTER 1: INTRODUCTION

Captive Reintroductions

The reintroduction of primates has become a fairly successful tool to specifically increase viable populations in the wild and raise the numbers of endangered primates in general. Reintroduction projects have been conducted for both New World and Old World monkeys. The problems that reintroductions face include a lack of post-release information, and substantial economic cost of implementing reintroductions and conducting subsequent monitoring efforts (Stoinski and Beck, 2004). Without information on why some animals may not survive post-release, it is challenging to improve reintroduction techniques. Studies conducted to date on post-release primate species have noted behavioral changes in the natural setting occurring immediately, and/or continuing as long as two years after release (Stoinski et al., 2002; Keith-Lucas, 1999; Soorae and Baker, 2002). Many reintroduction programs have been designed for primate species including drills (*Mandrillus leucophaeus*), golden lion tamarins (*Leontopithecus rosalia*), orangutans (*Pongo spp.*), golden langurs (*Trachypithecus geei*) (Soorae and Baker, 2002; Vogt et al., 2008), and Hatinh langurs (*Trachypithecus hatinhensis*).

One example of a successful primate reintroduction project is that conducted for the golden lion tamarin. This small-bodied species of Neotropical primate had numbers as low as 100-200 individuals in the wild as recently as 1975 (Soorae and Baker, 2002). The low numbers of these animals can be attributed to hunting and habitat loss in the Brazilian forest (Soorae and Baker, 2002). Reintroduction of tamarins was unsuccessful
at first, due to their inexperience with branches that were less than 2 cm in diameter in the natural setting (Stoinski et al., 2002). To address this problem, animals that were raised/born in captivity were allowed to explore forested areas within some zoological park borders to become accustomed to different branch types that constitute a vital part of their natural habitats (Soorae and Baker, 2002). Golden lion tamarin populations in the wild increased to an estimated 1000 individuals as of December 2000 (Soorae and Baker, 2002). In 2003, the species was taken off the critically endangered list and moved a step down to endangered (Kierulff et al., 2008). The population is estimated to have remained stable since the year 2000 and is projected to remain around 1000 (Kierulff et al., 2008).

Captive propagation of primates may be the only way to preserve some species that have been forced into forest fragments by human activities, as well as those with low population numbers due to hunting pressures. Improved reintroduction techniques can help ensure these species will survive in the wild, rather than simply in captive settings. The International Union for the Conservation of Nature (IUCN) defines reintroduction as “an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct” (IUCN, 1998). In 1995, the IUCN council approved a document outlining comprehensive steps that should be taken in order to be successful in the reintroduction of a species. The steps outline the importance of a multidisciplinary team, evaluation of reintroduction site, socio-economic and legal practices and the need for background research (IUCN, 1998). Although the guidelines state that each case should be considered differently and be fine-tuned to fit together with the species in question, future work will be needed to refine these
guidelines, as research is conducted on captive reintroductions for additional species, such as the limestone langurs that are the subject of this proposal.

**Vietnam as a conservation priority**

Vietnam stretches a total of 1650 km from 23°30’N to 8°30’N in length and encompasses 331,123 km² of land (de Jong et al., 2006). Three-quarters of the country is covered by hilly and mountainous terrain (ICEM, 2003). Vietnam’s unique landscape allows for a variety of habitat types including limestone karst forests, broadleaf evergreen forests, the Red and Mekong river delta habitats, evergreen forests, mangrove forests, monsoon forests, montane forests and semi-deciduous forests (de Jong, et al., 2006).

The availability of different ecological niches together with the tropical monsoon climate of Vietnam in part explains the nation’s tremendous biodiversity (IECM, 2003). Vietnam is home to some of the most endangered animals in the world including a number of endemic species. At present, surveys have recorded 275 mammals species, 180 reptiles, 80 amphibians, 2470 fish, 5500 insects and more than 12000 plants (Zingerli, 2005). Vietnam serves as the home to well known megafauna as the tiger (*Panthera tigris*) and the Asian elephant (*Elaphus maximus*) and includes rarities such as the Javan Rhino (*Rhinoceros sondaicus*) (IECM, 2003). Importantly, Vietnam is home to five critically endangered species of primate; Cat Ba langur (*Trachypithecus poliocephalus*), Tonkin snub-nosed monkey (*Rhinopithecus avunculus*), Grey-shanked douc (*Pygathrix cinerea*) eastern black-crested gibbon (*Nomascus nasutus*) and Delacour’s langur (*Trachypithecus delacouri*) (Mittermeier et al., 2009). Due to
economic and rapid social change along with political instability, many of the species in Vietnam are still poorly studied (Zingerli, 2005). Hunting pressure, human population increase and a continued push for more agricultural land have put extreme pressure on Vietnam’s biodiversity (Nadler et al., 2003).

Conservation in Vietnam has begun to take a step in the right direction. Efforts to protect wildlife in Vietnam began with the first national park, Cuc Phuong National Park, established in 1966. Since the establishment of CPNP there has been a push for additional protected areas in Vietnam. By the early part of this century, Vietnam was home to thirty-five national parks, sixty nature reserves, thirty-seven cultural-historic environmental sites and a few marine protected areas (IECM, 2003). As the years have progressed, forest cover has continued to drop due to human activities, and the number of smaller protected areas has increased (Wege et al., 1999; IECM, 2003). Heightened knowledge of biodiversity in Vietnam and the international attention Vietnam’s wildlife receives is needed to allow threatened species to survive into the future.

*Cuc Phuong and the Endangered Primate Rescue Center*

Cuc Phuong National park, recognized in 1966, was the first national park established in Vietnam (Sourcebook, 2001). The park originally encompassed 25,000 ha of land, until 1988 when the boundaries were redefined by the approval of Decision No. 139/CT to 22,200 ha (Sourcebook, 2001). The Chairman of the Council of Ministers that initiated the investment plan for the park made this decision. CPNP currently stretches over three separate provinces; most of the park can be found in Ninh Binh province with
11,350 ha, Hoa Binh province with 5,850 ha and Thanh Hoa province comprising the remaining 5,000 ha (Sourcebook, 2001).

CPNP is largely covered by reasonably undisturbed karst limestone forested habitat (Rugendyke and Nguyen Thi Son, 2005). This distinctive form of habitat is home to a very biologically diverse ecosystem. The park provides habitat to a great variety of flora, which includes 1,980 vascular plants, 68.9% of which represent the native flora of Vietnam, including five species endemic to Cuc Phuong (Sourcebook, 2001; Rugendyke and Nguyen Thi Son, 2005). Along with the high diversity of floral species, CPNP is home to a great variety of vertebrate species. CPNP’s plant species diversity supports a significant number of animal species that seek refuge in the karst-forested landscape. A total of 248 bird species, 240 mammalian species, 111 snail species and over 8000 insect species have been recorded in CPNP (Sourcebook, 2001; Rugendyke and Nguyen Thi Son, 2005). Megafaunal species include the tiger, leopard, Asiatic black bear, white-cheeked gibbon, and Delacour’s langur. Many of the latter have been hunted to the point of extirpation in the park (Nadler et al., 2003). Despite the fact that the critically endangered Delacour’s langur serves an icon for the park, it is estimated to have suffered a 20% drop in population within the park boundaries between 2000 and 2004 (Nadler et al., 2007).

The Delacour’s langur inspired the development of the Endangered Primate Rescue Center (EPRC), which is located within the boundaries of CPNP in Ninh Binh Province.
Established in 1993, the EPRC has been a model for captive breeding of some of the world’s most endangered primates including Delacour’s langur (*Trachypithecus delacouri*), as well as the grey-shanked douc langur (*Pygathrix cinerea*), the Cat Ba langur (*Trachypithecus poliocephalus*), and the Hatinh langur (*Trachypithecus hatinhensis*) among others (Nadler, 2007). The EPRC has worked vigorously to keep up with the influx of primates that are confiscated from markets and the illegal pet trade around the country. Starting with only 8 individuals in 1993, the center grew to 148 primate occupants by the end of 2009, providing refuge for 115 langurs, 19 gibbons and 14 lorises (Nadler, 2010a). The EPRC helps to support law enforcement by working with the Forest Protection Authorities, it enhances the local economy by employing 20 local Vietnamese people at the center and supports the local economy by purchasing supplies from the local villages. The EPRC has hosted numerous researchers in an effort to better understand the ecology, biology and ontogeny of endangered and endemic primates. The center has constructed a safe zone for the Delacour’s langur located in Van Long Nature Reserve (Nadler, 2009a). Protection and education efforts of these boundaries are enforced by twenty rangers that have been hired by the EPRC (Nadler, 2009a). In an effort to save this critically endangered primate species, surveys of the remaining populations at Van Long and other areas may permit future translocation projects.

The captive breeding program at the ERPC has helped augment dwindling numbers of Vietnamese primate species in the wild through reintroduction efforts (Nadler, 2008). In 2007, a group of Hatinh langurs were transferred to Phong Nha-Ke Bang National Park and released into a semi-wild enclosure (Nadler, 2009a). Eight
Hatinh langurs were captive bred at the EPRC and while there, were housed into one male, three female groups (Vogt et al., 2008). In only three short days the animals had investigated the entire 20 ha enclosure and by the end of the study had merged into a single group (Vogt et al., 2008).

The success at the EPRC in breeding these rare primates in captivity makes it a leader in primate reintroduction projects. Like Phong Nha-Ke Bang National Park the center has two semi-wild enclosures. These enclosures each encompass a karst hill and are 2 ha and 5 ha in size. They serve as the “half-way house” from life in a cage to that of living in a natural environment, which can still be monitored by the keepers at the center. The center provides an opportunity to study the species that currently occupy the two semi-wild enclosures and compare their behavior to those animals that live in cages on rationed food collected by the keepers daily. Because of the diversity of individuals in both captive and semi-wild conditions, the EPRC serves as an ideal study site for documenting the behavior and activity budgets of Delacour’s langurs and Hatinh langurs, as well as for exploring age-class differences that may be important considerations in captive reintroduction efforts.

**Biology of Leaf Monkeys**

Old World monkeys are generally divided into two subfamilies, the Cercopithecinae and the Colobinae (Osterholz et al., 2008). Colobines are further split into Asian and African clades. The Asian clade is a more diverse group of monkeys, further divided into the langurs (*Presbytis, Trachypithecus, Semnopithecus*) and odd-
nosed monkeys (*Pygathrix, Rhinopithecus, Nasalis, Simias*). (Osterholz et al., 2008). Colobines are generally called “leaf monkeys” because of their specialized folivorous diets (Nadler et al., 2003). The leaf monkeys of Vietnam are characterized by details of their craniodental and digestive morphology related to their ingestion of hard to process plant material (Nadler et al., 2003).

For example, foliage passing through the complex digestive system of leaf monkeys must pass through three functional regions even before emptying into the small intestine. The first section is known as the *saccus gastricus* and is where microbial fermentation takes place (Milton, 1998). The *saccus gastricus* maintains a pH of 5.5-7.0 in order for microbes such as bacteria and sometimes fungi to thrive and assist in the breakdown of cellulose and secondary compounds ingested by the animal (Milton, 1998; Nadler et al., 2003). Connected to the *saccus gastricus* is the *tubus gastricus*, which empties into the pyloric region of the true stomach (Milton, 1998). From the stomach, food proceeds through the small intestine and the remainder of the digestive tract. Colobines notably possess a larger cecum and proximal colon than do most other primates (Milton, 1998). Despite a common pattern of elaboration of the gut in colobines, some variation has been observed in morphology. For example, some colobines such as *Procolobus, Rhinopithecus, Pygathrix* and *Nasalis* possess a structure called a presaccus that is thought to enable them to better process plant material in their digestive tract rather than relying as heavily on mastication (Wright et al., 2008). In contrast, many other colobines such as *Colobus, Semnopithecus, Trachypithecus and Presbytis* exhibit digestive systems more similar to those of other Ceropithecines (Wright et al., 2008), and
are thought to devote a greater proportion of effort to oral processing of leafy foods. A comparison of *Trachypithecus* and *Pygathrix* conducted in captivity supported this hypothesis by looking at the time spent on masticating and dental morphology of the two and concluded that *Trachypithecus* uses its mouth to breakdown plant material while *Pygathrix* relies heavily on its specialized digestive system (Wright et al. 2008). From the literature it is clear that more work needs to be done on how diet affects behavior and activity patterns in Asian colobines living in the wild, as species may be more selective about the physical/chemical properties of foods when they have the opportunity to choose among a greater variety of items in the natural habitat.

**Two Species Selected for This Study**

Vietnam is home to 10 species of leaf monkeys, of which three are certainly endemic (Nadler et al., 2003). Endemic species include the Delacour’s langur (*Trachypithecus delacouri*), Tonkin snub-nosed monkey (*Rhinopithecus avunculus*) and the Cat Ba Langur (*Trachypithecus poliocephalus*) (Nadler et al., 2007). In addition, the recently discovered grey-shanked douc langur (*Pygathrix cinerea*) is currently only found in Vietnam and may also be endemic pending more intensive surveys in neighboring nations (Nadler et al., 2003; Ha Thang Long, 2007). Although Vietnam has some of the greatest diversity of leaf monkeys, relatively little is known about these species in the wild. Recent surveys have demonstrated a dire need for immediate conservation efforts in Vietnam, particularly for the Delacour’s langur (Nadler et al., 2003).
Hatinh langur (*Trachypithecus hatinhensis*)

The Hatinh langur (*Trachypithecus hatinhensis*) was first described in 1942 from the hamlet of Cuc (Ha, 2006). Since the time of its discovery, it has been the subject of differences of opinion regarding nomenclature. Originally named *Presbytis francoisi hatinhensis* in 1970 by Dao Van Tien, it was later referred to *Trachypithecus francoisi hatinhensis* (Ha, 2006). Subsequent observations of its closer resemblance to the Laos langur than the Francois langur justified the name *Trachypithecus laotum hatinhensis*. After molecular analysis and comparison of cytochrome B sequences the Hatinh langur was raised to species status and given the name *Trachypithecus hatinhensis* (Groves, 2007). There have been few studies specifically on the Hatinh langur in the wild. Most have been in Phong Nha-Ke Bang National Park, which houses the only protected Hatinh populations (Ha, 2006; Haus et al., 2009). Behavioral and morphological studies have been done in captive situations at Phong Nha-Ke Bang National Park and at the Endangered Primate Rescue Center (Haus et al., 2009; Nadler, 2010b; Vogt et al., 2008). There remains much to be learned about Hatinh langur diet, social activity patterns, time allocation and behavior in the wild.

Most monkeys in the genus *Trachypithecus* are similar in appearance. The Hatinh langur exhibits a dark black body, long thin tail, and crest of hair on top of the head that forms a sort of “faux-hawk”, a feature also observed in the other six *Trachypithecus* species (Nadler, 2010b). *Trachypithecus hatinhensis* infants are born with yellow/orange pelage and are nearly completely black around three months of age (Ha, 2006). The primary distinguishing feature of Hatinh langur pelage is a thin white moustache that
continues onto the cheeks and ends on the nape of the neck (Nadler, 2010b). A melanistic black form of *T. hatinhensis* has also been reported (Nadler, 2009b). This form was originally thought to be a Hatinh langur subspecies, but further investigation demonstrates that individuals with this pelage pattern are genetically indistinct from *T. hatinhensis* and some even develop the white “moustache” later in life (Nadler, 2009b).

Hatinh langurs belong to the “limestone langur” group (Nadler, 2003) and inhabit forested limestone regions east of the Mekong in central Vietnam and eastern Laos (Haus, 2009; Groves, 2007). Although their historical range may have extended to additional habitats, Hatinh langurs are currently restricted to just two provinces of Vietnam, Quang Binh and Quang Tri and the eastern part of Khammouan Province in Laos (Nadler, 2010a). Hatinh langurs inhabit mainly densely vegetated areas although during foraging will sometimes utilize more open areas (Ha, 2006). Little published data are available on the diet of these animals in the wild due to the rough terrain of their preferred habitats, making it difficult to observe these animals feeding (Ha, 2006). At the Endangered Primate Rescue Center, the species feeds three times daily on a variety of leaves obtained from a plantation and locally from the surrounding area. Hatinh langurs are supplemented during the winter months with local sweet potatoes twice a day in addition to their foliage. This provides additional nutrients when local plants are not receiving as much rainfall and there are fewer young leaves high in protein.

Given the landscape in which these animals live, they readily take advantage of the limestone and use the caves and small crevices for nighttime sleeping sites (Ha, 2006). Adults are usually found sleeping apart from one another in separate caves or
crevices (Ha, 2006). The langurs will generally keep the same sleeping quarters for years as long as there is no disturbance forcing them away (Ha, 2006). In published observations of wild Hatinh langurs, activity is initiated at sunrise to begin foraging and return to their sleeping areas around 1600h, engaging in some social interaction prior to sleep. Groups follow the lead of the dominant male, who calls them to return to the sleeping quarters (Ha, 2006).

The Hatinh langur currently faces extreme pressure from hunting and forest degradation (Nadler et al., 2003). The black market trade uses bones in traditional medicines such as “langur balm”, some are traded live and others are hunted for meat (Nadler et al., 2003). Studies of this species are important for preserving struggling populations, and ongoing reintroduction efforts are needed to increase genetic diversity and develop additional viable populations.

**Delacour’s langur (Trachypithecus delacouri)**

Delacour’s langur were first recognized as scientifically unique with specimens collected from the wild in 1930 (Nadler et al., 2003). They were given the name *Pithecus delacouri* in 1932, but in 1952 the taxon was subsumed as a subspecies of *T. francois* (Nadler et al., 2003). The phylogenetic position of this langur appears to have finally been put to rest and is now more widely accepted as a unique species based on studies of its behavior, vocalizations, morphology and genetics (Nadler et al., 2003). Delacour’s langur belongs to the same group of “limestone langurs” as the Hatinh langur described above (Nadler et al., 2007). Like the Hatinh langur, there are few studies on these animals
in their natural habitats. This can be attributed to the fact that the largest population of these animals (~50 individuals) lives in Van Long Nature Reserve, which is comprised of steep limestone karst hills that are extremely difficult to traverse (Nadler et al., 2007). The majority of studies conducted in natural habitats are surveys or are aimed at diet and feeding behaviors (Workman, 2010; Nadler, 2007; but for locomotor and positional behavioral studies see Stevens et al., 2008 and Workman and Schmitt, 2012).

The pelage of the Delacour’s langur is distinctive from that of other members of the genus *Trachypithecus*. In Delacour’s langurs, a dark body is contrasted with striking white pelage starting at the middle of the back and down to the point above their knees (Nadler et al., 2003). This pattern mimics a pair of “white shorts”, giving the animal its Vietnamese nickname, Vooc Mong Trang meaning “The langur with white trousers” (Nadler et al., 2003). *T. delacouri* exhibits tufted fur on the top of the head as in other members of *Trachypithecus*. Whitish-grey cheek hairs are longer than in other members of the genus and reach around the ears to form a white patch (Nadler et al., 2003).

This species inhabits limestone karst forests not unlike other members of the “limestone langur” group (Nadler et al., 2007). There are 19 subpopulations of *T. delacouri* in Vietnam (Nadler et al., 2003). Due to habitat separation, very few of the populations have an opportunity to interact leaving them genetically isolated from one another (Nadler et al., 2003). Populations are spread throughout four provinces in Vietnam; Ninh Binh, Ha Nam, Hoa Binh, Thanh Hoa and Ha Tay (Nadler et al., 2007). There are currently believed to be 270-353 individuals living natural habitats (Nadler et al., 2003).
As this species is an endemic to Vietnam it is a priority for the Vietnamese government in terms of protection (Nadler et al., 2003). As with many other species, the Delacour’s langur is prone to hunting by poachers and measures must be taken to enhance protection of these animals in their natural habitats.
CHAPTER 2: AIM OF STUDY

The species examined in this study (*T. hatinhensis* and *T. delacouri*) are ideal for addressing how captive-bred animals respond to reintroduction into natural habitats for a variety of reasons. First, both langurs are represented at the EPRC and have bred successfully in captivity. Second, both are currently housed in semi-wild as well as caged enclosures, and individuals residing in the semi-wild enclosures are slated for reintroduction into wild settings in the near future. Importantly, both species also belong to the same “limestone langur” group and inhabit similar conditions in the wild, making them interesting candidates for exploring time budget patterns among closely related animals. Finally, both species are endemic or near endemic to Vietnam and have been listed endangered (Hatinh langur) and critically endangered (Delacour’s langur), hence information about their biology is a priority for informing the conservation effort.

**Goal I: Compare time budgets of Hatinh and Delacour’s langurs**

The first goal is to explore whether the time budgets of the two study species differ from one another, with comparisons made between Hatinh and Delacour’s langurs in both the caged and semi-wild settings. No extensive behavioral studies have to date been published on Delacour’s langurs in their natural habitat, and very little has yet been recorded on the Hatinh langur. The species are similar in body size and proportions, are closely related, and live in limestone karst forested habitat, relying heavily on leaves as their main food source (Nadler et al., 2003; Nadler et al., 2007; Workman, 2010). Hence I don’t expect to find appreciable differences in the time budgets of the two study species.
when housed in similar enclosure types. As the study species are highly folivorous, I would expect most of the activity budget in both langur species to be allocated to resting in order to digest the cellulose and toxins present in the leaves (Nadler et al., 2003; Huang et al., 2008; Matsuda et al., 2009; Li and Rogers, 2004).

**Goal II: Compare time budgets in caged vs. semi-wild habitats for both langur species**

The second goal of this study is to examine how time budgets differ between the two different types of housing conditions (caged vs. semi-wild), with individual comparisons made for each of the study species. Given the drastically different conditions of caged and semi-wild living environments, the time budgets of the different groups are expected differ significantly in the following ways. Because langurs occupying the semi-wild enclosures have access to a larger habitat area, which provides a richer environment than those living in cages they are expected to spend more time foraging/feeding, more time traveling, and less exhibiting social behavior due to the complexity of their environment (Jaman and Huffman, 2008). Greater variety of locomotor substrates and the higher habitat heterogeneity can alter the way in which primates behave, with significant effects on time budgets (Li and Rogers, 2004; Jaman and Huffman, 2008).
Goal III: Determine whether any habitat-specific behavioral patterns differ with age/sex in either langur species

The third goal is to collect data from age classes (adult, juvenile, infant) in males and females within each species, in order to explore whether and how sex and age class may influence time budgets in captive and semi-wild conditions. Adult females, particularly those with dependent offspring, are expected to spend more time engaged in feeding than are adult males. Similar age class differences are hypothesized in both species, with juveniles expected to exhibit more time engaged in movement and social interactions than adults (Jaman and Huffman, 2008; Li and Rogers, 2004). This study will be the first to compare activity budgets of these two species in captive and semi-wild enclosures at the EPRC.
CHAPTER 3: METHODS

Study Site

The study took place at the EPRC located in Cuc Phuong National Park, Vietnam. The center currently has 43 cages with a surface area of 2,750 m², 6 indoor enclosures with a total of 110 m², 4 outdoor quarantine cages with 10 m², 2 indoor quarantine areas with 50 m² and 13 loris cages with a total of 100 m² (Nadler, 2007). The two caged enclosures used for this study share the same dimensions (10.1m x 5.1m x 3.2m) and are labeled 6B and 10B. Cage 6B houses 4 Delacour’s langurs (1 adult male, 1 adult female, 1 juvenile female and an infant male). Cage 10B houses 6 Hatinh langurs (1 adult male, 2 adult females, 2 juvenile males and 1 infant male). The two semi-wild enclosures (Hill 1 and Hill 2) are 2 ha and 5 ha respectively. The hills consist of fairly undisturbed karst limestone forest and are each enclosed by a solar powered electric fence. Hill 1 currently houses two muntjacs, five Delacour’s langur (1 adult male, 2 adult females, 1 juvenile male and an infant female) and 1 northern white-cheeked gibbon (female). The hill also contains two cages where one is used for the langurs to return to when called and the other one is used for the gibbon. Hill 2 houses 8 Hatinh langurs (2 adult males, 2 adult females, 2 juvenile males, 1 infant male and 1 infant female). Hill 2 also contains a cage where the langurs are trained to return to when called as well as a building formerly used to house elephants. This building is now used for the Hatinh langurs to sleep in during the winter months when the temperature drops below temperatures they would normally see in their historical range. The house serves as a proxy for a limestone cave environment,
as the animals are often found sleeping on a portion of cement located under the roof, but not inside the house.

**Data Collection**

Between July 3rd and August 31st, 2011 I observed Delacour’s langurs and Hatinh langurs in two types of enclosures, semi-wild and caged. The caged groups were selected in order to make a reasonable match with group compositions available in the semi-wild enclosures. Observations of the animals alternated daily between caged and semi-wild enclosures to ensure even sampling of study species in each enclosure type. The total number of observations for cages 6B, 10B, Hill 2, and Hill 1 were 10021, 13984, 3362 and 2585 respectively. Each enclosure type was observed for a total period of 12 days throughout the study period. I identified individuals using records kept at the EPRC (Table 2). Animals of different age/sex classes can easily be discerned using perigenital coloration, body size, pelage color and other features specific to the individual (specific characteristics/features provided by Elke Schwierz). Adults were defined as animals that have reached reproductive maturity, which are five years for males and four years for females (Nadler, 2003). Juveniles are defined as animals that are under the age for sexual maturity yet not dependent on their mothers. Infants were defined as animals still dependent on mothers for all or part of their dietary intake.

Observations began in the morning between 5:30 and 7:00 depending on weather conditions and ended at 18:00 for the evening. I used scan sampling every 3 minutes (Altmann, 1973; Di Fore and Rodman, 2001). Animals that are housed in the semi-wild
enclosures were not seen in every scan and therefore the total amount of data collected will likely vary for those animals. The following behaviors were recorded for each scan; feeding (Fe), foraging (Fo), moving (Mo), resting (Re), social behavior (SB), play (Pl) and anti-predator behaviors (APB). A detailed description of each of these behaviors is provided in Table 1.

All observations were recorded in a water-resistant notebook. Each evening the data collected during the day was transcribed into a spreadsheet (Microsoft Excel for Mac, version 12.3.2). A total of 29,952 individual activity observations were made. Each individual observation is treated as a separate data point when used in succeeding analyses in order to reduce the potential biases introduced by the scan sampling technique (Clutton-Brock, 1977).

**Data Analyses**

Time budgets were calculated as the percentage of all observations occupied by each of the seven behavioral categories (Long et. al, 2010). Pearson’s chi-squared test was used to assess intraspecific patterns for different habitat types in Hatinh langurs (Cage 10B and Hill 2), and Delacour’s langurs (Cage 6B and Hill 1) Delacour’s and Hatinh langurs (Hill 1 and Hill 2) and Hatinh and Delacour’s langurs (Cage 10B and Cage 6B).

I used a Poisson regression model was selected to compare count data collected from scan samples, comparing male and females using species, age and sex as variables. Bivariate trellis plots were constructed using R to illustrate significant patterns in time
budgets for langurs housed in caged/semi wild conditions, as a function of age/sex class. All of the data were analyzed using Microsoft Excel for Mac Version 12.3 and R lattice graphics, utils, and stats packages.
CHAPTER 4: RESULTS

Activity Budget

The activity budget for the seven behaviors with respect to enclosure type is shown in Figures 1, 2, 3 and 4. Hatinh langurs in Cage 10B spent most of their time resting (53.51%) and feeding (31.94%) with little time allocated to other behaviors; moving, social, playing, foraging and anti-predator (5.63%, 4.85%, 3.42%, 0.54%, and 0.10%). Hatinh langurs on Hill 2 also spent a majority of their time resting, feeding and playing (56.96%, 16.83% and 10.04%) with a small amount of time spent on other behaviors; moving, social, anti-predator and foraging (8.88%, 6.85%, 0.42% and 0.03%).

Delacour’s langurs also spent a majority of their time resting and feeding. In Cage 6B 51.50% of their time was spent resting and 31.94% was spent feeding. Little time was spent on the remaining behaviors; moving, playing, social, foraging and anti-predator (7.21%, 3.88%, 3.02%, 0.56% and 0.20%). The Delacour’s langurs on Hill 1 engaged less in resting (44.80% of time budget) when compared to the other groups. Although they spent much of their time on feeding (28.02%), they spent more time on non-feeding/resting behaviors than did other groups. This group allocated 13.49% and 11.36% of their time to social and moving behaviors respectively. They spent small amounts of time on behaviors such as playing, foraging and anti-predator (1.70%, 0.58% and 0.04%).
Comparisons Between Different Species in Same Enclosure Types

Chi-squared analyses of Delacour’s and Hatinh langurs housed in caged settings were found to differ significantly in time spent feeding, moving, resting and engaging in social behavior (p<0.05 for each comparison). These langur species exhibited no significant differences in foraging, anti-predator and playing behaviors in the caged setting (p>0.05). Percentages of time spent on each behavior are illustrated in Figure 1.

Further comparisons using chi-squared analyses revealed that activity budgets for Delacour’s langurs and Hatinh langurs housed in semi wild conditions on Hill 1 and 2 exhibited significant differences in the following behaviors; feeding, foraging, resting, social, anti-predator and playing behaviors (p<0.05 for each comparison). Groups did not, however, differ in their time spent traveling (moving) (p>0.05). Specific chi-squared and p-values for the comparisons between the two species in each enclosure type are summarized in Table 3. Percentages of time spent on each behavior are illustrated in Figure 2.

Comparisons Between Same Species in Different Enclosure Types

Chi square analyses of Hatinh langur time budgets in different enclosure types (Cage 10B and Hill2) revealed significant differences in the amount of time spent feeding, foraging, moving, resting, and engaging in social and playing behaviors (p<0.05 for each comparison). No significant differences were observed in anti-predator behavior (p= 0.85). Percentages of time spent on each behavior are illustrated in Figure 3.
Similar comparisons among Delacour’s langurs housed in different enclosure types (Cage 6B and Hill 1) revealed significant differences in the amount of time spent feeding, foraging, moving, resting, and engaging in anti-predator and playing behaviors (p<0.05 for each comparison). Differences in time spent engaging in social behaviors did not reach significance (p=0.06). Specific chi-squared and p-values are summarized in Table 4 for the comparisons for each species in the different enclosure types. Percentages of time spent on each behavior are illustrated in Figure 4.

Influence of langur age and sex on time budgets

I chose a generalized linear model with a Poisson distribution to explore for interactions between age and sex in the study sample. Significant interactions were found between age and sex (p<0.05) for feeding, foraging, moving, resting, social, and anti-predator behaviors (Figures 2a-2f).

Juvenile and infant males of both species differed significantly in their time allocated to feeding, moving, and resting behaviors (Figures 2a, 2c and 3d). In addition, infant males engaged in more social behavior whereas juvenile males spent less time engaging in foraging and anti-predator behaviors (Figures 2e, 2b and 2f). Only one ontogenetic difference in behavior was independent of subject sex given the Poisson distribution model (Figure 2g). Juveniles and infants of both sexes were both observed to engage more in play behavior than were adults (p<0.05).
CHAPTER 5: DISCUSSION

Time Budget Comparisons to Other Langur Species

In this study, Delacour’s and Hatinh langurs spent most of their time resting (44.80% - 56.96%) and feeding (16.83% - 34.54%) in both caged and semi-wild environments. A large percentage of time spent resting has been observed in many other species of langurs (Pygathrix cinerea Long et. al, 2010; Trachypithecus francoisi, Zhou et. al, 2007; Trachypithecus leucocephalus, Huang et. al, 2003, Li et. al, 2004; Trachypithecus poliocephalus, Schneider et. al, 2010). Time allocated to resting is likely related to diet in these animals. Longer resting periods allow for microbial digestion to break down the cellulose in the plant walls (Oates and Davies, 1994; Nadler et. al, 2003). The process by which these monkeys digest the leafy material is somewhat similar to that of a ruminant animal (Oates and Davies, 1994). Many of the microbes found in the rumen of artiodactyls are also found in the saccus gastricus of langurs in the genus Trachypithecus (Oates and Davies, 1994).

Yet in addition to the large amount of time spent resting and digesting, a high proportion of time was also allocated to feeding. Perhaps because Trachypithecus species do not possess a presaccus like that of colobines belonging to genera Procolobus, Rhinopithecus, Pygathrix and Nasalis they must do more of the initial processing orally (Oates and Davies, 1994). Indeed, they have been observed to masticate longer than those species possessing a presaccus and they may depend even more heavily upon enzymes produced by their large salivary glands to facilitate the breakdown of cell walls in their food (Wright et. al, 2008). It has also been observed that Trachypithecus individuals have
deeper mandibular corpora than other genera *Pygathrix*, which could be explained by the longer chewing rate exhibited by *Trachypithecus* (Wright et al., 2008). Since the behavioral category ‘feeding’ included mastication of foodstuffs, a large amount of time (16.83% - 34.54% of total time budget) was allocated to feeding in both species regardless of enclosure type. The necessary time required to both masticate and digest the leafy material does not leave a large amount of their activity budget remaining to participate in other behaviors (playing, social, moving). A more complex digestive system, deeper mandibular corpora, high cusped bilophodont dentition and enlarged salivary glands serve as adaptations for feeding on hard-to-digest plant materials may help explain their highly skewed time budgets, relative to those observed in more generalist feeding primate species.

*Comparisons Between Different Species in Same Enclosure Types*

Since both limestone langur species examined herein are close in body size, and they inhabit similar habitats in the wild, the null hypothesis proposed that they would not exhibit significantly different time budgets in a given enclosure type. Interestingly the null hypothesis was rejected for time spent feeding, moving, resting and engaging in social interactions within the caged setting (p < 0.05 for each). The null hypothesis was also rejected for animals inhabiting semi-wild enclosures for the following: amount of time spent feeding, foraging, resting and engaging in social interactions and anti-predator behaviors (p < 0.05 for each). Differences documented between caged Hatinh and Delacour’s langurs could be attributed to sampling bias due to weather conditions or
other factors. Observations in the dataset could be skewed if both species were not sampled with the same intensity for all times of day. Nonetheless, data discussed here are important in the context of how little observational data has been published for these species, and observed differences contribute to hypotheses about differences among these closely related langurs that can be tested in future studies.

Observations of both species in semi-wild enclosures was complicated by visibility and navigating high-relief karst terrain made slippery by rain. These factors provided challenges for obtaining the full 10-hour observation period each day. Animals were more easily visible was when they were feeding; hence observational data may reflect such practical limitations. Presumably that would be a limitation of most studies on these and closely related animals, but it bears mention here.

Comparisons Between Same Species in Different Enclosure Types

Cages at the EPRC differ greatly from the nearby semi-wild living environments, hence it was hypothesized that there would be a significant difference in the behavior of each langur species between the two housing environments. Because they had more opportunities to seek out preferred food items, langurs in semi-wild areas were expected to allocate more time to foraging, feeding and moving. Hatinh langurs in this study exhibited significant differences in six of the seven behaviors recorded (feeding, foraging, moving, resting, social and playing) when housed in different enclosures. Surprisingly, differences were often in the opposite direction from what was expected, with the Hatinh langurs in semi-wild conditions spending more time resting, and
engaging in play and other social behaviors (p < 0.05 for each). Hatinh langurs did, however, spend more time moving when housed in semi-wild conditions on Hill 2, which followed expectations that animals would travel more outside of the cages given opportunities to encounter the higher level of habitat heterogeneity.

Delacour’s langurs housed in different conditions also exhibited appreciable differences in their time budgets. Six of the seven behaviors observed were found to be significantly different between enclosure types (feeding, foraging, moving, resting, anti-predator and playing). Feeding, resting, and playing behaviors followed expectations and were significantly higher in the caged setting, whereas foraging, moving and anti-predator behaviors were higher in the semi-wild setting (p < 0.05 for all).

In general, animals in this study spent more of their time moving and socializing in the semi-wild enclosures. Increased habitat size and heterogeneity in the semi-wild setting on the hills, likely accounts for movement differences, with higher distances among food sources requiring greater time spent in travel. A greater amount of time spent socializing in semi-wild enclosures is most likely attributable to a greater number of juveniles and infants playing with one another in the semi-wild enclosures. For example, Hatinh langurs on Hill 2 and Delacour’s langurs on Hill 1 showed a significant increase in play behavior from those Hatinh langurs housed in Cage 10B and Delacour’s langurs housed in Cage 6B (p<0.05). This group had more juvenile/infants than did the Hatinh group housed in Cage 10B. Moreover, when the animals chased one another around the forest it was considered “social behavior” and animals took advantage of the different substrates available to them during their games of “chase”. The larger areas for
movement also allowed for longer periods of chasing from one tree to the next or from karst to karst, and indeed habitat heterogeneity has been observed to significantly alter time budgets in primates (Li and Rogers, 2004; Jaman and Huffman, 2008).

Influence of langur age and sex on time budgets

Age and sex differences in time budgets have been observed in a variety of species (Macaca nigra O’Brien and Kinnaird, 1997; Cebus olivaceus, Fragaszy, 1990; Long et. al, 2010; Trachypithecus poliocephalus, Schneider, 2010). These differences in time allocation patterns often include less time spent resting, allowing more time for immature langurs to engage in other behaviors i.e. play, moving, and social behaviors. Ontogenetic differences in time budgets observed in this study demonstrate that caged langurs follow the same pattern observed for closely related species in the wild. Juvenile and infant animals spend more time engaged in active behaviors, mirroring the pattern documented for young primates in nature (Schneider, 2010; Long et. al, 2010).

Conservation Implications

Future propagation of the limestone langur group in Vietnam, and indeed throughout Southeast Asia in general, is in the hands of small rescue/conservation centers like the Endangered Primate Rescue Center (EPRC). Small remaining population size for many species in the wild renders each individual critical for the population’s variability, such that further losses could be detrimental to the survival of the species as a whole. The EPRC has assumed a vital role in protecting Vietnam’s primates by providing a venue for
expanding our understanding of their biology and life history traits, and through efforts to protect wild populations and intercede in the illegal animal trade. Importantly, the EPRC has excelled not only in rescuing individuals of critically endangered species; it has also showed unparalleled success in captive breeding of these delicate animals. The next step for the conservation effort is to capitalize on this success via reintroductions of captive-bred animals back into suitable natural environments.

This observational study was conducted to help increase our understanding of how time budgets vary in these species as a function of living conditions, to develop baseline data that can inform soft-release techniques for captive reintroduction efforts. The IUCN recommends that animals housed in captivity first be transitioned into a semi-wild enclosure before release into the a natural habitat. The significant differences observed in the time budgets of both species between caged and semi-wild settings supports this recommendation of a soft release before reintroducing these species in order to allow the animals to adapt to larger ranges and different foraging requirements/opportunities. Practical considerations that also influence reintroduction efforts by the Center include budget, personnel time and space constraints.

The situation of the EPRC within the Cuc Phuong National Park (CPNP) can benefit future release endeavors. Coordination of efforts between the two entities may provide valuable opportunities to engage in and monitor captive releases with intensified protection efforts in place. A strong reintroduction project that increases primate density within the park is likely to bring an influx of revenue from visitors interested in the
flagship langurs. Managed well, an increase in park profits can further enhance protection efforts and contribute to the additional captive release efforts for these and other species.

**Conclusion**

Relatively little has been published on Delacour’s and Hatinh langurs in the wild. The present paucity of data on time budgets for these species hampers our understanding of how these animals may adapt to their surroundings outside of captivity. Conservation of all species in the limestone langur group is pivotal for preserving one of Vietnam’s most unique ecosystems, the limestone karst forests. These forests provide habitat for thousands of species of flora and fauna and rapid human-induced environmental change greatly threatens their future. The “limestone langurs” serve as flagship animals that promote the conservation of karst habitats in Vietnam and the biodiversity that they contain. More specifically the Delacour’s langur, as an endemic to Vietnam, could serve as an animal that Vietnam is proud to protect.

In order to be successful, conservation efforts must intensify through education and development of additional parks and protected areas. Largely due to Vietnam’s high number of critically endangered primates on the IUCN’s 25 most endangered list, international attention has focused on learning more about limestone langurs that are on the brink of extinction. This study, designed in collaboration with the EPRC’s ongoing conservation, captive breeding and reintroduction efforts, provides important behavioral data used to help conserve the habitats that will be needed to preserve the biodiversity so important to Vietnam’s future.
Table 1
Definitions of behavioral categories.

<table>
<thead>
<tr>
<th>Behavior</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feeding</td>
<td>Handling, processing or consuming plant material or insects</td>
</tr>
<tr>
<td>Foraging</td>
<td>Manipulating plant material in search of favored food items, moving to another branch or bundle of leaves to feed or looking intently around for a certain leaf species before moving to gather it</td>
</tr>
<tr>
<td>Moving</td>
<td>Changing position or location on bamboo poles, on the cage wires, on the ground or in the trees</td>
</tr>
<tr>
<td>Resting</td>
<td>Inactivity, where the animal is sitting or lying down that is not associated with eating, foraging or social activity</td>
</tr>
<tr>
<td>Social Activity</td>
<td>Interacting with another group member or species whether aggressively, allo-grooming or play. Mothers with infants riding ventrally were not considered to be in the realm of social activity, but the activity in which the mother was otherwise involved was the other activity. The infant was then categorized as “resting” or “feeding” appropriately.</td>
</tr>
<tr>
<td>Anti-Predator Behavior</td>
<td>Looking vigilant into the sky at large birds, on the ground for snakes and/or making alarm calls</td>
</tr>
<tr>
<td>Play</td>
<td>Acting in a playful manner with inanimate objects. Jumping, swinging, or bounding playfully from substrates or other group members without them being engaged</td>
</tr>
</tbody>
</table>
Table 2

Vital statistics of individual observed in the study. Animals born outside the center do not have exact birthdates, but age was approximated to the best of the center’s ability. Names are given to the animals at the center as a way of record keeping and distinguishing them apart.

<table>
<thead>
<tr>
<th>Name</th>
<th>Species</th>
<th>Cage Number</th>
<th>Sex</th>
<th>Age Class</th>
<th>Birthdates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tilo</td>
<td><em>T. hatinhensis</em></td>
<td>10B</td>
<td>Male</td>
<td>Adult</td>
<td>06.02.96</td>
</tr>
<tr>
<td>Heinrich</td>
<td><em>T. hatinhensis</em></td>
<td>10B</td>
<td>Male</td>
<td>Adult</td>
<td>20.10.06</td>
</tr>
<tr>
<td>2-74</td>
<td><em>T. hatinhensis</em></td>
<td>10B</td>
<td>Male</td>
<td>Infant</td>
<td>06.04.11</td>
</tr>
<tr>
<td>2-60</td>
<td><em>T. hatinhensis</em></td>
<td>10B</td>
<td>Male</td>
<td>Juvenile</td>
<td>01.04.09</td>
</tr>
<tr>
<td>Cuc</td>
<td><em>T. hatinhensis</em></td>
<td>10B</td>
<td>Female</td>
<td>Adult</td>
<td>07.01.01</td>
</tr>
<tr>
<td>Hanh</td>
<td><em>T. hatinhensis</em></td>
<td>10B</td>
<td>Female</td>
<td>Adult</td>
<td>04.04.02</td>
</tr>
<tr>
<td>Kurt</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Male</td>
<td>Adult</td>
<td>1995</td>
</tr>
<tr>
<td>2-75</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Male</td>
<td>Infant</td>
<td>???.05.11</td>
</tr>
<tr>
<td>2-59</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Male</td>
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<td>29.12.08</td>
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<tr>
<td>2-56</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Male</td>
<td>Juvenile</td>
<td>???.09.07</td>
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<tr>
<td>2-62</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Male</td>
<td>Juvenile</td>
<td>???.05.09</td>
</tr>
<tr>
<td>Erna</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Female</td>
<td>Adult</td>
<td>1993</td>
</tr>
<tr>
<td>Minni</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Female</td>
<td>Adult</td>
<td>1994</td>
</tr>
<tr>
<td>2-76</td>
<td><em>T. hatinhensis</em></td>
<td>Hill 2</td>
<td>Female</td>
<td>Infant</td>
<td>???.05.11</td>
</tr>
<tr>
<td>Jonathan</td>
<td><em>T. delacouri</em></td>
<td>6B</td>
<td>Male</td>
<td>Adult</td>
<td>21.02.98</td>
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<tr>
<td>1-25</td>
<td><em>T. delacouri</em></td>
<td>6B</td>
<td>Male</td>
<td>Infant</td>
<td>20.03.11</td>
</tr>
<tr>
<td>Johanna</td>
<td><em>T. delacouri</em></td>
<td>6B</td>
<td>Female</td>
<td>Adult</td>
<td>09.07.03</td>
</tr>
<tr>
<td>Jojo</td>
<td><em>T. delacouri</em></td>
<td>6B</td>
<td>Female</td>
<td>Juvenile</td>
<td>29.07.08</td>
</tr>
<tr>
<td>Longtail</td>
<td><em>T. delacouri</em></td>
<td>Hill 1</td>
<td>Male</td>
<td>Adult</td>
<td>1990</td>
</tr>
<tr>
<td>Gil(NG)</td>
<td><em>T. delacouri</em></td>
<td>Hill 1</td>
<td>Male</td>
<td>Juvenile</td>
<td>08.01.08</td>
</tr>
<tr>
<td>Manu</td>
<td><em>T. delacouri</em></td>
<td>Hill 1</td>
<td>Female</td>
<td>Adult</td>
<td>28.07.96</td>
</tr>
<tr>
<td>Buschi</td>
<td><em>T. delacouri</em></td>
<td>Hill 1</td>
<td>Female</td>
<td>Adult</td>
<td>27.10.05</td>
</tr>
<tr>
<td>1-23</td>
<td><em>T. delacouri</em></td>
<td>Hill 1</td>
<td>Female</td>
<td>Infant</td>
<td>20.05.10</td>
</tr>
</tbody>
</table>
Table 3

Reported $X^2$ and p-values for both interspecific (Cage 6B|Cage 10B and Hill 1| Hill 2) and intraspecific comparisons (Cage 10B|Hill 2 and Cage 6B| Hill 1). Areas highlighted in grey show significant p-values (p<0.05).

<table>
<thead>
<tr>
<th>Comparisons Between</th>
<th>Feeding</th>
<th>Foraging</th>
<th>Moving</th>
<th>Resting</th>
<th>Social</th>
<th>Anti-Predator</th>
<th>Play</th>
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<tbody>
<tr>
<td></td>
<td>$X^2$</td>
<td>p-value</td>
<td>$X^2$</td>
<td>p-value</td>
<td>$X^2$</td>
<td>p-value</td>
<td>$X^2$</td>
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<tr>
<td>Cage 10B and Cage 6B</td>
<td>40.22</td>
<td>&lt;0.001</td>
<td>0.67</td>
<td>0.41</td>
<td>3.90</td>
<td>&lt;0.05</td>
<td>48.28</td>
</tr>
<tr>
<td>Hill 1 and Hill 2</td>
<td>20.11</td>
<td>&lt;0.001</td>
<td>10.29</td>
<td>&lt;0.001</td>
<td>0.04</td>
<td>0.84</td>
<td>185.06</td>
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<tr>
<td><strong>Intraspecific</strong></td>
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</tr>
<tr>
<td>Cage 10B and Hill 2</td>
<td>2580.22</td>
<td>&lt;0.001</td>
<td>62.06</td>
<td>&lt;0.001</td>
<td>127.42</td>
<td>&lt;0.001</td>
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<td>Cage 6B and Hill 1</td>
<td>1775.08</td>
<td>&lt;0.001</td>
<td>26.80</td>
<td>&lt;0.001</td>
<td>178.31</td>
<td>&lt;0.001</td>
<td>2478.01</td>
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Table 4

Poisson estimated values of the seven behavioral categories in relation to age/sex classes with respect to species. Grey highlighted areas show significant differences used for comparison.

Significant Codes: $p<0.000$ ‘***’, $p<0.001$ ‘**’, $p<0.01$ ‘*’, $p<0.05$ ‘-’, $p<0.1$

<table>
<thead>
<tr>
<th></th>
<th>Feeding</th>
<th>Foraging</th>
<th>Moving</th>
<th>Resting</th>
<th>Social</th>
<th>Anti-Predator</th>
<th>Playing</th>
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<td>0.03</td>
<td>1.86***</td>
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<td>4.08***</td>
<td>0.07</td>
<td>6.49***</td>
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<td>0.04</td>
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<td>0.10</td>
<td>0.38</td>
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<td>-0.20***</td>
</tr>
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</table>
Figure 1. Bar graph showing percentage of total observed time allocated to each behavior for both Cages 6B and 10B.
Figure 2. Bar graph showing percentage of total observed time allocated to each behavior for both Hill 1 and Hill 2.
Figure 3. Bar graph showing percentage of total observed time allocated to each behavior for both Cage 10B and Hill 2.
Figure 4. Bar graph showing percentage of total observed time allocated to each behavior for both Cage 6B and Hill 1.
Figure 5a. Bivariate trellis plot showing intraspecific comparisons of feeding behavior between infants, juveniles and adults divided into male and female groups. 

Figure 5b. Bivariate trellis plot showing intraspecific comparisons of foraging behavior between infants, juveniles and adults divided into male and female groups.
**Figure 5c.** Bivariate trellis plot showing intraspecific comparisons of moving behavior between infants, juveniles and adults divided into male and female groups.

**Figure 5d.** Bivariate trellis plot showing intraspecific comparisons of resting behavior between infants, juveniles and adults divided into male and female groups.
Figure 5e. Bivariate trellis plot showing intraspecific comparisons of social behavior between infants, juveniles and adults divided into male and female groups.

Figure 5f. Bivariate trellis plot showing intraspecific comparisons of anti-predator behavior between infants, juveniles and adults divided into male and female groups.
Figure 5g. Bivariate trellis plot showing intraspecific comparisons of play behavior between infants, juveniles and adults divided into male and female groups.
REFERENCES


APPENDIX A: HATINH LANGURS IN CAGE 10B (*T. hatinhensis*)

**Image 1:** Infant male resting

**Image 2:** Adult female grooming (social behavior) adult male
APPENDIX B: DELACOUR’S LANGUR IN CAGE 6B (T. delacouri)

Image 3: Infant male resting

Image 4: Adult male resting
APPENDIX C: HATINH LANGURS IN CAGE 10B (T. hatinhensis)

**Image 5**: Adult female and infant male resting

![Adult female and infant male resting](image5.png)

**Image 6**: Adult male resting

![Adult male resting](image6.png)
APPENDIX D: DELACOUR’S LANGUR ON HILL 1 (*T. delacouri*)

**Image 7:** Infant female feeding

**Image 8:** Juvenile male resting